DECEMBER 2022

VIEWPOINT

OFFICIAL QUARTERLY MAGAZINE OF CEAI

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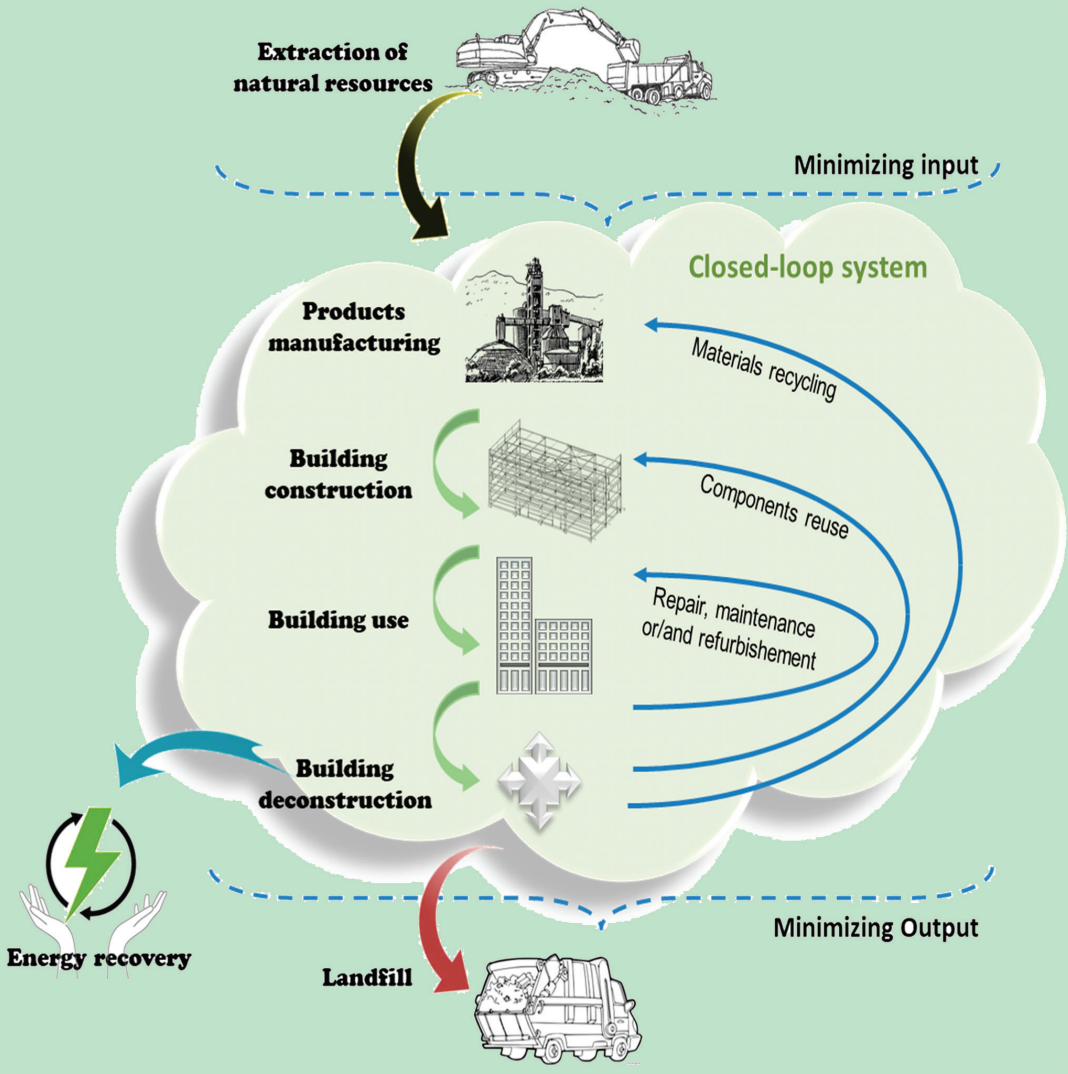
Circular Economy towards Sustainability



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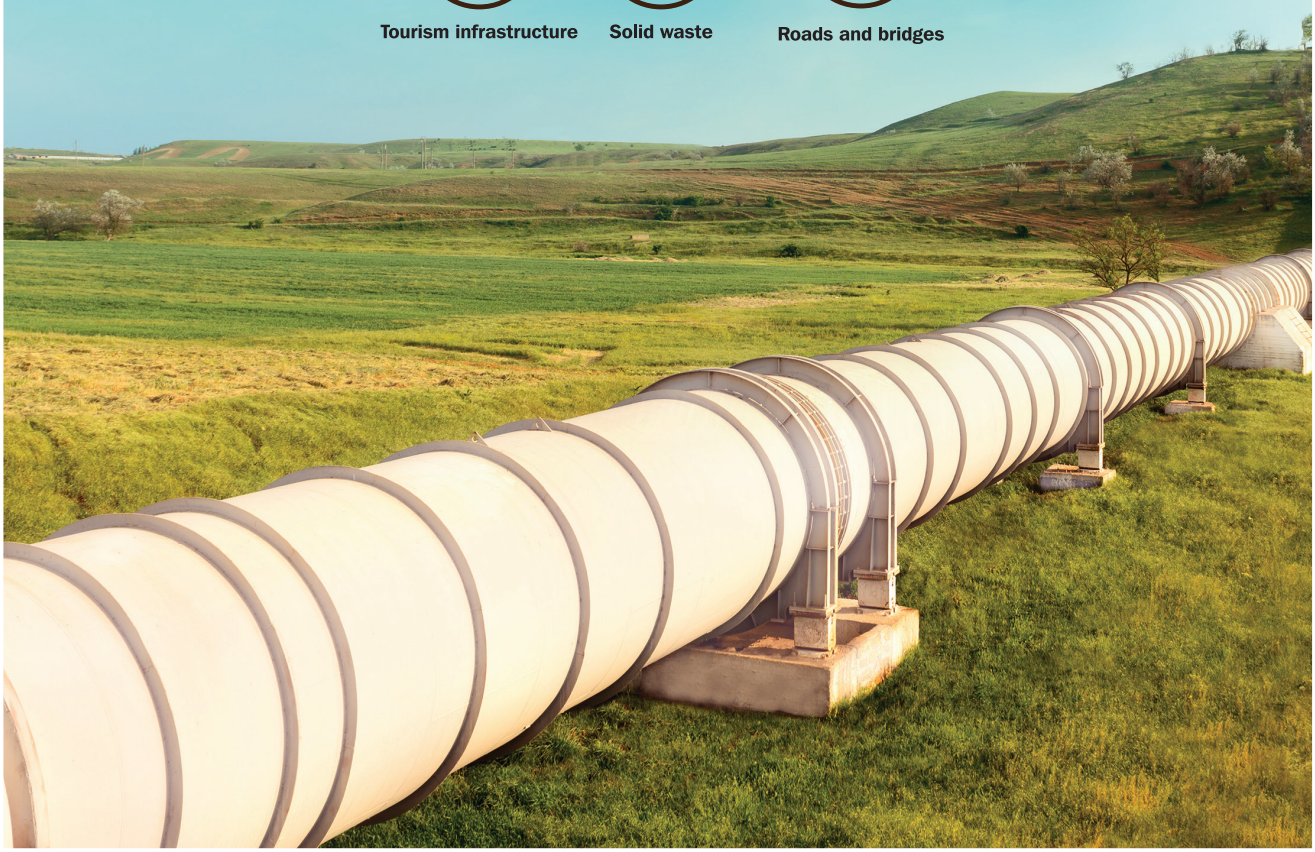

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CONTENTS

Art#	Article Name	Pg#
	Message from Chief Editor	v
	Message from Guest Editor	vii
	Message from President	x
	Message from President Designate	xii
1	Leveraging Circular Economy to meet Net Zero Targets *- Dr. Prasad Modak, Dr. Shilpi Kapur Bakshi*	1
2	Role of Consulting Engineers in Transforming Current Linear Economy to a Sustainable Circular Economy *- Shantanu Shantaram Apte, Luqman Ummer*	11
3	Need for a Shared Responsibility Structure in the EEE Value Chain to Transition towards Circularity *- Mehar Kaur*	18
4	Overview of Technology Perspective in Circular Economy and Sustainability *- Sanjoy Chowdhury*	23
5	The Need for Inclusive and Circular Management of Plastic *- Manisha Jain, Nathaniel Bhakupar Dkhar*	29
6	Approaches to Mitigate the Danger of Plastics to Marine Ecosystems *- Prahlad Tewari, Dr. Neha*	36
7	Demolition Waste Management in India Using Circular Economy *- Namya Sharma, Prof. Pradip Kalbar, Prof. Salman Muhammad*	41
8	Uses of Waste Materials for stepping up Circular Economy *- Dr. Swapan Kumar Bagui, S K Puri*	52
9	Building A Sustainable Future Together – Sharing Experience of Recycling Concrete Debris *- Anup Mathew, Abhijeet Gawde*	59
10	Quality Of Water – Challenge for Sustainable Construction *- Dr. Mahesh Kumar*	65
11	Nature-Based Solutions as Enablers of Circular Economy in the Water Sector *- Prof. Pradip Kalbar, Shweta Lokhande*	73
12	Safe Reuse of Treated Water in India – A Sustainable Development (Circular Economy) *- Dr. Vivek Kumar Singh, Dr. Ajay Pradhan*	81
13	Wastewater: An Untapped Environmental Wealth *- Dr. Kriti Akansha, Anagha Krishnan*	87
14	Making Textile Industry Circular and Inclusive in India *- Rashi Agarwal, Megha Roy, Krunal Parekh*	92
15	Role of Structural Engineers in Sustainable Development – An Indian Perspective *- Sindhu Nair*	98
16	Sustainable Engineering and Circular Economy for Roads & Highways – Case Studies *- Manoj Kumar, Sandip Bhattacharjee, Dr. Swapan Kumar Bagui, Jitendra Wadhwani, Anukul Saxena, Subhajit Mitra*	104
17	Reducing Transportation Costs by Optimal Utilisation of National Highway Capacity *- Lt Gen S Ravi Shankar (Retd)*	114
18	Environmental Benefits and Challenges of EVs in India: Key findings from LCA Analysis *- Trinayana Kaushik, Arpita Pandey, Mandavi Singh, Souvik Bhattacharjya*	118
19	Knowledge Resources:Circular Economy Websites: A Compilation	123
20	Environment Friendly House - Living with Nature *- Dileep Halbe*	125
	CEAI News	127
	Other News, Views, Notes	137
	Tech Quiz	140

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Cover image is from *"Implementing Circular Economy Strategies in Buildings—From Theory to Practice"* by Kamel Mohamed Rahla, Ricardo Mateus and Luís Bragança

About CEAI

Consulting Engineers Association of India (CEAI) is the apex body of consulting engineers in India having membership of organisations as well as individuals. The membership represents large, medium and small consultancy companies/ organisations both in the private and public sector and eminent individual consultants. EPC organisations are also members of CEAI since they have planning and design engineers, apart from construction management consultants.

CEAI is the Member Association, of the International Federation of Consulting Engineers, commonly known as FIDIC, the acronym for Fédération Internationale Des Ingénieurs-Conseils, representing the Consulting Engineering Fraternity in India. FIDIC has membership of more than 100 Member Association of various countries and is headquartered in Geneva.

CEAI was incorporated in 1996, with the merger of two leading national associations Association of Consulting Engineers (India) {ACE(I)}, incorporated in 1960 and National Association of Consulting Engineers {NACE}, incorporated in 1976. Thus, CEAI has, behind it six decades of accumulated knowledge and experience.

- CEAI promotes the interest and works to enhance the status of the consulting engineering profession in India
- CEAI advocates global networking and co-operation
- CEAI's activities include:
  - Quality development of Consultants.
  - Productivity enhancement.
  - Promotion of ethical practices.
  - Facilitation and interaction with government and other authorities/ bodies to streamline and improve the system of engagement of consultants.
- Regional Centres in Jaipur, Bengaluru, Kolkata and Mumbai to broad base activities.

Aims & Objectives

- Promote the professional interest and establish the rights and privileges of the status of consulting engineering profession in India
- Represent the consulting engineering profession within India and abroad. Connect the members locally and globally.
- Disseminate among the members information on all matters pertaining to engineering, especially knowledge and information related to consulting engineering profession by way of holding Conferences, Seminars, Courses, Workshops, Field/ Site Visits, etc. and thus assist in Continuing Education for the Professional Development of Members.
- Act as the principal champion for consulting engineering profession through constantly informing and educating the public and lawmakers about key engineering issues and making it possible to have the voice of the profession heard by the policy makers.
- Promote adoption of equitable forms of contracts and other documents used in consulting engineering practice.

Vision

- To represent, promote and enhance the status of consulting engineers in India as an honoured and dignified profession for nation building and propagate Indian engineering consultancy globally.

Mission

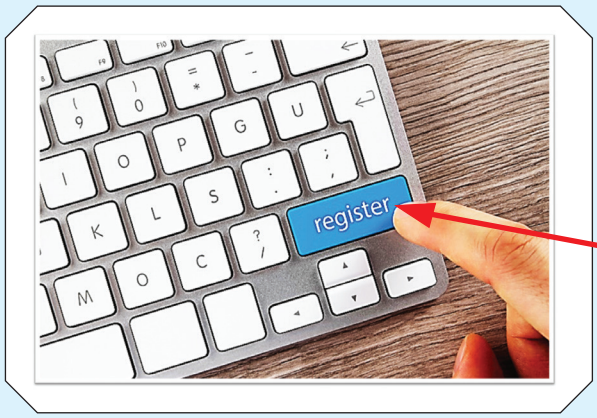
- Promote interests of the consulting engineering profession nationally and internationally.
- Promote sustainable, safe and sound engineering practices.
- Upgrade engineering knowledge and skill.
- Propagate code of professional ethics, safety, health and environment.

Values

- Commitment with tenacity to high ethical values, integrity, professionalism and achieving technical excellence and inclusive development.

Code OF Ethics

- CEAI has adopted a Code of Ethics, to which all members must abide. It is not just for the quality of the jobs they work on, but for the safety and well-being of the public at large.
- CEAI is the profession's most respected voice on the practice of ethical engineering.
- The code specifies the responsibilities of Consulting Engineers towards the society as well as the profession, to refrain from performing services unless competent to do so, to act in the legitimate interest of client, to be impartial, to maintain ethical relations with other consultants.



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To Grow

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Dear Members, Readers & Engineers

2023

Wishing You

A Bright, Prosperous

&

Happy New Year

May The New Year See You

Soaring

&

Conquering New Frontiers

Preserving & Enriching

The Earth

&

The Solar System

For Posterity

Interacting Ethically –

Be it Social or Professional

With Integrity

As The Criterion Of One's Conduct

CONSULTING ENGINEERS ASSOCIATION OF INDIA

Message from Chief Editor

Dear Fellow Consulting Engineers & Readers,

Wishing each and every one of you, your near and dear ones and your friends a ***Happy and Prosperous New Year***. The results of the sustained drives that the nation has seen has helped it to tide over the lingering effects of the pandemic and move forward to a speedy and bright upliftment. However, in doing all that it is necessary to give due consideration to what human actions have on Nature and those less fortunate.

Coming down to brass tacks, the scenario is that the world has witnessed mankind's transforming habits from necessary and adequate to excessive and wasteful consumption of the Earth's resources. Those have been prompted by consumerism advertising campaigns in all media platforms or through attractive retail displays subconsciously triggering desire to acquire.

The environmental pundits predict that some of the non-regenerative and non-renewable resources may not be available in the next few decades. Besides, their excessive consumption is resulting in many other problems - primary ones being polluting the air, water and land; encroachment on natural habitats which are resulting in the extinction of certain flora and fauna species and creating bio-diversity issues consequently resulting in the upsetting of nature's weather cycle. The results are for all to see but the learnings are taking time for the masses to realise the impact of unfettered consumption of nature's irreplaceable resources.

It is here that the Engineers have to step in and conceptualise, plan, design and construct/ manufacture what is necessary using replenishable and recyclable materials as well as systems that prevent, reduce the generation of waste with an effort to recycle the same where feasible.

Many in the engineering fraternity in India are seized of the matter and have taken steps to mitigate the effects but the urgency of implementing measures across the board has to percolate to those involved in setting up infrastructure and manufacturing industries.

It is there again that the Engineers have to play a role – that of educating those whom they deal with in their line of work. The caveat would ofcourse be that the solutions that the Engineers put forth would need to be ones which are based on what would benefit nature, all available latest research in this domain and in no way would cause any adverse effects during the designed service life of the product. The moto would thus be *Use and Reuse with Design for Long Service Life what is Fit for Its Purpose with Due Regard to Personnel Safety*

The papers in this issue deal with ***Technology, Engineering, Policy etc. for Circular Economy so that what is done is Sustainable.*** They provide suggestions and directions on how to move forward on the two critical interlinked and interdependent matters of sustainability and circular economy based on technology/ engineering. It has been stressed that scientists and engineers have to take up the gauntlet and be in the forefront to pull mankind out of the mire or atleast not let it sink further duly implementing all statutory provisions of the state/country

To drive that it is necessary that the professionals including the scientists and engineers be signatory to a legislated code of conduct that would legally bind them and make them responsible and accountable for all that they do.

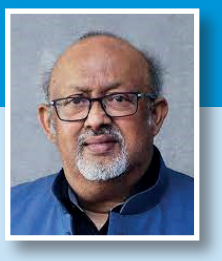
It has been stressed time and again, that a professional engineering association which serves as a guardian of the code of conduct is the need of the time and for that legislation is necessary to give it the teeth that are essential for it to function effectively. For that to become a reality the government has to move the papers for legislation for the profession of engineering. Till then it is upto each and every one of us to stretch ourselves and

Pledge to Make OUR EARTH a Haven

for Ours and Future Generations

Happy Reading, Learning & Pledging

A P Mull



Message from Guest Editor

Circular Economy (CE) is considered as one the important strategies to address the Sustainable Development Goals (SDG). A multi-stakeholder platform for CE encouraging a partnership approach towards resource conservation, resource efficiency and resource recycling has been found to be promising. In many countries, policies and strategies on Circular Economy are formulated to build the recycling infrastructure, promote new business models and spur innovations, especially in waste collection and responsible product design.

Resource extraction across the world is getting increasingly intensive. Material flows of both virgin and used/ secondary materials are getting skewed. Some of the important factors responsible for the shift are market globalisation, presence of perverse subsidies (i.e., unrealistic resource pricing) and unevenness in environmental governance.

Given that India has been on a pace of rapid economic growth, it faces several environmental and resource use challenges today. Our resources are under threat due to intensive depletion and serious degradation. Further, realisation has also dawned that the risks related to the country's resource security are compounded due to looming threats of climate change. The policies and strategies for responding to these challenges need mainstreaming of sustainability across all developmental sectors.

Strangely, and oddly enough, the national governments, particularly the Ministries of Environment across the world focused more on the management of residues rather than management of the resources. Legislation was evolved to establish limits on the residues that were required to be met prior to disposal but not much attention was paid on the limits of extraction of resources and resource pricing. The Government of India is not an exception to this bias.

However, in 2015, the Ministry of Environment, Forests and Climate Change (MoEFCC) constituted the Indian Resources Panel (IRP), as a step to address India's resource security in a strategic perspective. India was the first country in the world to take such an initiative. Following the establishment of IRP, India's apex policy body NITI Aayog came up with an action plan to accelerate Resource Efficiency (RE) and Circular Economy. In partnership with EU's Resource Efficiency Initiative (REI), several sectoral publications were brought out between 2017-2019, involving dialogue with multiple institutions. Around the same time, the Ministry of Finance, Government of India set up a Task Force on Sustainable Public Procurement (SPP). In 2019, MoEFCC established a Resource Efficiency cell and formulated a draft National Resource Efficiency Policy. In 2021, NITI Aayog took the lead to prepare sectoral as well as cross sectoral circular economy action plan by consulting the 11 line Ministries.

In addition to addressing environmental Sustainability, the Circular Economy improves the businesses' competitiveness, generates employment, increases green investment flows and foster inclusive development. Essentially, it aims to redesign the production and consumption systems by closing the loop and avoiding compromising on the resource security. Circular Economy is indeed critical to achieve accelerated decarbonisation while not compromising economic growth. It is therefore an opportunity for the Indian government to leverage this concept and meet its economic, environmental and social objectives.

The various missions launched by the Government such as Make in India, Zero Defect India and programmes like Smart Cities and *Swachh Bharat Abhiyan* (Clean India) resonate with the principles of Circular Economy. India is now the presidency for the G20 deliberations. Topics such as resource efficiency and circular economy, extended producer responsibility and bioeconomy have been identified as important areas for discussions. To take forward some of these areas, MoEFCC is considering to set up a network of Centres of Excellence in Circular Economy.

The concept of Circular Economy considers 6Rs such as Reduce, Reuse, Repair, Refurbish, Recover and Remanufacture. These 6Rs strengthen resource security and betterment of livelihoods through components such as social (employment and engagement, especially of the informal sector to ensure inclusivity), innovation (for the start-ups) and green investments.

To implement Circular Economy, new business models need to be identified and nurtured. The business models would need to map the life cycle and include those around recovery and recycling, product life extension, sharing platform, product as a service and circular supply chain. For the consulting engineering fraternity, these business models can serve as great opportunities to leverage on the Circular Economy.

The Circular Economy requires a change in the way we live. Given the rising rate of urbanisation, the increasingly prosperous middle class (especially in Asia) and the promotion of consumerism through media, it is extremely difficult to expect this change will ever happen! If you say no to a product because you feel there is no need, someone will simply dump the product on you (as a free trial or as a friendly gift) to trap you or enslave you! Taming wasteful consumption is therefore the first step. The LiFE initiative launched by the Government of India on sustainable lifestyles is therefore extremely relevant to promoting an environment conscious lifestyle that focuses on 'mindful and deliberate utilisation' instead of 'mindless and destructive consumption'. That will also help reduce global GHG emissions and help meet the NetZero target of 2070.

We therefore need to educate the citizens on the consumption itself and guide them to make "green choices" i.e., avoiding the use of products to the extent possible that use harmful chemicals and non-biodegradable materials in the first instance. This will ensure circularity in its downstream use. The production patterns should be influenced by responsible consumption. The manufacturers would need to extend their involvement beyond the factory gates and take responsibility across the life cycle. That is the principle of Extended Producers Responsibility (EPR). Like in many countries, especially in the European Union (EU), India has also legislated EPR in different waste streams including electronic and plastic wastes.

Product/packaging redesign by companies need to exhibit out-of-the-box thinking to find ways to reduce material and energy intensity and increase recycled content. Products need to be redesigned to reduce/eliminate

hazardous substances, increase recyclability (and improve safety during recycling) and make remanufacturing possible with most of the components getting reused. That requires innovation, risk appetite and top management commitment – and that cannot be achieved overnight. In India today there are only a handful of eco-design schools.

However, working only on the "upstream" alone is not sufficient. Years of inefficiencies in manufacturing practices, rising waste volumes across the world need to focus on recycling. The "downstream" industry addresses recycling and recovery– extracting metals, biosolids, refuse or solid derived fuels, biogas, syngas, heat, electricity, engineered materials, etc. from and reversing material flows and thereby reducing the consumption of virgin resources. The global waste recycling industry today supports significant employment – both in formal and informal sectors. Millions of poor people in the world's largest cities earn their livelihood because waste is around. India's recycling industry is supported by more than 4 million waste-pickers, waste collectors (*kabaddiwalas*) and small-scale informal recyclers. Fostering a Circular Economy therefore has to be inclusive.

There are many examples of conflicting interests between the stakeholders involved "upstream" and "downstream". In "Reduce", top management, product designers and consumers play a dominant role whereas in "Recycle", waste pickers, community and waste processing specialists have a greater interest. The two groups rarely have a dialogue. That defeats sustainability and does not encourage Circular Economy in true sense. An integrated approach is the need of the hour.

We also need to develop standards on recycled products and the recycled content. While India has initiated that process, there is a long way to go. The Task Force set up on Sustainable Public Procurement (SPP) and the reconstituted committee on India's Eco-Mark ecolabel may perhaps accelerate effort in that direction.

Transition to a Circular Economy is possible when policies and strategies are evolved at a regional scale. Implementing circular principles at project level alone does not often lead to the desired upscaling and replication to achieve the impact on a sustained basis. Strategising Circular Economy on a regional scale is to be done by formulating an enabling framework and by ensuring a multi-stakeholder involvement for delivery. When conceived at a regional level, coordination between various departments and agencies also becomes necessary. Such a coordination helps to ensure harmony and synergy between various Circular Economy related interventions. A system of performance or outcome indicators needs to be evolved that helps in adoption of policies and strategies.

When we think of an enabling framework on a regional scale, we must address all the interconnections, e.g., in the case of water, we must widen the canvas by factoring the inseparable nexus between water, agriculture, food, waste and energy. Apart from recognising the nexus, consideration is also needed to account for the impact of climate change. Climate change for instance can affect the water availability as well as water quality, requiring additional set of mitigation and adaptation measures. We expect to see pilots on regional circular economies in these perspectives.

For rapidly growing economies such as India, transiting to a Circular Economy would be critical as it would help the country to progress towards the Sustainable Development Goals.

In this background, I am happy that the Consulting Engineers Association of India (CEAI) has selected

Sustainability and Circular Economy as the topic for this issue of ViewPoint. I am glad that the issue has attracted a wide spectrum of articles contributed by the industry professionals and academia covering both policy and practice. Given the broad canvas of the subject, I am sure that this issue will serve as a useful resource to those interested in the subject. Finally, I must thank my colleague Dr. Shilpi Kapur Bakshi for her hard work in editing the papers and coordinating with CEAI for this publication.

WISHING ALL A VERY BRIGHT AND HAPPY NEW YEAR

Dr. Prasad Modak
Managing Director, Environmental Management Centre Pvt. Ltd.
Director, Ekonnect Knowledge Foundation

Message from President

CEAI has completed 26 years of glorious service to the Engineering Consulting fraternity to the members in particular as well as the engineering fraternity in general. On behalf of CEAI, I offer my heartfelt sympathies to the friends and families of those who lost their near and dear ones during the pandemic but still bravely faced the odds. We at CEAI too lost our staff member. Some senior members also bid adieu to life on earth.

At the outset, it would be good to recall that the association functions on a system of shared responsibilities and duties. As the last message as President, I would like to record that the tasks during the two years tenure could be executed and completed with the active help from my senior colleagues, Past Presidents and the Executive Committee Members. The joint commitment of all the willing members made it possible to overcome all hurdles with relative ease. The interactions and meetings with various agencies, Government Authorities, etc. helped in solving detrimental and intricate issues. The efforts of CEAI Committees and Sub-Committees and their prompt support coupled with the efficiency of the Secretariat are commendable and contributed to keeping members updated with Circulars and Notices on the developments. The joint efforts also helped in tackling many problems from time to time.

CEAI's Website was given a through makeover and is now being maintained by a third-party vendor regularly. It can be you're a reference point for topic-wise list of important Circulars and Notices and publications as well. CEAI's social network sites like Twitter, Facebook and LinkedIn are regularly updated and maintained by the external consultant.

Some of the major activities organised by CEAI were:

- Conferences and Webinars
- Sponsored Webinars organized by CEAI
- Technical Talk
- Branding of CEAI with a new logo
- Revamping of Website and Social Networking platform
- Implementation of an Employees Benefits Scheme
- Digitalization and organisation of Data and Operation

- Signing of MoU with Services Export Promotion Council (SEPC)
- CEAI Academy was set up
- Renovation and upgradation of facilities at CEAI Secretariat
- Released a Compendium Contribution of Consulting Engineers to commemorate 'Azadi ka Amrit Mahotsav'

The two years have given me a greater insight and understanding of CEAI and I have gained vast knowledge on the complex issues relating to the professional engineering sectors and how we can jointly face them subject with **continuous assistance from all quarters, specially, from Members**, to support the cause of the engineering fraternity and creation of a healthy business environment for all. We need to stand United to address and win over the barriers to the profession. CEAI needs support from not only each and every Member but also those in the profession to raise issues which are common in nature and affecting the engineering fraternity so that these can be taken up with the authority concerned for redressal. Even the individual issues could be taken with the authorities if CEAI is informed about them. CEAI could help in resolving them.

CEAI would also be a part of correcting and resolving issues and practices which adversely affect the profession. CEAI could raise and prevail upon the concerned authorities before such practices get roots.

Though the economic scenario in India looks good, however, that in many other countries the world-over seems to be grim with new challenges of a new Covid strain surge in China, Korea, the US, Japan, etc., plus the ongoing conflict between Ukraine and Russia.

Dear colleagues, last but not the least, change is inevitable. The Governing Council for the term 2023-2024 will need all our support to take off with full of vigour and bring more innovative ideas and practices with Mr. R S Sharma at its helm.

Wishing all the enthusiastic readers and our members Happy and Purposeful Years ahead.

Dr. Ajay Pradhan
President

Message from President Designate

Dear Colleagues, Friends and Members,

India's economy has recovered well and is booming with a record collection in Tax revenues. The infrastructure development in the country is also increasing with large investments planned in the current and future years. Engineering consultants play an important role in the development of infrastructure and other economic and social sectors. The demand for consultancy is also high and connected with it are high expectations regarding quality and delivery. In that scenario it is upto the Consulting Engineers to rise up to the quality of services expected of them by the government as well as funding agencies. With Consulting Engineering firms facing an acute financial crunch due to contractual conditions and the stiff competition for trained man-power and also jobs, CEAI has a great responsibility towards the country, the owners and client as well as the Consulting Engineering fraternity per se to look at all aspects and provide workable solutions. We therefore have to work hard to improve the health, wealth as well as the knowledge and the quality standards of the Consulting Engineering services in India.

It is desired to enlarge the CEAI base to cover all sectors of Consulting Engineering services, spread over all regions of the country so that it becomes one voice to reckon with.

Friends, I assume charge of the office of President CEAI at a time when there are high expectations from all fronts. My predecessors have carried out the tasks very well in spite of many odds, primarily the pandemic situation.

I firmly believe and have the confidence that with the support of the Governing Council and other members in conjunction with guidance from seniors, we will be able to fulfill our goal and take CEAI to greater heights.

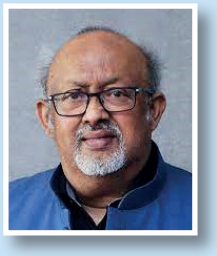
Wishing all Members and Readers

A Happy New Year

Rama Shanker Sharma
President Designate

01

Leveraging Circular Economy to meet Net Zero Targets



Dr. Prasad Modak
Managing Director

Dr. Shilpi Kapur Bakshi
Vice President

Environmental Management Centre Pvt. Ltd.

Introduction

India over the last several decades has been on a growth path with rising per capita income. This growth has been coupled with urbanization, consumption of natural resources raising issues on resource depletion, resource degradation and resource security. Figure-1 shows the trend in per capita total material consumption since 2000 in India (TERI 2019). The looming threat of climate change has further compounded the situation due to the rise in the greenhouse gases (GHG) emissions resulting from the economic activities. In the Independence Day speech on 15th August 2021, Honourable Prime Minister of India Shri Narendra Modi emphasized on the need of "*action plan to build a circular economy (CE) so that the resources are conserved to improve economic, natural, and social capital and at the same time reduce carbon emissions*" (PMINDIA 2021)

Using CE strategies to decouple economic growth from material consumption and waste generation will help make India more competitive, self-reliant, and future ready. Recently in March 2022, in one of the post budget webinars, the Honourable Prime Minister re-emphasized on the importance of CE in context of the depletion of all types of natural resources that is being witnessed and identified it to be the demand of the hour in such a scenario and encouraged people to make CE mandatory part of their lives (PIB 2022).

Ellen MacArthur Foundation made an estimate of benefits from CE transformation for India in terms of the economic, environmental and social value. These benefits were estimated to be an annual value creation of USD 624 in 2050, amounting to 30% of India's current GDP and a 44% reduction in GHG emissions in 2050, compared to the business as usual (BAU) scenario. Other benefits include reduced traffic congestion and air pollution, lower use of virgin materials, water use reduction, innovation and technology upgradation and creation of business models leading to profits, inclusivity and material cost savings (EMF 2016). The International Labour Organization (ILO) estimates that a net growth of 6 million jobs globally can be expected by 2030, notably in waste management and recycling, and the services sectors, repair and renting models (ILO 2018).

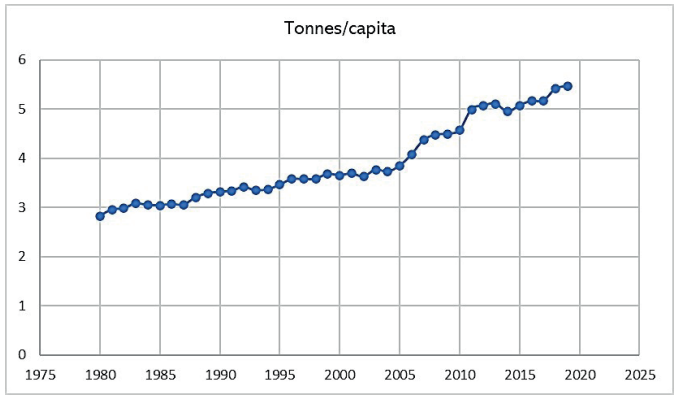


Figure-1: Material consumption in India: Total, Tonnes/ capita, 1980 – 2019

Source: OECD (n.d.)

At the Glasgow Committee of Parties (COP) held in November 2021, where 136 countries have pledged to reach net zero, India has declared a target of reaching net zero by 2070.

The Union Budget 2022-2023 identifies CE transition as supporting productivity enhancement as well as creating large opportunities for new businesses and jobs. This chapter elaborates on how CE strategies can be leveraged to meet the country's net zero targets while achieving economic growth and ensuring resource security.

Circular Economy in Indian Context

The evolution of CE in India over the last few years is presented in Figure-2, highlighting the key initiatives undertaken by the different line ministries and NITI Aayog and showing the commitment of the Government of India towards transitioning to CE. In addition to these initiatives, there have been notifications of various waste management related rules, such as the Plastic Waste Management Rules, e-Waste Management Rules, Construction and Demolition (C&D) Waste Management Rules, (Draft) Battery Waste Management Rules that strengthen the recycling component of the material and waste streams.

In March 2021, NITI Aayog constituted 11 sectoral CE committees that focussed on key hotspot sectors/ waste streams to introduce CE. These committees were spearheaded by key line ministries and sectoral and industry experts and each committee prepared a detailed action plan to foster a circular economy in the respective sectors. Some of the recommendations made by these committees have already promoted action in terms of policy push or a sectoral intervention.

Though the traditional focus of CE in India has been on managing waste at the downstream stage of the life cycle of products, there is increasing emphasis on upstream and midstream stages of the value chain through innovative design, reduction in raw material used and substitution of virgin raw material with secondary materials. These efforts have led to significant GHG emission reduction.

Taking the example of C & D Waste Management Rules, 2016, it promotes C & D waste utilization. Sub-rule (11) notes '*shall make provision for giving incentives for use of material made out of construction and demolition waste in the construction activity including in non-structural concrete, paving blocks, lower layers of road pavements, colony and rural roads'*. There are some pioneering examples of productive utilization of C&D

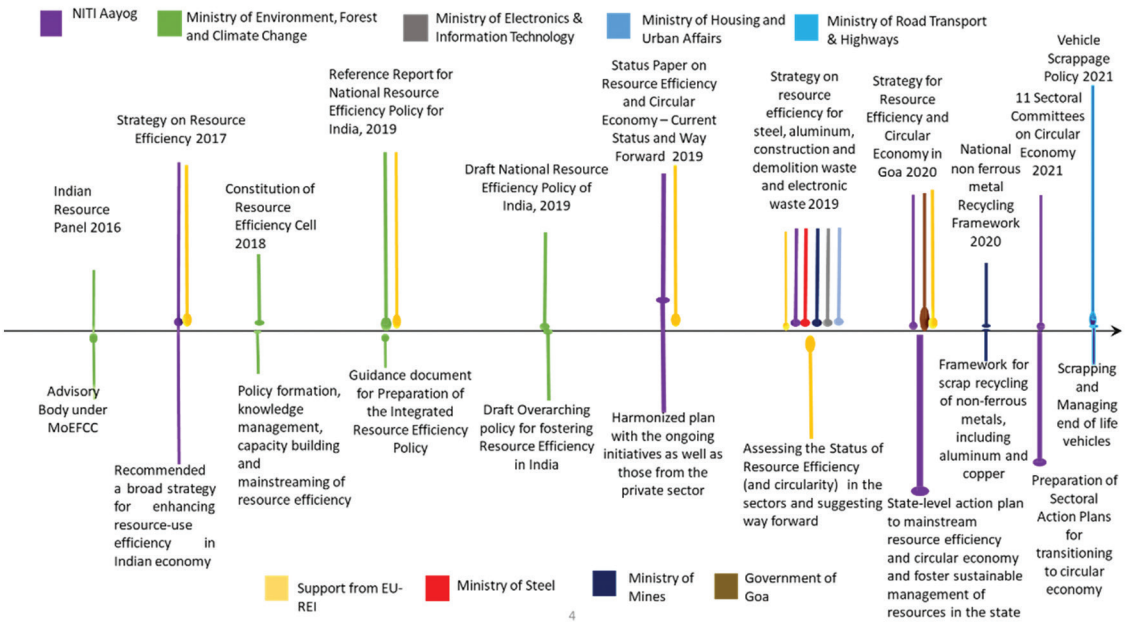


Figure-2: An overview of circular economy related interventions in India

waste in Delhi NCR where recycled concrete aggregates are being successfully used in manufacturing high quality concrete blocks and pavers. GreenPro Ecolabelling, developed by the Confederation of Indian Industry (CII) has more than 600 products, including a large set of construction products from more than 80 companies (CII 2021) and has established market linkages through that certification, which provides confidence in product quality control and addresses the mindset barrier. Though the initial focus of the labelling was on green building materials/ products, it gradually expanded focus to industrial products, consumer items and services.

Mainstreaming Circularity in Key Sectors to Reduce GHG Emissions

The Circularity Gap Report 2021by Circle Economy highlighted that the majority (70%) of GHG emissions are associated with material handling and use. The report identifies housing, nutrition, mobility, communications, services, consumables and healthcare as the seven core societal needs with big potential to cut down attributed emissions and resource use once circular interventions are implemented.

Research by Ellen MacArthur Foundation in the global context has shown that with existing technologies, transition to renewable energy will only address 55% of the emissions, and the remaining 45% decrease to achieve net zero goal will need to come through the transition to a circular economy (EMF 2021). Focusing on five key sectors (cement, plastics, steel, aluminium, and food), the study illustrates how circular strategies can reduce GHG emissions while making the sectors resource efficient and competitive.

Built Environment Sector

The built environment sector, a major consumer of cement and plastics, is a major contributor to GHG emissions which includes emissions from the construction of the buildings infrastructure (materials used, material intensity in the form of embodied GHG emissions and methods of construction), the supply chain emissions and those from the use of the building. A study on circular cities in that context has identified 5 key circular interventions for GHG emission reduction from the sector (Arup & enel Foundation 2021). These include enhance building use and occupancy to reduce the overall demand for new buildings in the city, switching materials from traditional carbon-intensive materials to renewable and/or low-carbon materials such as timber or low-carbon concrete, using materials efficiently through design changes and improvement in fabrication yields, recover, reuse, repurpose materials to replace use of virgin materials and extending life of materials and components through circular design. India's Smart Cities Mission can easily dovetail the above considerations.

Cement concrete is the key material that is indispensable for the construction sector. Material efficiency is a key to facilitating decarbonisation in the cement industry and the measures span the entire lifecycle including material substitution and designing new materials that can be easily reused in other construction, reduction in Portland cement's clinker intensity, extending lifetimes of buildings and their components through reuse and refurbishment, and processing construction and demolition waste to produce concrete. Waste from various industries is being utilised by the cement industry as alternative fuels and raw materials (AFR) and help in the management of residues. Estimates have suggested that there has been a reduction in the CO_2 emission factor from 1.12 t of CO_2/t of cement in 1996 to 0.670 t of CO_2/t of cement in 2017 and enhanced blended cement production from 68% in 2010 to 73% of total cement production in 2017 (Kukreja, K. et.al. 2020).

Future construction should prioritise a circular, zero-waste approach that is based on the use of reused and reusable materials, modular and off-site construction methods alongside design for maintenance and deconstruction to mitigate the carbon impact of buildings (WEF 2021). With the recent Union Budget 2022-23 providing a sharp increase by 35.4% in the capital expenditure outlay, it would be critical to promote and adopt circular economy principles in the creation of new infrastructure in the interest of decarbonization.

Automotive Sector

Another sector that presents significant opportunities to reduce GHG emissions is the automotive sector. With India being the third-largest oil importer in the world, in

its drive to minimise dependency on oil and fuel imports, there is a significant movement towards greener mobility options such as electric vehicles. In 2015, the government rolled out its flagship Faster Adoption and Manufacturing of Hybrid and Electric vehicle (FAME) I scheme with an allocation of around INR 8000 million for faster adoption of electric mobility and development of its manufacturing eco-system in the country. FAME II was announced in 2019. In this year's Union Budget, provisions have been made regarding battery swapping policy and interoperability standards.

However, given that the electric vehicles use lithium-ion battery technology, technologies for managing its battery waste becomes extremely important if the electric mobility options need to be sustainable. Currently, there are gaps related to commercialisation of lithium-ion battery recycling in an environmentally sustainable manner. Supporting the development of such technologies through production linked incentive (PLI-Re) will promote LIB recycling plant operations and encourage manufacturers to reuse the recycled material and promote circular economy, thereby leading to the sustainability of this low carbon mobility option.

To further gear the economy towards clean energy, push is being given for gradual adoption of hydrogen-fuelled vehicles. The Honourable Prime Minister launched the National Hydrogen Mission on India's 75th Independence Day on 15th August, 2021. The Mission aims to aid the government in meeting its climate targets and making India a green hydrogen hub, helping in meeting the target of production of 5 million tonnes of Green Hydrogen by 2030 and the related development of renewable energy capacity. To take that forward, the first part of India's National Green Hydrogen/ Green Ammonia Policy was announced recently in February 2022 (PIB 2022) which provides incentives for potential manufacturers, generation companies and distribution licensees to boost large scale indigenous production of green hydrogen, to decarbonise the energy sector and reduce India's heavy dependence on fossil fuels and crude oil imports. There is also scope for the private sector to promote innovations so that India's full potential can be utilized.

In August 2021, the Honourable Prime Minister announced the Vehicle Scrappage Policy/ Voluntary Vehicle-Fleet Modernization Program (V-VMP) with an objective to phase out unfit and polluting vehicles plying on Indian roads in an environment friendly and safe manner. The policy is expected to formalize the currently informal scrapping sector and promote safe and environment-friendly scrapping of vehicles, which would also lead to reduction in emissions while increasing material circularity.

The International Resource Panel in its 2020 study has estimated the GHG emissions reduction opportunities from the material cycle of passenger cars in 2050 by 57%–70% in G7 countries; 29-62% in China and 39-53% in India and the reduction in total GHG emissions for the manufacturing, operations, and end-of-life management of cars in the G7 by 30–40% in 2050 and in China and India by 20-35% (IRP 2020). The study finds the largest reductions of life-cycle emissions can be attained by changing patterns of vehicle use e.g., car-sharing.

Plastics Sector

In case of plastics, GHG emissions from the production process generate on average 2.5 tonnes of CO_2 per tonne of plastics, while the decomposition of plastics at end-of-life (in particular if it is incinerated) produces about 2.7 tonnes of CO_2 per tonne of plastics (Material Economics 2018). These emissions could be reduced by following circular strategies such as avoiding single use plastic. In August 2019, the Honourable Prime Minister of India announced the decision to phase out single use plastic by 2022, improving segregation, increasing recycled content in plastic goods and reducing consumption of virgin plastic. On 5th April 2022, the government announced its initiatives such as a National Dashboard on elimination of Single Use Plastic and Plastic Waste Management, Extended Producer Responsibility (EPR) Portal for Plastic Packaging, Single-Use Plastic Compliance Monitoring Portal and Mobile App for Single-Use Plastics Grievance Redressal as tools to empower citizens to check the plastic menace. These e-governance tools on plastic will be integrated with the Central Pollution Control Board (CPCB) Portal for Plastic Waste Management.

E-waste

Sectoral focus such as on e-waste management also opens up many opportunities to integrate circularity and contribute to emission reduction. The CE committee on e-waste constituted by NITI Aayog has highlighted the importance of environmentally friendly metal recycling technologies that prevent pollution emanating from existing crude methods of recycling as well as from landfilling of the e-waste. The business models for implementing such recycling facilities can be made inclusive by involving the informal sector, providing them required skills and ensuring that the workspaces are safe. The Ministry of Electronics and Information Technology (MEITY) has come up with a scheme of setting Eco-parks on that basis.

Businesses Setting Net Zero Targets and following CE Based Management Systems

Developing solutions to reduce GHG emissions requires not only access to technology, enabling regulations and market instruments, but also depends heavily on the commitment and leadership of the industry. Indian industry has been active on that front and an increasing number of companies have announced net-zero ambitions to motivate/ mandate them to develop solutions. These include private industry giants such as Reliance Industries (RIL), Tata Consultancy Services, HDFC Bank, Wipro, Infosys, Mahindra & Mahindra, JSW Energy, ITC, Adani, Dalmia Cement, and public undertakings such as Indian Railways (Change Started 2021). Capital markets are also increasingly building emissions related risks into their asset prices and showing preferences for investment in low carbon businesses.

Many Indian companies have also pledged to reduce GHG emissions according to the Science-Based Target (SBT) Initiative — a global alliance that enables businesses to establish their own climate pledges. It should be noted that one of the core strategies being adopted to move towards these targets is minimising waste, even to the extent of zero waste target. There is also a focus on more efficient use of materials, the substitution of virgin with secondary/ recycled raw materials and fulfilling of the extended producer responsibility (voluntarily or by mandates) along the value chain of their products and services.

Promotion of management systems such as ISO 14015 (Zero Waste Landfill) can help to encourage waste prevention through redesign of resource life cycles that allows reuse of all products. Such management systems can foster circularity at the organizational level encouraging them to use the discarded materials and close the loop in their supply network, reducing the direct and indirect emissions linked to their businesses. There is however a need to raise efforts for promotion of ISO 14015 in India's corporate sector. Training on these waste management systems for all employees and contractors that handle waste is a necessary first step. Making them aware of waste hierarchy, implementing techniques that focus on the prevention of waste, as opposed to traditional downstream waste management will be a key approach. There is also a need to modify the production and delivery systems to move towards the ultimate goal of zero waste.

The Technical Committee ISO/TC 323 CE, that was constituted in 2019 by the International Organization for Standardization (ISO), is currently developing six standards that aim to cover all aspects of CE including public procurement, production and distribution, end of life as well as wider areas such as behavioural change in society, and assessment, including circularity footprint or index. Adoption of these standards by the business houses will provide a common global framework for participating parties and can guide a systematic and continual improvement towards decarbonization through circular actions. Importantly, these management systems will greatly influence the supply-chains. Industry associations such as CII, Federation of Indian Chambers of Commerce & Industry (FICCI) and Associated Chambers of Commerce and Industry of India (Assocham) could take a lead in facilitating adoption of both ISO 14015 and ISO/TC 323 standards by making their members aware of the benefits of these standards and motivating them to adopt them. Public procurement could include these standards in their tender specifications. In addition, management systems like AMS 55001 that are linked to the SDGs could be considered by companies holding infrastructure assets for sustainable management.

Market Based Strategies

Eco-labels can help producers differentiate their environmentally friendly products from alternatives, stimulating the market development and innovation in such products as well as allowing consumers to make more informed purchasing choices. These labels on products with recycled content and those with low carbon intensity during production and use can act as seals of approval that indicate fewer impacts on the environment than functionally or competitively similar products. These labels generally rely on life-cycle assessment to determine the environmental impact of a product 'from cradle to grave'. In contrast to a self-styled environmental symbol or claim statement developed by a manufacturer or service provider, these labels are awarded by third party organizations to products that meet environmental, social and ethical criteria. Countries such as Korea, Japan and the UK have introduced labels for low carbon products.

There is merit in revising the ECO-Mark scheme of India to lay emphasis on resource efficiency and to incentivize manufacturers to include concepts of Design for the Environment (DfE) in the product design stage. The scheme may include low carbon products as promoted in countries such as Korea, Japan and the UK. The scheme should also include packaging products that use secondary raw materials such as agricultural residues.

Sustainable Procurement Policies (SPP) can be considered as key drivers for the eco-labelled products, as by driving demand from the market. Though the types of products and services covered under sustainable public procurement programmes vary, a key objective is to address the environmental concerns from mitigating climate change, reducing GHG emissions, promoting energy efficiency and protecting soil, water, biodiversity, and health. There is already a shift from SPP to circular procurement and circular supply chains. Circular procurement of low carbon goods or services could be promoted that seek to contribute to closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across their whole life cycle.

Tax based emission reduction approaches such as the GST reduction in low carbon goods and services can complement the sustainable procurement outcomes related to mitigating GHG emissions and fostering circularity. India's Ministry of Finance (MoF) has already set up a task force on Sustainable Public Procurement.

Another key instrument that can encourage achieving decarbonisation, with significant potential to improve circular material flows for all focus materials are the carbon taxes. These taxes capture the external costs and impacts of GHG emissions by adding an extra cost to the use of fossil fuels. Carbon taxes may be introduced for select high GHG emission sectors and could be levied with the energy and fuel related payments. Further, apart from creating a push towards decarbonization and CE, carbon taxes could be a significant source of revenues for the Government. Until a national policy on carbon tax emerges, corporates can introduce internal carbon pricing across their verticals to be prepared for the transition.

Common Circular Infrastructure

There is a need to push for developing infrastructure that enables implementation of CE actions. That would include waste recycling facilities, common material recovery facilities, sharing networks, reverse logistics and marketplaces for secondary raw materials/ used goods. That infrastructure also has significant potential to reduce emissions. For example, the common infrastructure for waste management such as the Material Recycling Facilities (MRFs) can be a catalyst for decarbonization and the circular carbon economy by diverting waste from landfills to resource recovery. MRFs include businesses that provide opportunities for waste sorting, recycling, and recovery on a scale. These businesses are set up as an independent facility servicing waste management for an industrial cluster or for urban areas. Integrated MRFs with Conversion Technologies can achieve a net reduction in cumulative GHG emissions as compared to landfilling post-recycled residuals from a mixed-waste MRF. While the States and Urban Local Bodies (ULBs) may facilitate establishment of common circular infrastructure by forming Special Purpose Vehicles (SPVs), dedicated funds could be set up for Viability Gap Funding (VGF)

with land provided on lease by the State Governments/ Urban Local Bodies (ULBs)

The Swachh Bharat Abhiyan (SBA) launched by the Honourable Prime Minister Modi in 2014 can provide a platform to meet the objectives of both circularity and decarbonization. Apart from promotion on bio methanation of organic municipal waste, projects on urban mining can make an important contribution. Urban mining looks at the reclamation of secondary resources from urban dump sites and can recover resources while transforming the dumpsites to safe landfills. Urban mining as anchored and promoted in the SBA can play a key role in the context of circular, safe and low carbon cities in India.

Circular Business Models

CE is best achieved through a careful balance between a regulatory push and private sector and community involvement. Here promotion of business models plays an important role. The business models should not only focus on use of secondary materials (SM) and resource efficiency but also address increased resource circulation through product life extension. All these efforts should lead to significant reduction of GHG emissions. A policy for product life extension could be considered with mobile phones as the pilot.

Important to highlight here are the business models created as part of the formal informal sector integration, which are increasingly being developed to manage different waste streams, particularly for plastics and e-waste and helping in fostering inclusivity. Genesis of many such business models is from eco-innovation and social innovations where these innovations are targeting the disadvantaged sections/poorer sections of the society to foster their socio-economic improvements. Some categories of such business models are cross-subsidisation (Aravind Eye Care), financing purchase (SELCO, Rickshaw Bank), micro-finance (RangDe, MicroGraam), pay-per-use (Sulabh Shauchalay, Sarvajal ATMs), and no-frills offering (Janta Meals, LifeSpring Hospitals). There are also models for para-skilling (Bank Mitra, wPower), shared channels (India Post, Frontier Markets), aggregated market linkage (eChoupal, GoCoop, Ethicus), supply-demand matching (BookMyBai, BabaJobs), and skilling (DesiCrew, Rural Shores, Youth4Jobs) (Yourstory 2019). Many of the successful business models on CE are described by Prasad Modak including those in India (Modak 2021).

Technology Development, Innovations and Partnerships

Development of technologies that align the twin objectives of CE and decarbonisation should be made a key focus. The World Economic Forum (WEF) has highlighted the need for technological innovations to scale up the solutions (WEF 2021). Examples are technologies that foster development of low carbon materials or improve process and recycling efficiencies. For example, Energy Storage in the UK has developed a technology that enables lithium-ion batteries for EVs to be repaired, upgraded and reused when they are no longer suitable for EVs (Energy Storage 2019). That extends their use life and reduces reliance on virgin lithium which is a critical raw material and faces vulnerability in the supply chain.

The steel sector roadmap developed by the Steel Research & Technology Mission of India (SRTMI) aims to promote “zero discharge, zero waste and zero harm”. There technology upgradation will play a key role. Another example is India’s cement sector. That sector has shown tremendous strides in technological upgradation and assimilation of the latest technology. Almost 99% of the total capacity in the industry is based on modern and environmentally friendly dry process technology that has helped achieve improved energy, environment, and quality standards. There is, however, still scope to further continue that upgradation towards low carbon pathways for carbon emission reduction and increased resource efficiency.

Digital technology plays a key role in designing and implementing circular solutions that can lead to emission reduction. For example, digital technology enables smart reverse logistics to achieve increased waste recirculation and reuse. Internet-of-Things (IoT) sensors embedded in smart bins provide data about waste filled in the vehicles so that waste collection vehicles can optimise schedules using the most optimal routes and save fuel and thus reduce GHG emissions.

The transition to net zero will be most successful across industry if cross-partnerships are leveraged to tap the circularity potential, whether through industrial symbiosis or through design of integrated circular business models structured around low carbon products and service provision. The collaborations could occur between innovators, industry leaders and policy makers. A joint initiative - "Circular Economy for Net-Zero Industry Transition" – by the WEF in collaboration with the Mission Possible Partnership and the governments of the Netherlands and Japan was launched in 2021. That joint initiative is to raise the decarbonisation ambition for harder-to-abate materials (steel, cement, chemicals, and aluminium) towards a 1.5-degree pathway through catalysing scalable CE solutions. In that regard, efforts to develop and use low-carbon emitting technologies (LCET) for fostering circularity should be strengthened. A focused program on the development of LCET in the priority sectors earlier listed could be taken up at the Council of Scientific and Industrial Research (CSIR) laboratories and the Department of Science & Technology (DST).

Need for an Integrated Approach

An integrated approach in policy and implementation that recognises the climate mitigation potential of CE actions is surely perhaps the way ahead. Figure-3 illustrates the CE strategies for (smart and sustainable) decarbonisation. The key approaches include policy support on net zero targets, market-based instruments including fiscal measures for incentivising efficiency improvements and addressal of knowledge and information gaps. Operationalising actions under the different approaches could be done through developing inclusive business models, technology upgradation and financing common circular infrastructure as discussed earlier.

Here learning from the international context could be brought in. For example, the 2050 Long-term Strategy of the EU develops possible scenarios to achieve a climate neutral EU in 2050. The scenarios aim at the full deployment of all technology options as well as a more circular economy. In addition, several cross-cutting requirements are identified to ensure that low carbon and circular public procurement requirements are placed

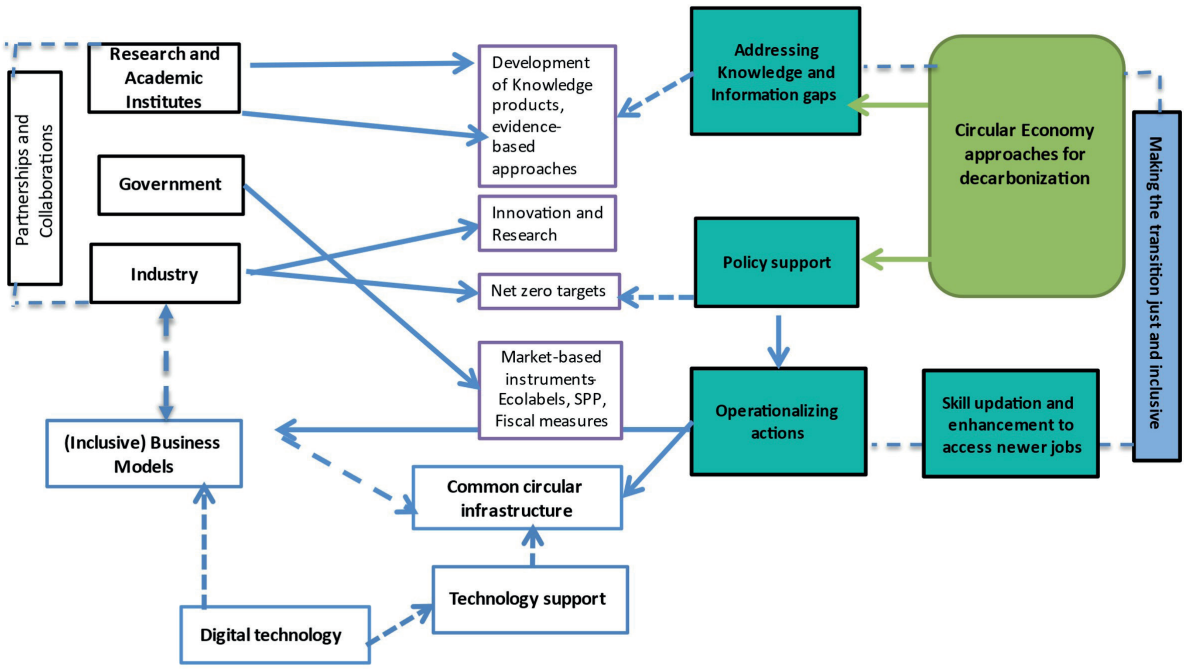


Figure-3: Integrated Approach towards Circular Economy and Decarbonisation

in all future revisions of EU sector legislation for key sectors. These sectors include buildings, vehicles, public works, and infrastructure.

Building Climate Resilience

It is important that the potential of CE to build climate resilience is fully recognised. The Platform for Accelerating the CE has argued that 'the best way to build resilience against future pandemics and the impact of climate change is to move to a CE' (Ishii & Houten 2020). The authors recommended (a) implementing economic stimulus packages focused on green and circular investment, (b) developing policy frameworks to support the formation of a CE (e.g., phasing out single-used plastics), (c) adopting circular business models and (d) promoting innovation to stimulate creativity and future solutions. The need for 'green, circular, scalable, customisable technologies' and increased interconnectivity for greater resilience and enhanced response capacity has also been highlighted (Fokeer & Domenech 2020). It may be observed that under the leadership of the Honourable Prime Minister, actions on many of the above have already been taken.

Looking Ahead

The UN World Social Report 2020 states that 'a just, equality-enhancing transition towards inclusive green economy calls for the integration of climate action with macroeconomic, labour and social policies aimed at job creation, skills development and adequate support for those who will be harmed'. For that, diversification of the economy and the resource use base, will help protect the vulnerable communities from the burden of the transition.

The shift to a CE is expected to generate net employment gains, with new jobs created mainly in recycling, rental and repair services, remanufacturing, secondary material production, and the sharing economy (McCarthy, A. et. al. 2018). However, focus on skill updation and enhancement is imperative to allow people to access the newer jobs and the changing nature of work. It is also important that the jobs are safe and decent. Hence to ensure that the net zero transition is just, efforts being taken by the Ministry of Skills and Entrepreneurship need to be stepped up with more involvement of the private sector for financing, and Community-Based Organisations (CBOs) for ground level support.

Transforming to CE will help India to decouple economic growth with GHG emissions and help meet the commitment to be net zero by 2070. We however need evidence-based demonstration about the inter-linkages between CE and decarbonisation. While many strategies have already been implemented in that regard, an integrated approach is required with inter-ministerial coordination supported by an overarching institutional arrangement. Such an approach when adopted on a mission mode will make India future ready and take on a leadership towards a smart and sustainable growth.

References

1. TERI (2019) Reference Report for "National Resource Efficiency Policy" for India. The Energy and Resources Institute. Available at https://www.teriin.org/sites/default/files/2019-04/National-Policy-Report.pdf; Last accessed on 6th December 2022

2. PMINDIA (2021) PM's address from Red Fort on 75th Independence Day -https://www.pmindia.gov.in/en/news_updates/pms-address-from-the-red-fort-on-75th-independence-day/?comment=disable

3. PIB (2022) https://pib.gov.in/PressReleseDetail.aspx-?PRID=1802833#:~:text=%E2%80%9CWorld%20is%20witnessing%20depletion%20of,mandatory%20part%20of%20our%20lives%E2%80%9D&text=The%20Prime%20Minister%2C%20Shri%20Narendra,Energy%20for%20Sustainable%20Growth'%20today.

4. EMF(2016), Ellen MacArthur Foundation, Circular Economy in India: Rethinking growth for long-term prosperity, 2016, http://www.ellenmacarthurfoundation.org/publications/

5. ILO (2018), World Employment Social Outlook 2018: Greening with jobs, Geneva: International Labour Organization, Available at https://www.ilo.org/weso-greening/documents/WESO_Greening_EN_web2.pdf

6. OECD (*n.d.)* https://data.oecd.org/materials/material-consumption.htm

7. CII (2021) 'GreenPro' certified Products, Materials and Technologies Directory Available at https://ciigreenpro.com/uploads/newsletters/Directory%20on%20Green%20Products,%20Materials%20&%20Technology_2021.pdf; Last accessed on 6th December 2022

8. EMF (2021) Ellen MacArthur Foundation, Completing the picture: How the circular economy tackles climate change (2021) Available at https://emf.thirdlight.com/file/24/cDm30tVcDDexwg2cD1ZEcZjU51g/Completing%20the%20Picture%20-%20How%20the%20circular%20economy%20tackles%20climate%20change.pdf

9. Arup & enel Foundation (2021) Circular Cities. Impacts On Decarbonization and Beyond Available at https://circulareconomy.europa.eu/platform/sites/default/files/circular_cities_-_impacts_on_decarbonization_and_beyond_0.pdf; Last accessed on 6th December 2022

10. Kukreja, Kapil & Sharma, Prateek & Mohapatra, Bibekananda & Saxena, Ashutosh. (2020). Indian Cement Industry: A Key Player in the Circular Economy of India. 10.1007/978-3-030-44248-4_18. Available at https://www.researchgate.net/publication/343242799_Indian_Cement_Industry_A_Key_Player_in_the_Circular_Economy_of_India

11. WEF (2021) Net Zero Carbon Cities: An Integrated Approach INSIGHT REPORT JANUARY 2021 Available at https://www3.weforum.org/docs/WEF_Net_Zero_Carbon_Cities_An_Integrated_Approach_2021.pdf

12. PIB (2022) https://pib.gov.in/PressReleasePage.aspx?PRID=1799067

13. IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hertwich, E., Lifset, R., Pauliuk, S., Heeren, N. A report of the International Resource Panel. United Nations Environment Programme, Nairobi, Kenya. Available at https://www.resourcepanel.org/reports/resource-efficiency-and-climate-change

14. Material Economics (2018) The Circular Economy – A Powerful Force for Climate Mitigation. Available at https://materialeconomics.com/publications/the-circular-economy-a-powerful-force-for-climate-mitigation-1

15. Change Started (2021) https://changestarted.com/big-indian-companies-that-have-made-climate-commitments/

16. SBT https://sciencebasedtargets.org/

17. Yourstory (2019) Book Review of Social Entrepreneurship in India: Quarter Idealism and a Pound of Pragmatism, by Madhukar Shukla; Available at https://yourstory.com/2020/03/social-entrepreneurship-india-startups

18. Modak, P. (2021) Practicing Circular Economy, CRC Press, ISBN 9780367619572

19. WEF (2021) 4 ways the circular economy can help heavy industry reduce emissions. Available at

20. https://www.weforum.org/agenda/2021/04/4-ways-circular-economy-help-heavy-industry-reduce-emissions-wcef/

21. Energy Storage (2019). Cycle of life: a circular economy approach to lithium batteries. Available at Cycle of life: a circular economy approach to lithium batteries - Energy Storage News (energy-storage.news)

22. Ishii, N., & van Houten, F. (2020). To build a resilient world, we must go circular. Available at https://www.weforum.org/agenda/2020/07/to-build-resilience-to-future-pandemics-and-climate-change-we-must-go-circular/

23. Fokeer, S., & Domenech, T. (2020). Why innovative manufacturing and circularity are key for a resilient manufacturing industry post-COVID-19. Available at https://www.greengrowthknowledge.org/blog/why-innovative-manufacturing-and-circularity-are-key-resilient-manufacturing-industry-post

24. https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/02/World-Social-Report2020-FullReport.pdf

25. McCarthy, A., Dellink, R. and Bibas, R. (2018), *The Macroeconomics of the Circular Economy Transition: A Critical Review of Modelling Approaches*, OECD Environment Working Papers, No. 130, Paris: OECD Publishing, p. 12, Available at https://read.oecd-ilibrary.org/environment/the-macroeconomics-of-the-circular-economy-transition_af983f9a-en#page8

02

Role of Consulting Engineers in Transforming Current Linear Economy to a Sustainable Circular Economy

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Abstract

The two terminologies - Circular Economy (CE) and Sustainability are used interchangeably, but they are not quite synonymous. The thought process in current engineering disciplines is largely driven by Linear Economy (LE) principles resulting into efficiency and efficacy without proper holistic consideration to Ecology. This paper provides an understanding of the need for combining ecological perspectives with engineering disciplines to realize the dream of CE. This paper discusses the pivotal role that Consulting Engineering community can play in transforming LE to CE.

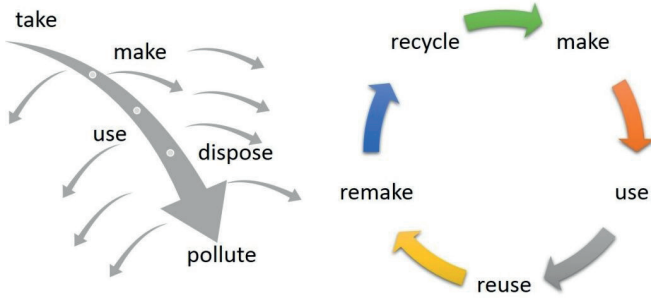
Introduction

The Industrial Revolution of the late 18th and early 19th centuries, has thus far exerted unprecedented impact on the global economy. It was driven by adoption of radically new manufacturing processes in a few countries which controlled the global trade routes and had access to seemingly unlimited low-cost resources and captive markets. The mantra was to produce more and more. That mantra spawned the Linear Economy (LE) which survived recessions and world wars and the economic booms thereafter. It led to the emergence of the consumer society. It was well into the 20th century before the finiteness of resources started becoming evident and the consumption driven model was challenged by emerging concepts of sustainability. The folly of depending solely on fossil fuel and causing irreparable damage to the environment in terms of pollution and climate change, was as clear as the proverbial writing on the wall. Nations and governments started framing policies and setting common Sustainable Development Goals. The most affected party, the Generations Next, became assertive and vociferous. The stage was set for the emergence and global acceptance of the concept of Circular Economy (CE).

Although the terminologies CE and Sustainability are used interchangeably, these two concepts are not one and the same. Geissdoerfer et al. (2017) researched the similarities and differences in these terminologies and found that there are more than 300 definitions in circulation for sustainability itself. For this paper, the definition of sustainability considered is as provided by ISO 15392, 2008 - *"a situation in which human activity is conducted in a way that conserves the functions of the earth's ecosystem"*. Geissdoerfer et al. (2017) also provided the definition of CE as *"a regenerative system in which resource input and waste, emission*

and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling". CE necessitates rethinking of entire product life cycle starting from design, engineering, sourcing, manufacturing, distribution, consumption up to disposal / recycling.

These two concepts are depicted in Figure-1.



Linear Economy (LE) Circular Economy (CE)

Figure-1: *A Simple Illustration of Linear Economy and Circular Economy*

Courtesy: www.entrepreneurship-campus.org/

This paper discusses the roles and contribution of Consulting Engineering in the transformational journey from LE to CE.

Role of Consulting Engineers in Asset Creation and Asset Operationalization – in a Linear Economy

A Linear Economy is characterized by its focus on driving growth through increasing consumption. Manufacturing processes traditionally take raw materials from nature, which are then processed into products for consumption. At the end of their useful life, the major portion of the products go back into nature as waste. Such a relation between earth resources and waste is a major concern to the entire ecology. More the consumption in LE, the greater the ecological degradation. It thus necessitates careful thought of the ecological impact at the design stage itself. In their study of the role of process engineering in CE, Londoño et al. (2021) cite the study conducted by The Sustainable Europe Research Institute (SERI). As per its estimate, each year Economic Co-operation and Development (OEDC) countries reuse, recycle, compost or digest just 55% of the extracted material and products while 45% or so ends up in the land fill. That is a very huge amount of mass and energy wastage.

Under the LE environment, the Consulting Engineers are mandated to continuously improve efficiencies of the systems, processes, procedures, plant & equipment, with the objective of increasing production and driving consumption.

The services such as safety assessments, value engineering, risk analysis, time study, energy audit etc. are now standard items in the repertoire of Consulting Engineers. Such services help to drive down unit production cost, enhance operation predictability and repeatability by reducing or eliminating or mitigating risks, thereby driving production with consistent product quality, leading to enhanced consumption. In all that, the crucial aspect of ecological considerations at each stage of product creation, usage and retirement after useful service life, is missed altogether.

In a LE eco-system, Consulting Engineers ensure that efficiencies and economies of scale are built into the systems and processes from conceptual stage, through design and engineering, procurement to execution. Redundancies are evaluated and captured at the design stage itself so that unplanned down times can be avoided. Reliability studies and preventive maintenance techniques help to develop robust standard operating procedures. Ergonomic studies help to improve employee productivity and user experience. Code compliances, statutory certifications and disaster management systems contribute to reducing insurance costs.

As technologies evolved, Consulting Engineers were uniquely positioned to advice customers regarding economies of scale and capacity finalization. Debottlenecking studies helped to unlock capacities with minimal investments. Almost all services were aimed at increasing production and consumption for the present, without any significant consideration of its impact on the future.

Role of Consulting Engineers in Asset Creation and Asset Operationalization – in a Circular Economy

A Linear Economy becomes Circular when businesses cease to prioritize profit over ecological sustainability. Manufacturers are mandated by government policies and trade policies such that the needs of the future are a consideration in their business growth policy, in recognition of the finiteness of global resources.

Reh, L. (2013) emphasized the critical role played by process engineering experts in the CE journey. The process engineers work in various aspects of production set up, safety, mass and heat balance, energy recovery, reduction of harmful exhausts etc. Thus, the engineering stream becomes very vital to ensure that production processes and manufacturing plants are set up in such a way that 4R (Reduce, Reuse, Recycle and Restore) of CE get adequately addressed. Thought through process design can have significant impact on raw material extraction, mass transportation, energy conversion and production of end products without having any harmful affluent as a byproduct.

There again, like in a LE, Consulting Engineers find themselves best positioned to bring a positive impact. The demands of the CE are such that Consulting Engineers only need to make incremental changes to their services portfolio, while at the same time draw synergies from those already existing in their menu. After all, Consulting Engineers by the very nature of their business, not only keep abreast of the demands of the industry in a broad-based manner but tend to be usually ahead of the curve.

Schönborn et al. (2021) proposed the concept of redefined Ecological Engineering. They argue that the last couple of centuries have witnessed unprecedented technology led advancements in the quality of lives of human beings. The engineering disciplines played a key role in those advancements. However, in hindsight, the linear thinking approach has resulted into environmental degradation and has had a negative impact on the ecology. It is time to combine the ecology-based systems thinking as part of engineering discipline. As most of the material flow, energy conversion, product creation and usage are driven by engineering disciplines, it is imperative that the ecology-based thinking during the conceptual and design phases can have a positive impact on the path of CE.

Demestichas et. al (2020) studied the role of engineering especially that of ICT (Information and Communication Technologies) on the journey towards CE. The authors studied various ICT technologies like Communication, Computing Technologies, Cyber-Physical Systems, Data Analysis & AI, Data collection & IoT, Data Management & Storage, Software & Simulation Technologies, Other smart technologies, etc. They further analyzed the impact of these technologies on the 4 important pillars of CE viz. Reduce, Reuse, Recycle and Restore. The research comprehensively establishes the positive impact of engineering and technology in making CE a reality.

Innovative elements of waste management in terms of reduction, reuse and recycling need to be built into the DNA of a product lifecycle from design and sourcing to use and discarding/recycling. The portfolio of Consulting Engineers in that scenario may typically include system elements that are restorative and regenerative by design, such as:

- Renewable energy options
- Extending product life
- Concepts of use and reuse
- Use of bio degradable materials
- Recycling options
- Additive manufacturing techniques
- Less harmful plastics
- Energy, utilities & consumables optimization techniques
- Debottlenecking studies
- Technology upgrades
- Energy recovery from waste disposal/ incineration

Discussion

a. Changes due to the Move from 'Linear' to 'Circular' Thinking

Whereas "sustainability" came into vogue in the latter half of the last century, the more comprehensive concept of CE is recognized and accepted globally

as our best bet for "*meeting current needs without compromising the ability of future generations to meet their needs",* only in this century. Though the concept is still in the nascent stage, it is evolving rapidly as the necessary frameworks and guidelines are getting established at global and national levels. Those may be followed by revisions or updates of applicable legal statutes in the local, national and international arena.

The Consulting Engineers can exert far reaching impact on tender documents in terms of contractual scope, guarantees, warranties, penalties and other terms & conditions. Even the text of standard supporting documents such as Bank Guarantees, etc. may be affected.

New codes and standards may come into existence in the domain of materials, design, engineering & execution. Scope of procurement and sourcing due diligence and supply chain boundaries may get enlarged. Established norms of cost and schedule may cease to be applicable.

New quality standards and certifications may come into existence. Audit procedures and expectations may change. Prevailing Safety, Health & Environment policies may get rewritten. New local and national environment regulations and emission targets may become applicable.

Modified costing standards and procedures may come into existence which would change the way projects are evaluated and IRR is determined. Opportunity costs may play a larger role in calculating the lifecycle cost.

As new metrics emerge and get established, the Consulting Engineers would be forced to adapt quickly by re-thinking, re-learning and re-training. Deliverables would be impacted in terms of changes to existing ones or addition of new ones.

Nikolaou et al. (2021) studied large volume of literature related to both sustainability and circular economy and suggested that instead of research in isolation, the interdisciplinary research in the areas of engineering and management is the need of the hour.

Prof. Roger H.W. Sargent pioneered the concept of Process System Engineering (PSE) in the mid-20th century. Avraamidou et al. (2020) provide a detailed illustration and analysis of how the objectives of PSE and CE significantly overlap as depicted in Figure-2. The authors in this article have further explained how the progress made in the field of PSE can help CE aggressively leapfrog.

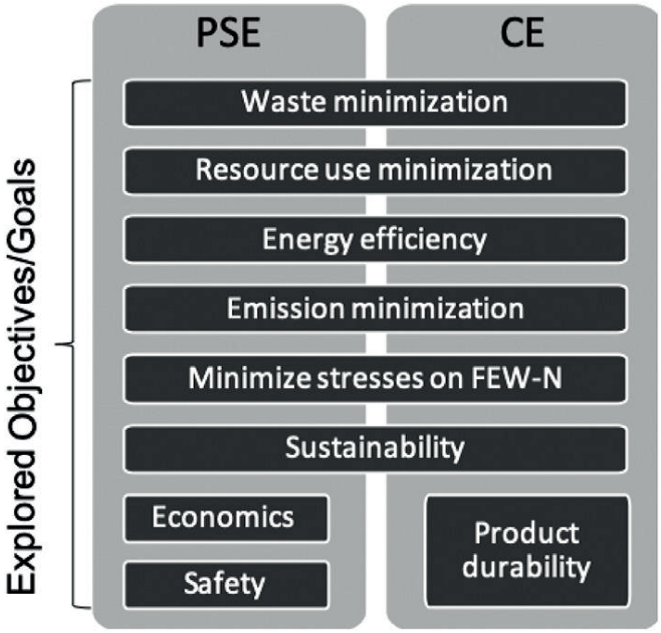


Figure_2: *Explored Objectives in Process Systems Engineering and set Goals of Circular Economy.*
Figure Credit: *S. Avraamidou, S.G. Baratsas and Y. Tian et al. Computers and Chemical Engineering 133 (2020) 106629*

The plastic industry is taken as an illustration for the role of consulting engineers in CE.

b. Impact on Plastics Industry – A Micro View

One of the most maligned industries in the name of negative impact on environment is the plastics industry. It is an industry whose products have found worldwide acceptance due to the versatility of the material - in varied sectors from household to aviation, from healthcare to automobiles, from packaging to beauty products. Plastics enjoy tremendous advantage in terms of strength to weight

ratio, ease of manufacturing, durability, aesthetics, customizable compositions, etc.

However, the near indestructibility of plastics, itself became a curse for the industry when traces of micro-plastics started turning up even in the most unimaginable places such as deep sea, arctic snow and even in drinking water. While the subject is still under study for its impact on environment, animal, marine and human life, scientists and world opinion are generally in agreement that it is a matter of serious concern for the future, if nothing is done now.

According to the United Nations Environment Programme (www.unep.org/interactives/beat-plastic-pollution), the annual generation of plastic waste currently is 400 million tonnes globally. That has led governments and international bodies to fund research programs, in order to facilitate informed decision making and to create legislations for regulating the manufacture, use and disposal/ recycling of plastics. The rise in use of single-use plastic has been identified as a major menace. That has resulted in bans even at local administration levels such as panchayats.

Global industry leaders have also risen to the occasion and have started coming up with their own programs and initiatives for transformation, aligned with government and international sustainability targets. Such programs are focusing on the entire value chain in collaboration with upstream and downstream partners.

A pertinent example would be that of SABIC (Saudi Arabia Basic Industries Corporation), one of the largest players in chemical industries. Its TRUCIRCLE™ (www.sabic.com/en/sustainability/circular-economy/trucircle-portfolio-and-services) program focuses on:

- Designing for Recyclability – tailored resins for the development of products that have improved recyclability characteristics
- Mechanically recycled products – Compounds with high recycled content and booster resins for recycle containing compounds that can improve processability and end-use properties
- Certified circular products – Virgin resins and chemicals from difficult to recycle used plastics produced through feedstock recycling
- Certified renewable products – Resins and chemicals from bio-based feedstock that are not in competition with the human food chain and that can help mitigate potential effects of climate change
- Closed loop initiatives – Value chain collaborations to create virgin materials and help prevent that valuable used plastics become waste

Similar programs are being implemented by other global industry leaders such as Dow Chemicals, Exxon Mobil, Lyndon Bassel, etc.

c. Impact on Overall Macro-Economics

Opportunities/ Benefits

According to World Resources Institute (www.wri.org) the shift to a Circular Economy proffers the following opportunities:

- Better use of finite natural resources like forests, water, metals & minerals. That could be from the development of improved sustainability-based processes or enhanced recycling resulting in reduced usage of virgin raw material.
- Reduced greenhouse gas emissions leading to positive impact on climate change and environment. Emissions are being generated at almost every stage of a product's life cycle starting from manufacturing and transportation up until their disposal.
- Protection of human health and biodiversity by means of reduced environmental pollution resulting from excessive waste generation.
- Boost economies in terms of direct investment opportunities in manufacturing, supply chain industries etc. or indirect benefits to fishing, tourism industries etc. or creation of new

industries in the field of waste management. Adoption of innovative practices will get a stimulus.

- Creation of new job roles and job opportunities. For e.g., when recycling becomes a formally recognized industry, many unorganized workers can come under the umbrella of a formal job and get the opportunity to enjoy better working conditions leading to a safer and more secure lifestyle.

Risks

On the other hand, there are risks or downsides too:

- The global economy is interconnected between almost all the industries in the world in terms of feedstock, supply chain, etc. One raw material can be the feedstock for many industries, the products of which could be feeding into many other industries. That means that whereas isolated circularities can exist, a systemic change to circular economy would happen only if a multiple number of interconnected industries would implement adequate transformation programs in a coordinated manner.
- Shifting to sustainable resources or raw materials in one industry may be at the expense of an increase in the demand and consumption of resources in another industry which may not be proportionate to the expected benefits. Such shifts would be meaningful only if the other industry is also operating in a sustainable manner.
- CE is likely to see investment and employment opportunities shifting from the earlier stages of the value chain to the later stages such as repair, resale, recycling, etc. at the cost of opportunities in production and manufacturing. That could have a negative impact on social wellbeing and equity in lower income countries where production and manufacturing facilities tend to be located.
- Not all forms of waste are recyclable. That can make the proposal to shift less appealing in some industries. Lack of awareness and technical skills in the workforce can also become a hurdle. The market is yet to reach maturity levels that can foster access to favorable financing.
- A final important factor in reaping the economic benefits of a Circular Economy are the changes that would be necessary in the customer behavior and consumption pattern. That would be in terms of extending the useful life of a product by means of repair and maintenance, responsible recycling or disposal etc.

Conclusions

Any economy, whether Linear or Circular, is characterized by production and consumption. In either model, any resource that is taken from nature, eventually finds its way back to nature. But the difference is, “HOW”, “WHEN” and “WHAT”.

“HOW” in terms of how much is taken from nature, “WHEN” in terms of at what all stages of the product life cycle is it going back to nature and “WHAT” in terms of what all forms is it being returned to nature.

All three of them are heavily determined by the elements which are built into the design, engineering and manufacturing of these products, either at basic engineering or FEED (Front End Engineering & Design) stage.

Consulting Engineers are a repository of data, knowledge, experience, best practices, lessons learned, cost analysis and case studies in project design and engineering in the capex space. They have the wherewithal to strengthen organizational executive management decision making process by providing data based strategic inputs and analytical support. They are also well positioned to work together with owners, authorities, construction & fabrication contractors, plant & equipment manufacturers and vendors, maintenance contractors, et al. to meet the stringent standards of the future.

Almost all the nations of the world under the aegis of various international organizations have pledged support to the cause of Circular Economy. All the leading

corporates in all the various industries are already on-board and have declared their intentions with clear objectives and targets. It is only a matter of time before the rest also follow.

CIRCULAR ECONOMY IS NO MORE A CHOICE BUT A NECESSITY

References

1. Avraamidou, S., Baratsas, S. G., Tian, Y., & Pistikopoulos, E. N. (2020). Circular Economy-A challenge and an opportunity for Process Systems Engineering. *Computers & Chemical Engineering*, *133*, 106629.
2. Demestichas, K., & Daskalakis, E. (2020). Information and communication technology solutions for the circular economy. *Sustainability*, *12*(18), 7272.
3. Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The Circular Economy–A new sustainability paradigm? *Journal of cleaner production*, *143*, 757-768.
4. Londoño, N. A. C., & Cabezas, H. (2021). Perspectives on circular economy in the context of chemical engineering and sustainable development. *Current Opinion in Chemical Engineering*, *34*, 100738.
5. Nikolaou, I. E., Jones, N., & Stefanakis, A. (2021). Circular economy and sustainability: the past, the present and the future directions. *Circular Economy and Sustainability*, *1*(1), 1-20.
6. Reh, L. (2013). Process engineering in circular economy. *Particuology*, *11*(2), 119-133.
7. Schönborn, A., & Junge, R. (2021). Redefining ecological engineering in the context of circular economy and sustainable development. *Circular Economy and Sustainability*, *1*(1), 375-394.
8. www.entrepreneurship-campus.org/
9. www.sabic.com/en/sustainability/circular-economy/trucircle-portfolio-and-services
10. www.unep.org/interactives/beat-plastic-pollution
11. www.wri.org

IBEF
INDIAN BRAND EQUITY FOUNDATION
Indian Economy News

India among top 5 countries in global climate change performance index

November 23, 2022

According to the global Climate Change Performance Index (CCPI), India is among the top five countries and performs the best among the G-20 countries.

The index is released by the German organisations German Watch, New Climate Institute, and Climate Action Network International.

The CCPI seeks to increase transparency in global climate politics and makes it possible to compare country climate protection initiatives and advancements.

According to the CCPI, 2023, India moved up two positions to take the eighth spot. The only four nations that were rated above India in the most recent CCPI report, which was presented at COP27 in November 2022, were Denmark, Sweden, Chile, and Morocco, which were ranked fourth, fifth, sixth, and seventh, respectively. No nation received the first, second, or third places, which meant India effectively has the highest ranking among all developed economies, according to the report.

India scored highly in the categories of GHG emissions and energy use while receiving a medium rating for climate policy and renewable energy.

Disclaimer: *This information has been collected through secondary research and IBEF is not responsible for any errors in the same.*

Source: https://www.ibef.org/news/india-among-top-5-countries-in-global-climate-change-performance-index

03

Shared Responsibility Structure in the EEE Value Chain to Transition Towards Circularity

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Introduction

Electrical and Electronic Equipment (EEE) have penetrated almost every aspect of our lives. With growing population, increasing urbanisation, and flagship programmes such as Digital India, EEE is now a necessity. The importance of EEE was further highlighted during the recent COVID-19 pandemic, which increased the demand for telecommuting for work, education, and entertainment thereby disrupting the global manufacturing supply chains and straining the limited raw materials, including mineral stocks and resources, available. The widespread use of and dependence on EEE has facilitated convenience in the lives of people. However, this has resulted in excessive resource and virgin raw material consumption and widespread disposal of obsolete and end-of-life EEE at a global level. Estimations for resource consumption suggest that in the past four decades, the metal requirement has increased by 87%, and that by 2060 the global consumption of materials would double (MeitY). In terms of e-waste generation, the Global E-waste Monitor 2020 highlighted that India was the third largest generator of e-waste with 3.2 MT after China (10.1 MT) and USA (6.9MT) in 2019.

To keep up with the demand and swift progressions in the field of science and technology, the major EEE manufacturers have invested heavily in R&D of their products to stay ahead of their competitors. However, rarely has this translated into innovative, scalable solutions to reduce resource consumption upstream, or create design changes to enable easy repairability or dismantlability downstream for high value recycling and reduced residual waste generation.

To decouple resource consumption and e-waste generation from growth in the EEE sector, it is necessary to transition away from the resource intensive, linear, take-make-dispose economy, and towards circularity and resource efficiency throughout the EEE supply and value chain. The concept of circular economy is based on retaining the value of resources, products, and materials by keeping them in use for as long as possible, simultaneously striving to minimise waste generation and prevent leakages at each life-cycle stage. That can happen by extracting the maximum value through reuse, repair, recover, remanufacture and regeneration of products and materials at the end of each service value. In the context of EEE, that may be achieved by tapping into e-waste as a potential source of Secondary Raw Material (SRM). This article presents a framework by which a shared responsibility structure for key stakeholders along the EEE value chain could enable such a transition towards circularity in India.

Challenges Faced by the EEE Sector

The main challenge faced in the EEE sector remains a lack of clarity on the definition of EEE. There is a need to

have a common consensus of what EEE entails. There are many definitions for EEE, which present a challenge in quantifying the magnitude of the problem. According to E-waste Management Rules, 'e-waste' means electrical and electronic equipment, whole or in part discarded as waste by the consumer or bulk consumer as well as rejects from manufacturing, refurbishment and repair processes. The E-Waste Management Rules until recently only included 21 categories of EEE that fall under two broad sections

i. Information Technology and Telecommunication Equipment (ITEW), and

ii. Consumer Electrical and Electronics and Photovoltaic Panels (CEEW).

The United Nations Institute for Training and Research (UNITAR)'s Global E-Waste Monitor 2020 however has a much broader definition of e-waste, according to which EEE becomes e-waste once it has been discarded by its owner as waste without the intent of reuse. Varied definitions and gross underestimation of categories of EEE has given rise to different estimates for e-waste generation for India in national and international reports. The estimated e-waste generation in India was about 1.02 MMT in 2019-20. However, the values reported by the Central Pollution Control Board (CPCB) are less than a third of the e-waste generation reported by the UN, according to which India generated nearly 3.2 MMT of e-waste in 2020 (MoEFCC 2020; Fortis, V. et. al. 2020). Recently however, the E-waste Management Rules 2022 have expanded the 'e-waste' definition to include solar PV modules/ panels/ cells. Further, the new rules increase the current, limited two categories of EEE to seven categories. The new categories are:

iii. Large and Small Electrical and Electronic Equipment (LSEEW);

iv. Electrical and Electronic Tools (with the exception of large- Scale Stationary Industrial Tools) (EETW);

v. Toys, Leisure and Sports Equipment (EETW);

vi. Medical Devices (with the exception of all Implanted and Infected Products) (MDW); and

vii. Laboratory Instruments.

The new E-Waste (Management) Rules, 2022 therefore, provide a more holistic definition of EEE and e-waste, which would allow for a more accurate estimation of e-waste generation.

Currently, e-waste management faces many leakages throughout its value chain, leading to inaccurate estimation of resource consumption and waste generation. According to the rules, the EEE manufacturers are mandated to collect and ensure recycling and disposal of e-waste generated during manufacturing, refurbishers to collect e-waste generated during refurbishing and hand it to recycler, and recycler is to keep record of e-waste collected, dismantled, recycled on the portal, readily available for verification and audits. The Urban Local Bodies are to ensure that the e-waste is collected and channelised to authorised recyclers. From the refurbishers the e-waste is sent to authorised recyclers who may take help from dismantlers and are required to recycle e-waste, and send the non-recyclable, residual waste from recycling to Treatment, Storage, and Disposal Facility (TSDF) for final disposal. However, in terms of on-ground implementation, the desired e-waste flow processed formally is still relatively low, although there has been a growth in the formalised and authorised e-waste recycling and dismantling sector. Over 90% of India's e-waste is handled and processed by the unregulated, informal sector in an unsafe manner using non-scientific methods for resource extraction with irresponsible disposal of remnants and residual waste. The informal processing of waste, without any monitoring and tracking, leads to lack of accurate e-waste inventory. Moreover, the majority of e-waste handled in India is under-reported due to the invisibility of the informal sector, resulting in further leakages of recoverable valuables along the linear EEE value chain.

A transition to circular economy in the EEE sector therefore goes beyond strengthening the current e-waste flow presented in the rules through better downstream waste management and instead urge stakeholders to treat e-waste as a valuable resource of critical raw materials to meet the growing demand through Sustainable Consumption and Production (SCP) practices, as explained in the United Nations Sustainable Development Goals (UN-SDG-12). It has been established that e-waste can act like a concentrated

ore with nearly 1.5 kg of recoverable gold available in one tonne of mobile phone's polychlorinated biphenyls (PCB) as compared to one tonne of natural ore, which has an extractable reserve of 1.4 grams of gold only[1]. Therefore, urban mining of e-waste for high-value metal extraction can not only reduce environmental pressure on limited virgin raw materials but can also insulate the EEE supply chain from price volatility and global supply stocks resulting from materials scarcity. That would create a robust, secure and continuous supply chain of raw materials at a pre-determined price range. The FICCI Circular Economy Report, 2018 provided a strong business case for urban mining of gold from e-waste to have scope for value generation of 0.7 to 1 billion USD (FICCI & Accenture 2018).

Fostering Circularity in EEE Value Chain

Fostering circularity along the EEE value chain to create a robust supply chain, achieve price stability and material security is only possible through a shared responsibility structure where key stakeholders are made responsible to design, manufacture, consume, and dispose of EEE in a safe and sustainable manner. That would also address the adverse environmental and social impact along the entire life cycle and follow the waste hierarchy. Further, a combination of policies should be implemented to create an enabling ecosystem for shared responsibility. For that, the Extended Producer Responsibility (EPR) is one of the most robust policy approaches in the area of waste management to implement circularity.

*EPR is based on the **Polluter-Pays Principle** wherein the producer's responsibility of a manufactured product is extended to the post-consumer stage of the life cycle. In doing so, the EPR aims to achieve the two main goals of:*

i). *Shifting full or part responsibility of waste management at end-of-life (EOL) away from financially constrained municipalities and government to the producers, thereby internalising the EOL management cost.*

ii). *Providing incentives to producers to incorporate environmental considerations such as "design-for-repairability" right to "design for dismantlability" while designing their products.*

In 2011, the E-Waste Management Rules in India introduced the EPR approach for increasing the downstream segregated collection of Waste Electrical and Electronic Equipment (WEEE). The producer was made responsible for channeling e-waste to an accredited dismantler/ recycler to ensure environmentally sound waste management. The 2016 rules mandated producers of EEE to acquire EPR authorisation, including importers, e-retailers, on-line sellers, and others however, the mechanism of EPR implementation is not detailed. The E-Waste (Management) Rules, 2022 introduces the mechanism for EPR implementation as it not only places the responsibility to carry out reverse logistics on the producers but also includes collection targets for manufacturers and producers who are to ensure at least 60% e-waste collection and recycling by 2023, 70% by 2025-26 and 80% from 2027-28 onwards. The Annual EPR certificates, given to certify the quantity of e-waste collected and recycled, have the provision to be traded, so surplus quantities may be sold to non-compliant companies and help them meet their EPR target. Further the new notification indicates the movement towards systematic inventorisation through digital online portal to track EEE. Tracking of EEE produced, sold, refurbished, recycled, and disposed is needed to close the circularity loop for e-waste and EEE production. Finally, for the first time the e-waste rules, to make the key stakeholders responsible, have also instituted environmental compensation and prosecution for non-compliance in meeting the annual EPR targets.

The EPR approach presented in the E-Waste (Management) Rules, 2022, are in line with circular principles, and can be successfully implemented through a shared responsibility structure amongst key stakeholders. However, the new rule covers only four stakeholders of the e-waste value chain - manufacturers, producers, recyclers, and refurbishers, thereby excluding Producer Responsibility Organisations (PROs) and importers, and hence do not fully explain the integration of the informal sector into the formal chain. Inclusion of refurbishers and their mandate to carry out refurbishing as per Compulsory Registration Scheme (CRS) guidelines is a step towards incorporating circular principles. Limiting or deregulating the rules to only these stakeholders makes

the monitoring and tracking process for e-waste simpler but puts a lot more pressure on the stakeholders included, especially the recyclers, to maintain, collect, dismantle, recycle, and safely dispose of e-waste and maintain its inventory. Moving forward it is necessary to identify and finalise the stakeholders along the EEE value chain and comprehensively describe their responsibilities to be more in line with circular principles.

Shared Responsibility Framework for a Circular EEE Value Chain

There is a need to design a shared responsibility framework for successful implementation of EPR in line with circular principles describing the implementation of the framework at a local level; as waste generation and collection are local level issues. That would enable the national level policy makers to interact with local governments and implementing agencies such as the recyclers to understand their needs and gaps in the current scenario. The elements of a shared responsibility structure could include the following:

- ***Definition of Overall Objectives, Scope of Activities, along with Time-bound Targets*** on the reuse of secondary raw materials, reuse and refurbishing of products, collection of e-waste and recycling, in line with circular principles. That would enhance the scope of EPR activities from waste management to more upstream and midstream focus on design-for-recycle, reuse of materials and sustainable consumption.
- ***Roles & Responsibilities of Stakeholders*** to be clearly defined for regulatory enforcement and for addressing key gaps such as *who owns the waste* and which stakeholder is responsible for the EEE materials, products, and waste during different stages of the value chain and waste management process. That would include ***Strengthening the Role of Consumers & Bulk Consumers*** to become the core of the EEE value chain and its end-of-life management. ***Consumers as Agents of Change*** can drive e-waste management towards formal channels and be incentivised to move towards creating a market for refurbished and reused products through sustainable, green procurement.
- Improve e-waste collection efficiency through ***Informal Sector Integration*** and tap into the informal market of secondary raw materials by converting the informal into semi-formal clusters/ micro-industries that could also be regulated, provided financial support, and handheld to become formal clusters. Although state governments are required to ensure recognition and registration of workers involved in dismantling and recycling and assist in formation of groups to facilitate setting up of dismantling facilities, clear mechanisms and steps needed for integration with the informal sector for waste management, including trading of e-waste are to be laid down. Further, these semi-formal clusters will allow for tracking of e-waste material flow, critical raw materials, and secondary raw materials recycled.

The Tentative Rate-Card System

In some best practices of State Pollution Control Boards (SPCB), they along with municipalities and the informal sector have come up with a tentative Rate-Card System whereby the informal dismantlers and recyclers together with the government set a price per kilogram of different categories of EEE (ITEW and CEEW) items to be collected, which is used to facilitate e-waste collection. Such best practices should be replicated and scaled on a national level.

Developing mechanisms for ***Transparent data collection, tracking, reporting, and enforcement*** such as through a ***digital transformation*** of EPR development and implementation. An Online Portal as given in the E-Waste (Management) Rules, 2022 requires key stakeholders to be registered on the portal and provides key details including production, collection targets, EPR implementation status, and file returns and information on EPR credits. Elements of such a portal may be extended to track EEE, e-waste, and its material flows including critical raw material and secondary raw material flows.

- Developing a ***Circular Economy Index*** for the EEE sector that addresses key aspects of the EEE value chain from upstream eco-design to midstream sustainable consumption, product performance, and productivity, and safe disposal. Further a monitoring mechanism to have parameters to digitally

track circular economy indicators and monitor implementation of the circular economy index.

- Designing ***Effective Business Models, Funding Mechanisms, and Economic Instruments*** to facilitate effective e-waste collection, reuse such as through lease-subscription models, refurbishing, and recovery in a manner that allows EPR to create a self-sufficient model and enables a robust supply chain with continuous supply of (quality) raw materials and foster price stability.
- Institutional Strengthening by establishing an overarching advisory board to oversee the implementation of EPR and the E-Waste Management Rules composed of key stakeholders. That could be in the form of a ***Steering Committee*** at a national level with representation from MeitY, MoEFCC, Niti Aayog, and ***State-Level Advisory Boards (SLABs)*** including experts from EEE, e-waste, telecommunication, and others to ensure effective state and local level implementation and make provision of EPR schemes such as incentives to incorporate circular upstream measures such as *design-for-recycle*.

E-Waste Advisory Boards

They can take the responsibility of creating a sustainable EEE and E-Waste Management Ecosystem through social measures which would include:

i). Conducting regular stakeholder engagement & consultations

ii). Knowledge sharing of global best practices and pilot projects and their key outcomes for adaptability of EEE to the Indian sector.

iii). Encouraging awareness generation and tracking measurable behavior change.

iv). Scaling high-value recycling of metals through national level capacity development programmes.

v). Influence policy to encourage circularity in EEE such as with policies on (i) Secondary Raw Material tracking, (ii) MSME semi-formal cluster formation, (iii) use of safe, indigenous technologies, etc., and guidelines for implementing eco-design

Develop Guidelines, ***Standards/ Certifications on Refurbishing, Recycling Methods, and Occupational Safety*** with the help of key bodies such as the Bureau of Indian Standards (BIS) for safe handling of waste and to scale high-value recycling of materials in a standardised manner. The standards and certification would need to be reviewed every three to five years for updating according to new technologies present in the market. This is to move the EEE sector towards circularity while keeping products from India competitive in global markets.

- **Creating** robust reverse logistics and stable supply chains such as through semi-formal clusters, tapping into efficiencies of the informal sector, that may be tracked through the online portal. Creation of reverse logistics to be based on data collected and its analysis such as cost analysis of urban mining compared to mining of virgin materials.
- Finally, to ensure the success of a shared responsibility framework for EEE and E-Waste Management, make EPR development and its implementation a dynamic process by developing an ***Impact Assessment Module*** for real-time tracking of EPR performance, monitoring the reverse logistics, identifying gaps, and developing preventative measures to address any potential issues.

References

1. MeitY (2021) Circular economy in electronics and electrical sector. New Delhi: Government of India.
2. The Global E-waste Monitor (2020) GEM_2020_def_july1_low.pdf (ewastemonitor.info)
3. MoEFCC (2020) Guideline document on uniform framework for extended producer responsibility. New Delhi: Government of India
4. Forti, V., Balde, C. P., Kuehr, R., & Bel, G. (2020) The Global E-waste Monitor 2020: Quantities, Flows and the Circular Economy Potential
5. FICCI & Accenture (2018). Accelerating India's Circular Economy Shift: A Half-Trillion USD Opportunity
6. E-Waste (Management) Rules, 2022 (https://moef.gov.in/wp-content/uploads/2022/11/E-Waste-Management-Rules-2022.pdf)

04 Overview of Technology Perspective in Circular Economy and Sustainability

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Introduction

The global community is facing challenges from climate changes and environmental threats as never seen before. The disasters hitherto known as occurring naturally have now accelerated due to anthropogenic actions of the civilized world to such a level that it wouldn't be exaggeration to substitute the term "natural disaster" with "human assisted disaster". Frequent floods, draughts, cyclones, change of season, forest fires, rise of water level, melting of arctic ice sheets, disruptions in biodiversity, etc. are shaking the global community. But the response and awareness to the catastrophes still remain questionable. Under the present circumstances, mitigating climate change is not an option but a compulsion. The United Nations Framework Convention on Climate Change (UNFCC), the entity to support the global response to climate change is in place now and conferences amongst almost all the countries are held annually (COP) to discuss, review and commit towards the mitigation plans and targets. The Inter-Governmental Panel on Climate Change (IPCC) formed by World Meteorological Organization (WMO) and United Nations Environmental Programme (UNEP) undertake thorough study of climate change and help COP to adopt mitigation targets and measures. According to an estimate [1] carbon dioxide (CO2) contributes to more than 50%of the total GHG emissions (Figure-1). Energy, Industry and Transportation [2] contribute to 70%of the global GHG emission (Figure-2) sector wise.

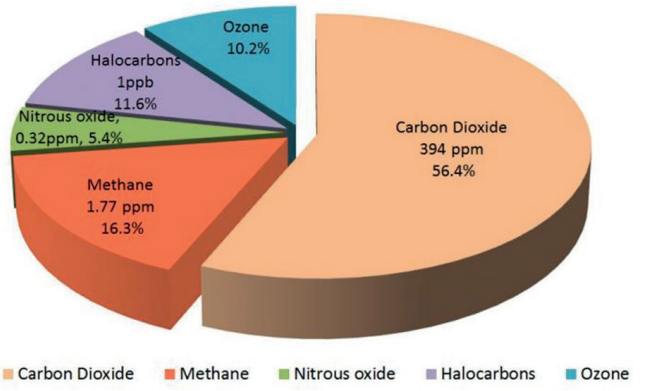

Figure-1[1]

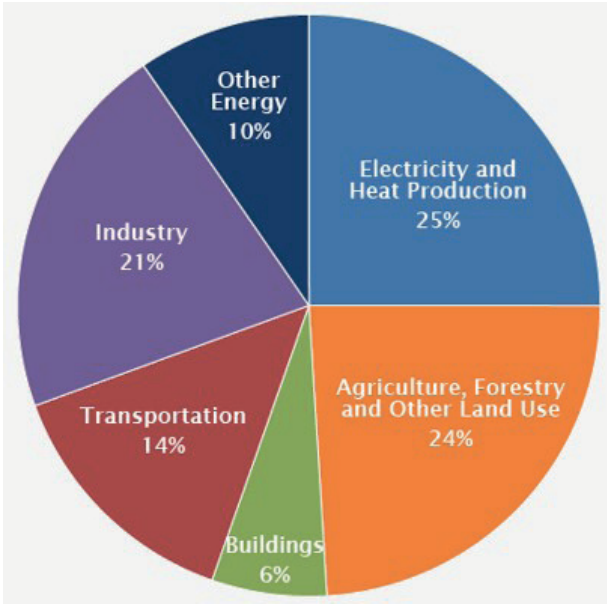

Figure-2[2]

It should be noted that about 80% of CO_2 remains for about 200 years in the atmosphere and the balance 20% may remain as long as 30000 years [3]. Figure-3 helps to easily understand the contributions and permanence of various GHGs in the atmosphere and also their severities.

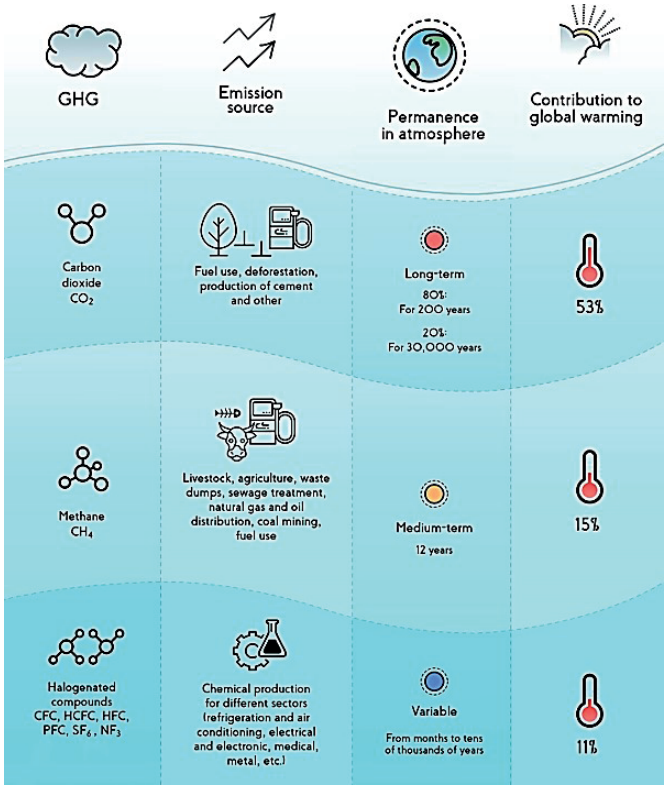

Figure-3[3]

Taking a cue from the above discussion it is obvious that the uncontrolled rise in global temperature, that too in the last two decades, - is the main concern for climate change and the resulting disasters. COP 21 (popularly known as the Paris Agreement) adopted the first concrete resolution and the commitments from the countries towards the mitigation of climate change. It was resolved to contain the increase in the global average temperature to well below 2° C above pre industrial levels and pursuing efforts to limit the temperature increase to 1.5° C above pre industrial levels.

Climate Change Mitigation vis-À-vis Circular Economy

In order to restrict global warming to the desired level, emission of GHGs, CO_2 in particular, needs to be drastically reduced. Along with that, it is necessary to reduce/ reuse wastes generated in industries and agriculture, Therefore, the end-of-life concept in the Linear Economy has to be replaced with Reuse/ Recycle measures resulting in lesser use of parent resources in the Circular Economy. Circular Economy thus would enable prolonged life cycle of resources bringing sustainability and greener environment. At the same time, it is not possible to do away with the emission of GHGs. Emissions to the atmosphere can be reduced in the Circular Economy and the objective is to reduce the content in the atmosphere to such a level so that the same can be removed from the atmosphere as well. That would make the environment carbon neutral (net zero). Hence, the Circular Economy is a major pillar in the roadmap towards carbon neutrality.

Innovations and Examples for Circular Economy and Decarbonisation

The shift from Linear Economy to Circular Economy introduces a new regime of thoughts and compels the scientists and engineers to think something different than the conventional practices. Therefore, development of new technologies along with innovations to make the existing technologies suitable for circularity have become essential. Research is being done to find out alternative low carbon materials to substitute/ reduce the use of materials emitting large quantum of carbon to the atmosphere. The major attention is to convert waste to resources and conserve the natural resources by reducing their extraction and use.

Driven by the global endeavour and support by the State, a lot of innovations are happening on the technology and engineering front to embrace the Circular Economy and Sustainability in the fight against global warming. Startups are playing a phenomenal role in the technology development along with the big corporations. Report [4], based on studies carried out on a big sample size, demonstrates the recent noteworthy achievements by the startups. It has revealed that primarily eight areas are leading the trend in the innovations and development of technology to embrace circularity. They are:

(i) Waste to Resource
(ii) Reuse
(iii) Internet of Waste
(iv) Artificial Intelligence
(v) Biobased Materials
(vi) Remanufacture
(vii) Blockchain
(viii) Repair

The extent of the impacts on the Circular Economy by the technologies developed in the above fields have been assessed and are as shown in Figure-4.

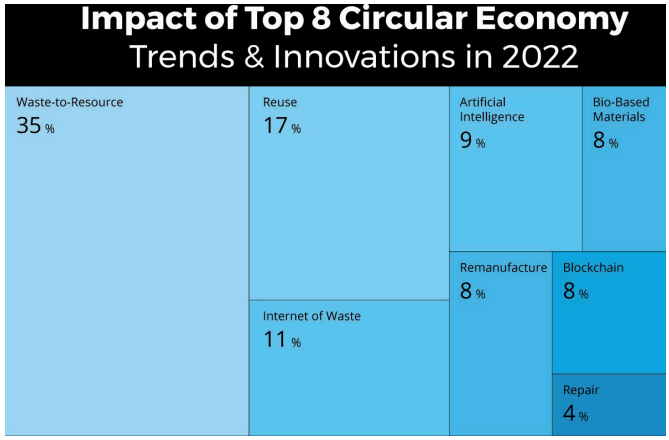

Figure-4[4]

A few of the top recent innovations [4] in the landscape of Circular Economy for sustainability are summarized in the table below.

Sl. No.	Field	Description
	Waste to resource	Textile wastes like jeans/ workwear are upcycled to make sneakers. Sole is made of eco-rubber produced from recycled rubber (70%) and original rubber (30%). Insoles and laces are made from plant-based materials and recycled cotton. Upon reaching the end-of-life sneakers are shredded and reused for manufacturing of new ones.
	Reuse	Reusable cutleries like tray, bowls, etc. and packaging are made from recyclable polypropylene. Consumers can return the items to the participating partners. Items are verified by scanning the QR codes for verification. Then these are fed to the gastro dishwasher for reuse.
	Internet of waste	IoT based smart bins are made to automatically segregate the paper, plastic and cans. IoT based solutions are offered to identify filling of bins, route optimization for collection of waste, monitoring of waste collection, analyses and reports on amount and type of waste, time spent for collection, etc.
	Artificial Intelligence	A digital twin has been developed which connects the waste management infrastructure. The AI based tool identifies flow, composition and characterises the waste in real time.
	Bio based materials	Pre-engineered tiles and wall panels are made from agro products and mycelium strains are grown on these substrates. It reinforces the products to impart strength creating items for interior decorations (tiles & wall panels) devoid of woods, plastics.
	Remanufacture	Old and used compressors are inspected for reconditioning and reuse. The parts found unsuitable are replaced with new ones. The remanufactured compressors undergo testing and warranties, even extended warranties as for new ones are given.
	Blockchain	The solution credits points to the consumers after analysing the recyclable items returned by them in smart bins. The points can be redeemed for purchasing new goods/ services. The solution captures all carbon footprint data of the returned items during manufacturing to disposal in a public ledger which helps the government to take efficient environmental decisions based on evidenced data.
	Repair	The solution provides repair and maintenance services to the consumers by integrating the device manufacturers, retailers, service providers and insurance companies.

Apart from above the fields wherein considerable progress in technology and engineering has been made and/ or research is being done with the objective of decarbonisation, include Hydrogen and Hydrogen Infrastructure, Renewables, Modularisation, Substitution of high carbon emitting materials with alternative materials of low carbon footprint.

Hydrogen and Hydrogen Infrastructure

The research is emphasising and concentrating now on cost affordability for hydrogen adoption. Figure-5 [5] below predicts that green hydrogen may be cost competitive vis-à-vis grey hydrogen by the year 2050.

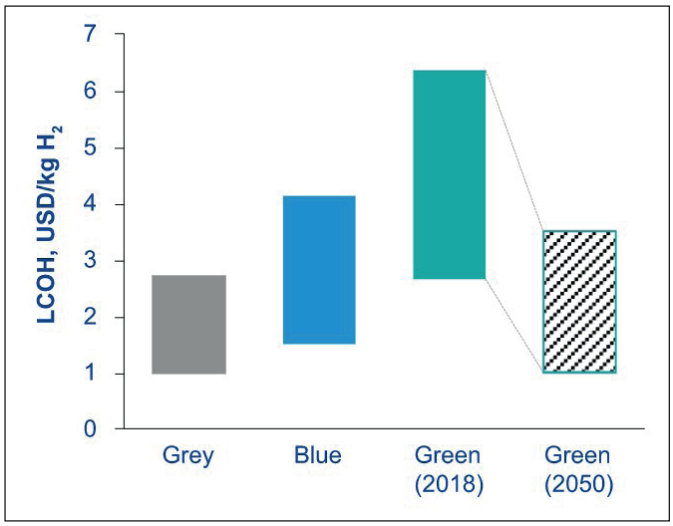

Figure-5[5]

Renewable Energy

Conforming to the COP21 goal of limiting global warming below 2°C by the end of the century is making a shift from fossil fueled power to renewables. According to the report [6], gross power generation would almost double by 2050 with renewable energy contributing 85% of the total electricity generated. Solar and wind would share the major part, about 60% of the renewables [6]. In line with that, numerous innovations and patents are being reported in the floating solar and offshore wind power.

Countries sensitive to ambitious climate targets are planning to increase the share of renewables up to 60 to 70 % in the power mix by 2035 accelerating deployment of Long Duration Energy Storage (LDES) as the lowest cost flexibility solution [7].

Modularisation

Modularisation enables reuse and less wastage thus resulting in prolonged life of structures. Though modularisation is not so new a technology compared to other circular economy technologies, but it is an evolving procedure to suit the type and nature of requirements. The best example of modularisation in recent times is the Football stadium called "974" in Doha, Qatar for the FIFA World Cup 2022. It is a modular design and 974 recycled shipping containers have been used to build it. It is being dismantled now as the matches are over and it is planned to be reassembled on a continent on the other side of the globe [8].

Alternative Materials

While development of alternative materials for low carbon footprint is a vast area, construction materials like cement, steel and bitumen are largely responsible for carbon emission. Some developments of alternative materials in this respect are illustrated.

Materials	Benefits
Cement made by 95% fly ash and 5% renewable liquid additives [9]	i. Recycling of industrial waste Fly ash. ii. Nearly zero carbon footprint. iii. 95% savings in use of virgin materials like Limestone. iv. 50 % less use of water
Geoploymer cement/ alkali activated cement This is produced from aluminosilicates instead of conventional raw material calcium oxide which is more damaging to the environment [9].	Aluminosilicates are obtained from Fly ash. 95% less CO2 compared to Ordinary Portland cement (OPC).

Sequestrated carbon cement CO_2 is processed with seawater to produce cement [9].	i. CO_2 recycling ii. Raw materials do not need mining
Glass Fibre Reinforced Polymer (GFRP) rebar [10]	i. Savings in Carbon footprint. ii. Less energy consumption
Bio bitumen [11]	Agricultural wastes like rice, wheat straw are used as feedstock. Lignin is used to have binding and viscous properties. Lignin is a co product obtained from Ethanol plant, paper making and compressed biogas plants.

Major Challenges to Technology and Circular Economy

1. Technology Readiness Level (TRL): As mentioned earlier, technologies and innovations are the major pillars for decarbonisation. Research and experiments, onboarding of new technologies have taken a front seat, but the scale of technology readiness and implementation for achieving net zero by 2050 is still a question mark. The good thing is that Reports [12] suggest that technologies for achieving 60% of the targets set for 2050 in respect of emission abatement have already matured. Challenges remain for the balance 40% of emission abatement where 25 to 30 % of the technologies are being developed but have not matured and 10 to 15 % of them are still in the R&D stage.

2. Investments and Funding: The cost of advancement and innovations in climate technology necessitates large investments. Report [12] indicates that $ 1.5 to $ 2.0 trillion may be the quantum of investment per year by 2025. They have been estimated for technologies over a horizon of five sectors namely, (i) Electrifying Industry, transportation, building, (ii) Greening the agricultural equipment, bioengineering etc., (iii) Remaking the grid for clean power, (iv) Green Hydrogen, and (iv) Carbon Capture, Use and Storage (CCUS). Investments on the technologies in the above area are estimated to abate carbon burden to the tune of 40% by 2050. Figure-6 presents the details in a compact manner.

Investments and funding along with associated risks pose a big challenge on the timeline putting a spanner on net zero by 2050.

1. Workforce training: Almost all of the climate technologies are new. They will involve new methods/ processes for operations, maintenance,

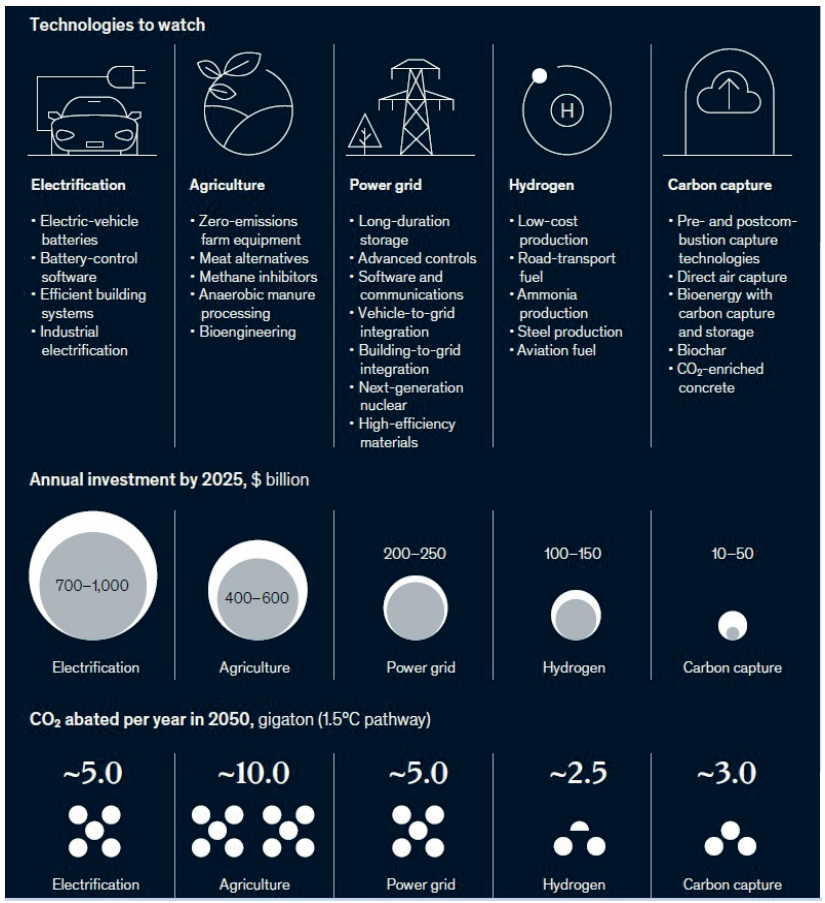

Figure-6[6]

logistics, supply chain management, etc. Hence, the workforce would need to undergo a complete change in the deployment and skill parameters. For example, the manpower working in a power plant run on fossil fuels should be deployed in power plants run with renewables like solar or wind or hydrogen fuel in the new regime. Therefore, the workforce would be required to unlearn, learn and relearn. Given the huge scale and current status of Technology Readiness Level (TRL), transformation and adaptability by the workforce within the short time frame of 2050 is a big challenge.

2. Integration of infrastructures: New climate technologies would require changes in software, hardware, logistics, operating systems in addition to new equipment, new layout, processes, etc. Retrofit of building and industrial structures and integration of software and other infrastructures to the existing ones would be complicated and may even necessitate thorough overhauling. Research studies and development of carbon footprint are primarily concentrated on process technology, efficiency enhancement, and alternative materials. While doing so, studies regarding estimation of carbon footprint that these developments bring along with them are found to be lagging. In depth detail estimation is essential for taking into consideration carbon consumption at each and every stage of the life cycle including those during retrofit/ integration of capital assets, in order to find the net gain/ loss in carbon footprint. It is a challenging task to capture the carbon data, analyse it and verify the same for correctness.

Conclusions

The world is sitting on the volcano of a climate disaster as is evident from the address delivered by the UN Secretary-General Mr. António Guterres at the COP27 held in November 2022. He concluded that the world was "on a highway to climate hell with our foot on the accelerator". The awareness and response to the crisis all over the world is yet to achieve a level that would give comfort to the society. However, better late than never, a framework has been set up by the United Nations and countries are gearing up gradually to mitigate the challenges globally.

In the fight against climate disaster, apart from subjecting the community to climate literacy, the three major pillars are - conservation of resources, reduction of waste and decarbonisation. Therefore, a Circular Economy is a must for survival or sustainability. Technology and Innovations go hand in hand with a Circular Economy. It is a good thing that a lot of research is being done for sustainable technologies with the participation of Industries, Academia, Startups and results are also visible.

Industry - academia collaboration is poised to play a big role on the roadmap. Industrial experience, supply chain, brand and resources can be gainfully deployed with the knowledge, experimentation, infrastructures of academic institutions to propel research and achieve the goal.

The major challenges as discussed lie with the technology readiness level and funding. However, at the current level of climate movement, active participation by the countries all across the world and the COP27 proceedings, it is expected that Investments, Funding, State regulations would be more climate friendly and further the pace of technology invention and deployment.

References

1. Climate Science Investigation, NASA
2. Environment Protection Agency, EPA, USA
3. https://www.activesustainability.com/climate-change/how-greenhouse-gases-contribute-global-warming/?_adin=02021864894
4. https://www.startus-insights.com/innovators-guide/top-8-circular-economy-trends-innovations-in-2021/
5. https://home.kpmg/xx/en/home/insights/2020/11/the-hydrogen-trajectory.html
6. Global Energy Transformation – A roadmap to 2050, International Renewable Energy Agency (IRENA)
7. Net-zero Power – Long duration energy storage for a renewable grid, McKinsey & Company
8. https://en.wikipedia.org/wiki/Stadium_974
9. https://www.globalcement.com/news
10. https://mrg-composites.com/
11. https://praj.net/wp-content/uploads/2021/05/20210518-Bio-bitumen-Press-Release.
12. Innovating to net zero: An executive's guide to climate technology – by Tom Hellstern, Kimberly Henderson, Sean Kane, and Matt Rogers, McKinsey Sustainability

05

The Need for Inclusive and Circular Management of Plastic

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Introduction

Globally, India ranks fifth in terms of plastic waste generation, with an estimated 34,69,780 metric tons of plastic waste generated each year. There is a worrying trend with regard to the per capita plastic waste generation for the period of 2016 to 2020, showing almost doubling in five years (CPCB 2021).

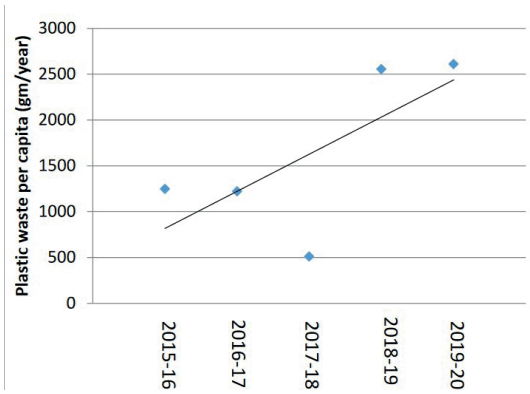

Figure-1: Per capita plastic waste generation (CPCB 2021)

However, according to a Centre for Science and Environment (CSE, 2020) report, about 5.5 million metric tonnes of plastic waste is reprocessed or recycled annually in India. That accounts for 60% of the nation's total plastic waste generation. Of that waste, 70% is processed in registered (formal) facilities, 20% is handled by the informal waste sector, and the remaining 10% is recycled at the household level.

The informal waste sector employs at least 15 million people worldwide and is estimated to be responsible for 58% of the plastic waste that is gathered and recycled, which is a significant contribution to the circular economy (IKHAPP, 2022). India accounts for at least 10% of those workers, who process 1.1 million metric tonnes of plastic waste annually, saving money and resources for municipalities that are frequently overburdened and lack the capacity to set up and maintain formal waste management systems. However, the size and waste-handling capabilities of the informal waste sector remain relatively unknown and the same remains with regard to the issues that they face. Since these workers do not have adequate training or access to safety equipment, they are more vulnerable to occupational health risks (Toxics Link 2016). Due to their disproportionate representation in labor-intensive, low-paying, and dangerous occupations, women, and children are especially at risk (Krishnan and Backer 2019). In spite of their abilities, expertise, and vast networks in waste management, waste workers in the informal sector continue to receive insufficient acknowledgement or credit for their role in reducing plastic pollution and are at considerable health risk.

Plastics are exceedingly difficult to disintegrate in the natural environment due to their longevity and resistance to deterioration. The majority of plastic goods only degrade into smaller and smaller particles that eventually become microplastics. Microplastics can collect in organs, enter the body by inhalation and absorption, and have even been detected in human blood (UNEP n.d.)

and the placenta (Ragusa *et al.* 2021). Additionally, during the production of plastics, some of the chemical additives to plastics are Persistent Organic Pollutants (POPs) that are chemicals of worldwide concern because they have the potential for long-range transport, persistence in the environment, and the ability to bio-magnify and bio-accumulate in ecosystems, as well as their significant adverse effects on human health and the environment) themselves. Plastics come into contact with POPs when in use and have the ability to adsorb them to their surface, acting as a vector. Open burning of plastic waste has also been identified as a significant source of gaseous and particle POPs emissions (INOPOL 2022). As plastic pollution poses a growing threat to human and environmental health, innovative measures are needed to address this global threat.

In the midst of a global debate around plastic being a mismanaged commodity that needs to be replaced by alternatives vis-à-vis plastic being a valuable resource that needs a structured management system, circular economy solutions can help to bridge the gaps. The main goal of a circular economy is to be regenerative and restorative. As a result, materials flow continuously through a closed-loop system instead of being used once and then discarded; keeping the value of plastics in the economy while preventing their leakage into the environment is a key component of this system. Plastic circular economy solutions include - producing plastics from alternative non-fossil fuel feedstocks; using plastic waste as a resource; redesigning plastic manufacturing processes and products to improve longevity, reusability, and waste prevention. Solutions for increasing circularity in the plastic sector also include collaboration between businesses and consumers to encourage recycling and increase the value of plastic products; encouraging sustainable business models that promote plastic products as services; encouraging sharing and renting products; taking fiscal and regulatory measures to assist the circular economy; creating powerful information platforms to aid circular solutions. A major rethink is necessary to get society away from the "take, make, dispose" mentality that has long inspired business models. That would entail improving recycling, encouraging reuse, developing a market for recycled materials, and redesigning products with end-of-life considerations in mind (Nicola Ledsham n.d.).

A circular economy that reduces waste, increases value, and effectively uses plastic must be the 'New Plastics Economy'. However, it would not be able to solve the issue of excessive plastic use entirely. A comprehensive solution aims to reduce demand and create only essential plastic items, by discouraging the use of non-essential plastics and promoting sustainable and recyclable alternatives (Barra *et al.* 2018). By doing that it may better preserve the environment and reduce greenhouse gas emissions, marine trash, and reliance on imported fossil fuels, amongst other benefits.

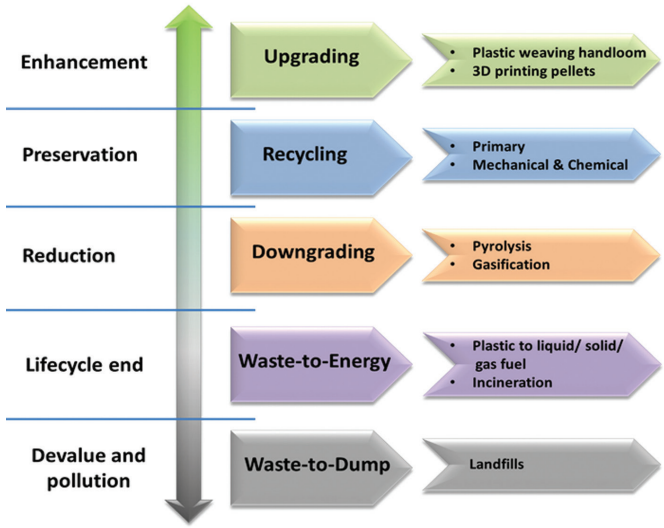

Figure-2: Plastic processing pathways (adapted from Chidepatil et al, 2020)

Drivers of Circular Economy (CE) in India

Research and innovation are underway in India to improve recycling output and efficiency of the informal sector. Plastic waste is mechanically recycled by formal recyclers using proprietary washing technology. Plastic recycling technology has also been integrated with data intelligence (location of informal waste collectors and waste processing capacity), increasing their performance in waste collection and recycling (Banyan Nation 2020). Meanwhile, the informal sector uses turbo washers and aglow machines to produce Polyethylene (PE) granules (Aryan *et al*. 2019).

Increased awareness among people is a major driver for such advancements, with continuous research on indigenous solutions for managing plastic waste, new startups, and businesses in the domain, and advocacy for a synergistic regulatory framework.

India's current regulatory framework for plastic waste management, the Plastic Waste Management (PWM) Rules, incorporates enabling features for a circular economy.

There are various circular economy-related economic and business opportunities in most of the areas covered by the push to Extended Producer Responsibility (EPR) approach for more responsible resource and product management. Closing the loop requires the public and private sector, the informal sector, and researchers to work together to tap into that potential.

- Waste collection**:** Separate transportation and source segregation are the first steps for the elimination of waste in circular economies. India has major gaps in its waste collection system, even for mixed Municipal Solid Waste (MSW). India generates over 26,000 tonnes of plastic waste daily, and over 10,000 tonnes of it goes uncollected, according to the CPCB (CPCB 2021). With EPR focus on mandatory pre and post-consumer target package waste collection, source segregation is the only effective step to ensure better recycling counts. Therefore, Producers/ Brand owners/ Importers have an opportunity to set up and maintain collection centres.
- Re-designing and alternative sustainable solutions for packaging**:** The majority of packaging products cannot be recycled, reused, or composted. PWM Rules ban Single Use Plastic (SUP) and mandate the recycling of rigid plastic packaging waste. Therefore, redesigning packaging materials and finding alternative solutions are the biggest opportunities for reducing, recirculating and returning.
- Credit Market**:** As part of the EPR guidelines, surplus credit certificates may also be sold or purchased and carried forward against the previous year's targets. Cloud/ AI-based systems/ software can perform auto-calculations, track vendors/ recyclers, maintain online environmental returns records, identify sellers or buyers based on demand and supply, etc. (Duhan 2022)

Overall, for India's transition to a circular plastic economy, there needs to be a technology-enabled, accountable, and quality-assured collaborative supply chain of virgin and recycled materials.

Deterrents of Circular Economy in India

In spite of recent developments in waste sorting technology, separate collection remains more cost-effective, and an essential precondition to viable recycling (Calleja 2019). According to experts, poor segregation, collection, and disposal mechanisms are responsible for India's plastic menace (Sachdeva 2019).

Investing in recycling facilities would be impossible without a clear and reliable demand for recycled plastics. The lack of markets for recycled plastics is one of the biggest barriers to a circular economy. Most plastics come from fossil fuels, which are currently cheaper than recycled materials. As such, the economics of plastic recycling is weak. The demand for post-consumer resin (PCR) must be driven by using it wherever possible. The use of PCR would create vital end markets that make domestic recycling viable.

The economy loses 95% of the value of plastic packaging every year - worth 105 billion Euros. This is a wasted opportunity, and that's why the first axis of the Plastics Strategy is improving plastic recycling economics and quality. Purifying waste streams and improving recyclates means turning back to the beginning: the design and manufacture of plastics. Plastic is particularly difficult to recycle due to its versatile polymers and additives, making it more complex and challenging than most other materials (Calleja 2019).

The circular economy transition is facilitated by an enabling regulatory framework. What is less certain is how consumers, retailers, and producers would react to these proposed changes. In India, the governance system creates a tangled web for implementing plastic waste management policies, with each state bringing its own policies. The result is a more complicated enforcement

process and a diluted effort to combat plastic pollution. In addition to strengthening the Urban Local Bodies (ULBs), it is recommended that a uniform policy be adopted that emphasises segregation and collection mechanisms.

Recycling: Potential and Efficiency

Plastic waste recycling can be broadly categorised into mechanical recycling, chemical recycling, biological recycling, and energy recovery (Al-Salem *et al.* 2017). Compared to secondary recycling, primary recycling is preferred and uses fewer operating units, and is contamination-free, which saves energy and resources. Plastic waste recycled using secondary recycling (mechanical recycling) is the second preference (CSE 2021). Recycling plastic waste is complex due to its degradation and heterogeneity, which are significant challenges for recyclers. Consequently, problems arise with recycling of mono and mixed plastics. Developing innovative solutions to remove volatile organic compounds from recycled plastics is one of the main technological challenges in mechanical recycling (Cabanes *et al*. 2020). As a result, mechanical recycling becomes redundant when compared to chemical recycling, where technological advancements can manage these issues more efficiently. Among the benefits of chemical, recycling are a reduction in landfilling and reduced GHG (green-house gasses) and CO_2 (carbon dioxide) emissions. However, chemical recycling in India is still in its infancy. Additionally, chemical recycling is still not widely adopted on an industrial scale because of the high energy requirements and low cost of petrochemical feedstock (Schandl *et al.* 2020).

Designing for Recyclability

Design for recycling is one of the most important factors in ensuring that plastic and plastic packaging undergo a circular transition. Recycling capacities are influenced by many factors, including compatibility of ingredients, separation ease, and additive use (Design for recycling guidelines n.d.). Since the benefits and drawbacks of various recycling mechanisms are sufficiently evident from the data, it becomes imperative that the circular economy landscape develops a product and efficiency-based recycling architecture. That would ensure that the life-cycle impacts are also integrated into design decisions rationally and proportionately. That interplay between material composition, functionality, and treatment at the end of a product's life cycle needs to be recognised more widely.

Informal Waste Sector and their plight

The informal waste sector includes all types of unregistered workers involved in waste collection, recovery, and recycling. Recycling activities are on a small scale, unregulated, and provide a source of income for many underprivileged people (IKHAPP 2022). Informal waste sector employs a large number of waste pickers, also called scavengers (Velis 2017). These are the most labour-intensive and least rewarding steps in the recycling process. There are more than 15 million informal workers in the waste sector. According to a United Nations study, informal waste pickers in low-income countries collect 50-100 percent of waste at no cost to the municipality (Medina 2010). Tricycle pickers can collect up to 50 kilograms of waste per day, while single waste pickers can collect 10-15 kilograms. There is enormous potential for improvement in end-of-life management through the informal recycling sector. Overburdened municipal waste management systems in developing and emerging economies rely on the sector to recover plastics. Despite their environmental and economic importance (Aparcana 2017; Kariuki *et al.* 2019), waste pickers are frequently marginalised (Aparcana 2017) as dirty outlaws of society. They face asymmetric power relations, exploitation, and volatile prices that threaten their livelihoods. There are occupational health risks associated with waste pickers and collectors who are not equipped or trained to work safely. Women and children frequently overrepresent in such labour-intensive, low-paying, and dangerous occupations, which intensifies gender bias and exploitation already prevalent in the workplace (IKHAPP 2022). Social exclusion, lack of basic protection schemes, lack of citizenship rights, and exploitation all contribute to their precarious plight.

Technological advancements in the plastic value chain may threaten the jobs of informal workers. The machines are not as efficient as informal workers who have been

doing the work for generations. In particular, there has been a shift towards formalisation of waste pickers. A joint initiative between Coca-Cola India Foundation and Chintan aims to formalise that sector, but a holistic framework is still lacking (Pandey 2022). International negotiations on plastic pollution present an opportunity to counter the marginalisation of the informal recycling sector (IKHAPP 2022).

Conclusions: People's Movement, What Can We Do?

A circular economy reduces 'waste' by using resources in their original form, resulting in less 'waste' that needs to be managed. To stop plastic waste from entering the environment, systemic reform is needed. People as individuals and as a part of a community play a pivotal role in the 'refuse', 'reuse', and 'upcycle' of plastic products and can make a significant impact on the system. Simple solutions to reduce plastic's impact on the environment are listed below:

1. Reduce the use of disposable plastics: UNEP estimates that around five trillion plastic bags are used annually worldwide. There is a tremendous amount of waste that may not be disposed properly. In the light of the government's ban on several single-use plastic items, people should consciously replace them with reusable alternatives. According to the UNEP *'one million plastic bottles are purchased every minute'*, which amounts to 525.6 billion annually. Reusable water bottles would reduce that reliance significantly. Water bottles with a built-in purification system can be used in areas with poor water quality

2. Switch to plastic-free personal care products: There is a growing concern about microplastics. Microplastics come from several sources, including personal care products like shampoo, deodorant, day cream, cosmetics, face wash, etc. Using products without plastic will reduce microplastic leaching into the environment.

3. Reusing and Repurposing: There are several innovative ways to recycle and repurpose several plastic items. Buying second-hand items helps reduce the plastic packaging that newly purchased items come with, and potentially save money as well. Resources would be conserved and harmful emissions would be reduced.

4. Upcycling: Plastic waste can also be dealt with by upcycling (converting waste into higher-quality items). Upcycling usually requires none or only limited processing of the plastic, thus saving a lot of energy and resources.

5. Cleaning polluted environments: Clean-up initiatives have been taken by individuals and organisations. The beach clean-up initiative is a good example of how clean-up activities can improve the environment. In addition, awareness generation through these activities can have a ripple effect on bringing about sustainable waste management in the region.

6. Support proper management of plastic waste: By supporting legislation that reduces plastic waste and encouraging elected officials to enforce these regulations, the plastic waste can be reduced. Although individuals can make a difference by their habits; corporations and industries would make a bigger impact. Pressurise manufacturers to reduce plastic waste by advocating for change and using products from a more sustainable competitor.

Waste pickers working in the informal sector collect significant amounts of recyclable plastic, which saves the government money and protects the environment. Considering that the sector recycles waste in the country, waste management should integrate these efforts into a formal setting. It is necessary to engage in participatory research to better understand the informal waste sector for all to benefit through better management. Achieving good health and well-being for waste workers is paramount. Historically oppressed and marginalised people, such as waste workers, have very limited access to high-quality healthcare services because of inequity. The work of informal waste workers needs to be recognised and dignified locally, nationally, and internationally. That would require the following reforms:

1. Interventions in health and well-being must be

specifically adapted to the needs of waste pickers, particularly informal workers.

2. Occupational groups involved in collecting, sorting, processing, and selling waste items should be recognised. Their wages should also reflect their efforts and risks.

3. Providing waste workers with assistance to acquire requisite documents is essential to breaking the link between getting services.

4. As part of current discussions for a legally binding international agreement on plastic pollution, the historical and present contributions of the informal recycling sector to the management of the world's plastic waste should be adequately acknowledged.

5. It is essential to acknowledge the diversity of the informal sector while designing and implementing waste management policies and programs.

6. Additional research is required to understand the informal waste sector so that integrated benefits for all can be achieved

Inclusive and circular management of plastics requires collective effort. The scale of the problem requires more action than has been taken to stem plastic pollution.

References

1. Al-Salem SM, Antelava A, Constantinou A, Manos G, Dutta A (2017) A review on thermal and catalytic pyrolysis of plastic solid waste (PSW). J Environ Manag 197:177–198. https://doi.org/10.1016/j.jenvman.2017.03.084

2. Antonio Ragusa, Alessandro Svelato, Criselda Santacroce, Piera Catalano, Valentina Notarstefano, Oliana Carnevali, Fabrizio Papa, Mauro Ciro Antonio Rongioletti, Federico Baiocco, Simonetta Draghi, Elisabetta D'Amore, Denise Rinaldo, Maria Matta, Elisabetta Giorgini, Plasticenta: First evidence of microplastics in human placenta, Environment International, Volume 146, 2021,106274, ISSN 0160-4120, https://doi.org/10.1016/j.envint.2020.106274.

3. Aryan Y, Yadav P, Samadder SR (2019) Life cycle assessment of the existing and proposed PW management options in India: a case study. J Clean Prod 211:1268–1283. https://doi.org/10.1016/j.jclepro.2018.11.236

4. Banyan Nation (2020) Recycling and monitoring PW Flow in the city. ASCI J Manag 49:73–76

5. Barra et al. 2018. Plastics and the circular economy. Scientific and Technical Advisory Panel to the Global Environment Facility. Washington, DC. Accessed from https://www.thegef.org/sites/default/files/publications/PLASTICS%20for%20posting.pdf

6. C. Velis (2017). Waste pickers in Global South: informal recycling sector in a circular economy era. Waste Manag. Res., 35 (4) (2017), pp. 329-331, 10.1177/0734242X17702024

7. Cabanes A, Valdés FJ, Fullana A (2020) A review on VOCs from recycled plastics. Sustain Mater Technol 25:e00179. https://doi.org/10.1016/j.susmat.2020.e00179

8. Chidepatil A, Bindra P, Kulkarni D, Qazi M, Kshirsagar M, Sankaran K (2020) From trash to cash: how blockchain and multi-sensor-driven artificial intelligence can transform circular economy of PW? Adm Sci 10(2):23. https://doi.org/10.3390/admsci10020023

9. CPCB (2021), Annual Report 2019-20 on Implementation of Plastic Waste Management Rules, 2016

10. CSE (2020) Managing PW in India: challenges and Agenda. Retrieved from https://www.cseindia.org/content/downloadreports/10352

11. CSE (2021) Plastic recycling decoded. Retrieved from https://www.cseindia.org/plastic-recycling-decoded-10885.

    Calleja D. (2019) "Why the "New Plastics Economy" must be a circular economy", Field Actions Science Reports [Online], Special Issue 19. 2019, Online since 01 March 2019, connection on 21 September 2021. URL: http://journals.openedition.org/factsreports/5123

12. Design for recycling guidelines n.d. https://recyclass.eu/recyclability/design-for-recycling-guidelines/

13. Duhan, Sonia. September 15, 2022. Invest India Editorial. "Circular economy: Potential and opportunities under the Plastic Waste Management Rules". Accessed from https://www.investindia.gov.in/team-india-blogs/circular-economy-potential-and-opportunities-under-plastic-waste-management-rules

14. IKHAPP Policy Brief Series (2022). Hans Nicolai Adam, Louis Pille-Schneider, Caroline Enge, Emmy Nøklebye, Girija K. Bharat, Mary Abraham and Nathaniel Dkhar, Important but ignored? The role of the informal recycling sector in a prospective international agreement on plastic pollution, IKHAPP Policy Brief series. https://ikhapp.org/wp-content/uploads/2022/03/IKHAPP-Policy-Brief-informal-sector.pdf

15. INOPOL (2022) Plastic Waste Management Strategy Report for Gujarat. India-Norway Cooperation Project on Capacity Building for Reducing Plastic and Chemical Pollution in India.

16. J.M. Kariuki, M. Bates, A. Magana. (2019). Characteristics of waste pickers in Nakuru and Thika municipal dumpsites in Kenya**.** CJAST (2019), pp. 1-11, 10.9734/cjast/2019/v37i130272

17. Krishnan, S., Backer, A. (2019) The Role of Gender in Waste Management: Gender Perspectives on Waste in India, Indonesia, the Philippines and Vietnam. Singapore: GA Circular. Available at: https://oceanconservancy.org/wp-content/uploads/2019/06/The-Role-ofGender-in-Waste-Management.pdf.

18. Medina, M. (2010). Scrap and Trade: Scavenging Myths. Tokyo: United Nations University. Available at https://ourworld.unu.edu/en/scavenging-from-waste.

19. Nicola Ledsham n.d. accessed at https://www.sustainability.com/thinking/creating-a-circular-economy-for-plastics/

20. S. Aparcana. (2017). Approaches to formalization of the informal waste sector into municipal solid waste management systems in low- and middle-income countries: review of barriers and success factors. Waste Manag., 61 (2017), pp. 593-607, 10.1016/j.wasman.2016.12.028

21. Schandl H, King S, Walton A, Kaksonen AH, Tapsuwan S, Baynes TM (2020) National circular economy roadmap for plastics, glass, paper and tyres. Australia's National Science Agency, CSIRO, Australia. ISBN 978-1-4863-1495-9

22. Shailender Pandey. May 11, 2022. The Statesman. "Integrated Waste Management Solutions enable rag pickers to live life with dignity" Accessed from https://www.thestatesman.com/cities/delhi/integrated-waste-management-solutions-enable-rag-pickers-live-life-dignity-1503070780.html

23. Sheena Sachdeva. November 27, 2019. Business World. "How Well Are We Segregating Plastic Waste In India". Accessed from https://www.businessworld.in/article/How-Well-Are-We-Segregating-Plastic-Waste-In-India/27-11-2019-179473/

24. Toxics Link (2016) WEEE Plastic and Brominated Flame Retardants. A report on WEEE plastic recycling. New Delhi: Toxics Link. Available at: http://toxicslink.org/docs/Report-WEEE-plastics.pdf.

25. UNEP n.d. accessed at https://www.unep.org/interactives/beat-plastic-pollution/

IBEF
INDIAN BRAND EQUITY FOUNDATION
Indian Economy News

Under Phase-II of FAME India Scheme, around 7.45 lakh Electric Vehicles supported till 07 Dec 2022 by way of a Demand Incentive amounting to about US$ 386 Million (Rs. 3,200 Cr)

Press Information Bureau December 14, 2022

Under Phase-II of Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles (FAME) India Scheme, around 7.45 lakh of Electric Vehicles (EVs) have been supported till December 7, 2022, by way of Demand Incentive amounting to US$ 386 Million (Rs. 3,200 Cr). Ministry of Heavy Industries (MHI) has also sanctioned 6,315 e-buses to 65 cities/State governments for intra and inter-city operations across 26 states and UTs.

A notification was provided by the government regarding Phase II of FAME India Scheme, which started on April 1, 2019, for a period of five years, and total budgetary support of US$ 1.2 billion. This phase aims to support 7,090 e-Buses, 5 lakh e-3 Wheelers, 55,000 e-4 Wheeler Passenger Cars and 10 lakh e-2 Wheelers., through demand incentives, which are provided to buyers of EVs in the form of a reduction of the purchase price of EVs.

Various steps have been taken by the Government to address the challenges faced in the adoption of electric mobility in the country, which include the increment of demand incentive, approval of Production Linked Scheme (PLI), reduction of Goods and Services Tax, etc.

Disclaimer*: This information has been collected through secondary research and IBEF is not responsible for any errors in the same.*

Source: https://www.ibef.org/news/under-phase-ii-of-fame-india-scheme-around-7-45-lakh-electric-vehicles-supported-till-07-dec-2022-by-way-of-a-demand-incentive-amounting-to-about-us-386-million-rs-3-200-cr

06

Approaches to Mitigate the Danger of Plastics to Marine Ecosystems

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Introduction

Over the past few decades, the demand for plastic products has grown dramatically due to their durability, mouldability and light weight properties and at the same time being affordable and having high production volume. The global annual production of plastic in the year 2019 alone reached 460 million tonnes, and in the same year, 353 million tonnes of plastic waste was also generated. Out of that plastic waste that gets generated 50% ends up in landfills (OECD 2022). The trend is similar in India too with the demand for plastics in the year 2021-2022 being about 20.89 million tonnes of which about 40% is generated as plastic waste (PlastIndia 2022). According to the Central Pollution Control Board (CPCB), about 3.46 million tonnes of plastic waste was generated in the year 2019-2020 from 35 states/UTs in India (CPCB 2021). In simple terms, the usage of plastic and its post-usage dumping has increased multitudinously.

A lot of plastic products are for single use and reach the ecosystem as waste in a short time span. Most of it is non-biodegradable and non-compostable and gets accumulated in the environmental ecosystem.

Recent years have seen a significant increase in the amount of plastic debris entering the marine ecosystem creating a variety of adverse impacts on the marine life. Our planet is considered a blue planet due to its vast oceans and seas, but it is becoming endangered due to unprecedented marine litter, caused by human activities. Every year, approximately 8 million tonnes of plastic waste ends up as litter in marine ecosystems, causing harm to the marine ecosystems that produce most of the oxygen necessary for life to exist. It has adversely affected coastal cities and habitats by causing environmental, economic, human health related problems along with posing cultural and aesthetic threats.

What is Marine Litter? Marine litter is any persistent, manufactured, or processed solid material discarded, disposed of, or abandoned in the marine and coastal environment.

Land-based source: Wastes from dumpsites located on the coast or banks of rivers; rivers and floodwaters; industrial outfalls; discharge from storm water drains; untreated municipal sewerage; littering of beaches and coastal picnic and recreation areas; tourism and recreational use of the coasts; fishing industry activities; ship-breaking yards; and natural storm-related events.

Sea-based sources: Waste from shipping (merchant, public transport, pleasure, naval, and research vessels) and fishing (vessels, angling, and fish farming) activities; offshore mining and extraction (vessels and oil and gas platforms); legal and illegal dumping at sea; abandoned, lost or otherwise discarded fishing gear; and natural disasters.

The issue is of great concern, especially to India as it is already one of the world's largest contributors to marine litter and the world's twelfth largest source of marine pollution owing to an increase in coastal populations, coastal urbanisation, and, more recently, the increased plastic use

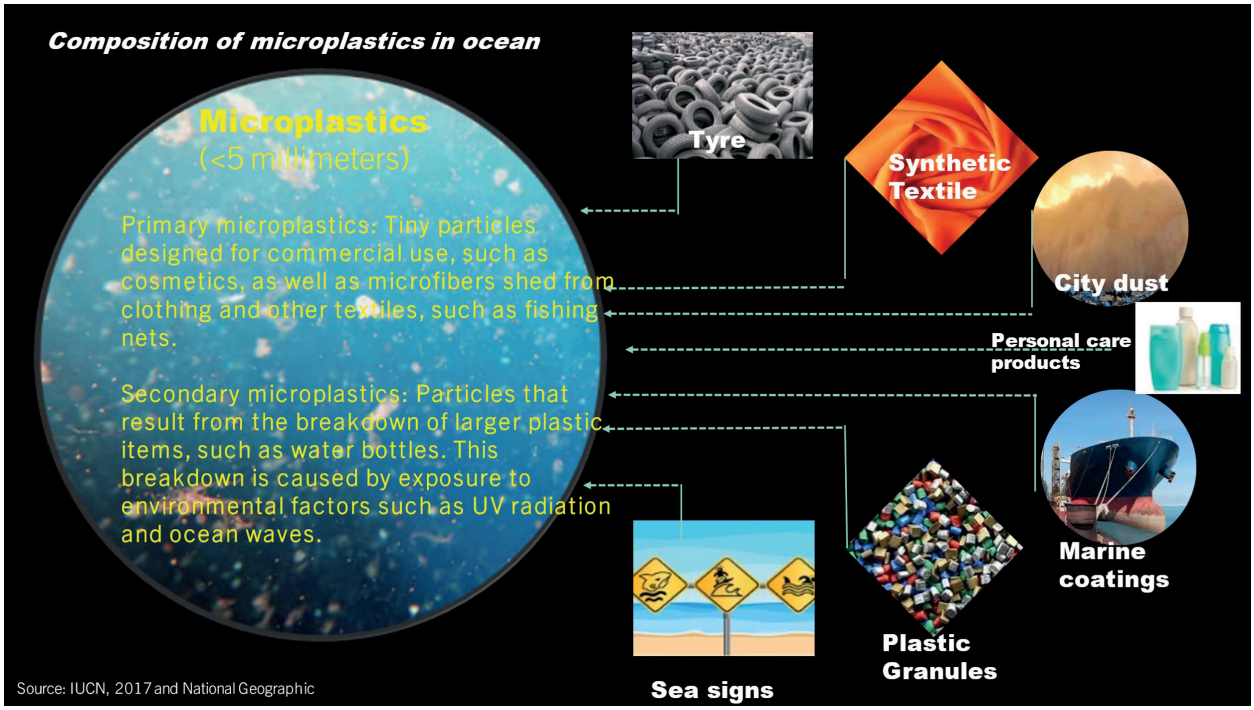

Figure-1: Type of microplastics

during the COVID-19 pandemic. Marine litter originates from multiple sources including land-based sources such as Single Use Plastics (SUP) in tourism clusters, and sea-based sources such as waste dumping, and discarded and abandoned fishing nets. Rivers also carry plastic debris into the sea and as per an estimate they account for 15-20% of all plastic entering the oceans. Ten rivers worldwide carry 90% of plastic debris into the sea, three of which, namely the Indus, Ganga, and the Brahmaputra, flow in India, further aggravating the situation. According to a report by the Ellen MacArthur Foundation, that quantity is equivalent to dumping one truckload of plastic waste every minute, and if the trend continues, there would be more plastic in the sea by 2050 than fish. The problem of marine litter has affected most of the oceans of the world irrespective of whether the ocean is situated in densely populated regions or in remote areas. Marine debris can transcend international borders and disperse across great distances from its point of origin. It also raises health issues since microplastics are consumed by marine life, and because of the related food supply chain, microplastics may eventually make their way to humans. Thus, marine litter is a complicated and multi-faceted problem that has a big impact on human activities and the marine and coastal environment around the world. These effects are cultural and cross-sectoral, and they are primarily caused by inadequate solid waste management practices, a lack of collection and recycling infrastructure, various human activities, lack of public awareness of the potential consequences of their actions, ineffective legal and enforcement frameworks, institutional barriers and a lack of financial resources.

It is thus important to understand various sources of marine litter and the approaches to be adopted to mitigate the danger of plastics reaching the marine ecosystem. That would also be important to contribute to United Nations Agenda 2030 for Sustainable Development that intends to "prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution" by 2025. (SDGs)

Sustainable Solid Waste Management

According to government estimates, India produces over 65 million tonnes of waste each year, of which over 62 million tonnes is Municipal Solid Waste (MSW), which includes organic waste and recyclables including paper, plastic, wood, and glass. Only around 75 – 80% of municipal waste is collected, and only 22 to 28 percent of this is processed and treated. The remaining MSW is mismanaged - littered

and dumped. The amount of MSW generated is expected to increase to 165 million metric tonnes by 2031, and then to 436 million metric tonnes by 2025 (Factly 2021). Selected key approaches to reduce the plastic waste leakage into waterways and the sea during various stages of solid waste management are discussed in subsequent paragraphs.

Segregation at Source

Generate awareness to educate households to segregate wastes as dry waste and wet waste at the household level. Dry waste may further be segregated as plastics, metals, papers, glass, etc. Segregation of waste is encouraged as per Solid Waste Management Rules (SWM) 2016. The other key highlights of the SWM 2016 rules includes segregation at source, collection, and disposal of sanitary waste, collect back schemes for packaging waste, user fees for collection, waste processing and treatment, promoting the use of compost, and promoting waste to energy. The new rules have given local bodies across India the power to decide and implement user fees. Municipal authorities will levy user fees for bulk generators' collection, disposal, and processing. As per the rules, the generator will have to pay a "User Fee" to the waste collector and a "Spot Fine" for littering and non-segregation, which the local bodies will decide.

Figure-2: Waste segregation

Sound Collection and Safe Transportation of Wastes

The door-to-door collection system to be introduced, and it needs to be ensured that the waste collectors are trained to segregate the waste into various types. Further, it needs to be ensured that the collected and segregated wastes are transported in a tidy and closed container to avoid leakages of plastics and wastes in the marine ecosystem.

Avoid Single-Use Plastics

Reducing consumption of single-use plastics is the quickest and simplest way to get started. Reusable or biodegradable containers made from environmentally friendly materials such as glass, food-grade stainless steel, bamboo, rice husk, and others can be used in place of plastic bags, water bottles, food containers, drinking cups, and containers for beverages. On the regulation side, the Government of India has banned the manufacture, sale, and use of identified single-use plastic items like plates, cups, straws, trays, and polystyrene from July 1, 2022. One of the single-use plastic items is the plastic carry bags, which despite a ban are rampantly available in all the cities and even in the villages of the country. Thus, there is a need to come up with innovative solutions in the form of alternatives to plastics to reduce single-use plastics related menace. Some examples are listed below

- Replace plastic glass and cutleries with refillable bottles, metallic or wooden cutleries.
- Replace toiletry (shampoo sachets, tea and coffee sachets, shaving kits) with refillable shampoo dispensers. Hospitality and tourism sector in particular, can avoid providing plastic kits unless demanded by the customer.
- Replace plastic bags with paper or textile bags. Provide bags on a returnable basis under suitable deposit schemes.

Figure-3: Use of refillable dispensers (PC: Prahlad)

Establish Resource-Efficient Plastic Processing Units

Resource-efficient waste and plastic processing units should be established for sorting, shredding, baling, compacting, and packing to encourage upcycling of plastics into high-quality recyclates for use as secondary raw materials. For example, PET bottles can be recycled back into PET bottles and are additionally used for manufacturing bags, pipes, construction materials, textiles, and furniture. These processing units have a high potential to develop into successful business models considering stringent regulations related to recycle of plastic waste to reduce its slippage to marine litter and other dumping sites.

Adoption of Waste Hierarchy by Individuals and Enterprises

Adopting a waste hierarchy of refusing, reducing, reusing, and recycling by individuals and enterprises would help reduce plastic in the waste streams and would also support the Plastic Waste Management rules of 2016 and their subsequent amendment in 2018.

Adopting Circular Economy and Resource Efficiency Approach

Adoption of resource efficiency would encourage waste minimisation during production, transportation, and usage in the value chain. Circular Economy approaches would support the design of products for reuse and recyclability as well as develop business models that enable reuse, repair, and sharing to ensure that the product remains within the value chain for extended life.

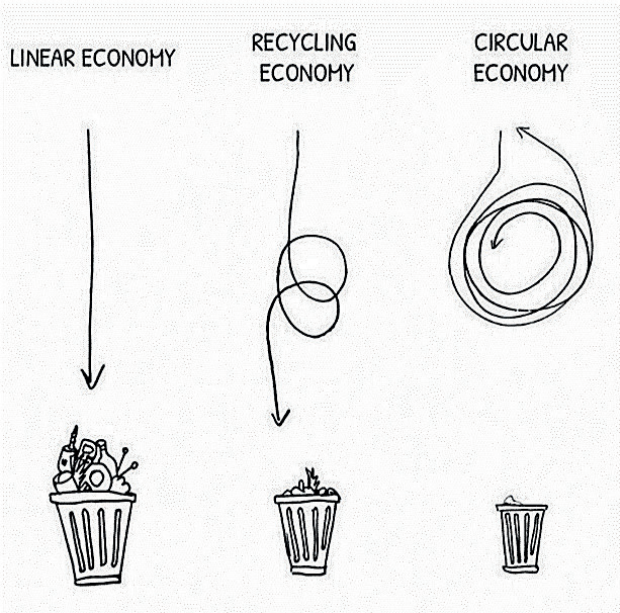

Figure-4: Linear, Recycling, and Circular Economy (Reference: Circular Flanders)

Bleach clean-ups: End-of-pipe approach to reduce ocean plastic pollution is to organize and/or participate in the beach or river clean-ups drives. During such clean-up drives, abandoned nets, plastics, glass bottles, slippers, thermoforms, etc are collected from the beaches. The waste collected needs to be segregated into various types and sent for further recycling and upcycling through an authorized waste recycler.

Figure-5: Beach clean-up in Kerala

Conclusions

It is evident that urgent steps as outlined are be taken and enforced to prevent the oceans turning into a sea of microplastics; they are necessary and essential for life on earth to sustain.

References

1. OECD (2022), Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options, OECD Publishing, Paris, Available at https://doi.org/10.1787/de747aef-en.

2. PlastIndia (2022) Plastic Industry Status Report-In-

dia-2021-22; Available at https://www.plastindia.org/plastic-industry-status-report

3. CPCB (2021) Annual Report 2019-20 on Implementation of Plastic Waste Management Rules, 2016; Available at https://cpcb.nic.in/uploads/plasticwaste/Annual_Report_2019-20_PWM.pdf

4. National Geographic (u.d.) Resource Library. Microplastics. Available at https://education.nationalgeographic.org/resource/microplastics

5. Boucher, J. and Friot D. (2017). Primary Microplastics in the Oceans: A Global Evaluation of Sources. Gland, Switzerland: IUCN 43pp. Available at https://www.iucn.org/sites/default/files/content/documents/2021/ban_tin_so_2_iucn_eng_2.4.2021_-_final_final.pdf

6. SDGs (u.d.) Transforming our world: the 2030 Agenda for Sustainable Development; Available at https://sdgs.un.org/2030agenda

7. Factly (2021) Municipal Solid Waste generated in India set to increase 7 times in the next 30 years; Available at https://factly.in/review-municipal-solid-waste-generated-in-india-set-to-increase-7-times-in-the-next-30-years/

8. Circular Flanders; Available at https://www.loopsustainability.com/blog/what-is-the-circular-economy

THE ECONOMIC TIMES News

English Edition | 08 December, 2022, 03:53 PM IST | Today's Paper

Urbanisation going to be key, says NITI CEO

SECTIONS

Urbanisation going to be key, says NITI CEO

PTI Last Updated: Dec 08, 2022, 01:04 PM IST

Synopsis

"Urbanisation is going to be the key. By 2047, 50 per cent of the population will live in urban areas, if you don't have basic services in urban areas, then it is going to be a big challenge," he noted

NITI Aayog CEO Parameswaran **Iyer** on Thursday said that urbanisation is going to be the key as 50 per cent of **India's** population **will** live in urban areas by 2047. Addressing an event organised by industry body **FICCI**, Iyer said many states have done wonderful work in solid waste management.

"Urbanisation is going to be the key. By 2047, 50 per cent of the population will live in urban areas, if you don't have basic services in urban areas, then it is going to be a big challenge," he noted.

He said the circular economy is now also becoming increasingly important.

Replying to a question on issues of cleanliness of India's tourist destinations, Iyer said," If you want to promote tourism in India aggressively, you better have clean places around, you better have better behaviour by tourists and by the locals."

Most beautiful tourist destinations in India are littered.

Source: https://economictimes.indiatimes.com/news/india/urbanisation-going-to-be-key-says-niti-ceo/printarticle/96079724.cms

07

Demolition Waste Management in India Using Circular Economy

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Abstract

Infrastructural development plays a vital role in shaping a country's economic growth and well-being, however, that on the other hand, also results in large-scale extraction of natural resources. For ensuring an environment's positive and sustainable growth in urban areas, Construction and Demolition (C&D) waste management requires due attention. The Circular Economy (CE) framework integrated with the lifecycle approach can be instrumental in developing a holistic solution to the multidimensional problem of urban waste management and meeting various sectoral-specific sustainability targets. The debris generated from demolition activities constitutes the major proportion of C&D waste, and through necessary interventions, the overall resource productivity of the C&D sector can be optimized, and the disruption caused in natural resource cycles can be prevented. This study attempts to chart a roadmap for Demolition Waste Management (DWM) in the Indian construction sector by identifying major challenges in CE implementation and proposing the corresponding corrective actions. The outcomes of the study also highlight the extent of effort required for implementation and the impact that would be created from each measure, thereby enhancing the ease of application. The findings can prove valuable for academicians and practitioners while framing policies or establishing guidelines at any stage of construction.

Introduction

The Indian construction sector is experiencing multifaceted growth, driven strongly by national infrastructural development and the upgradation of smart cities, industrial corridors, affordable housing, roads/ highways, rail lines, airports and sea ports. The infrastructural growth relies heavily on resource extraction and can also be attributed to the high scale waste production. The existing Construction and Demolition (C&D) processes in India need to be improvised to optimize the sector's resource productivity and ensure a sustainable growth and consumption pattern. The traditional construction methods and ideologies mostly follow a unidirectional path of "take-make-dispose" (Esa et al., 2017), meaning that the resources are extracted from nature, transformed into new products, and used in construction. Eventually, after the end of the useful life of the products and materials, they are disposed of as waste (Sariatli, 2017). Many construction products and materials are being designed with the short-term vision of a single lifetime use, depriving the opportunity for the materials to be retained in the construction cycle despite having the potential for reuse. The imbalance created in nature due to both excessive material extraction and waste disposal has given rise to several challenges in the construction sector. Issues such as difficulty in raw material availability, price inflation have made unlawful resource extraction, illegal trading, material adulteration more prevalent in many parts of the country. Additionally, debris generated from demolition activities is the major contributing source of the C&D waste stream (US EPA, 2021; Wu et al., 2016).

C&D Lifecycle of a Building from the Circular Economy Perspective

For the development of a holistic understanding of Demolition Waste Management (DWM) strategies, the principles of Circular Economy (CE) need to be integrated into lifecycle thinking in the building construction sector. In this study, a building's lifecycle has been divided into five stages: design and planning, construction, operation, pre-demolition, and post-demolition. The initial stage in the lifecycle of a building is the design and planning stage, where conceptualization and design development take place. The need and requirements of building construction have been identified before this stage. The next stage in a building's lifecycle is the construction stage, in which the execution of design takes place under a contractual setup. The desired facility is handed over to the customer at the end of the stage. The use and operation stage of the building starts when a customer takes the occupation of the building and uses the structure for the required purpose. That phase includes repair and maintenance of the building, and generally, the service life of a reinforced concrete building is estimated to be 50 years making it the longest phase in a building's lifecycle (Brejnrod et al., 2017; Cuéllar-Franca and Azapagic, 2012). Once a building cannot cater to the customer's need or becomes structurally unserviceable, the pre-demolition stage of a building begins. In this stage, the necessity of building demolition is evaluated, and demolition activities are carried out if needed. Once the decision for demolition is taken, end-of-life management practices of a building commence, and the last stage in the building C&D lifecycle, the post-demolition stage is reached. Post-demolition stage is crucial from the waste management perspective as the major C&D waste contribution in the building's lifespan occurs during that stage if adequate attention is not given from the initial phases of the building lifecycle. Figure-1 represents the C&D lifecycle considered in this study. The lifecycle mapping of a building is important to improve the application of DWM through CE interventions, as all the stages are interlinked, and outcomes of an action taken at any stage can cause cascading effects on the subsequent stages.

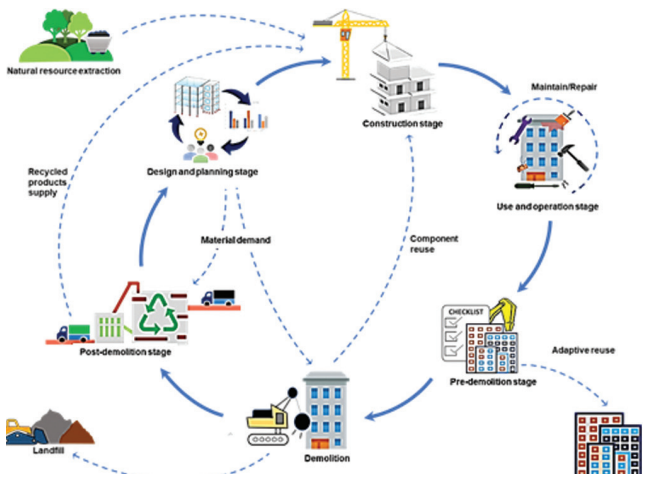

Figure-1: C&D lifecycle of a building from CE perspective (Source: Sharma et al., 2022)

A global literature review by Sharma et al. (2022) has synthesized the strategies for DWM in buildings from

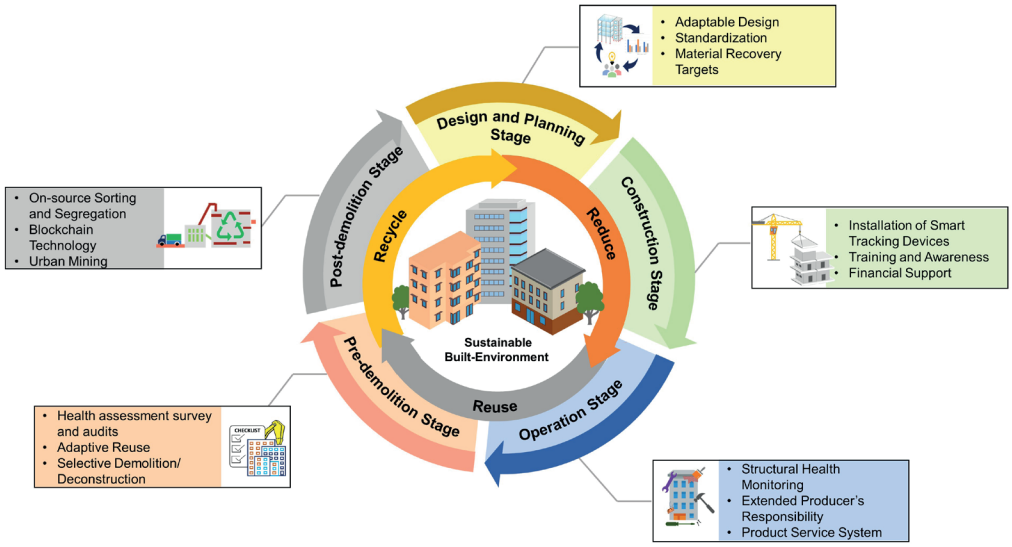

Figure-2: Few important DWM strategies in building lifecycle (Source: Sharma et al., 2022)

the literature, such as incorporation of sustainability concepts in building design, subsidy-penalty-reward mechanisms, stakeholder participation enhancement, recycled material market improvement and mapped to the five lifecycle stages of a building: design and planning, construction, use and operation, pre-demolition, and post-demolition stage, for the development of holistic understanding of the sustainability issues of the sector. Some other important global strategies are depicted in Figure-2. The outcomes of the study highlighted that in the initial stages of the building lifecycle, the reduce and reuse intervention of the CE model is found to be more prominent, while in the later stages, such as pre and post-demolition stages, reuse and recycle interventions were found to be more dominant in the literature, reflecting European Union waste hierarchy framework in building lifecycle stages (EC, 2022).

Assessment of the Indian Construction Sector

India is the second largest contributor worldwide of concrete debris generated from C&D activities (Zhang et al., 2020; Akhtar and Sarmah, 2018), however, the recycling and recovery capacity of India stands strikingly low at 1% [207]. The inefficient demolition methods, monolithic building design and inadequate monitoring of waste management norms have led to higher rates of demolition waste generation in growth-driven countries like China (1116 to 1634 kg/m2) and India (1735 kg/m2) as compared to other developed countries (Islam et al., 2019; Ram and Kalidindi, 2017). Needless to state, the management of building demolition waste has become a pressing concern in achieving sustainable development goals in urban areas. Additionally, the lack of infrastructure and market support also negatively impacts resource recovery. The unfortunate paradox lies in the fact that while the world is experiencing a shortage of materials, the materials in use are being disposed of without harnessing their best potential. Implementation of DWM strategies can optimize resource productivity in the construction sector and make it more resilient to the dynamically evolving demands of urban development.

The CE school of thought advocates the practice of a sustainable model of production and consumption in business and operations. Pearce and Turner developed the global model of CE in 1990 to restore the balance in nature and decouple environmental well-being from economic growth. Reduce, Reuse and Recycle have been considered the integral principles behind the concept of CE (Tong et al., 2018; Ghisellini et al., 2016), which help any system minimize resource and energy wastage by slowing, narrowing, and closing the loops (Geissdoerfer et al., 2017). 'Reduce' can be termed as proactive initiatives taken to prevent or optimize resource consumption and waste generation. 'Reuse' refers to the repeated use of any component of C&D after the original purpose is served. The element can be repurposed for some other use or can be reused for the same purpose, provided the quality of the material matches the expected use (Tong et al., 2018). The act of processing the used or unused elements discarded as waste during C&D to make a new product is called 'recycling' (Huang et al., 2018). Adopting CE measures leads to process improvement and can yield financial gains in businesses. The World Economic Forum states that an economic benefit of more than one trillion dollars' worth per annum can be achieved by 2025 through material savings by implementing CE (WEF, 2014). Moreover, replicating profitable business models across various geographical locations and leading to long-term partnerships among collaborators and similar success stories can prove instrumental in promoting CE in C&D sector (EMF, 2017; Shooshtarian et al., 2021).

The efficiency of resource utilization should be combined with measures of resource recirculation (Modak, 2021). The application of CE integrated with lifecycle thinking in C&D sector can lead to the development of sustainable infrastructure resilient to future demands, CE business models, generation of employment opportunities, promoting technical knowledge growth related to CE in the built environment, thereby making significant contributions towards achieving Sustainable Development Goals (SDG) 9 (Target 9.1, 9.2, 9.3, 9.5). DWM in cities will also improve air quality,

decrease waste generation per capita, and increase the resource efficiency of the construction sector, helping in realizing SDG 11 (Target 11.6, 11.b). Furthermore, implementation of reduce, reuse, and recycle DWM strategies in a building lifecycle can minimize the harmful effects of the waste on human health, fulfilling SDG 12 (Target 12.2, 12.4, 12.5).

Current Status of C&D Waste Management in India

The important role C&D waste management plays in resolving the impending building material crisis was identified by the Indian government in 2010 vide the Ministry of Urban Employment & Poverty Alleviation (MoUEPA, 2010). The Indian waste management sector has evolved with time and defined Construction and Demolition Waste Management Rules in 2016 to address this sector's unique challenges and opportunities. Faruqi and Siddiqui (2020) have comprehensively outlined the development of important guidelines, legislations, and technical codes established for C&D waste management from 2000 to 2017 in India. In 2019, the Ministry of Environment, Forest and Climate Change (MoEFCC) released a national policy framework for enhancing resource efficiency in the Indian building and construction sector (MoEFCC, 2019), to spell out India's continued commitment towards achieving global dematerialization. The Indian government has also taken initiatives to promote the application of C&D in the market. For example, in the nationwide infrastructure improvement program Atal Mission for Rejuvenation and Urban Transformation (AMRUT), C&D waste in planned to be used in paver block manufacturing for pedestrian facilities in500 Indian cities (NIUA, 2020). The Pradhan Mantri Awas Yojna of the Indian government for affordable housing emphasizes the use of alternate technologies for building construction under the 'light house projects' initiative Ministry of Housing and Urban Affairs (MoHUA, 2022). Promoting better and more resource-efficient methods of construction can result in an eventual reduction in demolition waste generation in the future. Cities exceeding a population of five lakh people have been mandated to establish C&D waste recycling facilities under the Swachh Bharat Mission, 2021 of the Indian government Prime Minister's Office (PMO, 2021). However, presently out of 89 such urban agglomerations only around 17 C&D recycling plants are operational Ministry of Home Affairs (MoHA, 2011) with capacities ranging from 150 MT per day to 2000 MT per day (Nair, 2021).

The Indian construction sector has been examined by various researchers from the perspective of CE application in C&D waste management sector. Bakos and Schiano-Phan (2021) have proposed guidelines for the transition of the Indian construction sector to CE based on six regenerative design pillars to construct a "Circular Campus" in Sri city, India. The understanding of CE framework in the Indian construction sector is also a vital aspect in promoting CE practices. J.S and Thomas (2021) conducted a questionnaire survey based on which they identified lack of technical knowledge and inadequate access to information about recyclable materials being the major constraints in the CE implementation. Overall, the Indian construction sector is still in the transition phase and intends to shift towards a more resource-efficient operation and waste management. However, the implementation of the existing guidelines and regulations for C&D waste management is poor. The lack of willingness of users to implement the C&D waste management regulations in India, as suggested by Kolaventi. et al. (2022), is due to an inadequate focus on the behavioral aspects in waste management plans. Moreover, due to the lack of criminal action against the offenders, the burden of bearing the transportation cost and insufficient awareness among waste generators have constantly resulted in an increase in incorrect waste disposal mechanisms (Jain, 2021). The existing tax regime (Goods and Service Tax) on recycled products (18%) is also not supportive of promoting recycled materials over virgin materials Central Board of Indirect Taxes & Customs (CBIC, 2022). Moreover, the significant contribution of C&D waste from urban areas classified as 'towns', apart from million-plus and megacities (Jain et al., 2019), also requires adequate and immediate attention in

national C&D waste management strategies. In view of such a scenario, the goal of the Indian government to increase the share of recycled products in total public procurement of construction up to 30% by 2025 (MoEFCC, 2019) and recycle 50% of demolition waste by 2025 become more difficult to achieve.

Demolition Waste Management Challenges in India and the Way Ahead

The Indian construction market is fast growing and barriers such as insufficient infrastructural support, region-based variation in construction types, the strong traditional foundation of the construction industry, and the existing mindset of the stakeholders have made C&D waste management a more daunting task. However, the C&D sector also promises opportunities for the economic and social development of the masses. Incorporating CE principles integrated with lifecycle perspective can lead to developing novel business ideas, creating job opportunities, and promoting social inclusion. The inherent inert nature of C&D waste gives it an advantage over municipal solid waste in the ease of handling and storage. The diversified nature of DWM in Indian scenario requires the need for significant technology, regulatory and policy-related interventions. Additionally, identifying the key stakeholders and role assignment during the right stage can help bring systemic changes in a sector (Modak, 2021). As identified by Sharma et al. (2022), Table-1 highlights the ten most significant challenges faced by the C&D sector in implementing CE strategies along with suggestions to overcome each concern. Efforts, impact, and the status of each strategy's implementation in the Indian context are also qualitatively measured, with the aim to assist practitioners, academicians, and policymakers in prioritizing national strategies.

Conclusions

India is witnessing multifaceted infrastructural growth, with the national construction sector predicted to become the third largest worldwide by 2023 (OE, 2021). The fast-paced growth of the sector needs to be braced with resource-efficient and sustainable development pathways. The CE framework emphasizes bringing upon a paradigm change by encouraging innovative, environment-positive and sustainable business solutions. Moreover, the sustainability issues of the sector need to be addressed through a systematic shift in the construction sector. CE principles should be integrated with the lifecycle thinking perspective in the construction sector to prevent the gains obtained from CE intervention from being outweighed by the excess emissions generated during implementation (Niero and Kalbar, 2019). In the Indian context, most of the existing policies focus on isolated and end-of-pipe solutions to resolve and tackle the C&D waste management issues. However, a holistic and comprehensive approach must be adopted to reduce the overall environmental impact of the construction sector. Government guidelines and policies need to focus more on lifecycle perspective in CE measures. Initiatives such as market development, eco-innovation in construction, adaptive reuse of buildings, and more inclusiveness of the informal sector in the DWM policies can be instrumental in bringing a change in this traditional setup. Indian standard codes should bring technical acceptability to regenerative design methods and formalize more resource-efficient demolition processes. Additionally, for achieving the national climate goals, C&D waste quantification and stock assessment of in-built construction materials in existing infrastructures is needed to be prioritized. DWM also presents some opportunities in the Indian construction sector such as developing novel business approaches, enhancing stakeholder capacity, and integrating the principles of CE from the initial stages of construction. Building DWM also contributes significantly in the realization of SDGs by 2030. Overall, the CE framework of reduce, reuse and recycle have a vast potential to create more value from the existing resources and pave the way for sustainable construction in India.

Table-1: Challenges and actions for improvement in the Indian scenario of Demolition Waste Management (Source: Sharma et al., 2022)

S. No.	Strategies	Indian Context		Action Type			Action By	
		Challenges	Proposed Actions	R	T	I	Primary	Secondary
1	Design for adaptability	• Linear construction practice currently prevailing in India. • Lack of building designs incorporating the end-of-life perspective in building elements.	• Indian design standards can adopt more futuristic design principles such as disassembly/ deconstruction. • Interventions like permitting the use of interchangeable elements, easily modifiable design can be a good starting point.	✓	✓		Technical (standardization) bodies in India like BIS; Project Design and Planning bodies	Project Design and Planning bodies, Building Owners
2	Urban mining	• No pre-defined mechanisms and repositories in place to monitor the extraction, storage and retrieval of building elements from one demolition project to another building construction. • Quality assurance mechanisms for retrieved elements not yet identified.	• Collection systems, storage and traceability of the extracted building elements in warehouses can be initiated and monitored through a centralized database • Guidelines for material testing should also be established.	✓	✓	✓	Technical bodies in India like BIS, BMTPC; Urban Local Bodies (ULBs); Demolition Contractors	Project Design and Planning bodies
3	Waste quantification and formulation of indicators for better assessment	• India's last C&D waste estimation was done in 2013. These estimates have become obsolete and of not much relevance today. • Direct, comprehensive and reliable indicators cannot be formulated to monitor the policy's ground-level implementation due to inadequate data.	• National-level studies can be carried out to estimate the C&D waste generation rates for different types of building topologies across India. Emphasis also needs to be provided to evaluate the existing in-built material stock. • Better indicator development of waste would help in understanding the current gaps in C&D waste management plans and establish more practical national goals.		✓		ULBs	Technical Education Institutes in India

S. No.	Strategies	Indian Context		Action Type			Action By	
		Challenges	Proposed Actions	R	T	I	Primary	Secondary
4	Standardization of building components	• The dimensions of building elements vary from project-to-project basis. • Additionally, the elements are not designed to be dismantled at the end of life, then the salvaging any building element might not be resource efficient.	• Building component sizes can be pre-fixed corresponding to different load ranges and focus can be made in identifying optimal design solution with best combination of new and reused materials. • Emphasis can be given to incorporate mechanical joints in construction elements for easy extraction.	✓	✓		Technical bodies in India like BIS, NBCC; Project Design and Planning bodies	Construction Contractors
5	Selection of construction material	• Recycled aggregates, products made from C&D waste, secondary building materials have started showing presence in Indian construction market but their application is still limited to some construction projects. • Use of composite materials in facades, fixtures and fittings is still prevalent which creates difficulties in recycle or reuse.	• Life cycle assessment of materials can be made mandatory before material selection in design stage. • Material alternatives which are locally available, which have a longer lifespan, are easily reusable or recyclable and non-hazardous in nature should be strongly recommended in building construction. • The C&D recycling infrastructure also needs to be strengthened to meet the demands the market.	✓		✓	ULBs; Project Design and Planning bodies	
6	Defining material recovery targets		• The targets for building deconstruction, waste diversion and material recovery can be specified before execution of demolition activities.	✓		✓	Building Owners	Demolition Contractors

S. No.	Strategies	Indian Context		Action Type			Action By	
		Challenges	Proposed Actions	R	T	I	Primary	Secondary
7	Recognition of the informal sector in the mainstream C&D waste management policies	• The provision of using C&D waste in non-structural construction applications in "Swachh Survekshan 2021" has indirectly provided some recognition to the informal waste sector, but there is need to further dissolve the boundary between formal and informal sector.	• The informal sector supplies salvaged building components like wooden frames, windows, paver blocks in Indian low-income housing groups and informal settlements. The policies at the national level should aim to improve the existing business systems and involve them in the mainstream C&D sector by providing them with employment benefits, business and technological aids.	✓			ULBs	
8	Providing interface between construction contractors and recyclers	• Several construction contractors are not aware of the technical know-how of recycled product application . • Lack of awareness regarding the availability of various C&D waste products is also a hinderance in application.	• A centralized portal can be set up which enables the recycled product manufactures to understand the requirements of construction and accordingly suggest suitable alternatives for any project. • Such platforms can also be used for information exchange and training purposes.			✓	C&D Recycling Companies	Construction Contractors
9	Policies to support companies adopting sustainable construction practices	• The competitive nature of Indian construction industry (EBITDA margins around 8 to 12 percent) limits their capacity to take cost intensive resource efficiency measures.	• Construction companies utilizing recycled products or opting for resource efficient designs can be awarded with some level of economic relaxations.	✓			ULBs	Construction Contractors

S. No.	Strategies	Indian Context		Action Type			Action By	
		Challenges	Proposed Actions	R	T	I	Primary	Secondary
10	Adaptive reuse/ Repurposing of building	• There are very few examples available of successful reuse of buildings in India.	• Government guidelines and policies regarding infrastructural planning need to encourage adaptive reuse of buildings and also promote the same among the other private players. • Through collaborative participation of the planning, design and waste management bodies avenues of reusing the existing infrastructure can be identified.	✓			ULBs	Building Owners

Representation symbols used in table:

R = Regulatory and guidelines;

T = Technical; I = Infrastructural

Note: The existing level of implementation in Indian scenario, effort and impact have been qualitatively determined by the authors based on their experience, industrial practice in India and academic knowledge.

References

1. Akhtar, A., Sarmah, A.K., 2018. Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. J. Clean. Prod. 186, 262–281. https://doi.org/10.1016/j.jclepro.2018.03.085
2. Bakos, N., Schiano-Phan, R., 2021. Bioclimatic and Regenerative Design Guidelines for a Circular University Campus in India. Sustainability 13, 8238. https://doi.org/10.3390/su13158238
3. Brejnrod, K.N., Kalbar, P., Petersen, S., Birkved, M., 2017. The absolute environmental performance of buildings. Build. Environ. 119, 87–98. https://doi.org/10.1016/j.buildenv.2017.04.003
4. CBTC (Central Board of Indirect Taxes and Customs), 2022. GST Rates [WWW Document]. URL https://cbic-gst.gov.in/gst-goods-services-rates.html (accessed 5.4.22).
5. Cuéllar-Franca, R.M., Azapagic, A., 2012. Environmental Impacts of the UK Residential Sector: Life Cycle Assessment of Houses. Build. Environ. 54, 86–99. https://doi.org/10.1016/j.buildenv.2012.02.005
6. EC (European Commission), 2022. Waste prevention and management - Environment [WWW Document]. Eur. Comm. URL https://ec.europa.eu/environment/green-growth/waste-prevention-and-management/index_en.htm (accessed 5.5.21).
7. EMF (Ellen MacArthur Foundation), 2017. Circular economy introduction [WWW Document]. URL https://www.ellenmacarthurfoundation.org/circular-economy/concept/building-blocks (accessed 8.6.21).
8. Esa, M.R., Halog, A., Rigamonti, L., 2017. Developing strategies for managing construction and demolition wastes in Malaysia based on the concept of circular economy. J. Mater. Cycles Waste Manag. 19, 1144–1154. https://doi.org/10.1007/s10163-016-0516-x
9. Faruqi, M.H.Z., Siddiqui, F.Z., 2020. A mini review of construction and demolition waste management in India. Waste Manag. Res. 38, 708–716. https://doi.org/10.1177/0734242X20916828
10. Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
11. Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007
12. Huang, B., Wang, X., Kua, H., Geng, Y., Bleischwitz, R., Ren, J., 2018. Construction and demolition waste management in China through the 3R principle. Resour. Conserv. Recycl. 129, 36–44. https://doi.org/10.1016/j.resconrec.2017.09.029
13. Islam, R., Nazifa, T.H., Yuniarto, A., Shanawaz Uddin, A.S.M., Salmiati, S., Shahid, S., 2019. An empirical study of construction and demolition waste generation and implication of recycling. Waste Manag. 95, 10–21. https://doi.org/10.1016/j.wasman.2019.05.049
14. J.S, S., Thomas, A., 2021. Integrated Model and Index for Circular Economy in the Built-Environment in the Indian Context. Constr. Econ. Build. 21, 198–220. https://doi.org/10.5130/AJCEB.v21i3.7684
15. Jain, M.S., 2021. A mini review on generation, handling, and initiatives to tackle construction and demolition waste in India. Environ. Technol. Innov. 22, 101490. https://doi.org/10.1016/j.eti.2021.101490
16. Jain, S., Singhal, S., Jain, N.K., 2019. Construction and demolition waste generation in cities in India: an integrated approach. Int. J. Sustain. Eng. 12, 333–340. https://doi.org/10.1080/19397038.2019.1612967
17. Kolaventi., S.S., T.P., T., Siva, S.K., 2022. Implementing construction waste management in India: An extended theory of planned behaviour approach. Environ. Technol. Innov. 27, 102401. https://doi.org/10.1016/j.eti.2022.102401
18. Modak, P., 2021. Practicing Circular Economy, Practicing Circular Economy. https://doi.org/10.1201/9781003107248
19. MoEFCC (Ministry of Environment, F. and C.C.G. of I., 2019. National Resource Efficiency Policy, 2019 (Draft).

20. MoHA, 2011. Population Enumeration Data [WWW Document]. URL https://censusindia.gov.in/2011census/population_enumeration.html

21. MoHUA (Ministry of Housing and Urban Affairs), 2022. Light House Projects [WWW Document]. URL https://ghtc-india.gov.in/Content/LHP.html

22. MoUEPA (Ministry of Urban Employment and Poverty Alleviation), 2010. Shortage of Building Materials in Country [WWW Document]. Press Inf. Bur. Gov. India. URL http://pibmumbai.gov.in/scripts/detail.asp?releaseId=E2010PR1421

23. Nair, S., 2021. India manages to recover and recycle only about 1 per cent of its construction and demolition (C&D) waste, says new CSE analysis [WWW Document]. CSE Media Resour. Cent. URL https://www.cseindia.org/india-manages-to-recover-and-recycle-only-about-1-per-cent-of-its-construction-and-demolition-10326 (accessed 7.5.21).

24. Niero, M., Kalbar, P.P., 2019. Coupling material circularity indicators and life cycle based indicators: A proposal to advance the assessment of circular economy strategies at the product level. Resour. Conserv. Recycl. 140, 305–312. https://doi.org/10.1016/j.resconrec.2018.10.002

25. NIUA (National Institute of Urban Affairs), 2020. Sustainable Construction and Demolition Waste Management Talraining Manual. New Delhi: Deutsche Gesellschaft fu¨r Internationale Zusammenarbeit (GIZ) GmbH

26. OE (Oxford Economics), 2021. Future of Construction.

27. PMO (Prime Minister;s Office, I., 2021. Cabinet approves the continuation of Swachh Bharat Mission (Urban) [SBM U] till 2025-26 for sustainable outcomes [WWW Document]. URL https://www.pmindia.gov.in/en/news_updates/cabinet-approves-the-continuation-of-swachh-bharat-mission-urban-sbm-u-till-2025-26-for-sustainable-outcomes/ (accessed 1.17.22).

28. Ram, V.G., Kalidindi, S.N., 2017. Estimation of construction and demolition waste using waste generation rates in Chennai, India. Waste Manag. Res. 35, 610–617. https://doi.org/10.1177/0734242X17693297

29. Sariatli, F., 2017. Linear Economy Versus Circular Economy: A Comparative and Analyzer Study for Optimization of Economy for Sustainability. Visegr. J. Bioeconomy Sustain. Dev. 6, 31–34. https://doi.org/10.1515/vjbsd-2017-0005

30. Sharma, N., Kalbar, P.P., Salman, M., 2022. Global review of circular economy and life cycle thinking in building Demolition Waste Management: A way ahead for India. Build. Environ. 222, 109413. https://doi.org/10.1016/j.buildenv.2022.109413

31. Shooshtarian, S., Hosseini, M.R., Kocaturk, T., Ashraf, M., Arnel, T., 2021. The Circular Economy in the Australian Built Environment: The State of Play and a Research Agenda. Geelong, Australia.

32. Tong, X., Wang, T., Chen, Y., Wang, Y., 2018. Towards an inclusive circular economy: Quantifying the spatial flows of e-waste through the informal sector in China. Resour. Conserv. Recycl. 135, 163–171. https://doi.org/10.1016/j.resconrec.2017.10.039

33. US EPA (United States Environmental Protection Agency), 2021. Sustainable Management of Construction and Demolition Materials [WWW Document]. URL https://www.epa.gov/smm/sustainable-management-construction-and-demolition-materials (accessed 7.4.22).

34. WEF (World Economic Forum), 2014. Not to be used Towards the Circular Economy : Accelerating the scale-up across global supply chains. World Econ. Forum 1–64.

35. Wu, H., Duan, H., Zheng, L., Wang, J., Niu, Y., Zhang, G., 2016. Demolition waste generation and recycling potentials in a rapidly developing flagship megacity of South China: Prospective scenarios and implications. Constr. Build. Mater. 113, 1007–1016. https://doi.org/10.1016/j.conbuildmat.2016.03.130

36. Zhang, N., Duan, H., Miller, T.R., Tam, V.W.Y., Liu, G., Zuo, J., 2020. Mitigation of carbon dioxide by accelerated sequestration in concrete debris. Renew. Sustain. Energy Rev. 117, 109495. https://doi.org/10.1016/j.rser.2019.109495

08

Uses of Waste Materials for stepping up Circular Economy

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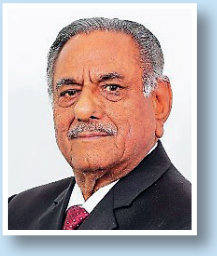

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Abstract

The Circular Economy (CE) approach requires re-evaluating the production cycles so that its principles can be applied to the construction industry which is characterized by high consumption of materials and also production of waste. The waste generated in industrial and other processes.

This paper presents the proper uses of the waste materials for the use in road construction projects so as to . minimise environmental hazards, reduce the disposal area required and also reduce the cost of road construction for embankment filling, reinforced concrete work, cost of cement treated base and cement treated sub base.

Introduction

Intensive construction works during past two decades are resulting in reduced availability of natural resources especially aggregates, sand and fresh water which would lead to a crisis in the future. There is therefore, a need to minimise and limit the use of natural resource and explore use of alternative resource or reuse waste products obtained from industrial and other sectors to reduce environmental pollution and decrease waste disposal costs. That needs a reverse logistics network based multi-period optimization for recycling and its consumption, but also convert the Construction and Demolition Waste (CDW) and other waste product into new construction materials to economically benefit the construction industry.

Adopting a Circular Economy (CE) approach means re-evaluating the production cycles. The principles of CE (Anastasiades et al. 2020) can be applied to the case of the construction industry characterized by high consumption of natural raw materials and high production of waste. It is "circular" as opposed to the linear, traditional, and classical economies, which do not emphasise either the origin of resources or the destination of waste, but focus only on the production process (Migliore et al. 2020).

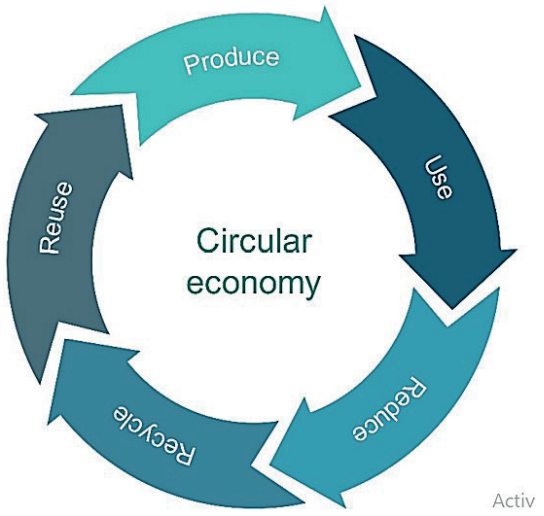

Figure-1 Basic Principle of Circular Economy

Circular Economy, a closed loop economy has been introduced and promoted since the 1970s by Stahel (1976) which advocated a potential circle of production and usage that would minimise waste generation while maximising resource use. Based on that foundation, CE conceptually focuses on de-linearisation of the relationship between ecological footprint and economic growth based on the 6 Rs of Reuse, Recycle, Redesign, Remanufacture, Reduce, Recover as shown in Figure-1 (Geissdoerfer 2017)

Definition of Circular Economy

In simple words, the Circular Economy is an economic system that eliminates waste and promotes the continual use of resources (Sauvé et al.2016). It is a commercial system that supports efficiency through reducing waste and the uninterrupted use of resources. The main idea is to close the entire loop in the production cycle and maximise the recycling and reuse of material throughout its lifecycle. However, it has some limitations and that is that all waste / recycled materials are not fully useable. These lose their properties mainly grading for the case of aggregate. They become and need fine coarser aggregate to achieve the desired gradation as per contract and 100 % recycling would not be possible.

Application of Waste/ Recycle Materials

Alternative Materials for Reducing Dry Shrinkage Cracks

The main concern about applying Cement Treated Base (CTB) under asphalt pavement is the possibility of reflection cracks. A crack in CTB can occur because of dry shrinkage at an early age which then it is propagated to the asphalt layer and causes that also to crack. The reflection crack can cause unevenness and structural failure and increase maintenance and repair costs. The shrinkage of cement materials can be classified as autogenous shrinkage, dry shrinkage, and carbonation shrinkage.

Generally, there are two methods for reducing the early-age dry shrinkage. The first involves controlling the mix design by altering the amounts of water, cement, and aggregate. The second method involves adding fly ash or admixture (Sherman 1974).

Fly ash has been used in several projects in India in concrete works in the building sector, Pavement Quality Concrete (PQC), Dry Lean Concrete (DLC), Plain Cement Concrete (PCC) construction, cement treated base, cement treated sub base and improved subgrade, where large quantities of wasted fly ash can be used.

Bottom Ash as Pavement Insulation Layer

Bottom ash a by-product of coal combustion when burned in the boiler furnace of electric power plants is mainly composed of silica, alumina, and iron and is utilized in highway construction primarily in cold-mix asphalt, embankments, and base courses. A few studies have investigated the ability of bottom ash mixed with subgrade and base materials to limit frost depth. A study conducted in Helsinki, Finland, over the course of three winters revealed that frost depth in bottom ash sections was 40% to 60% of that in gravel sections. Mechanically and chemically stabilized bottom ash can be considered a high-quality base material for highway applications. From experimental results, it was concluded that most bottom ashes met several performance criteria, such as physical appearance, gradation, and soundness, which make them suitable for pavement construction. The application of bottom ash on top of saturated silt was found to effectively mitigate frost heave and transverse cracking in western Canada. In a study conducted by Nixon and Lewycky in Edmonton, Alberta, Canada, pavement sections composed of a 500 mm gravel base course and a 1,100 mm bottom ash insulation layer showed a maximum frost depth of 1.5 m, with no frost reaching to the underlying silt layer. It is a good technical solution of the waste material through circular economy and most cost effective solution. It could be used in the Himalayan regions of India.

Waste Foundry Sand

The annual generation of Waste Foundry Sand (WFS) a by-product of the metal casting process is very large. It is sand that has lost the properties required for metal casting. A major portion of that sand is disposed of as solid waste (*Lee 2001*). Typical engineering properties of WFS are presented in Table-1, because of which it can be used to construct an embankment and Reinforced Earth Retaining Wall in lieu of borrow material. Foundry sand/ natural sand mix asphalt layer can be provided to reduce reflection cracks.

Test		Properties
Direct shear (AASHTO)	Cohesive intercept	0.3 t/m^2(15.2 kN/m^2)
	Friction angle	38^0
CBR(AASHTO-193)	CBR	6.2
Hydraulic conductivity (ASTM D1883, D5084)	Falling head, fixed wall	1.7 x 10^{-6} m/s
Liquid limit (ASTM D4318)		--
Plastic limit (ASTM D4318)		NP
Specific gravity (ASTM D854)		2.46
Percentage of coarse particles (ASTM D422)		60%
Percentage of fines (Passing No. 200 sieve)		40%
Standard Proctor Compaction Method B (ASTM D 698)	Optimum moisture content	27.1%
	Maximum dry unit weight (kN/m^3)	1.75 g/cc

Note: CBR = California Bearing Ratio, NP = non-plastic.

Table-1: Typical Engineering Properties of Waste Foundry Sand

RAP in Asphalt Pavement

Reclaimed Asphalt Pavement (RAP) technology is used in several projects in India as base layer and recommended resilient modulus value of 800 MPa for the determination of the pavement thicknesses. The complete guideline is available in IRC:37, MORT&H Specification and other guideline.

Shredded Tyres

Several studies were carried out by FHWA–INDOT–Purdue University Joint Transportation Research Program (JTRP), which indicated that a mixture of shredded tyres and sandy soils can be used as an embankment fill in highway construction. The fill material has been shown to provide durability, low unit weight, apart from eliminating disposal costs and environmental concerns. The environmental effects on the construction site can be diminished by properly encapsulating the tire-shred fill and preventing water from entering the fill. The largely positive results observed in tire-shred embankments in various parts of the United States such as Indiana, support the feasibility of this application.

A special provision for fills built of shredded tyres and sand was proposed as given below (Lee et. al 1999):

The fill is to be constructed with tyre shreds of maximum size 9.5 mm and sand in proportions of 50:50 by weight; the source of shredded tyres to be approved by the Consultants. Sand to meet the standard specifications, but with maximum size not exceeding 4.75 mm.

A 150 mm thick layer of compacted aggregate under-drain covered by geotextile to be laid to act as a barrier between the natural soil and the tyre shreds and sand. A 300mm layer of approved tyre shreds to be placed on the geotextile, which in turn is placed on a sandy fill.

Six to eight passes of a vibratory compactor to be used to compact the voids in the tyre shreds; the fill must be of substantial uniformity.

An encasement of 900 mm of cohesive soil to be constructed at the same time the tyre shreds fill is constructed; the tyre shreds and sand fill to be encapsulated with geotextiles for drainage/ filtration purpose; the top 900 mm of the embankment fill to be constructed with clayey soils.

Cement Kiln Dust (CKD)

Cement Kiln Dust (CKD) is a by-product of the cement manufacturing process. It can be used for soil subgrade stabilization. It can also be used for stabilisation of

soil under pavements, thus providing a much better alternative than the usual one of disposal in a landfill. The percentage of CKD is to be finalised based on laboratory test results by trial and error (Indiana CCP Reuse 1999).

Crushed Glass

Glass recycling programs have enabled collection of large quantities of glass in many parts of the country. With a diminishing glass recycling market, bottles and jars used for packaging food and beverages are disposed of in landfills. Waste glass can be used in embankment construction (Solid Waste Disposal Overview 1999).

For 100% crushed glass to be used as bedding material, the requirements are: (*a*) the source of the crushed glass to be glass beverage and food containers that have been processed by equipment specifically designed to crush glass into aggregate; (*b*) the resultant material must be relatively free of bottle caps, labelling paper, clay balls, and other unsuitable materials; and (*c*) 100% crushed glass must have particle size gradations as indicated in the Table-2 (Solid Waste Disposal Overview 1999).

Sieve Size (mm)	Percentage Passing
12.5	85 - 100
4.75	45 - 85
2	25 – 70
0.425	10 - 30
0.075	0 - 10

Table-2 Grading of Crushed Glass

Use of Recycled Materials to Build Paver Blocks for Low-Volume Roads

Constructing, renovating, and demolishing buildings, roads, bridges, and other structures generate large amounts of debris. Most of these are recoverable, and some of it can be reused or recycled. Construction and demolition (C&D) materials such as concrete, bricks, wood, and asphalt are some of the most common wastes in landfills. Some experiments have been done with C&D materials recovered through recycling, thereby reducing the volume of materials in the solid waste stream. There are several cases in which recycled materials have been used to successfully create a composite material.

The amount of C&D debris produced from constructing, renovating, and demolishing buildings in Medellin, Colombia, has motivated research for use of demolished material as aggregates to produce concrete and other products used in the construction industry. Likewise, the integrated solid waste management program in Fortaleza, Brazil, has been developed on the basis of waste minimisation and maximum utilisation of waste components through a waste source separation and selective re-collection that involves the whole community .Other countries such as Chile (Howland 1998) and Spain (Sabater 2003) have developed programmes to promote clean production strategies.

Reuse for Block Pavement Construction

Compared with natural aggregates, aggregates made from waste derived mainly from recycled concrete have a low specific gravity and high water absorption characteristics (Cho, Y., and S. Yeo 2004). However, if Recycled Concrete Aggregates (RCAs) are used to produce paver blocks them that turn the recycled construction materials into an eco-friendly material. In their research, an attempt has been made to engineer a composite material that, with the use of recycled materials, can achieve the strength, durability, and aesthetic quality needed for landscape and hardscape applications.

Rigid Pavements Containing Recycled Concrete Aggregate

Interest in Portland Cement Concrete (PCC) recycling with Recycled Concrete Aggregate (RCA) was widespread in the mid-1970s. Increased interest is expected because of the decreasing availability of new aggregates; the emphasis being placed on green highways; and the exceptionally lower carbon footprint for projects using recycled material. In 1994 Federal Highway Administration (FHWA) sponsored research to combine field/ site evaluations with related laboratory and petrographic examinations in an effort to determine why some RCA concrete pavements performed well and few did not perform well (Gress, et. al. 2009).

Specifications Developed by Indian Roads Congress (IRC)

IRC has developed some codes for use of various types of Waste Materials/ Recycling Materials in the Road Sector as described below.

The justification for reclaiming the pavement materials, consisting mainly of aggregates and bituminous binders, is both environment friendly as well as makes economic sense. The aggregates existing in the pavement are part of natural resources drawn from the environment and should not be simply dumped at dump sites if a pavement fails or becomes unserviceable because that would cause damage to the environment because that would further aggravate degradation of the environment since more virgin aggregates would be extracted from the environment to replace the materials removed. Economic justification comes from the utilisation of the bitumen already existing in the pavement, which leads to reduction in the requirement of expensive virgin bitumen (IRC:120-2015).

Many institutes and Public Works Departments (PWDs) such as Central Road Research Institute (CRRI), National Council for Cement and Building Material (NCCBM), Municipal Corporation of Delhi (MCD) PWD, Haryana, etc. in India carried out experimental works using C&D waste from various construction activities related to buildings. The waste materials were used to produce recycled concrete, cement concrete, concrete with fly ash and embankment construction works (IRC:121-2017).

Safe disposal of plastic waste is a serious environmental problem. Being a non-biodegradable material, even if it is dumped in landfills, it finds its way back in the environment through air and water. Plastics lead to choking of drains and drainage channels; they can be eaten by unsuspecting grazing animals causing them to fall ill or even die; it can contaminate the construction fill, etc. The best way of disposal of waste plastic is its recycling to the maximum extent and many developed countries have recycled waste plastics to manufacture various products, including some used in heavy construction, e.g., railway sleepers. Trial tests were conducted in Delhi, Chennai and Bangalore (IRC:SP-98-2013).

Steel and other slags are the waste product during manufacturing of steel and other materials and they pose a challenge for their safe disposal. However, those waste materials could be used for construction of subgrade, sub base, base course, Mix Seal Surfacing (MSS), Open Graded Pavement Concrete (OGPC) and Bituminous Macadam (BM) works (IRC: SP: 121-2018).

As can be seen from the above discussions there are several uses for waste and recycled materials and they should be used so that Circular Economy is truly deployed. It is for the consulting engineers to recommend and convince the authorities/ clients of the environmental and financial benefits that accrue.

Policy for Use of Waste Material

IRC has developed some codes for use of waste and recycled materials however, there are still several waste materials which have not been fully studied in India. A policy needs to be formulated and a committee appointed to oversee and assist the use of waste material in road construction and other fields.

Conclusions and Recommendations

The paper presents the many applications of waste and recycled materials for construction of road projects. The Indian Roads Congress has developed several Codes and Specifications for uses of such materials. Research works in these fields is very limited in India and hence increased funding should be given Government and Private organisations/ associations for developing Specification based on laboratory tests and field trials. With depleting natural resources there will be a time when sourcing of good quality aggregates in India in future will be a major issue. Therefore, re-use of existing materials is essential. Specifications could also be relooked at especially for roads with low traffic volumes, PMGSY and other projects.

Properties of waste and recycled materials should

be tested for the specific uses intended. during the Detail Project Report stage and recommendations incorporated for their use during execution of the project.

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References

1. Anastasiades, K., J. Blom, M. Buyle, and A. Audenaert. 2020. "Translating the circular economy to bridge construction: Lessons learnt from a critical literature review". Renewable Sustainable Energy Rev. 117: 109522. https://doi.org/10.1016/j.rser.2019.109522.

2. Migliore, M., C. Talamo, and G. Paganin. 2020. "Construction and demolition waste" in Strategies for circular economy and cross-sectoral exchanges for sustainable building products, 45–76. Cham, Switzerland: Springer.

3. EEA (European Environment Agency). 2019a. Assessing air quality through citizen science. EEA Rep. No. 26/2019. Copenhagen, Denmark: EEA.

4. EEA (European Environment Agency). 2019b. Resource efficiency and the circular economy in Europe 2019—Even more from less. An overview of the policies, approaches and targets of 32 European countries. EEA Rep. No. 19/2019. Copenhagen, Denmark: EEA.

5. European Commission. 2018. Development and implementation of initiatives fostering investment and innovation in construction and demolition waste recycling infrastructure. Brussels, Belgium: European Commission.

6. Deloitte. 2017. "Study on Resource Efficient Use of Mixed Wastes, Improving management of construction and demolition waste—Final Report". Prepared for the European Commission, DG ENV. Accessed April 6, 2020. https://ec.europa.eu/environment/system/files/2021-01 /resource_efficient_uses_mixed_waste_Final_Report.pdf

7. Legambiente. 2016. "Dossier recycle 2015". Accessed December 4, 2019. https://www.legambiente.it/sites/default/files/docs /dossier_recycle_2015_-_def.pdf

8. Neville, A. M. (1995). Properties of Concrete, 4th ed. Longman Group Limited, London.

9. Kim, J. C. (2003). "Dry-Shrinkage Mechanism of Concrete and Its Prediction Model". Proc., Korean Society of Pavement Engineers, Vol. 5-3, pp. 32–41.

10. Sherman, G. B (1974). "A Laboratory Study of Factors Affecting the Shrinkage Characteristics of Cement-Treated Base". D-3-34. FHWA, Washington, D.C., 1974. www.dot.ca.gov/hq/research/researchreports/5/reports/74-43.pdf.

11. Lee, J., R. Salgado, A. Karim, and C. W. Lovell (2001). "Compaction and Shear Strength of Fly and Bottom Ash Mixtures", Journal of Solid Waste Technology and Management, Vol. 27, No. 3, pp. 137–145.

12. Mukhtar, M. T., and B. J. Dempsey (1996). "Interlayer Stress Absorbing Composite for Mitigating Reflective Cracking in Asphalt Concrete Overlays". Transportation Engineering Series, No. 94. University of Illinois, Urbana- Champaign, Urbana.

13. Lee, J., R. Salgado, A. Bernal, and C. W. Lovell (1999). "Tire Shreds and Rubber Sand as Lightweight Backfill Material". Journal of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 2, pp. 132–144.

14. Howland, J (1998). "Quality Control System for the Production of Concrete Paving Blocks, Pave Colombia". Proc. International Workshops on Concrete Block Paving, Cartagena de Indias, Colombia.

15. Sabater, J., and C. Carvajal (2003). "Diagnóstico del Sector de la Recuperación de Madera en España. Residuos". Vol. 71, pp. 110–113.

16. Cho, Y., and S. Yeo (2004). "Application of Recycled Waste Aggregate to Lean Concrete Subbase in Highway Pavement". Canadian Journal of Civil Engineering, Vol. 31, No. 6, pp. 1101–1108.

17. David L. Gress, Mark B. Snyder, and Jeffrey R. Sturtevant (2009). "Performance of Rigid Pavements Containing Recycled Concrete Aggregate Update for 2006", Transportation Research Record: Journal of the Transportation Research Board, No. 2113, Transportation

Research Board of the National Academies, Washington, D.C., pp. 99–107

18. IRC:120-2015 "Recommended Practice for Recycling of Bituminous Pavements"
19. IRC:121-2017 "Guidelines for use of Construction and Demolition Waste in Road Sector"
20. IRC:SP-98-2013 "Guidelines for the use of Waste Plastic in Hot Bituminous Mixes (Dry Process) in wearing courses"
21. IRC:SP-107-2015 "Guidelines for Gap Graded Wearing Course with Rubberized Bitumen-Rubber"
22. IRC:SP:108-2015 "Guidelines on Preparation and Implementation of Environment Management Plan (EMP)"
23. IRC:SP:121-2018 "Guidelines for use of Iron, Steel and Copper Slag in Construction Rural Roads"
24. Geissdoerfer M, Savaget P, Bocken NMP, Hultink EJ (2017) The Circular Economy – A new sustainability paradigm? J Clean Prod 143:757–768. https://doi.org/10.1016/j.jclepro.2016.12.048
25. G. Stahel, W.R. and Reday, "The potential for substituting manpower for energy", Rep. to Comm. Eur. Communities, no. April, 1976
26. Sauvé S, Bernard S, Sloan P (2016) Environmental sciences, sustainable development and circular economy: alternative concepts for trans-disciplinary research. Environ Develop 17:48–56.
27. Indiana CCP Reuse, Coal Combustion By-products and Percent Use. Indiana Electric Utility, Indianapolis, 1999.
28. Solid Waste Disposal Overview. National Solid Management Association, Washington, D.C., 1991.

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Two Top International Engineering Societies Collaborate to Support Climate Research

August 18, 2022

Students, Early-Career Engineers to Investigate Sustainability Solutions to Approach Decarbonization Through Digitalization

NEW YORK — Two of the world's premier engineering professional societies today announce a collaborative sustainability research effort focused on applying new technologies to combat climate change in a project called "Decarbonization through Digitalization."

The American Society of Mechanical Engineers (ASME) and Verein Deutscher Ingenieure (VDI), the German Association of Engineers, together will investigate approaches engineers can take to mitigate climate change in both the German/European and U.S. contexts. The research will center on fossil fuel dependency, both in terms of the various geopolitical drivers that affect the issue, and the role major corporations play in actively addressing the problem.

Source: https://csengineermag.com/two-top-international-engineering-societies-collaborate-to-support-climate-research/?_kx=3OUzBBB2i7fP9AovOAbIC2QAO2fbJG5mJIizYPm4bs%3D.KeXG6N

09

Building A Sustainable Future Together – Sharing Experience of Recycling Concrete Debris

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Godrej Construction

Globally, human beings consume billions of tonnes of natural resources annually, which cannot be replenished completely. As a result, the human race would eventually run out of these limited resources. Adding to that, Solid Waste Disposal and Management is a growing cause of concern across the world. Rapid urbanization is changing the nature of solid waste management from a low priority, localised issue, to a more pervasive social and environmental problem. The estimated Global average volume of Construction & Demolition (C&D) waste constituting as part of Solid Waste is approximately 20 to 30%.

Globally, the construction sector is amongst the largest consumers of natural raw materials. It is a sector, which is vulnerable to raw material supply problems and price volatility. With new buildings and infrastructure projects construction work is on the rise, the demand for building materials is expected to increase. That may result in acute shortage of building materials. Across the Construction & Real Estate sector, it is now established that adopting an improved construction process could reduce the adverse impacts on the environment.

It is therefore essential to consider 'waste' as an opportunity to 'Recover, Reuse and Recycle' rather than a waste that can be discarded. To maintain the right balance between the adverse effects of rapid urbanisation, growth in population, increased natural resource consumption and the challenge of climate change, it is imperative to adopt a circular economy in our journey of achieving economic growth. Adoption and implementation of Circular Economy principles is the need of the hour to make C&D waste a resourceful opportunity for sustainable construction.

As per the World Green Building Council's report, building and construction sectors are responsible for 39% of all carbon emissions in the world, with operational emissions (from energy used to heat, cool and light buildings) accounting for 28%. The remaining 11% comes from embodied carbon emissions that are associated with materials and construction processes throughout the whole lifecycle of buildings. Increasing use of recycled construction materials, coupled with the adoption of smart building design & engineering could substantially reduce such CO2 emissions.

C&D Waste – A Resourceful Opportunity

According to a report released by the Centre for Science and Environment (CSE) in 2020, India recycles just one percent of its Construction and Demolition (C&D) waste[1]. As per the estimate prepared by Building Materials and Technology Promotion Council (BMTPC) and the Centre For Fly Ash Research and Management (C-FARM) in the year 2016, the C&D waste generated in India was approximately 165-175 million tonnes

annually[2]. While Delhi NCR generates about 5,000 tonnes daily, Mumbai about 3,000 tonnes/day, Kolkata 2,000 tonnes/day and Chennai 1,500 tonnes/day. However, the official recycling capacity is a mere 6,500 tonnes/day. Management of C&D waste has become essential to ensure sustainable infrastructural growth across the globe. The major proportion of C&D waste comprises debris generated from the demolition activities of old buildings, roads, bridges, etc. Inadequate management of the C&D waste can lead to the disruption of natural resource cycles.

In the last few years, the Government of India has rightfully taken cognisance of the need for effective recycling and disposal of C&D waste. The Construction and Demolition Waste Management Rules, 2016 directed the State Governments to set up Construction Waste Recycling facilities in all cities with a population of over 10 lakhs. The rules apply to everyone who generates C&D waste including private organisations, government bodies, municipalities and even individuals who undertake remodelling and repair works for their dwelling units. However, on ground implementation of these rules has witnessed multiple challenges and the Ministry of Environment & Forest (MOEF) had proposed a 3 years action plan in 2019 for better governance, reduced landfill use, effective management of construction waste through recycling and increased focus on resource efficiency. Concerted efforts by Niti Aayog, MOEF, State governments and Urban Local Bodies (ULBs) along with recent critical policy developments are expected to accelerate effective C&D Waste management across various Indian cities. There are still very few C&D waste recycling facilities in operation within the country.

C&D waste can be considered as a resourceful opportunity with a potential of nearly 70% of waste that could be recovered using appropriate methods and guidelines during any demolition activity. Assessment of the structure by a reputed structural consultant before demolition work is essential to recover most of the materials for recycling using a suitable demolition method and segregating the waste generated at the source. These are key factors for the high level of C&D waste recovery.

In terms of waste streams, concrete, bricks, blocks and other fine materials form a major fraction of the overall C&D waste generated. The composition of C&D waste is highly variable depending upon the type of project, construction technique and site location of the project.

Construction Initiative - 'Recover, Recycle and Rebuild'

To demonstrate that the principles of Circular Economy are workable, Godrej Construction a pioneer in adopting sustainable construction practices in India and committed to minimizing the impact of construction on the environment took the initiative to do so. In line with its core values Godrej Construction (GC) has implemented various initiatives across its lines of business - all its building construction projects are designed using Green Building principles. Many of the buildings are certified as Platinum or Gold-rated Green Buildings. Recently, the IT Park, 02 Godrej Business District (GBD) at Vikhroli, Mumbai was awarded a Platinum rating for Health & Well-being for the built environment by Indian Green Building Council (IGBC). 02 GBD IT Park building is also a LEED Platinum rated green building and the common areas of the building are 100% powered by renewable energy.

Godrej Construction has set up an automated Recycled Concrete Materials (RCM) manufacturing plant at Vikhroli, Mumbai. The plant manufactures concrete blocks for walls and pavers using concrete debris recycled from demolished concrete structures from building and infrastructure projects, which would otherwise end up in already overflowing city landfills. In India, Concrete debris is a major waste stream in the total C&D waste generated. So far over 28,000 metric tonnes of concrete debris has been recycled by implementing Circular Economy principles in the Construction Materials line of business. The recycled concrete materials from the plant are also used for constructing customised Prefabricated Concrete Products such as Box Culverts, Ducts, Drain Covers which are being used for the major infrastructure projects in Mumbai. The manufacturing of the blocks and its product properties by virtue of the raw material used that is locally sourced and thus have

higher recycled content, have resulted in efficiency in production, responsible management of water and waste during manufacturing ensuring zero discharge from the facility. High recyclability of waste product are inherently greener than normal concrete or building blocks, effectively reducing the overall negative impact on the environment over the service life of the building. Besides, the use of Recycled Concrete Materials has helped reduce the demand for quarrying stone aggregates and natural river sand.

Godrej Construction is one of the first in the RMC industry to switch to 100% green energy. It has received the '*GreenPro'* certificate from IGBC for a variety of the RMC products such as Enviro TUFF, Xtra TUFF, Easy TUFF and other construction materials such as TUFF Blocks AAC, Recycled Concrete Blocks and Pavers making them beneficial for use in Green Buildings. The company's three RMC plants in the Mumbai-MMR and Pune region have been commended with the '*GreenPro'* Certification by IGBC.

Demonstration Project on Use of Recycled Concrete Aggregates (RCA)

A successful demonstration project was conducted on the RCA using fine aggregates produced at Godrej Construction's Recycled Concrete Materials plant. For the project, Godrej Construction associated with two leading organisations - the Central Public Works Department, Government of India and SINTEF, Norway. The latter is a world-renowned organisation in scientific research on C&D waste and its practical applications.

A full-scale demonstration project on RCA was initiated under the joint Indo-Norwegian initiative. The main objectives of the project were to:

- demonstrate the value-added benefits by using RCA in making of recycled concrete products, and
- assess natural CO_2 binding potential of RCA.

The demonstration project was carried out in two phases. In the first phase, two types of concrete blocks – one containing natural aggregates and other containing RCA - were produced at the Godrej plant. They were separately sampled for CO2 binding measurements and shipped to the SINTEF Laboratory in Norway. The blocks were crushed and exposed to CO2 exposure into a patented test apparatus in SINTEF's laboratory. The exposure involved changing relative humidity (RH), pressure, exposure period, etc. The results of CO2 uptake were observed at defined frequencies.

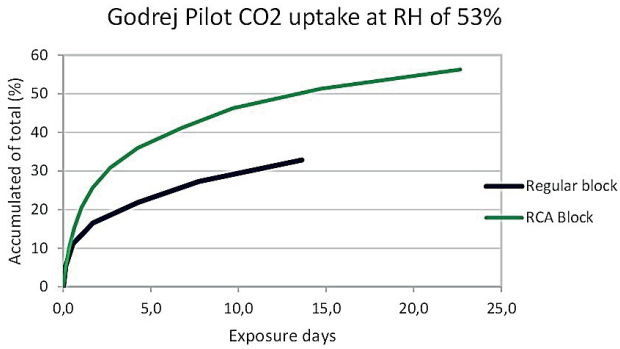

Figure- 1: CO2 Uptake Measurement Results – Relative Humidity (RH) of 53%

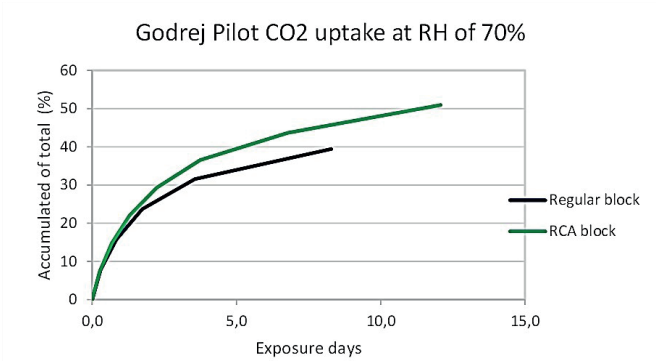

Figure-2: CO2 Uptake Measurement Results – Relative Humidity (RH) of 70%

The test results in Figures-1 and 2 reinforce the theory that concrete containing recycled aggregate has a higher CO2 binding capacity owing to carbonation.

In the second phase of the demonstration project, concrete debris was collected from a demolition site of a hotel building in Mumbai. The structure was around 8 to

10 years old and was approximately 6.5 km away from the Godrej's recycling plant. Ultrasonic pulse velocity and carbonation tests were carried out on the site before collecting the debris for ascertaining the quality of in-situ concrete.

The debris was then pulverised in the recycling plant and RCAs were produced. RCA sampling was done at defined intervals during the production. Five samples were collected in an hour from different batches of production, put in different bags and labelled. Hourly samples were mixed with each other to make a composite sample for testing.

The composite samples were tested at a 3rd party laboratory for checking various physical properties of the RCAs produced. The tests included sieve analysis conforming to IS 2386, Part 1, and other physical tests conforming to IS 2386, Part 3. The results of the test are shown in Table-1.

The test results were encouraging and demonstrated that the RCAs produced through good quality feedstock and well controlled production process possessed properties more or less similar to those of naturally sourced aggregates.

Table-1:- Third Party Test Reports on Physical Properties of Recycled Concrete Aggregates (RCA)

TEST REPORT ON PHYSICAL PROPERTIES OF FINE AGGREGATE

Source of Sample	:	Sample supplied by the customer.
Number of Sample Tested	:	01(One only)
Condition of Sample	:	Satisfactory
Customer's Reference	:	Email dt.27.02.2020
Lab Reference Number	:	2020/MAR/326786
Nature of sample#	:	RECYCLE AGGREGATE
ID Marks#	:	sample 2/Date of sampling 26.02.2020
Period of Test	:	04.03.2020 to 13.03.2020

1. SIEVE ANALYSIS: AS PER IS 2386 (PART 1)-1963 RA 2016

Sl. No.	Sieve Size mm	% Passing	LIMITS AS PER IS 383 – 2016			
		RECYCLE AGGREGATE	ZONE I	ZONE II	ZONE III	ZONE IV
1	10	100	100	100	100	100
2	4.75	78.38	90-100	90-100	90-100	95-100
3	2.36	55.96	60-95	75-100	85-100	95-100
4	1.18	33.63	30-70	55-90	75-100	90-100
5	0.600	21.62	15-34	35-59	60-79	80-100
6	0.300	12.91	5-20	8-30	12-40	15-50
7	0.150	7.41	0-10	0-10	0-10	0-15
Fineness Modulus		3.90	NOTE- For crushed stone sands, the permissible limit on 0.150 mm Sieves is increased to 20 %.This does not affect the 5 % allowance permitted in Cl.6.3 applying the other sieve sizes.			

2. PHYSICAL TEST: IS 2386 (PART 3) -1963 RA 2016

Sl. No.	Test Conducted	RESULT	LIMITS AS PER IS 383 – 2016
		RECYCLE AGGREGATE	
1	Specific Gravity	2.22	2.1 to 3.2
2	Water Absorption (%)	8.87	Max. 10.0 % (Table 3 NOTE 1)
3	**Bulk density (kg/litre)**		
a	Loose	1.48	--
b	Rodded	1.61	--

As furnished by the customer.

Note: 1. The results relate only to the items tested.
2. Report shall not be reproduced except in full, without the written approval of the lab.
3. Any correction invalidates this report.

The fine aggregates obtained from RCAs were used in the making of solid concrete blocks. The recycled solid concrete blocks were also tested in a 3rd party laboratory as per IS 2185, Part 1, for ascertaining the average compressive strength, water absorption, dry density, dimensional accuracy, drying shrinkage and moisture movement. The test results, summarised in Table-2, demonstrated that the quality of recycled concrete solid blocks produced using RCAs was at par as per the acceptance criterion used for normal solid concrete blocks made with naturally sourced aggregates.

Table-2:- Third Party Test Reports on Solid Concrete Blocks made with RCA (Fine aggregates) and Physical Properties of Recycled Concrete Aggregates (RCA)

Results:

Sl. No.	Test Performed	Results	Limits as Per IS-2185(PART 1) -2005 RA 2015
1	Avg. variation in the length of 20 units (mm)	0.0	Not more than ± 5.0 mm
2	Avg. variation in the Width of 20 units (mm)	1.0	Not more than ± 3.0 mm
3	Avg. variation in the Height of 20 units (mm)	0.0	Not more than ± 3.0 mm
4	Avg. Compressive Strength (N/mm²)	Avg. strength 6.3 Min. Individual Strength 6.0	Solid load bearing unit C (5.0) Min.Avg.compressive strength of units 5 N/mm². Min compressive strength of individual units 4 N/mm².
5	Avg. Water Absorption (%)	7.1	The Avg. of the three units not more than 10 % by mass of the sample.
6	Avg. Dry Density (kg/m³)	1855	Solid load bearing units not less than 1800 kg/m³

Results:

Sl. No.	Test Performed	Results	Limits as Per IS-2185(PART 1) -2005 RA 2015
1	Average drying shrinkage (%)	0.021	The Avg. of the Three units Shall Not exceed 0.06 %
2	Average Moisture Movement (%)	0.012	The Avg. of the Three units Shall Not exceed 0.09 %

Promoting Higher Uptake of Recycled Products

To promote higher uptake of recycled products made using C&D waste in construction sector, it is suggested that more emphasis is needed on the following aspects:

- the government should evolve and implement public procurement policy on recycled products
- the government should lower the GST slab rates for recycled products
- BIS/IRC should incorporate new guidelines in relevant building design codes and standards to encourage usage of C&D waste right at the design stage of any project
- Incentivise all stakeholders involved in C&D waste management to provide financial benefits for better implementation of C&D waste rules and framework
- the government should also mandate the use of recycled products from C&D waste in all private and public infrastructure projects thus encouraging Circular Economy.

Incidentally, it is heartening to note that the Ministry of Road Transport & Highways (MoRTH) has recently taken few steps to finalise guidelines for value engineering during preparation of feasibility reports of proposed highway projects for promoting use of C&D waste.

Construction 3D Printing (3DCP)

The construction industry is leveraging technology to make construction management and site operations more efficient and sustainable. The major trends which are expected to witness increased adoption in near to medium term are Building Information Modeling (BIM), construction robotics, modular construction and the use of advanced building materials. Hence, startups and scaleups are increasingly developing innovative solutions around prefabrication, worker safety, and construction robotics. Construction 3D printing (3DCP) and green building solutions have the potential to significantly reduce the adverse impact of construction on the built environment.

3DCP can enable faster and more precise creation of complicated and bespoke structures and objects. It technology could optimise the design of buildings and infrastructure to use lesser raw materials, whilst also decreasing labour costs. Addressing the growing need for improving the productivity and sustainability within the Real Estate and Infrastructure sectors, Godrej Construction recently partnered with Tvasta, an indigenous start-up founded by the Indian Institute of Technology Madras alumni, to develop a Bus Shelter using 3D Printing Technology. The Bus Shelter was 3D Printed within a span of 32 hrs. and assembled on site within 8 hrs. thereby, speeding up the construction process that would otherwise take weeks to execute using traditional construction methods.

To promote the adoption of Circular Economy principles in the Construction industry, Godrej Construction, along with Tvasta have developed for the first time a very sustainable concrete mix design comprising of approximately 30% of Recycled Concrete Aggregates (RCA), sourced from concrete waste debris, recycled at the Godrej Recycled Concrete Plant. Going forward, Godrej Construction and Tvasta aim to pioneer the use of 3DCP technology for the development of appropriate sustainable infrastructure projects, housing solutions, disaster relief structures, national defence-related applications and various other public amenities in India, and globally.

Conclusion

Godrej Construction's recycled concrete manufacturing plant is perhaps the largest such unit in India. As metropolitan cities like Mumbai grow older, C&D waste management will become a major cause of concern for ensuring sustainable development within the city. Godrej Construction has taken an early lead to clearly demonstrate the company's commitment towards sustainable development and hopes that many others in the industry would follow in the endeavour to build more sustainable construction products for the benefit of the future generations. The mindset of the industry needs to change towards adopting cleaner production practices, preservation of non-renewable raw materials and better construction methods following the principles of circular economy to help reduce energy intensity and the carbon footprints of the construction sector.

Acknowledgement

The authors are grateful to Godrej Constructions for allowing the use of the data for this paper.

References

1. Report titled 'Another Brick Off The Wall – Improving Construction and Demolition Waste Management in Indian Cities', Anumita Roychowdhury, Avikal Somvanshi and Anurag Verma 2020, Centre for Science and Environment, New Delhi, Aug' 2020

2. Report titled 'Utilisation of Recycled Produce of Construction & Demolition Waste A Ready Reckoner' C-FARM, New Delhi & Building Materials & Technology Promotion Council (BMTPC), New Delhi, Oct'2018.

10

Quality Of Water – Challenge for Sustainable Construction

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Abstract

Water is one of the most important elements in construction. It is required for preparation of mortar, mixing of cement concrete and for curing work, etc. The quality and quantity of water effects the strength of mortar and cement concrete. Depending upon the quality and characteristic of water, the service life of the structure may vary from 15 to 100 years.

The characteristic of ground water in several parts of north India is changing fast thus resulting in reduced service life of Reinforced Concrete structures which may vary from 15 to 30 years depending upon the severity of characteristics of the ground water. Appropriate care in use of water during construction and protecting the structure from the aggressive environment help in giving a designed service life. It is therefore appropriate that investigations in respect of aggressive environment which may be in form of harmful salts or water be conducted based on which an appropriate modality could be defined for execution of the work.

Control of 'Water' as Construction Input

Water is turning to be a scarce commodity, because of over exploitation, mismanagement and also contamination by polluting activities of industries, urban and allied bodies.

To avoid damage to existing structures and to maintain the quality of works in progress or to be taken up, it is necessary to investigate the reasons concerning the nature of water to be used.

The working area for this paper has been confined to Haryana in general and the National Capital Region including Delhi. Treatment for use of water and precautions to be taken during construction have been suggested.

The paper deals with water systems with reference to geological characteristics governing salinity and sulphate attack, logistical constraints, standardisation of specifications requirements by PWD and MoRTH and the construction requirements.

Geographical Status of Water in Haryana

Large-scale urbanisation and unauthorised exploitation of ground water has taken its toll on the resources in the districts falling in the National Capital Region of Haryana. The Central Ground Water Board (CGWB) has classified 31 zones as Dark Zones (over-exploited areas) as listed in Table-1.

Table-1: List of Dark Zones as per CGWB

Sl. No.	District	Dark Zones (Over Exploited Areas)	Number of Areas
1	Millennium City Gurgaon	Gurgaon, Pataudi, Sohna and Farrukh Nagar	4
2	Palwal District	Palwal, Hodal and Hassanpur	3
3	Mewat District	Tauru and Ferozepur Zhirka	2
4	Faridabad District	Faridabad	1
5	Panipat District	Bapoli, Israna, Madlaunda, Panipat and Samalkha	5
6	Sonepat District	Ganaur, Rai, and Sonepat	3
7	Rewari District	Nahar, Bawal, Rewari, and Khol	4
8	Bhiwani District	Badra, Dadri, Kairu and Loharu	4
9	Mahendergarh District	Ateli, Mahendergarh, Kanina, Nangal Chaudhary and Narnaul	5

The same is true of other districts of Haryana, which is a water deficit State with respect to surface and ground water resources. The ground water level in the State particularly in the fresh water zone is depleting fast due to heavy exploitation of ground water and that is posing a serious problem. Increasing demand and scarcity of ground water resources underlines the importance of artificial recharge and water conservation. The State's Average Decline in Water Table Level from June 1974 to June 2013 was -7.97 m and from June 1999 to June 2013 it was -7.80 m. The situation is getting alarming even in respect of drinking water.

Study of River Water Entering Haryana

Shocking as it sounds, pollution has trickled through the troubled waters of the River Yamuna and percolated into the rapidly depleting ground water reserves of Delhi City. The study reveals that the concentrations of arsenic, mercury, nitrates, sulphates and dissolved solids in the Capital's ground water exceed permissible limits.

For the study 50 samples of groundwater were taken from random spots along a 22 km stretch between Palla and Okhla in Delhi. The results of the chemical analysis of the water samples are shown in Table-2.

Table 2-: Chemical Results of Water Sample

Pollutant	Results	MPL*
Nitrate	174 mg/L	100 mg/L
Sulphate	680 mg/L	400 mg/L
Flouride	3.10 mg/L	1.5 mg/L
Mercury	4.60 mg/L	1 mg/L
Arsenic	69.5 mg/L	50 mg/L

*Maximum Permissible Limit

The alarming presence of harmful substances in ground water can be traced to the continuous discharge of sewage and industrial effluents into the River Yamuna and consequently percolate into the groundwater aquifer which, being sandy, allows the pollution to spread at a rapid rate.

Another study was done on River Yamuna in Delhi from Okhla to Mathura where in 35 samples were taken. The quantities of cadmium and lead found in the river water are shown in Table-3. In Faridabad, cadmium is 0.1 mg/l which is 10 times more than the permissible limit. In Okhla, it is 4 times higher.

Table-3: Quantity of Cadmium and Lead in River Yamuna

Location	River Water	Ground Water within a distance of 100 m from the banks
Okhla	0.04 Mg/L	0.03 mg/L
Faridabad	0.1 Mg/L	0.03 mg/L
Varindavan	0.04 Mg/L	0.03 mg/L
Mathura	0.04 Mg/L	0.01 mg/L

The contaminated water of Badarpur falls in to the river near Jasola that from Sectors 31 and 3 of Faridabad fall near Palla Bridge into the River Yamuna. New sewerage plants have not proved to be effective. Besides, the chemical factories in the city also discharge their contaminated water into River Yamuna.

Geological Characteristics

The geological survey reports on the soils in India reveal that the soils in the drier parts of Punjab, Haryana, North Bihar, Uttar Pradesh, and Rajasthan tend to be saline and alkaline efflorescence's. They contain many undecomposed rocks and mineral fragments which on weathering liberate sodium, magnesium and calcium salts. Such soils are notably impervious and therefore have impeded drainage. As a result, large areas which were once fertile, have become impregnated with these salts (reh, kalar) thus destroying the value of the ground. The salts are normally confined to the top layers of the soil, being transferred from below by capillary action. Irrigation by canal water has resulted in the soils those areas of Punjab, Haryana and elsewhere in the country to change during the past three or four decades. The alkali content in those soils is high and there is a large excess of free salts, combined with deficiency in nitrogen and organic plant food material. Such lands pose problems not only for cultivation but also for construction of civil structures which are likely to see attack by the salts in the soil and ground water.

Case Studies of Haryana

A RCC structure is normally designed for 60 to 100 years of service life. Severe damage to various culverts, bridges and buildings prompted thinking and writing on the various aspects of water and suitability of the water for construction purposes. A few Case Studies are given hereinbelow.

Rohtak and Jhajjar Districts of Haryana

The ground water table level varies widely and is in the range of 1.2 to 4.7 m. The pH values of the soil samples at all depths range from 7.6 to 9.6, which puts them in the alkaline range.

The Chloride content in the samples varies from traces to as high as 1.296 %. The variation of chloride content either with depth at a particular location or with the location of the bore hole does not show any regular pattern.

43 samples out of the 60 soil samples tested from the 22 bore holes and from different depths contained Chlorides in a range upto 0.10 %, the remaining 17 samples were in the range of 0.10 to 0.50 %.

The Sulphate content ranged from traces to as high as 0.556 %. As for chlorides, no clear pattern either with depth at a particular location, or with the location of the bore hole was observed. Out of the 60 soil samples tested from the 22 bore holes and at different depths, 42 samples contained sulphates from traces to 0.1 %, 12 samples contained in the range from 0.10 to 0.20 % and 6 samples contained more than 0.2 %. The results of soil samples regarding chloride contents and sulphate contents are given in Table-4.

Table-4: Results of Soil Samples

No. of Samples	pH Value Range	Chloride Contents		Sulphate Contents	
		No. of Samples	Content %	No. of Samples	Content %
60 Samples from 22 bore holes	7.6 to 9.6	43	0.10	42	0.10
		17	0.10 to 0.50	12	0.10 to 0.20
				6	More than 0.20

- Chloride content - traces to as high as 1.296%
- Sulphate content - traces to as high as 0.556%

The sub soil water samples collected at the water table level from 21 bore holes was found to be neutral to slightly alkaline with pH ranging from 6.65 to 8.35. The water samples also contained high concentrations of chlorides and sulphates in general. It was seen that the water samples collected from 10 bore holes contained chlorides from traces to 0.1 percent, 7 samples in the range 0.10 to 0.50 percent, and 4 samples contained more than 0.50 percent. The sulphate content in 3 water samples was from traces to 0.015 percent, in 5 samples in the range 0.015 to 0.10 percent, in 4 samples in the range 0.10 to 0.20 percent and in 9 samples above 0.20 percent. These results have been shown in Table-5.

Table-5: Results of Water Samples

No. of Samples	pH Value Range	Chloride Contents		Sulphate Contents	
		No. of Samples	Content %	No. of Samples	Content %
21 Samples from 21 bore holes	6.65 to 8.35	10	0.10	3	0.015
		7	0.10 to 0.50	5	0.015 to 0.10
		4	More than 0.50	4	0.10 to 0.20
				9	More than 0.20

Results of further analysis of sub soil water samples revealed that they contained considerable amounts of alkalis particularly as sodium salts whereas only small amounts of calcium and magnesium salts were present. The quantity of magnesium ions, though much higher than in normal waters, still seem to be in the safe range for use in concrete works.

The maximum chloride content in Rohtak and Jhajjar districts was 0.5 % (5,000 ppm) in the soil and 1.296 % (12,960 ppm) in the ground water. Simultaneous presence of deleterious salts such as sulphates and chlorides in the soil and ground water in large quantities are harmful for concrete foundations of structures. Their possible interaction due to the periodic fluctuation of the ground water table can further aggravate the situation arising out of such type of salinity attack.

Sulphate (as SO_4) contents of the order of 1,000 to 2,000 ppm in the ground water are considered to be detrimental even to brickworks. As far as the pH is concerned, the range of values beyond permissible limits effect concrete and brickwork.

Based on the chemical analysis results on the soil and ground water samples, it can be concluded that:

i. The soil below the ground water table is slightly alkaline with pH ranging from 7.6 to 9.6.

ii. Considerable amounts of chlorides and sulphates are present in the soil samples. The chloride content ranged from traces to as high as 0.5 %and the sulphate content ranged from traces to as high as 0.556 %.

iii. The sub soil water is neutral to slightly alkaline in nature with pH ranging from 6.65 to 8.35. Considerable amounts of chlorides and sulphates were found in some samples. The chloride content in the sub soil water samples ranged from traces to

as high as 1.296 %. The sulphate content ranged from traces to as high as 0.49 %.

iv. The sub soil samples also contained small amounts of sodium, calcium and magnesium salts.

Sonepat District

The ground water samples were also studied in respect of Sonepat District and the results showed that quantity of 0.2 N H_2SO_4 required to neutralize 100 ml. of the water sample using mixed indicator was 22.1 to 33.57 ml. against maximum limit of 25 ml as per IS:456.

These results indicate that the ground water of Sonepat District is alkaline in nature and is neither meeting the requirements of MoRTH Specifications or other specifications applicable for construction projects. The situation is more prevalent as the distance from River Yamuna increases. However, with minor addition of acids of required normality, the water can be brought a level that meet the requirements of IS:456.

A sample calculation for making the water fit for use for construction purposes is given below.

HCl Acid of Specific gravity N

$N_1 V_1$	=	$N_2 V_2$				
Water		***Acid***				
$N_1 \times 100$		$Nx\ 34/\ 50$	(0.02N=N/50)			
N_1 (Normality of water)	=	(N × 34) / (50 × 100)				
Equivalent Weight	=	Mol. Wt. / Valency	100/2	=	50	
Strength of Alkalinity in term of $CaCo_3$ Equivalent						
Alkalinity	=	(34 x 50) / (50 x 100)	gm/L (Eq. Wt. of $CaCO_3$	=	340	mg/L
Normality	=	Strength (Alkalinity)/ Equivalent				
		340 mg/L – 250		=	90	mg/L
580 mg. of Alkalinity is neutralized with HCl = 1 ml						
90 mg of Alkalinity is neutralized with HCl = (1 × 90)/ 580 = 0.155 ml.						
1 L of water needs 0.155 ml. to neutralize the Alkalinity						
1000 L of water need 0.155 ml. HCl to neutralize the Alkalinity. 0.155 × 1000 = 155 ml						

Hence, 155 ml of HCl of Normality N-12 is required to be added to 1000 L of water so as to make it safe for use on bridges and culverts on highways. The requirement would vary from area to area.

Salinity Problems - Effect on the Durability of Concrete of Bridges, Culverts & Structures

Portland cement on hydration gives rise mainly to calcium silicate hydrates and calcium hydroxide. The calcium silicate hydrates are responsible for the strength of concrete and the calcium hydroxide is uniformly distributed in the calcium silicate hydrate matrix. Acidic waters with pH below 6 or so dissolve the calcium hydroxide and also effect the stability of the calcium silicate hydrate matrix both leading to deterioration of concrete. On the other hand, alkaline waters with pH in the range of 7.5 to 10 or so are harmless to concrete.

The sulphates react with the calcium hydroxide giving rise to gypsum with a molar volume nearly 2.20 times that of calcium hydroxide. Also, the sulphates react with the tricalcium aluminate in Portland cement which gives rise to a calcium sulphoaluminate solid solution with a molar volume 2.5 times the original volume. Thus, both these reactions lead to severe cracking of concrete structures exposed to sulphatic environments. The cracking also creates conditions for the reinforcement corrosion which in turn may lead to spalling of concrete.

Chlorides such as $MgCl_2$ and $AlCl_3$ react with lime and form unstable and water-soluble compounds which are

detrimental to concrete. The chlorides of alkali metals (NaCl, KCl) which do not react with lime or with other components of the hardened concrete are harmless but in concentrated solutions, they tend to leach lime from concrete. On the other hand, the soluble chlorides may induce corrosion of the steel reinforcement and as such reinforced concretes exposed to chloride environments need to be protected against attack and deterioration.

Magnesium ions are introduced into ground water mainly in the form of $MgSO_4$, $MgCl_2$ and $MgHCO_3$. The majority of magnesium ions originate from dolomitic rocks. Surface waters rarely contain more than 25 mg/L of Mg^{++} ions whereas the ground water may contain as much as 300 mg/L. As such, the magnesium ion contents in water are usually 1.3 g/L.

All salts of magnesium with the exception of hydrocarbonate are destructive to concrete of bridges and culverts and are even more aggressive than $CaSO_4$ and Na_2SO_4, because in this type of attack, the entire calcium content of the binding agent of the concrete may be replaced gradually by magnesium which may lead to the deterioration of concrete.

Measures to Counter Salinity Attack

Investigations of the soil and ground water of Rohtak and Jhajjar districts, as discussed above, shows that the foundation conditions will be aggressive to the usual concrete and brickwork constructions without any special precautions and treatments. The possible solutions to make durable constructions will involve proper choice of materials, adoption of proper construction practices, quality control and use of protective coatings or barriers, wherever necessary. The choice of construction material is as below:

Cement

The type, chemical composition and physical characteristics of the cement greatly influence the resistance of plain and reinforced concrete in the presence of sulphates and chlorides. So far as the sulphates are concerned, calcium aluminate or part of cement are susceptible to sulphate attack of concrete and so in such cases, use of sulphate resisting cements is the obvious solution. From this point of view, cements in decreasing order of preference are:

- High Alumina Cement
- Super Sulphated Cement
- Sulphate Resisting Portland Cement
- Portland Pozzolana Cement or Portland Slag Cement
- Ordinary Portland Cement.

Among the various cements listed above, high alumina cement is not suitable for use under tropical conditions. Super sulphated cements are not to be used above 40° C and as such both high alumina cement and super sulphated cement should not be considered.

Sulphate Resisting Portland cement has been recommended for countering the attack of sea waters which contain both sulphates and chlorides in amounts ranging up to 3.65 g/l and 19.00 g/l respectively. As such this type of cement conforming to the specifications for ASTM type V (ASTM C-150) will be preferable. Accordingly, the Portland cement should not contain more than 5 % of C_3A and not more than 20 % of $2C_3A+C_4AF$ or solid solution ($4CaO.Al_2O_3$ + 2 $CaO.Fe_2O_3$). A Portland cement as per IS: 269 with the additional stipulation of C_3A not more than 5 % and $2C_3A+C_4AF$ (or its solid solution) up to 20 % could also be considered for use. However, in the absence of this type of cement, the choice may fall respectively on such Portland Slag Cement (IS: 455) and Portland Pozzolana Cement (IS: 1489) which are known to possess sulphate resistance greater than that of Ordinary Portland Cement. Thus, except when Sulphate Resistant Portland Cement is being used, suitable precautions and protections need to be adopted in case of use of all other cements including Ordinary Portland Cement.

Canal Water

Water used for mixing and curing concrete and mortars should not contain harmful amounts of dissolved salts. The ground water samples containing large amounts of deleterious salts should not be used. Water conforming to requirements of IS: 456 and meeting specifically the limitations of solids content only should be used.

Waters from the irrigation canals in Rohtak and Jhajjar districts were also tested. The sample tested had pH 7.2 and contained chlorides and sulphates in traces only and was found fit for construction use.

Construction Practices for Bridges, Culverts and Other Structures

The foundations for the various structures in Rohtak and Jhajjar districts can be of one of the following types:

- Brickwork on Plain Concrete footing
- Reinforced Concrete foundations
- Reinforced Concrete pile foundations

The relevant construction practices recommended for these three types of foundations are described below:

Brickwork on Plain Concrete Footing

If this type of foundation is adopted, the concrete footing should be of minimum M 20 grade (corresponding to 1:1.5:3) and Sulphate Resistant Portland Cement or other alternative cements as discussed above should be used. The bricks should be of first class having not more than 10 % water absorption. The mortar should be of 1:4 proportion preferably with Sulphate Resistant Cement. The concrete footing should have a formed finish so as to result in a more impermeable construction. Such a construction is likely to cost approximately 48 % more than the usual brickwork foundation.

If for some reason, the above type of foundation is not feasible, e.g., for non-availability of bricks having less than 10 % water absorption or Sulphate Resistant Cement, then an alternative foundation can be adopted. That type of foundation envisages use of first class bricks as per PWD Specifications and Ordinary Portland Cement or Portland Pozzolana Cement or Portland Slag Cement. In that case, the foundation should be excavated, 75 mm thick lime-brickbat concrete in proportions 1:2:5 (1 part lime: 2 parts of sand: 5 parts of overburnt brick bats) by volume should be laid and consolidated. The top surface should be finished smooth with Cement-Lime-Sand Plaster. 1:1:6 (1 part cement: 1 part lime: 6 parts sand). When this surface has dried, it should be coated with two coats of bitumen (blown type grade 85/25, IS: 702). Then the usual base concrete (M 20 or 1:1.5:3) for the footing should be laid. That concrete should be form finished. The brickwork in cement mortar 1:4 should be provided with 12 mm thick cement plaster (1:4). On top of the plaster, a coat of bitumen (blown type grade 85/25, IS: 702) at the rate of 1.5 kg/m^2 on a coat of primer (of asphalt and kerosene in equal proportions) should be applied upto the HFL and also around the base concrete footing. This type of construction is likely to cost approximately 58 % more than the usual brickwork foundations.

Reinforced Concrete Foundations

Such concrete foundations should be made with proper type of cement of richer proportions and should have adequate cover and protective coatings.

The cement used should preferably be sulphate resistant type. If the same is not available, any other type of cement as discussed above may be used. The minimum cement content in the mix should be at least 370 kg/m^3 when sulphate resistant cement is used or 400 kg/m^3 when any other cement is used for a nominal maximum size of aggregate of 20 mm. If for some reason the nominal size of aggregate has to be restricted to 10 mm, the cement content in the mix should be increased by 50 kg/m^3. The water-cement ratio should not exceed 0.45. The concrete cover upto the plinth level should be increased by 25 mm over and above the minimum specified in IS: 456. The concrete foundation should rest on 75 mm thick lime sand brickbat concrete (1:2:5) finished smooth with 12 mm thick cement-lime-sand plaster (1:1:6), as in the case of brickwork foundations. Concrete of bridges and culverts should be protected all around including on the top of the plaster, upto the plinth level, with two coats of blown bitumen. This type of construction is likely to cost approximately 37 % more than the usual (unprotected) reinforced concrete foundation as per PWD Specifications. In this case, however, only Sulphate Resistant Portland Cement should be used.

If more durable foundations are needed, then concrete should be protected with a five course bituminous protective treatment all around (instead of bitumen coatings). Such a protective treatment should be laid

on top of the above plaster and taken right up to the plinth level. At the base, a 50 mm thick layer of cement concrete (of identical proportions as in the rest of the foundations) should be laid over the protective layer to prevent puncturing of the bitumen layers while placing the reinforcements. The cover of concrete should be in addition to that layer. On the vertical and top surfaces, a 120 mm thick brick lining should be provided to ensure that the protective treatment is secured to the concrete surface. Such a construction is likely to cost approximately 100 % more than the usual (unprotected) reinforced concrete foundation as per PWD Specifications. However, it would have a longer service life and considering that the structure would not need to be replaced earlier, it could be cheaper.

Another alternative solution would be to use two coats of epoxy paints on the concrete surface instead of two coats of bitumen as described in the first alternative above, the other details remaining the same. This type of construction is likely to cost approximately 175 % more than the usual (unprotected) reinforced concrete foundation as per PWD Specifications.

Reinforced Concrete Pile Foundations

If RCC pile foundations are to be adopted, special considerations and precautions become necessary. Generally, precast RCC piles with suitable protective treatments lowered in prebored holes would be preferable. For this, the type of cement, cement content, water-cement ratio and the cover thickness would be the same as above. The precast concrete piles should be protected with two coats of suitable bitumen or other material after proper curing and then lowered into the prebored holes, the intermediate space being filled with bentonite slurry. Epoxy paints would be more durable but the cost will be nearly three to four time more.

Other Precautions

Fresh concrete surfaces should not be allowed to come in contact with the aggressive soil and ground water from the foundation trenches at least for the first 14 days.

Concrete surfaces exposed to such aggressive environments should preferably be free from construction joints and should be dense. For that the concrete should be cast in a single uninterrupted operation. If construction joints become inevitable, then, they should be located beyond the range of levels of the fluctuating water table. Steps should be taken so that a perfect bond between the hardened and fresh concrete is obtained in such a case.

Water Treatment System at Site of Work

Wherever acceptable quality of ground water is not available or if there are no canals or water courses then, the alternative could be to use an acceptable water treatment system to bring the water to acceptable standards for construction.

Conclusions

The results of the investigation show that the water and soil in and around Rohtak, Jhajjar and the National Capital Region contains high percentages of sulphates and chlorides. The water in Sonepat district is alkaline and does not meet the requirements of IS:456.

Suitable measures are required to protect foundations from surrounding aggressive environment so that structures may live upto their service life. Appropriate treatment of water could be needed to make the water fit for use in the works.

Acknowledgements

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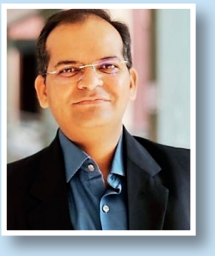
References

1. British Standards Institution – Structural Use of Concrete
2. Specifications for Road & Bridges works by Ministry of Road, Transport & Highways
3. Study Report of Guru Govind Singh Indraprastha University; Delhi
4. Haryana Vidhan Sabha Report, 2014 on Water Conservation Measures in Haryana

11 Nature-Based Solutions as Enablers of Circular Economy in the Water Sector



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Abstract

Freshwater availability is substantially reducing with rapid urbanization and economic development. The complexities of urban water infrastructure are growing and amidst international commitments to sustainable development goals, it is becoming increasingly important to assess the sustainability of the urban water infrastructure. The Circular Economy (CE) is one approach that reduces the dependence on natural resources with a focus on maximizing the usage of resources within the loop under consideration. In the context of wastewater treatment, several mechanized and natural treatment technology options are available. However, Nature-Based Solutions (NBS) are popularly emerging as sustainable wastewater treatment alternatives. Further, their usage also paves way for a CE through different means. The present article discusses the CE opportunities facilitated by the use of NBS in urban, peri-urban and rural settings. Further, an innovative approach of Hybrid Treatment Systems to achieve sustainable wastewater treatment is discussed and the economics of the same from a life-cycle perspective are also evaluated.

Introduction

The shift from a linear economy of 'take-make-dispose' to a Circular Economy (CE) is seen as the pathway to addressing sustainable development goals. Various policies in India also encourage the adoption of circular approaches in the sectors such as packaging, food, water, etc. CE is defined in numerous ways in the literature and after a strenuous review of CE definitions, Murray et al. 2017 have proposed their definition as "An economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize eco-system functioning and human well-being". The adoption of a CE in the water sector can potentially solve the challenges of freshwater scarcity and reduction in water pollution. The national framework on the 'Safe Reuse of Treated Wastewater' in India focuses on recycling wastewater, which is an essential component of attaining circularity in the water sector.

The expensive wastewater treatment technologies result in sewage treatment being an economic burden on municipal corporations. That problem can be solved by shifting from the linear approach of treating wastewater and disposing it of in the surrounding water bodies to a circular approach of extracting materials and energy from the sewage treatment plants and practicing reuse and recycling within the cycle. CE aims at minimizing waste generation and keeping the products and materials in use for as long as possible. In order to overcome freshwater scarcity, a paradigm shift is required. Although CE seems to be an attractive solution, it has numerous hurdles for implementation on a large scale. The various

challenges in attaining a CE in the Indian context have been documented by Kakwani and Kalbar (2020). Some of the technical challenges in wastewater treatment are lack of collection infrastructure, selection of appropriate technologies for a given context, low level of technology readiness, emerging contaminants that tend to remain unaddressed in centralized treatment plants, etc.

In that scenario, it is necessary to adopt a holistic approach in planning the wastewater treatment infrastructure and a CE perspective in implementing the same proves useful. Further, natural treatment systems, popularly recognized as Nature-Based Solutions (NBS) globally are potential alternatives for sustainable wastewater treatment in developing countries. They play a key role in attaining a CE as discussed in the subsequent sections.

Nature-Based Solutions for Attaining CE

CE emerged from several schools of thought as per the Ellen MacArthur Foundation. However, despite the various definitions of CE prevailing, the school of thoughts from which these evolve are essentially the same. In the wake of severe operational and maintenance challenges of the mechanized wastewater treatment technologies, there has been a growing interest of researchers in natural treatment systems such as the Constructed Wetlands (CWs), Waste Stabilization Ponds (WSPs), Duckweed Ponds (DPs), sewage-fed aquaculture, etc. The CWs have been found to be the most popular natural treatment technology in the Indian as well as the global context. The following subsections first discuss the various schools of thought on CE and subsequently, the association of various nature-based treatment technologies in attaining CE in the water sector.

Schools of Thought on CE

The popular schools of thought on CE include cradle-to-cradle, performance economy, biomimicry, industrial ecology, natural capitalism and regenerative design (Rocca et al., 2022). 'Natural Capitalism' focuses on investing in the regeneration of natural resources. 'Biomimicry' studies the principles on which nature functions and adopts engineering designs inspired by nature to solve problems. CWs can be considered as engineered solutions imitating the processes taking place in natural wetlands. The wastewater treatment in CWs occurs due to several interactions taking place between the sediments, media pores, plant and plant roots, biomass zones associated with plants as well as media. The carbon and nutrient cycles occurring naturally are the basis of constituent transformations occurring in the wetlands and other aquatic systems. Wetland plants have a unique strategy for coping in an anaerobic environment. The widespread aerenchyma tissues in the wetland provide low resistance to oxygen, thereby enabling it to pass oxygen from aerial parts to the plant roots. CWs surpass conventional technologies in this regard and are capable of removing metals without substantial costs and energy (Rana and Maiti, 2018).

Further, the approach to waste handling is now shifting from disposal to recovery. Wastewater treatment facilities are looked at as factories manufacturing valuable resources in all three forms namely solids, liquids, and gases. 'Performance economy' school of thought also considers today's goods as resources for tomorrow. Moreover, as per 'industrial ecology', the systems are designed such that the waste produced re-enters the productive-economic cycle. In wastewater treatment, sludge is a byproduct that can be considered for the manufacturing of compost and fertilizers. Further, in CWs or DPs, the harvested plants can be recovered and used in farms as compost or preparing organic fertilizers. Also, a series of CWs ensure adequate nutrient and heavy metal removal at a reasonably low cost whereas CWs followed by waste stabilization ponds facilitate adequate removal of pathogens. Thus, NBS ensure a treated effluent of recyclable quality that can be used for irrigation, landscaping, toilet flushing, industrial purpose, etc. That can facilitate collaboration between municipal STPs and other buyers of recycled wastewater such as industries or residential and commercial buildings, etc.

Components of NBS Contributing to CE

The NBS such as CW and WSP differ in their removal mechanisms owing to different components. Interestingly, the various components of such NBS can help in attaining CE in the ways as discussed below.

Substrates of CWs

Substrates or the filter media in CWs are its key components responsible for removal mechanisms such as adsorption, filtration, sedimentation and precipitation. Soil, gravel and other natural or waste products are used as filter media. Ballantine, et al. (2010) have reviewed potential materials that can be used as substrates in CWs and have classified them as naturally occurring, processed and modified, and waste materials. The waste materials analyzed include fly ash, alum from drinking water treatment plants, slag mixtures, etc. Thus, waste from thermal power plants and sludge from drinking water treatment plants can be reused as substrates in CWs, thereby reducing the cost of procuring soil or gravel as filter media and also partly reducing the burden on landfill. Further, soil and gravel from construction and demolition wastes can be used for sourcing substrate materials. Table-1 denotes the characteristic properties and suggested applications for some of the waste materials.

Table-1: Adapted from Ballantine et al., 2010

Sr. No.	Substrate material (Sourced from)	Characteristic properties and advantages	Suggested application
1	Drinking water treatment residual (Drinking water treatment plants)	• Effectiveness in removing P due to Al/ Ca/ Fe precipitation; P-adsorption through dewatered sludge cakes • Can be made freely available; environmentally friendly alternative as adsorbent use instead of disposing in landfill	Saturated material (nutrient rich and increased water holding capacity) can be used as agricultural soil amendments
2	Fly ash (combustion byproduct from thermal power plants)	Rich in Si, Al and Fe facilitates P removal by precipitation	Combination with coarse sand to prevent clogging due to low fly ash permeability
3	Slag (from iron and steel plants)	High porosity and high surface to volume ratio	P- retentive media in CWs treating wastewater

Plants Harvested from CWs

A number of species such as *Typha angustifolia, Phragmites australia, Typha capensis, Brachiria mutica, Typha latifolia, Colocasia esculenta, Phragmites karka, Canna indica etc.* have been used as CW species in the Indian context. The plant species used in CWs uptake nitrogen and phosphorus, hence, the harvested plants, that are rich in nutrients, can be used as fodder for animals. As phosphorus is a limiting nutrient, the recovery of it through wetland plant species is essential. Besides, the *Canna indica* species can also be harvested after a typical flowering cycle of two months and the harvested plants can be chopped and used as a compost or for mulching.

Duckweeds Harvested from DPs

The DPs belonging to the phytoremediation category of natural treatment systems are classified as macrophytes, that belong to the botanical family '*Lemnaceae*'. This family consists of four genera: *Lemna, Spirodela, Wolffia* and *Wolffiella*. The harvested protein-rich duckweed can be used as fish feed or poultry feed. Besides, the wax coat on the upper surface of the duckweed species prevents fungal growth, thereby facilitating longer storage periods (Ansal et al., 2010). Hence, duckweeds after sun-drying are also effective as pellets for fish feeds. Wastewater treatment using DPs is thus a system capable of generating revenue (example- through the sale of fish feed) to pay for its own operation and maintenance.

Hybrid Treatment Systems

The dependence of NBS such as CWs on natural mechanisms instead of electricity demands a larger land requirement. Hence, that is a major barrier in the adoption of these sustainable solutions, especially in the land-constrained urban areas. To overcome this drawback, the Hybrid Treatment System (HTS) approach was put forth by Kalbar (2021), which strategically combines the usage of Mechanized Treatment Systems (MTS) for secondary treatment followed by Natural Treatment Systems (NTS) for tertiary treatment. The hybrid approach as shown in Figure-1 can be significant for the urban local bodies in adhering to the stringent norms laid down by the National Green Tribunal in 2019.

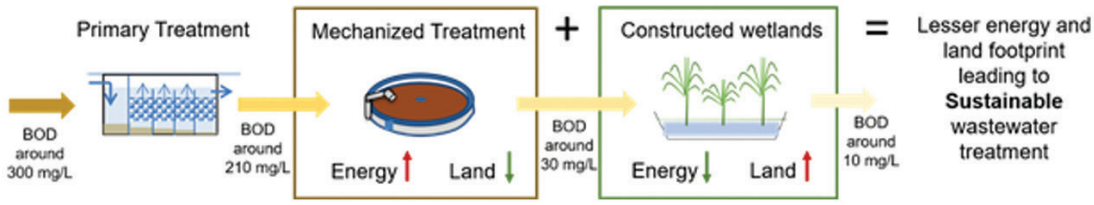

Figure-1: The approach of Hybrid Treatment Systems

Area and Cost Computations of HTS

To assess the feasibility of HTS it is necessary to do a comparison of land requirement and the O&M costs vis-à-vis the conventional mechanized and natural treatment used independently. The capital costs were excluded from the analysis since they are usually arranged through various funding modes in the Indian context. The O&M costs are borne by the public utilities in the long run and have been expressed in INR/m^3. A horizontal flow subsurface type CW is considered as representative of NTS for which the land requirement is estimated based on the design flow, design wetland depth, inlet Biochemical Oxygen Demand (BOD) and the target outlet BOD (Crites, 2014). For an inlet BOD of 300 mg/L, the land required was plotted as a function of varying levels of outlet BOD. Further, the trend in O&M costs for MTS, NTS and HTS with enhanced treatment efficiency was plotted after collating data from various Indian studies and from the author's personal communication with experienced practitioners.

The land requirement for CWs exponentially increased with a decrease in the outlet BOD concentration. Hence, the use of CWs (and other NBS) for upgrading the sewage treatment infrastructure beyond secondary treatment is eminently suitable in rural and peri-urban settings where land availability is not a major constraint. On the other hand, although the land required for MTS is the least, the O&M costs of MTS linearly increase with the BOD removal up to 30 mg/L. In addition, the usage of MTS for achieving tertiary treatment escalates the costs exponentially due to the requirement of advanced technologies which are essentially mechanized and energy demanding. However, as CWs are non-mechanized natural treatment systems, the O&M cost ranges around INR 6/m^3 and is not significantly impacted by BOD removal beyond 30 mg/L. Thus, due to the trade-offs associated with land and O&M costs for MTS and NTS such as CWs, each of the systems is suitable if used individually for only a specific local condition. At the same time, the O&M cost and land requirement for HTS lies between that for MTS and CW, since it overcomes the limitations of both systems. Hence, the proposed work suggests that wastewater treatment infrastructure should be designed using MTS for initial BOD removal up to 30 mg/L using lower land area and CWs should be used subsequently for achieving BOD removal beyond 30 mg/L at a low cost. This approach of strategically utilizing the advantages of MTS and CWs (as outlined in Table-2) to facilitate sustainable wastewater treatment is referred to as the 'Hybrid Treatment Systems'.

Table-2: Summary of the proposed Hybrid Treatment Systems Approach

APPROACH	HTS-1			HTS-2		
BOD removal	**Treatment system**	**Land requirement (m^2/ MLD)**	**O&M costs (INR/ m^3)**	**Treatment system**	**Land requirement (m^2/ MLD)**	**O&M costs (INR/ m^3)**
Upto 30 mg/L	MTS	1100	6	MTS	1100	6
Upto 10 mg/L	MTS + shallow bed CWs	3166	7	MTS + deep bed CWs	2029	7
Upto 5 mg/L	MTS + shallow bed CWs	4469	7	MTS + deep bed CWs	2616	7
Usefulness in different settings	Rural and peri-urban setting (both in centralized and decentralized manner) where land is available; suitable if STPs are located in main city or outskirts of city			Peri-urban and urban settings (both centralized and decentralized manner) in case of land constraint		

As observed from the above table, the trade-off between O&M cost and land area requirement for MTS and NTS necessitates the comparison of the two approaches from a life cycle perspective. Hence, life cycle costing (LCC) using the present worth method was carried out for five wastewater treatment technologies. The popular wastewater treatment technologies viz. activated sludge process, sequential batch reactor and membrane bioreactor were considered to represent MTS. Whereas CWs, which are gaining popularity in India were considered to represent NTS. Besides, the HTS approach proposed above was considered as the 5th choice of treatment technology. The various costs considered in the analysis include capital costs (civil works, electro-mechanical equipment and land requirement), annual O&M costs (labor, energy, chemicals and routine maintenance) and replacement costs for the electro-mechanical components. The land cost was assumed as INR 0.04 Lakh/ m^2 in urban areas whereas 2/3rd and 1/2 of this cost was assumed in peri-urban and rural areas respectively. The calculations were performed at an assumed discount rate of 10% for a 30-year design life of a STP.

The capital cost, O&M cost and LCC for all five technologies in an urban context are plotted in Figure-2. The choice of CWs turns out to be the most capital-intensive due to the associated land cost. Thus, if decision-makers or investors choose the technology based on capital costs, MTS would be the obvious choice. However, since MTS are energy-intensive, the monthly electricity bills are enormous, thus posing a financial burden on the public utilities. In circumstances where urban local bodies or Gram Panchayats cannot manage to generate the required funds to operate and maintain the STPs, they become dysfunctional and eventually result in complete wastage of funds and resources once they fail to sustain. Interestingly, the O&M costs for CWs is the least and its consideration for a design period of 30 years shows that CWs and HTS are the most economical options. This suggests the significance of O&M costs in the economic evaluation of the wastewater treatment technology selection as against the commonly adopted capital cost basis.

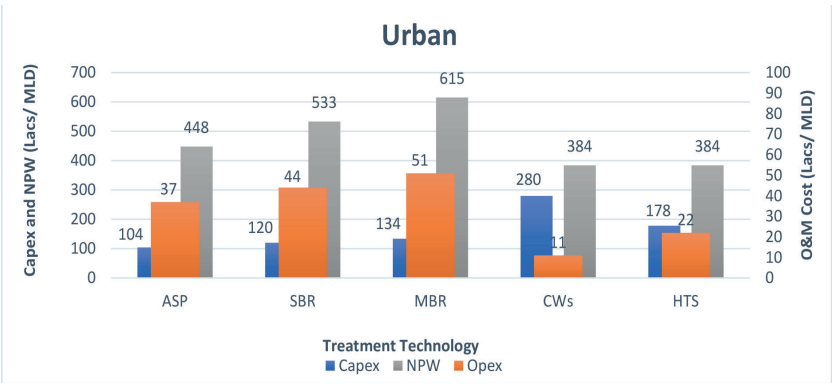

Figure-2: Trends of Capex, Opex and Net Present Worth for different technologies in urban setting

Application of 6R's Using HTS

The HTS approach involves the natural treatment technologies and hence has several advantages from the aspect of sustainability and CE. Several R's have been defined in literature on CE with the 3R's i.e., reduce, reuse and recycle being the most popular. Further, Modak (2021) has defined the 12 R's in CE namely refuse, reduce, re-design, reuse, repair, refurbish, renovate, recycle, recover, return, remanufacture, and rethink. However, the application of the R's depends on the application or the sector under consideration. In the context of the water sector, a framework for achieving CE has been developed by Kakwani and Kalbar, (2020), as shown in Figure-3. It defines the 6R's in the context of the water sector namely reduce, reuse, recycle, reclaim, recover and restore and puts forth several means of their application in a given urban locality.

Amidst the growing freshwater scarcity, it is vital to adopt the CE framework in the water sector. Interestingly, NBS provide several means of achieving CE through the 6R's in the water sector, as discussed below. Table-3 elaborates the circular and economy aspects when CWs individually or as HTS are used in urban, peri-urban and rural areas.

In a household, greywater from bathrooms can directly be ***reused*** for gardening purposes. Greywater or treated wastewater used for gardening or irrigation has positive benefits on the plant growth. The effluent of CWs does not adequately meet the microbiological standards; however, it is suitable to ***recycle*** wastewater for non-potable uses that do not demand outstanding water quality. Further, wastewater from municipal STPs can be ***reclaimed*** for irrigation or industrial uses. A quicker

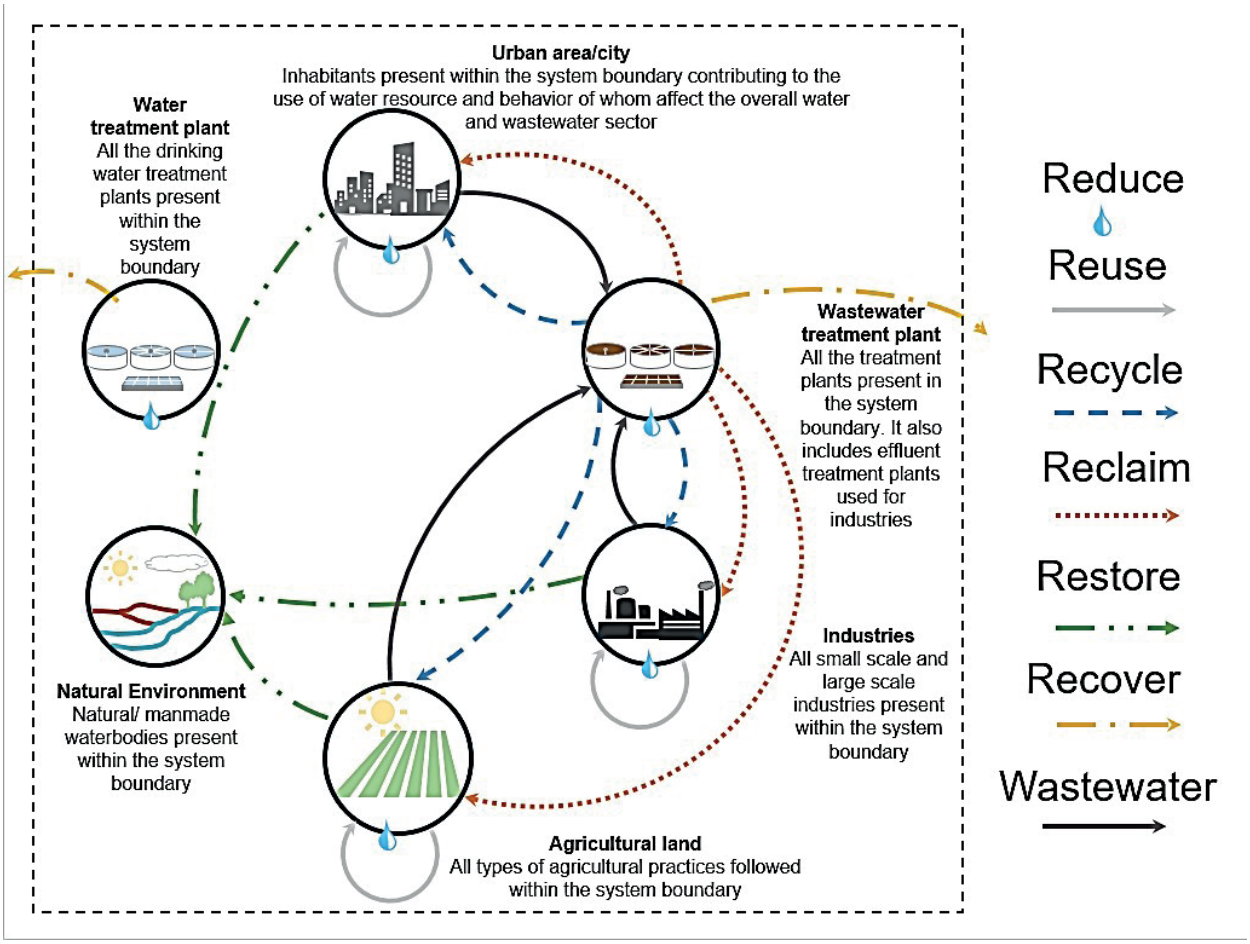

Figure-3: Framework for implementing CE in water sector (Source: Kakwani and Kalbar, 2020)

growth and an increment of 60% in plant biomass obtained from plots irrigated by treated greywater (as compared to potable water) might be attributed to the nutrient-rich greywater used for irrigation (Laaffat et al., 2019). In that way, the use of treated wastewater for toilet flushing and irrigation will ultimately help to ***reduce*** freshwater demand for a city's non-potable domestic uses and the agricultural water demand respectively. Besides, nutrients such as phosphorus and nitrogen can be ***recovered*** from the substrate or plant species of CWs respectively. Interestingly, CWs and other NBS such as green roofs also have applications in flood management where these eco-technologies play a significant role in ***restoring*** the flood water.

Table-3: Illustration of CE Benefits by Adopting CWs or HTS Approach

Scenario	Technology	'Circular' aspects	'Economy' aspects		
		Applications in different settings	Capex	Opex	NPW
			(INR Lakhs/ MLD)		
Urban	CWs	• Use of recycled water for non-potable uses such as toilet flushing and landscaping/ gardening	280	11	384
	HTS		178	22	384
Peri-urban	CWs	• Use of reclaimed wastewater for agricultural purpose in the adjoining farms • Using reclaimed wastewater by industries such as cooling purpose in thermal power plants	200	11	304
	HTS		136	22	342
Rural	CWs	• Use of reclaimed wastewater for agricultural purpose in the farms	160	11	264
	HTS		115	22	321

Conclusions

The present work shows the potential of NBS in attaining CE via different natural components of the treatment technologies. Further, the HTS approach combining mechanized and natural systems is shown to be effective in attaining treatment goals. Further, the role of O&M cost is proved to be crucial in the life cycle costing of wastewater treatment plants. In that regard, the use of NBS proves economical as well as environmentally sustainable. Hence, if the sewerage infrastructure is appropriately planned using NBS, it has tremendous scope for accomplishing CE. However, successful implementation of CE needs a futuristic approach in planning, collaboration between various stakeholders, coordination between different institutions. Further, there is a need to establish business models based on CE models that can inspire young entrepreneurs to adopt circular approaches in the water sector. Besides, policies promoting CE will accelerate the CE in water sector and hence are the need of the day. The hybrid treatment approach can potentially be considered by urban local bodies and Gram Panchayats. The inclusion of NBS will not only address the wastewater treatment issues, but positively impact other sectors and help attain other SDGs such as SDG 6 Clean Water and Sanitation and SDG 11 Sustainable Cities and Communities.

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References

1. Ansal MD, Dhawan A, Kaur VI (2010) Duckweed based bio-remediation of village ponds: An ecologically and economically viable integrated approach for rural development through aquaculture. Livest Res Rural Dev 22:

2. Ballantine DJ, Tanner CC, Ballantine DJ, Tanner CC (2010) Substrate and filter materials to enhance phosphorus removal in constructed wetlands treating diffuse farm runoff : a review wetlands treating diffuse farm runoff : a review. New Zeal J Agric Res 53:71–95. https://doi.org/10.1080/00288231003685843

3. Crites RW, Middlebrooks EJ, Bastian RK, Reed SC (2014) Natural wastewater treatment systems, 2nd edn. CRC Press, the Taylor & Francis Group, Boca Raton

4. Kakwani NS, Kalbar PP (2020) Review of Circular Economy in urban water sector: Challenges and opportunities in India. J Environ Manage 271:111010. https://doi.org/10.1016/j.jenvman.2020.111010

5. Kalbar, P. (2021). Need for Adopting Hybrid Treatment Systems to Reduce O&M Costs of Sewage Treatment and Recycling in India. Journal of Indian Water Works Association.

6. Kalbar, P.P. (2021) Hybrid treatment systems: a paradigm shift to achieve sustainable wastewater treatment and recycling in India. Clean Techn Environ Policy 23, 1365–1373. https://doi.org/10.1007/s10098-021- 02034-x

7. Laaffat J, Aziz F, Ouazzani N, Mandi L (2019) Biotechnological approach of greywater treatment and reuse for landscape irrigation in small communities. Saudi J Biol Sci 26:83–90. https://doi.org/10.1016/j.sjbs.2017.01.006

8. Modak, P. (2021) Practicing Circular Economy. CRC Press, Tailor and Francis Group.

9. Murray, A., Skene, K., & Haynes, K. (2017). The circular economy: An inter- disciplinary exploration of the concept and application in a global con- text. Journal of Business Ethics, 140, 369–380. https://doi.org/10. 1007/s10551-015-2693-2

10. Rana, V., & Maiti, S. K. (2018). Municipal wastewater treatment potential and metal accumulation strategies of Colocasia esculenta (L .) Schott and Typha latifolia L . in a constructed wetland. Environmental Monitoring and Assessment, 190-328.

11. Rocca L, Veneziani M, Carini C (2022) Mapping the diffusion of circular economy good practices: Success factors and sustainable challenges. Bus Strateg Environ 1–14. https://doi.org/10.1002/bse.3235

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Platform analyzes chemical waste, offers ways to make new products from it

Marie Donlon | May 11, 2022

In a bid to reduce the amount of chemical waste generated by the chemical industry, researchers from the Indiana-based company Alchemy have developed a computer system that analyzes chemical lwaste samples to determine pathways for synthesizing new chemicals.

According to the company, the chemical industry is responsible for the production of a significant amount of waste. Yet, waste from the production of pharmaceuticals, cosmetics and fertilizers, for example, could serve as the base materials for other valuable chemicals, the researchers suggest.

Noting that a small chemical waste sample contains a small number of molecules that could lead to millions of possible pathways toward a new product, the researchers are using the new platform to potentially streamline those pathways.

12

Safe Reuse of Treated Water in India – A Sustainable Development (Circular Economy)

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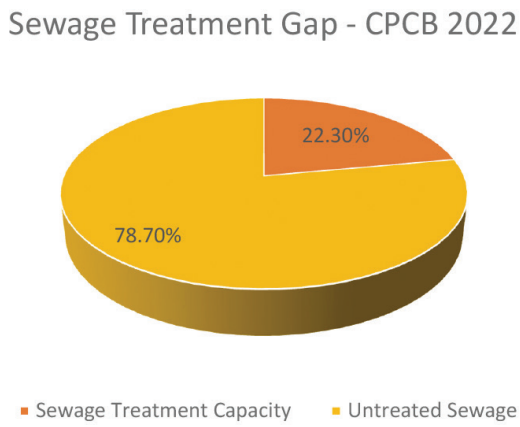
Abstract

Water is the most important natural resource necessary to sustain life. Increasing population and climate change impact water demand and supply. The hydrological water balance indicates more floods and droughts, with less water recharging groundwater thereby reducing water supply and leading to problems of water supply v/s demand. Water demand is not matched by the corresponding increase in water resources because it is increasing with India's rapidly growing urban population. In addition, growing domestic and industrial demands for water must be met for India to become a major hub for industries and development. Hence, it is important to reuse treated water as much as possible to meet the demand. Urban wastewater management needs a holistic approach involving public participation which needs to be increased for better adoption and use of recycled and treated wastewater. Safe Reuse of treated water offers a reliable, long-term source of water supply to help meet non-potable water demand. Extreme water scarcity across many parts of India is also a major driver for change in perceptions towards the safe use of treated water. Globally India is ranked as the 13th most water-stressed country. In the past few years, several pioneer States have initiated reforms to adopt the Safe Reuse of Treated Water (SRTW) by drafting reuse policies and frameworks. The underlying principles are common with a different emphasis to reflect local conditions and priorities. The most ambitious state Gujarat has set a target for 100% reuse by 2030. State policies also prescribe mandatory usage of Treated Used Water (TUW) for industrial estates/ zones within a certain distance from an STP. That ranges from 30 km in the case of Karnataka to 50 km in Gujarat, Tamil Nadu, and Haryana.

Introduction

India, with 1.38 billion people, is the "world's second most populous country". Of the total population, 65% (900 million) live in rural areas, and 35% (483 million) are concentrated in urban centres. Rapid urbanization creates opportunities for economic development but may also add pressure on freshwater resources to meet the food and water demands in water-scarce areas and those in which expansions occur at an unprecedented pace. With an increase in the population of such urban areas, it is important to identify water resources to sustain such expansion.

The estimated wastewater generation is approximately 39,604 Million Litres per Day (MLD) in the rural regions, while in the urban centres, it has been estimated as 72,368 MLD for the year 2020-21. According to a recent report published by the Central Pollution Control Board (March 2021), India's current water treatment capacity is 27.3% and the sewage treatment capacity is 18.6 % (with another 5.2 % capacity being added) of what is required. Though India's waste and sewage treatment capacity is higher than the global average of around 20%, considering the enormity of the problem, it is far from adequate, and without swift measures, there could be serious com-



plications without a prompt response. Untreated sewage waste is one of the major causes of surface water and groundwater pollution in India. As per government statistics, 62.5% of wastewater in urban India remained untreated or partially treated. The meagre infrastructural capacity of wastewater treatment and poor operation and maintenance add to the country's water pollution, conservation, recycling, reuse, and recharge troubles.

Although efforts are underway to increase the percentage of collected and treated used water, the scale of the challenge is large and there are resource and capacity constraints. Until recently, used water collection and treatment has been viewed as part of a 'linear' process, but more recently they are being seen as components of a wider circular economy approach, with waste considered as a resource and able to generate revenues. The shift in approach can facilitate cost-effective and fit-for purpose solutions to the prevailing capacity and financial constraints, thereby allowing a faster transition to universal collection and treatment. For India to achieve continued economic growth, poverty alleviation, hunger elimination, human development, and environmental improvement, new transformative solutions are needed rather than incremental improvements.

Requirement of Policy - Framework for Safe Reuse of Treated Water

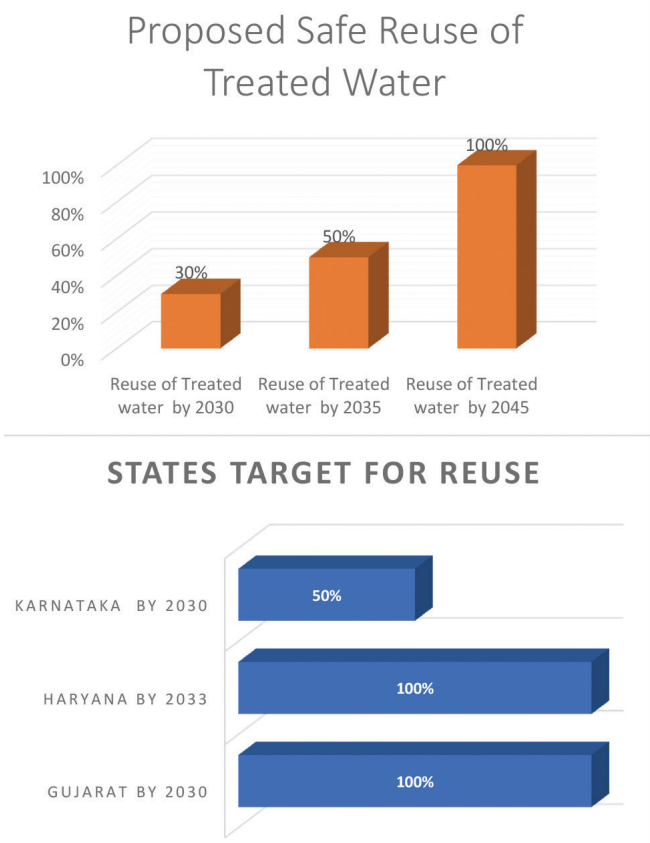
The Ministry of Jal Shakti's Department of Water Resources, River Development & Ganga Rejuvenation National Mission for Clean Ganga has taken the initiative to draft the policy and anticipates a situation where all States in India have adopted and started to implement Safe Reuse of Treated Water (SRTW) policies by the end of 2022. The Vision of the policy is for widespread and safe reuse of treated wastewater in India that would reduce the pressure on scare freshwater resources. The framework covers non-potable reuse of urban and rural used water. It holds the principle of integration and holistic management of the reuse of treated water by encouraging linkages to existing and proposed policies.

"Water" is a State subject, according to Schedule VII (Seven) of the Indian Constitution. However, when it comes to inter-state waters, the Parliament has the authority to enact laws. It enables the Parliament to legislate on regulating and developing inter-state waters in the larger public interest. However, the State retains the autonomy to frame laws regarding the use of water within the State on matters like water supply, irrigation, drainage and embankments, water storage, etc.

India's National Water Policy, 2012 mentions the common integrated perspective for the planning, development, and management of water resources which is hardly being achieved on the ground. It calls for integrating and executing urban water supply and sewage treatment schemes simultaneously. It also highlights the need to incentivise decentralised sewage treatment plants, recycling and reuse of treated water through planned tariff systems, and subsidized treatment of industrial effluents.

Some basic standards for Safe Reuse of Treated Water have been set by the Central Pollution Control Board (CPCB) and Central Public Health & Environmental Engineering Organisati0n (CPHEEO), however with the introduction of mandatory use and a wide range of potential end users, greater resolution of reuse standards specific to a particular end-use is required. That would provide clarity to allow selection of the most appropriate and efficient business model and facilitate monitoring and compliance mechanisms.

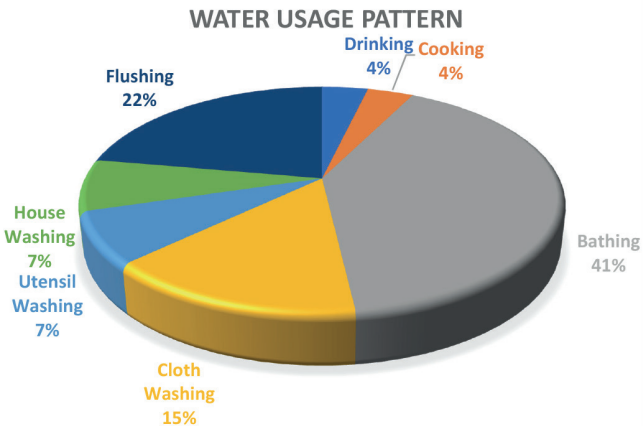
Today's need is for a dedicated policy and framework for safe reuse of treated water with defined integrated approach for sustainable development to meet the water demand across all the sectors. The increasing demands



across water using sectors as the economy grows, higher expectations from a more affluent society for more reliable supplies of water, and a changing climate that brings greater uncertainty in terms of extended periods of drought and variability of supply are the major challenges to be addressed.

The Safe Reuse of Treated Water policy framework is to provide a local source of water for cities and industry so that it obviates the need to transfer freshwater sources from ever increasing distances and thus foster self-reliance. That would provide clarity to allow selection of the most appropriate and efficient business model and facilitate monitoring and compliance mechanisms. A customised, decentralised approach is needed for better assessment and redressal of wastewater issues, as well as for the efficient functioning of policies and overall development of water governance needs at all levels.

Achieving resilience would require both enlightened government policies and successful initiatives by social and environmental innovators that demonstrate the capacity for adapting to these challenges. Safe Reuse of Treated Water can serve as model for creating a more resilient and sustainable economy in India. One way to stimulate rapid progress is development of circular economy solutions that create innovative pathways for utilization of wastewater, thus seeking to reduce pollution load and environmental pressures and improve community resilience, while stimulating the regional economy. As per water usage pattern treated water can plan for use and meet more than 40% daily requirement of fresh water. Norms and treatment standard to be defined to meet the quality water for daily use.



The concept of "circular economy" as a strategy for reuse of treated water and waste discharge elimination has been broadly adopted in the business world. In line with that "zero liquid waste" is now a focus for companies by finding uses for treated water and closing the loop in their water supply and demand network. Circularity not only offers economic benefits and reduces a company's ecological footprint, but also increases both business and community resilience by reducing dependence upon scarce resources and long-distance supply chains.

Initiatives of the Government of India

"Water (Prevention and Control of Pollution) Act of 1974 (amended 1988)": The CPCBs and State Pollution Control Boards (SPCBs) provide guidance, monitor compliance and enforce laws governing the treatment and disposal of sewage and industrial effluent. The

CPCB criteria should be followed by all STPs in India. (https://cpcb.nic.in/wqstandards/).

"Environment (Protection) Act of 1986": MoEF, Government of India set the discharge standard for STPs by this Act. It establishes limits for the discharge of different pollutants into specific environmental zones (surface water bodies, coastal and sea areas, lands etc.).

"Ganga Action Plan (GAP-I 1985, GAP-II 1993) and National River Conservation Plan": Ganga Action Plans were launched to clean the Ganga River by reducing the pollution load by intercepting and diverting the sewerage lines for treatment, establishing STPs, and creating affordable restrooms, constructing a riverside and increasing public engagement, knowledge, and capability.

"National Plan for Conservation of Aquatic Ecosystems (NPCA) (2015)": NPCA goals are to promote and support the conservation of wetlands and facilitate the development of a public inventory. Policy guidelines are for strengthening the capacity of wetlands administrators and stakeholders and seeks to provide a framework for the conservation and sustainable management of the wetlands.

"National Urban Sanitation Policy (2008)": focusses on sanitary and safe disposal of human waste and recommends recycle and reuse.

Other essential flagship national programs launched by the Government of India: In 2015, the "Namami Gange" 2015 programme for the construction and renovation of 5501 MLD sewage treatment capacity as well as the installation of 5,134 km of sewerage network, the government has approved 161 sewage management projects totalling INR 245.81 billion under the Namami Gange Program. A total of 92 of these projects have been finished, adding and renovating 1,643 MLD of STP capacity and installing 4,156 km of sewer network (PIB, 2022). Additionally, it includes sectoral initiatives like the "Smart City project 2017-2023" and the "AMRUT Mission 2015-2023" that aim to enhance both sewered and unsewered sanitation (Source: Urban Wastewater Scenario in India, NITI Aayog, 2022)

Challenges for Safe Reuse of Treated Water

The major challenge for use of treated water is its recognition as a resource and use for non-potable applications and industrial utilities due to the rising load of untreated sewage. Though few states have framed polices and prioritised the reuse of treated sewage however, there are many challenges to overcome for using it for industrial washing, horticultural irrigation, non-contact impoundments, and other purposes. The major challenges in setting up and operating schemes for reuse of treated water in India are discussed below.

Institutional challenges - The Urban Local Bodies (ULBs) in India are primarily responsible for all civic services including urban wastewater treatment facilities in their administrative area. In general, it is observed that ULBs lack the capacity to plan and implement projects with priority. The existing institutional, policy, and legal mechanisms to enforce the management of wastewater and control water pollution in the country are not sufficient to address the impending crisis. The performance audit of water pollution by the Comptroller and Auditor General (2011) found that "there is no specific policy at both the Central or State level that incorporates prevention of pollution, treatment of polluted water and ecological restoration of polluted water bodies and that without this, government efforts in these areas would not get the required emphasis and thrust." The enforcement (of the existing laws regarding wastewater management) capacities of State Pollution Control Boards (SPCBs), both in terms of power and resources, is thus limited.

Weak institutional mechanisms, absence of proper planning, supervision, limited knowledge, and a dedicated force are a big challenge for the execution and monitoring of environmental infrastructure for sewage treatment and reuse of treated water.

Regulatory challenges - Defined standards for different uses are the major challenges for authorities and relevant stakeholders for monitoring and adhering to the discharge standards. The domestic effluents monitoring is mostly limited to organic contaminants. When

it comes to water quality standards, in case of release to water bodies, again the standards are set for organic contaminants but not for other chemical contaminants. It is important to note that in case of release to the soil, there are no water quality standards. In a similar manner, no monitoring systems are defined for exposure pathways and the risks involved.

A well defined standard for discharges for different uses is required to ensure safe reuse of treated water

Economic challenges – The current sewage treatment capacity requirement is huge considering all classes of cities in India. The data indicates that the gap increases in the order of decreasing population of cities. That means that the smaller cities and towns face difficulty in finding necessary resources for setting up STPs, considering the higher capital expenditure and the operation and maintenance costs involved.

Private players are not coming up for investment due lack of policy for reuse of treated water, defined standard for different uses, work environment and Government support. High capital investment discourages the entry of private players since the average break-even time span is three to eight years. The cost of the utilities is rarely covered by the revenue from the STPs due to high uncertainty in demand. There is a huge demand risk involved with the low/ minimal water tariffs and little regulation governing user charges which makes the collection of user fees difficult. That discourage Public Private Partnerships (PPPs) in wastewater treatment.

Technological challenges - An adoptive solution and innovative technologies for wastewater treatment to a level for safe reuse is another major challenge. The limited funds and higher expenditures push the authorities to choose technologies with lower capital costs despite their poor performance parameters. To meet today's stringent discharge norms and treatment requirement for safe reuse of treated water, latest innovative technologies would have an important role to save land and meet the treatment challenges. Centralised treatment systems for large capacities require huge upfront costs, which thus restrict authorities for using innovative technology due to fund limitation. The knowledge gap regarding changes and scalability of newer technologies in the Indian context is also a major challenge. Hence, it is advisable for the authorities to plan for setting up new STPs based on latest technologies on a Life Cycle cost feasibility to meet the reuse norms. To attract private investors, authorities can invite tenders with defined use of treated water on a long-term concessionaire agreement to meet the treatment objective and ensure revenue generation.

Social challenges - Reuse of treated water is major challenge because people are reluctant some to time to use treated water for non-potable purpose as well. In many parts of the world, schemes related to the reuse of treated water are rolled back due to public opposition. People are usually not aware the water scarcity and need for use of treated water sustainability of water resources. Public Awareness and sensitisation would require to adopt a strategy and action plan by State Authorities that focuses both on realizing early gains where sources of supply and demand are aligned, in parallel with medium term programmes to introduce an enabling regulatory and pricing environment that provides incentives for change. Identifying and procuring land for the location of wastewater treatment plants (WWTPs) is another crucial challenge, as people do not prefer living near them. Despite the risks related to health, odour, noise, and aesthetic impacts, they are also likely to get affected by economic damage due to the depreciation of the value of land.

Expected Safe Use of Treated Water - Potential areas of reuse of treated water may vary from state to state depending upon availability of natural resources, variations in levels of urbanisation, industrialisation, development policies etc. The situation is not the same in all districts of a state; the districts can be classified as water scarce or water rich. Many states have a predominantly industrial-based economy, however some districts even in those are where agriculture dominates. Setting up priorities for reuse of treated water would depend on condition of the state and its requirement. Reuse of treated water offers a range of benefits to all States including reduced contamination to the environment, improved public health, and as a potential rev-

enue stream to improve the financial sustainability of STPs. the potential Non-Potable areas/ users for reuse of treated water are:

- Industrial Use - cooling, cleaning, flushing, etc. for industrial estates, power generation and railways.
- Agricultural Use – Irrigation, Horticulture, watering, etc. for forestry, horticulture and aquaculture.
- Municipal Use - landscaping, parks, toilet flushing, fire-fighting, cleaning, etc.
- Aesthetic and Environment Condition Improvement - including discharge into surface water bodies, maintenance of wetlands and environmental flows.
- Ground Water Recharge - aquifer recharge.
- Use for Construction Water – Treated water can be used for construction and reduce/ restrict fresh water use
- On-site use – Treated water can be used within STPs for landscaping and cleaning of desludging vehicles.

Conclusions

Secondary treated used water from STPs must be treated further to produce industry grade water for industry or industrial zone. The Safe Ruse of Treated Water would reduce chances of Water Scarcity since it would reduce the pressure on the surface water and groundwater resources. Health benefits, because of reduced pollution of water bodies and replacement of contaminated water by treated water. Environmental benefits – by reducing the contamination of surface water bodies and groundwater from pollution by human waste, health, and environmental benefits. Industries can take initiative under Corporate Social Responsibility to fill the required gap for financing of treatment. CSR initiative for water scarce areas would encourage infrastructure development for tertiary treatment to the level for safe reuse of treated water.

Three business approaches are defined in the draft policy framework as business models for the Safe Reuse of Treated Water in the industry:

1. **Minimum guarantee and fixed price model:** The implementing agency enters into a long-term contract with an industry or industrial zone for bulk consumption of Treated Water at an agreed price. The implementing agency can set up a tertiary treatment unit and operate it on its own.
2. **Reuse the buy-back model:** Implementing agency to enter into a PPP arrangement with a private entity to develop and operate a tertiary treatment unit. The implementing agency pays a fixed O&M cost to the private entity and provides full buy-back guarantee for Treated Water. The implementing agency is responsible to deliver Treated Water to the industries at a price fixed or as agreed with the industries.
3. **Reuse PPP model** – investment by end user: In this approach, the industry or industrial board purchases secondary treated water from the implementing agency.

Safe Reuse of Treated Water needs to be encouraged by enacting laws and laying down policies and frameworks at the Centre as well as at the State levels so that investing agencies see it as a viable venture.

13

Wastewater: An Untapped Environmental Wealth

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Introduction

Rapid industrialisation, urbanisation, and population growth have seriously threatened freshwater resources. Further aggravating the situation is the depletion of groundwater caused by excessive water extraction, decreased recharge, and pollution of water sources. Thus, the increased demand for treated wastewater to augment the water supply needs to be encouraged. This paper attempts to construct a scenario for wastewater reuse in India. Despite vast amounts of wastewater generated in India, its potential use is overlooked due to a lack of research, guidance, and a dependent institutional framework. To ensure the efficient use of treated water, an integrated strategy incorporating all aspects of technical viability, financial viability, and social acceptance, as well as a management structure that may complement the current supply, is recommended.

Background

Water, an elixir of life, has dwindled in quantity and quality, especially in India. A vast river network and 4% of the world's freshwater resources are insufficient to meet India's water needs. The utilisable water resource is significantly impacted due to topographical, interstate administrative, and technological constraints. In line with the report of the Intergovernmental Panel on Climate Change (IPCC), climate change impacts continue to exacerbate global warming, thereby causing more intense rains and changing rainfall patterns. An exponentially growing population and its associated pressure on the ecosystem make India very vulnerable to the impacts of climate change. It is estimated that by 2030, 1498 billion cubic metres (BCM) would be consumed, while 744 BCM would be available (Goyal and Kumar 2021). The mismatch between demand and availability would thus lead to water shortages. In the absence of scientifically designed and environmentally friendly water use policies and management plans, the predicted water problems could become more serious. As a result of the increasing and competing demands for water resource from multiple sectors, the stress on freshwater resources for higher hierarchy uses, untreated water polluting the environment, the high cost of wastewater treatment, and the unsustainable dependence on the Central and State governments for water treatment, it is imperative that there is a sustainable solution designed for treating wastewater and making it reusable for potable and non-potable uses.

Safe reuse of treated water can potentially solve the current water crisis as well as provide a source of revenue to the cash-strapped wastewater treatment facilities. As a result, the treated water can be used in different applications such as industrial processes, construction industries, thermal power plants, urban greening and landscaping, agroforestry and other lower hierarchy uses such as toilet flushing, and cleaning of urban spaces. It can emerge to be an assured and sustainable source of water, thereby helping enhance water security in water-stressed cities of India.

Enablers of Water Reuse

By 2050, the population of India is expected to surpass 1.66 billion and the national GDP is projected to grow by 6.0%, and the per capita income by 5.5%, thereby increasing the demand for food (Central Water Commission 2017). A nation with a history of agriculture like India has a political incentive to use water to protect food production, which would increase the demand for water. Around 80% of the country's drinking water and 45% of its agricultural water comes from groundwater which is declining. Agricultural areas have seen the most water shortages over the past decade due to overexploitation and unrestricted consumption, especially by industries (Central Ground Water Board 2017).

The connection between water, food, and energy is at the core of sustainable development. Water is utilised to produce most forms of energy. The agriculture sector is the major consumer of freshwater worldwide. Governments must assure integrated and sustainable management of water, food, and energy to balance the requirements of people, nature, and the economy to withstand the present and the future stresses. The major consumers of water are the chemical, pharmaceutical, power, food, and textile industries. In the metropolitan cities of Chennai, Bengaluru, and New Delhi, shortage of water supply has increased the production cost of freshwater and increased the cost of industrial water (UNICEF, FAO, and South Asia Consortium for Interdisciplinary Water Resources Studies 2013). Treated used water can be a reliable alternate source of water.

Reusing Treated Water – The Policy Perspectives and Implementation

India has been demonstrating a keen interest in the safe reuse of treated used water and in this regard, the upcoming National Policy Framework for the Safe Reuse of Treated Water (SRTW) in India is a great initiative. It provides a mandate as well as a framework for the States to take up treated water reuse initiatives. Several states already have their wastewater reuse policies and some of them are very successfully implementing them. The Surat Municipal Corporation, Chennai Metropolitan Corporation, and Nagpur Municipal Corporation are some of the exemplary cases in this regard.

In Surat, the treated used water finds reuse in various industrial clusters, gardening purposes at STPs and road dividers, sprinkling at MSW disposal sites, and sewer jetting machines. The Surat Municipal Corporation faces numerous challenges despite its success in safely reusing treated water. The challenges include fluctuating sewage quality and quantity, mixing industrial waste with sewage, interruptions in power supply that prevent treatment plants from functioning, and limited capacities of staff. In Chennai, treated water is reused for industrial purposes, gardening and landscaping. The Urban Local Bodies (ULBs) have been generating an income of INR 5.46 crores on an average for the last 20 years from the sale of treated water. The primary challenge for the Chennai Metropolitan Water Supply and Sewerage Board (CMWSSB's) was creating public awareness about the benefits of using treated water. Better technological equipment could also facilitate the operation of STPs and thus enhance the safe reuse of treated water.

In Nagpur, treated water is reused in thermal power plants in the city. Two centralised STPs of capacities 200 MLD and 130 MLD are being presented as successful reuse projects in the city. Having developed a successful public-private partnership model, all the stakeholders have benefited and an income of around INR 40 crore is generated each year from the sale of treated water (CPHEEO, MoHUA, 2021).

Challenges for Safe Reuse of Treated Water

The process of wastewater reclamation and utilisation in India has just begun. To attain sustainability and make water reuse successful in India, it is crucial to identify the obstacles to planning and implementing water reuse projects. Most cities have grown beyond capacity and lack proper sewage infrastructure, creating an urgent need for adequate management of sewage waste. About 62,000 million litres of wastewater are produced per day (MLD), which is 60–70% higher than the volume that is processed (CPCB 2015). Currently, most of the cities' sewage infrastructure is plagued with inefficient treatment capabilities, insufficient capacity utilisation, and non-compliance with quality requirements. The process of reuse is hampered in many ULBs by a lack of efficient and affordable treatment technology. That along with the

limited availability of skilled and knowledgeable workers on the operational aspects of water reuse systems, pose challenges to reusing treated water.

Thus, though reusing treated water is an alternative that is desirable and sustainable, there are several associated practical challenges. Internationally, these limitations are often brought on by a lack of advanced treatment methods, public health threats, institutional weaknesses, and economic constraints. There can be various factors that hinder the reuse of treated water, which include a shortage of funds for capital and operational expenditure, implementation mechanisms, and implementable business models in many of the ULBs. There is also a challenge associated with a negative public perception of using Treated Used Water (TUW) among user groups, which may cast a shadow upon the efforts of the ULBs. Hence, the use of instruments such as agreements and memorandum of association between the supplier and the treated water buyer would potentially help reduce these challenges and apprehensions.

A few challenges of SRTW have been reported from some of the ULBs of India, such as Hyderabad, where the reuse of treated sewage for irrigation has raised health concerns. There have also been unethical practices such as the use of untreated sewage for irrigation and a lack of quality control (Starkl et al 2015). Another example is the city of Varanasi where warning was issued against using treated water, even for agricultural uses, due to the intermixing of municipal wastewater with textile industry effluent since the latter has heavy metal contamination (Notification for not using treated wastewater for agriculture Uttar Pradesh Jal Nigam 2015).

According to the studies, planning for water reuse mainly depends on the quality of the at-source water and the planned treatment method. Besides, reclamation facilities lack quality and performance monitoring strategies. Safe reuse of treated water needs to be supported by the implementation of regulations. Though India's policy and guiding frameworks recognise the importance of reusing treated water, little attention has been paid to the design, operation, and maintenance aspects of managing such projects and the tariff structure for reselling treated water for various purposes needs to be more specific. Institutional and legal structures are needed to provide an enabling environment to steer past these initial roadblocks.

It is also imperative to address the socio-economic challenges including lack of information, education, and awareness about the potential benefits of safe reuse of treated used water and hazards associated with using untreated used water or letting it out into the environment. Concerns about potential health dangers from reusing treated wastewater are further exacerbated by a community's distrust of authorities and trust in the quality of the treated water. The study by Ravishankar et. al. (2018) for Bengaluru highlights that the city struggles to implement water reuse due to a lack of public awareness and the residents' unwillingness to reuse treated wastewater. In addition to planning for water reuse, the project must be primarily financially viable. Investment costs, construction expenses, ongoing operation, treatment expenses, distribution, and the sale price of treated water impact the design of the reuse water systems. Furthermore, it is difficult to find the necessary financing and experience to launch such ventures. Additionally, there is a lack of information regarding the financial viability of such initiatives, which makes it difficult to plan and manage them effectively.

The use of treated water for agricultural irrigation is increasingly gaining attention on a global scale. The scientific community is concerned about the issue of chemical compounds in treated effluents, as that poses several issues and challenges for both human and environmental health. More specifically, the presence of chemical compound residues from pharmaceuticals and personal care products in effluents, post-treatment process, may endanger human health, the soil and water resources of the area, which would jeopardise the sources of drinking water. The implementation of stringent quality standards for agricultural irrigation can help to reduce exposure to such risks. Although many water reuse legislation and guidelines have been implemented successfully, there are still significant information gaps regarding the dangers associated with emerging pollutants and associated health risks and regulatory aspects related to mitigating them (Helmecke et. al. 2020).

Future Perspectives on Treated Water Reuse

Treated water reuse can be a promising solution to tackle the problems of water scarcity and reduce the pressure on the existing water resources. Scaling up treated water reuse has enormous potential to address the existing gaps in water use practices in India, thereby paving the way for a better and sustainable future. Figure-1 presents the future aspects related to treated water reuse.

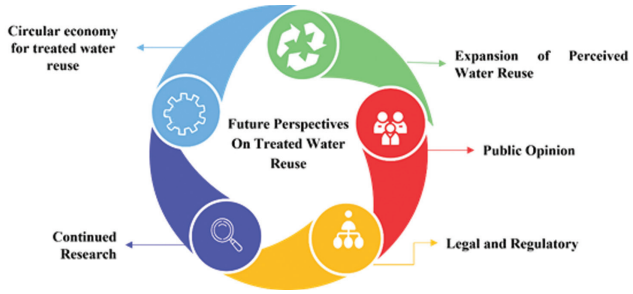

Figure-1: Future aspects related to Treated Waste Reuse

1. Expansion of Perceived Water Reuse

Mapping and redefining the water supply source is necessary. There are several other traditional sources of water that can be captured for reuse, in addition to treated wastewater. Re-framing the way water reuse is promoted and positioning it as a technique to recover valuable resources which include water, energy, nutrients, and salts would also be advantageous.

2. Public Opinion

To encourage the public to participate in the decision-making processes used for water-related issues, it is vital to assist people to understand the value of water. These initiatives must go above and beyond the methods of formal and informal education and public communication already in use to achieve these goals.

3. Legal and Regulatory

Regulations that are pertinent to the practice of water reuse must be developed in many different places. It would be advantageous to provide a set of guidelines that are broadly applicable and can be integrated into the current regulatory frameworks. Uncertainties on appropriate distribution of water rights to reclaimed water also need to be resolved.

4. Circular Economy for Treated Water Reuse

A complete transition to a circular economy for the safe reuse of treated water requires proper technologies, policies, and governance in place as well as the participation of the public in all the interconnected sectors. Even though the technology for the treatment of water for safe reuse does play a crucial role, a successful circular economy for the safe reuse of treated water can be implemented only with proper governance, appropriate information systems, awareness generation amongst the general public as well as stakeholder engagement.

5. Continued Research

Research should continue to find new solutions and contribute to the science of safe water reuse. Water reuse must remain at the forefront of technological advancements by addressing many challenges. Among these are the studies on the effects of emerging dangerous contaminants, the development of technologies to lower costs, the increase of output, the improvement of water quality, the enhancement of energy efficiency, as well as the extension of water reuse procedures to a large number of sources for water.

Conclusions

Achieving safe Reuse of Treated Water in India requires addressing a variety of issues, including public perception and acceptance, regulations, policies, pricing, trained personnel, and technology issues. A broader economic study is required to analyse the particular costs and benefits of water reuse as they change over time. A study of the effectiveness of reusing wastewater and an analysis of the results of subsidising water reuse are also required to ensure the financial viability of water reuse. Initiating public awareness programs regarding the benefits of treated water reuse and making the public aware about treated water being a sustainable solution for the environment and the resources would create a positive impact. The ULBs can generate a regular source of income by selling treated water for safe reuse to industries and other economic activities thus enhancing their production efficiency. The regulatory framework should include a mandate for the reuse of treated water in the industrial, construction, agricultural, and commercial

sectors. There should also be a proper monitoring system in place to ensure that all regulations are adhered to. Pilot water reuse projects can be implemented initially to help understand; later they can be scaled up as needed. Each new high-rise building/ community can also be mandated to ensure treated water is reused within the community for all purposes other than potable water. It is imperative to examine the reasons for underutilisation at the grassroots level to implement measures that would reduce the pressure on precious fresh water supplies. For a resilient and sustainable environment, treated water reuse must be the 'new normal' and that would also foster a circular economy of water. By safely reusing treated wastewater, India would also be able to fulfil some of the SDGs, including SDGs 6.1, 6.2, 6.3, and 11.6.

References

1. IPCC https://www.ipcc.ch/2021/08/09/ar6-wg1- 20210 809 -pr/ Accessed on 1st October 2022
2. Goyal, K., & Kumar, A. (2021). Development of water reuse: A global review with the focus on India. *Water Science and Technology, 84(10–11), 3172–3190.* https://doi.org/10.2166/wst.2021.359 Accessed on 2nd October 2022
3. Central Water Commission (CWC) (2017) Water – Its Conservation, Management and Governance. Government of India, New Delhi, India
4. Central Ground Water Board (CGWB) (2017) Annual Report 2016–17. Available from: http://cgwb.gov.in/Annual-Reports/Annual Report 2015-16.pdf 2nd October 2022
5. UNICEF, FAO, and South Asia Consortium for Interdisciplinary Water Resources Studies 2013
6. *Compendium on recycle and resuse of wastewater, CPHEEO, MoHUA, 2021*
7. Central Pollution Control Board (CPCB) 2015 Annual Report 2014-15. https://doi.org/10.1088/1751-8113/44/8/085201 . Government of India, New Delhi, India. Accessed on 3rd October 2022
8. Ravishankar, C., S. Nautiyal, and M. Seshaiah. 2018. "Social Acceptance for Reclaimed Water Use: A Case Study in Bengaluru" Recycling. 3 (1): 4.
9. Starkl, M.; Brunner, N.; Amerasinghe, P.; Mahesh, J.; Kumar, D.; Asolekar, S.R.; Sonkamble, S.; Ahmed, S.; Wajihuddin, M.; Pratyusha, A.; Sarah, S. Stakeholder Views, Financing and Policy Implications for Reuse of Wastewater for Irrigation: A Case from Hyderabad, India. Water 2015, 7, 300-328. https://doi.org/10.3390/w7010300 Accessed on 3rd October 2022
10. Notification for not using treated wastewater for agriculture, Uttar Pradesh Jal Nigam 2015
11. Helmecke, M., Fries, E. & Schulte, C. Regulating water reuse for agricultural irrigation: risks related to organic micro-contaminants. *Environ Sci Eur* **32**, 4 (2020). https://doi.org/10.1186/s12302-019-0283-0 Accessed on 3rd October 2022

NDTV

India Could Soon Experience Heat Waves Beyond Human Survival Limit: World Bank

The World Bank report titled "Climate Investment Opportunities in India's Cooling Sector" said the country is experiencing higher temperatures that arrive earlier and stay far longer.

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14

Making Textile Industry Circular and Inclusive in India

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Introduction

Circular Economy is a disruptive model that challenges the current Linear economic model. It aims to increase a product's longevity and retain it as part of the value chain for as long as possible by reusing, repairing, recycling, remanufacturing, refurbishing. In doing so, it significantly differs from the linear model of economy which is driven by the 'take-make-dispose' agenda.

The need to adopt a circular economic model arises from the need to bring overconsumption to a standstill. For instance, humans are already using more than 60% of the resources that the earth can produce every year (World Wildlife Fund, 2016). Therefore, it is not surprising that the world generates more than 2 billion tonnes of municipal solid waste globally which is expected to rise to 3.4 billion tonnes by 2050 (Kaza et al., 2018). There is a lot of value lost in the waste generated as well. For example, over USD 62.5 billion worth of e-waste ends up in landfills annually (Nijman, 2019).

One industry that has contributed significantly to the mounting problem of waste generated, particularly in the urban areas is the textile and fashion industry. The consumption of clothing is 400% more than that consumed about 20 years ago (Chen et al., 2021). Studies prove that about 148 million tonnes of clothing would be discarded annually by the year 2030 (Long, 2021).

Given the trends, it is only reasonable that many countries in contemporary times are adopting the circular economic model to reduce waste generation.

There are three reasons that set the rationale for taking a close look at the textile and apparel industry in India to make the transition happening in the industry just and inclusive. Firstly, as high as 7,800 kilotonnes of textile waste is accumulated annually in India and accounts for roughly 8.5% of the world's total textile waste (Fashion for Good, 2022). Secondly, the demand for apparels is ever-growing. For instance, the per capita expenditure on textile is expected to reach INR 6400 by 2023, up from INR 3900 in 2018 (Lopes, 2021). Lastly, India has been an advocate for adopting a circular approach on the global stage. For instance, it is an important agenda of India's G20 (Group of 20) Presidency and its Lifestyle for Environment (LiFE) campaign at the 27th Conference Of the Parties (COP), thereby pushing for the country to take a deep dive into the textile and fashion industry that is rife with many social and environmental challenges.

In this article, the authors highlight the key challenges faced by India, the policies and practices adopted and learnings from international practices. In doing so, the authors seek to analyze the methods that would aid India in embedding circularity in the operations of the textiles and apparel industry in India.

India's Current Scenario

The textile sector is one of India's oldest sectors, accounting for around 2% of the GDP and 18% of manufacturing (Government of India, 2020). India is the world's sixth largest textile exporter, with the exports accounting to around 12% of India's total exports (Government of India 2020)its performance in output was strong. About 54.6 per cent of the total workforce in the country is still engaged in agricultural and allied sector activities (Census 2011. The sector is critical to employment creation and the 'Make in India' initiative and is mostly composed of small-scale isolated units of spinning, weaving, knitting, fabric finishing, and apparel-making businesses It directly employs 45 million people and indirectly employs 60 million people (Government of India 2020)its performance in output was strong. About 54.6 per cent of the total workforce in the country is still engaged in agricultural and allied sector activities (Census 2011.

Challenges

Environmental Challenges

The fashion industry, particularly under the ambit of fast fashion, is under intense criticism owing to its negative environmental and ecological implications. Specifically in India, these effects relate to the following:

- Raw material requirements: For instance, cotton requires a lot of resources, and one cotton shit can consumer upto 2700 litres of water. Polyester, on the other hand, while using fewer resources, is non-biodegradable and adds significantly to the problem of microplastics (Drew and Yehounme, 2017).
- Chemical usage: Over 8000 chemicals are used in the textile and clothing industry, beginning with the manufacture of fibres and continuing through the dyeing, processing, and finishing of textiles. Textile dyeing and treatment are responsible for over 20% of water contamination (Textile Value Chain, 2020).
- Waste generation: Because of fast fashion trends (styles changing considerably faster and at much lower prices), customers are buying a lot more items but wearing them for a much shorter period. This has resulted in a vast amount of garbage being disposed in landfills - almost 85% of all clothing ends up in landfills (Mcfall-Johnsen, 2019).

Social Challenges

India's garment and textile industry is infamous for the harsh working conditions. They are reflected in:

- Low wages: Often, labourers are given very low wages, especially since the Minimum Wages Act in India is barely followed. In most developing countries like Bangladesh, China and India, "the minimum wage is half to a fifth of the living wage" (Textile Value Chain, 2022).
- Long work hours: As the wages are meagre, laborers are coerced into working for long hours. For instance, data shows that garment workers are usually forced to work for 14 to 16 hours a day, 7 days a week (DAKS India, 2021).
- Unsafe working conditions: It is also commonly reported that accidents and injuries, in addition to verbal and even physical harassment is a common occurrence (Textile Value Chain, 2022). For women, the conditions become much worse because of their exposure to cases of sexual harassment and violence (Meloot, 2019) as well as lack of access to hygiene and sanitation facilities at the factories (Mallika, 2021).

Systemic Challenges

In addition to the environmental and social challenges that surround the industry's functioning, there are systemic challenges that further hinder the industry's shift to a circular and inclusive model. They include:

- Fragmentation: The textile and apparel sector is extremely fragmented, with many MSME companies. Furthermore, there is limited pace for technological advancement, and the industry remains highly labour-intensive (Niti Aayog 2020). Due to the geographical and financial barriers, the collective bargaining strength is reduced, which makes the country vulnerable to inexpensive imported goods from China and Bangladesh.

- Lack of affordable resources: India's three key production elements- labour, land, and capital- are more expensive in comparison to neighbouring emerging nations (MoC&I 2018). This could potentially pose a problem to India's transition to a circular economy as it requires a shift in the processes and systems.

However, given the challenges, India has undertaken few actions to make the textile and apparel industry more circular and inclusive.

Policy and Regulatory Push

While very little has been covered within the domain of the textile and apparel industry, the Solid Waste Management Rules of 2016 do mention the inclusion and formalisation of waste pickers. Waste pickers facilitate the collection and sorting of solid waste including textiles. The Rules mention establishing a system that recognizes organisation of waste pickers and/or informal waste collectors and also facilitates their participation (MOEFCC, 2016). The Rules also call for local authorities to facilitate formation of Self-Help Groups (SHGs) for further integration into the solid waste management systems (MOEFCC, 2016).

Recently, the government has begun to assist MSMEs via incentives and has advocated the need for efficiency to them. Credit guarantee programmes, collateral-free loans, equity investment to assist expansion, and promoting public procurement from MSMEs by prohibiting worldwide bids for projects and supplies costing up to INR 200 crores are some of the examples (Jain, 2020).

Collaboration

Very recently, in October 2022, the Textiles Committee of the Government of India has entered into a collaboration with the United Nations Environment Programme (UNEP) to promote circularity and inclusivity in the textile industry (PIB, 2022). It has entered into a Cooperation Agreement on "*Mainstreaming Sustainability & Circularity in the Textiles Sector*" with the aim to decrease adverse environmental impacts and promote sustainable practices.

Lessons and Way Forward for India

As noted earlier, Circular Economy value chains focus on leveraging unlimited resources, such as labour, while reducing dependency on natural resources that are finite (Mazzoni, 2020). Globally, the shift to a Circular Economy in the textile sector is set to impact a variety of stakeholders, including, but not limited to, textile workers. The existing linear textile sector value chain, driven by growing demand and high cost and time pressures, is associated with low pay, hazardous working conditions, and circumstances akin to bonded labour or modern slavery in some instances (Ellen MacArthur Foundation, 2017). The shift to a Circular Economy offers an opportunity to bring in good practices for enhanced sustainability balancing social and environmental considerations. In this section, the experiences of three countries are reviewed through a social impact perspective to cull out learnings for the textile sector in India while adopting Circular Economy practices.

Netherlands

The Netherlands is going through an organic shift to a Circular Economy amidst a stagnating "end-of-life" textile sector (Suarez-Visbal, Stuckrath & Carreón, 2022). Even though the sector is organically transitioning to a Circular Economic model, the job creation in the sector is characterised by voluntary, contractual, temporary or part-time work schemes. The Circular Economy in the textile sector consists mainly of rental and resale startups. Applying a multi-dimensional Social Impact Assessment Framework (Social Impact Assessment Framework for Circular Economy with a Gender-Inclusion Lens (SIAF-CE♀), one study finds that the quality of jobs created through the shift to circular economy in textile sector is poor and the perception of workers on the livelihood sustainability, economic opportunity and gender inclusivity aspects remains abysmal.

While the Netherlands aims to become a Circular Economy by 2050, perhaps the startup-based circular economy in the textile sector needs to be addressed through stronger labour regulation. Though, the economic context of the textile sector in India may not be at the

same stage, the proliferation of startups in textile resale and rental needs to be anticipated and regulated through labour formalisation to avoid the pitfalls discussed above.

In this regard, providing a favorable environment to MSMEs is already on the government's radar. For instance, The Economic Survey of India (2019-20) suggests using e-commerce to link handicraft enterprises with worldwide customers. Online aggregation of MSMEs would also gather a fragmented industry on one platform.

Sweden

The majority of Swedish brands carry out fabric and garment production in countries such as Bangladesh, China, Italy, Poland, and India. The major cleavage among Swedish brands is that larger brands are able to mobilise the resources (time and financial capacity) necessary for adopting sustainable practices (Brydges, 2021) while the smaller brands are unable to. Often, the higher production costs associated with environmental sustainability are offset by reduced labour costs, such as by moving production to a country with less stringent labour law enforcement and lower minimum wages, such as Bangladesh (Brydges, 2021).

To transform this state of affairs, some brands are now adopting strategies like consolidating the number of facilities they work with so that they can recommend and monitor safer labour practices, or engaging intermediaries to audit factories and improve labour conditions. However, there is no incentive to encourage brands to adopt such practices. It is recommended that India, therefore, provides incentives and benefits to companies and/or brands that promote sustainable textile and fashion practices.

Germany

Germany has a tradition of donating post-consumer clothes to low-income countries under the garb of "charity". Despite the large volume of post-consumer waste exported by the country, the post-consumer waste collection process is blatantly unregulated (GIZ, 2019). Regulations about waste collection differ by brand and region, posing a challenge to brands looking to integrate waste collection stations at stores. The export of post-consumer clothes has also been criticized for stifling development and scaling up of recycling technologies such as mechanical recycling (GIZ, 2019). Moreover, the export of post-consumer waste is observed to have an adverse impact on local producers in importing countries.

In India, much of the post-consumer waste as well as pre-consumer waste generated during the production of textiles is handled by informal workers. There is no formal recycling arrangement for most of the textile waste. Certain communities in India have historically been involved in the collection, repair and resale of used clothes, creating longer product lives at low costs.

India is also a hub for mechanical recycling of post-consumer waste. However, the mechanical recycling process requires hundreds of kilos of fabric per colour for running a cycle for optimal operation of the machine. These fabrics need to be sorted manually by skilled workers, the cost of replacing whom with AI or technology is not profitable.

Combining the German and Indian experiences, a trend of outsourcing of the labour-intensive activities in the textile value chain to low-income countries can be observed. This is an important trend to note for countries like India while developing circular economy policies as the local context would greatly differ from higher-income countries already in the process of adopting circularity in textile value chains.

Most literature on the impact of Circular Economy on social dimensions of the textile sector has been limited to the job creation aspect (Suarez-Visbal, Stuckrath & Carreón, 2022). However, as these case studies show, there are multiple practical dimensions that need further attention. A comprehensive treatment of the topic is not possible given the limited scope of this paper. Nonetheless, the major learnings from this section for India is to take pre-emptive action through holistic regulations and incentives along with the introduction of circular economy policies.

Conclusion

While India is buffeted with challenges in its textile and apparel industry, there are signs that the country is

willing to undertake more such initiatives to enhance circularity and inclusivity in the industry. By introducing policies and regulations as well as collaborating with international institutions, India has the potential to pave the way for making its textile and apparel sector circular as well as inclusive.

With its already existing social and environmental problems along with the already present systemic challenges, it is crucial for India to adopt the circular model while facilitating inclusion of those who contribute the most to the sector, for instance, women. While international practices can shed some light on how India can become circular in the domain of textiles and apparels, it is also important to highlight that solutions that fit to India's local context are few. Nonetheless, with circular practices deeply embedded in the functioning and daily routines in general in India, it can be concluded that India has both the potential as well as the willingness to take the circular economic agenda forward.

References

1. Brydges, T. (2021). Closing the loop on take, make, waste: Investigating circular economy practices in the Swedish fashion industry. *Journal of Cleaner Production*, *293*, 126245.
2. Chen, Xuandong, Hifza A. Memon, Yuanhao Wang, Ifra Marriam, and Mike Tebyetekerwa. 2021. "Circular Economy and Sustainability of the Clothing and Textile Industry." *Materials Circular Economy* 3 (1): 12. https://doi.org/10.1007/s42824-021-00026-2.
3. DAKS India. 2021. "Working Conditions of the Factory Workers." DAKS India Industries Private Limited. 2021.
4. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. (2019). Circular Economy in the Textile Sector: Study for the German Federal Ministry for Economic Cooperation and Development (BMZ).
5. Drew, Deborah, and Genevieve Yehounme. 2017. "The Apparel Industry's Environmental Impact in 6 Graphics." World Resources Institute. 2017. https://www.wri.org/insights/apparel-industrys-environmental-impact-6-graphics.
6. Fashion For Good. 2022. "Wealth in Waste: India's Potential to Lead Circular Textile Sourcing - Fashion for Good." Fashion For Good. 2022. https://fashionforgood.com/our_news/wealth-in-waste-indias-potential-to-lead-circular-textile-sourcing/.
7. Galatti, L. G., & Baruque-Ramos, J. (2022). Circular economy indicators for measuring social innovation in the Brazilian textile and fashion industry. *Journal of Cleaner Production*, 132485.
8. Jain, Rounak. 2020. "Nirmala Sitharaman Announces Six Measures for the MSME Sector." 2020. https://www.businessinsider.in/india/news/fm-nirmala-sitaraman-announces-six-steps-for-msme-sector/articleshow/75717258.cms.
9. Kaza, Silpa, Lisa C. Yao, Perinaz Bhada-Tata, and Frank Van Woerden. 2018. *What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050*. World Bank.
10. Long, Jessica. 2021. "7 Surprising Facts about the Circular Economy for COP26 | World Economic Forum." October 21, 2021. https://www.weforum.org/agenda/2021/10/7-surprising-facts-to-know-about-the-circular-economy-for-cop26/.
11. Lopes, Flavia. 2021. "By Creating a False Demand for Fresh Looks, Fast Fashion Is Hurting the Environment." Scoll.In. 2021. https://scroll.in/article/1013398/by-creating-a-false-demand-for-fresh-looks-fast-fashion-is-hurting-the-environment.
12. Mallik, Manisha. 2021. "Managing Menstruation in Textile and Garment Industry of India." Beyond Blood. 2021. https://www.beyondblood.org/post/managing-menstruation-in-textile-and-garment-industry-of-india.
13. Mazzoni, F. (2020). Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster. *Insights into Regional Development*, *2*(3), 661-676.
14. Mcfall-Johnsen, Morgan. 2019. "The Fashion Industry Emits More Carbon than International Flights and Maritime Shipping Combined. Here Are the Biggest Ways It Impacts the Planet. | Business Insider India." Business Insider. 2019. https://www.businessinsider.in/science/news/the-fashion-industry-emits-more-carbon-than-international-flights-and-maritime-shipping-combined-here-are-the-biggest-ways-it-impacts-the-planet-/articleshow/71640863.cms.
15. Meloot, Srada. 2019. "Apparel Factories Ban Toilet Breaks to Maximise Production." India Flash. 2019.

https://indianf.com/apparel-factories-ban-toilet-breaks-to-maximise-production-hrw/.

16. Nijman, Shari. 2019. "Time to Seize Opportunity, Tackle Challenge of e-Waste." United Nations Environment Programme. 2019. https://www.unep.org/news-and-stories/press-release/un-report-time-seize-opportunity-tackle-challenge-e-waste.
17. MOEFCC. 2016. "MOEFCC Notification." https://cpcb.nic.in/uploads/MSW/SWM_2016.pdf.
18. Morlet, A., Opsomer, R., Herrmann, S., Balmond, L., Gillet, C., & Fuchs, L. (2017). A new textiles economy: Redesigning fashion's future. Ellen MacArthur Foundation.
19. PIB. 2022. "Textiles Committee Signs Cooperation Agreement with UNEP to Promote Sustainability and Circularity in Textile Value Chain." Public Information Bureau. https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1867109.
20. Suarez-Visbal, L., Stuckrath, C., & Carreón, J. R. (2022). Assessing through a gender-inclusion lens the social Impact of circular strategies in the Apparel Value Chain: The Dutch case. In Social and Cultural Aspects of the Circular Economy (pp. 136-159). Routledge.
21. Textile Value Chain. 2020. "Water Pollution Due to Textile Industry." *Textile Magazine, Textile News, Apparel News, Fashion News* (blog). September 11, 2020. https://textilevaluechain.in/news-insights/water-pollution-due-to-textile-industry/.
22. ———. 2022. "WORKING CONDITIONS IN THE TEXTILE INDUSTRY - Textile Magazine, Textile News, Apparel News, Fashion News." 2022. https://textilevaluechain.in/in-depth-analysis/working-conditions-in-the-textile-industry/.
23. World Wildlife Fund. 2016. "Living Planet Report 2016." World Wildlife Fund. https://wwfint.awsassets.panda.org/downloads/technical_supplement_ecological_footprint_2016.pdf.

A concrete challenge: Tel Aviv tech startup uses sensors to ensure better building

GreenVibe says its hardware and software system can provide real-time insights about on-site construction material and offer data-driven predictions about quality and readiness

By DANIELLE NAGLER 25 November 2022, 5:50 am|

For the past three years, Israeli tech startup GreenVibe has been tackling a concrete challenge. Literally.

The Tel Aviv-based company, founded in 2019, is looking to transform the construction industry by applying smart sensors to building materials — chiefly concrete — to optimize quality and speed up the building process.

Leveraging sensors made in-house, GreenVibe gathers data about concrete composition, feeding back measurements such as temperature, strength, density and humidity during the formulation and pour processes so that on-site construction engineers and development project managers can make better-informed decisions.

The company says its hardware and software system can provide real-time data about the material on construction sites and offer data-driven predictions about quality and readiness.

Concrete is the most widely used building material in the world, and its use is expected to multiply four-fold by 2050 from the existing approximately 30 billion tons used annually. It is cheap, simple to make, and ubiquitous. It is also currently responsible for around 8% of human carbon dioxide emissions because of the ways it is manufactured and used. And cement — its main ingredient — is the most polluting part of the mix.

Yet concrete makes a unique contribution to pretty much everything that is constructed, from tall glassy skyscrapers to bridges and roads, and seems to be in no danger of being replaced. This means the global challenge is to find ways to make the product and its usage more energy efficient and long-lasting.

GreenVibe is not alone in recognizing this. But its solution is gaining ground with leading construction companies because it is simple yet effective.

15

Role of Structural Engineers in Sustainable Development – An Indian Perspective

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Abstract

With the rapid change of climate in the past few years, shifts in temperatures, frequent occurrences of natural calamities, changes in weather patterns, etc. have become a cause for serious concern. The average global temperatures have increased by around 1°C since 1880. However, with the increased rate, it is projected to reach around 1.5°C by 2050 and 2-4°C by 2100. It is a known fact that human activity is the major contributor to the increase. It is imperative that each one of us acts with a sense of urgency to reduce the impact of our activities. This paper aspires to present the action that can be taken by Structural Engineers to reduce the impact of the Built Environment on the Global crisis and discusses the challenges faced in the Indian context.

Introduction

The effects of climate change include flooding and droughts, rising sea levels, declining biodiversity, to name a few. These changes are largely influenced by the increase in global temperatures. Greenhouse Gas emissions (GHG), primarily from methane and carbon dioxide, create a blanket over the earth's atmosphere, trapping the heat and resulting in temperature rise.

With a view to a global consensus to contain the impact, the UN has provided a framework for measuring sustainability. The 17 United Nations Sustainable Development Goals (UNSDGs) (refer Figure-1) are wide ranging and offer guidelines for everyone to work towards.

Figure- 1: United Nations Sustainable Development Goals

Current Scenario and Need

The Building and Infrastructure Sector contributes to approximately 37% of the global carbon dioxide (CO_2) emissions. That includes the emissions arising from the building during its two stages. The product stage (embodied carbon emissions) and during the use of the building (operational carbon emissions); collectively known as whole-life emissions (refer Figure-2). It is to be noted that embodied carbon includes the emissions during the construction, maintenance and eventual demolition of the building. While a lot of effort, over the last few years, has been to reduce the operational emissions, there has been little work on the reduction of

embodied carbon emissions. Majority of the embodied carbon emissions, unlike the operational emissions, take place during the short period of construction of a project.

The Paris Agreement committed to limiting the global average temperature rise to below 2°C in the 21st century. Net-zero means that the project's life cycle Greenhouse Gas emissions from all sources should total to zero, or less. Efforts to decarbonize and achieve 'Net-zero' status requires that the embodied carbon emissions be taken into account and a Life-cycle assessment be carried out.

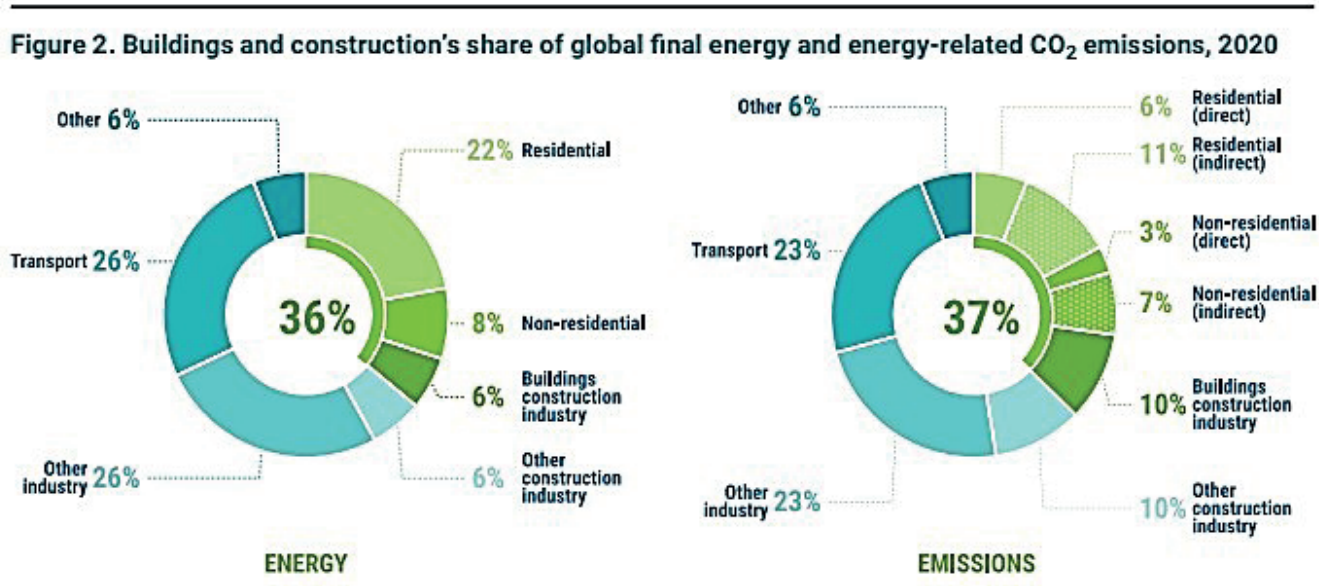

Figure-2: Building and Construction's share of global final energy and energy related CO2 emissions

Embodied Carbon Emissions

Embodied Carbon emissions amount to approximately 50% of the whole-life building emissions. Unlike the operational carbon emissions that are easy to track and measure, the embodied carbon emissions are difficult to measure. Some of the reasons attributed to the difficulty are as under:

- Variability of building materials
- Lack of data regarding the materials available in the industry
- Lack of data regarding processes during manufacture
- Multiple vendors for products and difficulty in tracking
- Lack of awareness about the need and method for measurement

Primary Construction Materials and Their Impact

Some of the commonly used materials in construction are concrete, steel, masonry, wood, different kinds of polymers, etc. Concrete and steel (both in the form of structural steel and reinforcement steel) remain the most widely used materials in construction. With increase in construction globally, the emissions due to cement manufacture have doubled in the last 20 years. For every ton of cement manufactured, the CO_2 emission is to the order of 810 kg to 900 kg, while the manufacture of structural steel, using conventional blast furnace, amounts to CO_2 emissions of 1.5 tonnes to 3 tonnes.

Concrete

The cement content in concrete is the major contributor

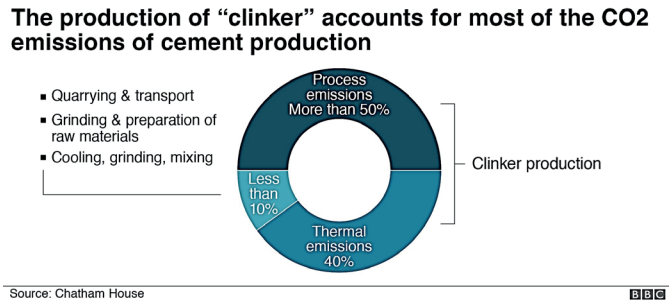

Figure-3: Processes and emissions in cement manufacture (Source: Chatham House)

(approx. 90%) to carbon emissions. The high number is attributed to the 'calcination' process, during the manufacture of cement. Limestone is heated at high temperatures of approximately 1450°C to form clinker.

Steel

The two main processes for manufacturing steel are the Basic Oxygen Furnace and the Electric Arc Furnace. The basic difference is that the Blast furnace uses iron ore as its base raw material with coal-based production for reduction of iron oxides while Electric Arc Furnace uses majorly scrap steel for manufacture with natural gas and hydrogen for the processes. The EAF process has 40-50% lesser CO_2 emissions than a conventional Oxygen Furnace.

Role of Structural Engineers

Emissions from materials used in construction, such as steel and cement, are expected to become the largest source of carbon emissions in the building sector in the coming decades. It is imperative that Structural Engineers need to play a key role through informed and efficient design of structures. The Design stage is the most crucial stage for a project as the majority of the decisions on the final product are taken at that stage.

The '3 Rs' of Sustainability viz. 'Reduce', 'Reuse' and 'Recycle' can be used by Structural Engineers to help control emissions. The primary effort needs to be to reduce the consumption of materials to the extent possible, next on reusing the available buildings and making them usable for alternative purposes and finally on recycling the materials that have already been used. It is to be noted that as one moves from Reduce to Recycle, the energy required for the processes keeps increasing, resulting in the highest emissions for the recycling process.

Reduce

Optimized and efficient design need to be the focus area for structural engineers. Such a design has the advantage of reduction of carbon emissions during the construction phase of the building and has an immediate impact, as opposed to the operating carbon reduction which happens over a long period after the building is constructed.

Figure-4: The 3Rs of sustainability

Reduction is possible in the following ways:

1) Reduction of primary material for construction i.e., reduction in quantity of concrete and steel used for a structure which can be achieved by:
   a) Exploring different structural systems and arriving at the most efficient system for a type of structure.
   b) Carrying out performance-based design of structures to evaluate the optimisation potential
2) Reduction of materials causing high emissions. For e.g., reducing the cement content in concrete and using alternative materials like flyash, GGBS, etc.
3) Substitution of high emission materials with low emission materials like sequestrated timber, reduction of clinker with the use of fired clay, etc. to the extent possible.
4) Specifying better quality and finish of concrete to avoid secondary materials for finishing.
5) Specifying, with durability aspects in mind to increase the design life of the building.

Reuse

The best form of reuse is 'Adaptive Reuse' where a building is made functional for a different use than what it was originally designed and built for. For such cases, the following may be adopted:

- Evaluate the current state of the building including condition of foundation, structural frame, deterioration of elements, local failures or damages, etc. Due diligence checks can be assisted with visual inspections and non-destructive testing of the buildings to conclude on the feasibility for reuse.
- Redesign and design of retrofit of these buildings for the new intended use.
- Provide methodology for the repair of the deteriorated elements of the structure.

The other form of reuse is that of the structural elements used in construction. Structural steel is one of the easiest materials that can be reused with no changes or minimal changes. Using the components, as is, without resorting to melting or the process of recycling ensures that the emissions are kept to a bare minimum. Concrete can be used as aggregates for use in concrete mixes. Such elements for reuse are best specified by the Structural Engineer, for implementation at site.

Recycle

Recycling of construction materials needs to be considered as the last option, after 'reduce' and 'reuse' strategies. The amount of energy involved in the recycling process makes it a lesser preferred option than the former ones.

Recycling is possible with a variety of construction materials. Steel can be extensively used in a recycled form. The emissions from the production of recycled steel using Electric Arc Furnace are considerably lower than the production of primary steel using the Blast Furnace. A multitude of waste products are used in other civil engineering applications. For e.g., plastics, rubber and tire, steel slag, crushed glass, rice husk, asphalt, etc. can be used for different elements. Again, specification of such materials by the Structural Engineer improves the implementation potential.

Other Measures

To assess the overall impact of materials, a thorough analysis and quantification is required in all stages of use of the material, starting from the manufacturing process to the end of life. Hence, a lifecycle assessment provides a holistic approach to capture impact at all the different stages. It is to be noted that the design of deconstruction needs to be considered as an integral part of the design process.

Exploring new ways to design buildings, slowly but surely implementing the outcome of various research carried out globally and implementing newer technologies like carbon capture, use of modified materials like hempcrete, geopolymer concrete, low carbon steel, etc. would make a difference.

Indian Context and Implementation

In the Paris Agreement and in the recently concluded COP 27, India has committed to pursuing low-carbon strategies for development and also for the integrated planning of cities for mainstreaming adaptation and enhancing energy and resource efficiency, while implementing an effective green building code. However, the challenges faced by India in implementing efforts for decarbonisation are manifold.

At a project level, there are impediments at every stage. Firstly, there is a lack of codes providing emission standards for any type of building. Having a databank of buildings and benchmarking emission targets are required to provide aspiration targets for designers.

The design phase of a building needs to be provided the required time and resources to work out different options and evaluate the merits and demerits of each. The evaluation of materials, life cycle assessment and recalibration of the building parameters need to be extensively carried out at that stage. Designers need to keep abreast of the changing trends worldwide and choose suitable systems and materials for their projects. All stakeholders of the project need to provide their inputs at this stage.

Material sourcing and procurement also play a crucial

role. Environmental Product declarations need to be mandated. Often product details are not available for local products and hence, emissions cannot be correctly estimated. Creating common sources for procurement of reusable materials would also help in ease of sourcing.

There is also a dearth of skilled and trained workmen in the industry. Often the workforce is migratory and seasonal. That creates issues with quality control at site. Better quality of construction ensures longevity, and that is where the focus needs to be. Rework at site is another example of wasted resources, which can be totally avoided. Better planning, ensuring that site engineers read and understand drawings, specifications and the contractual commitments regarding design service life, fitness for purpose, operability, maintainability, etc. before execution and raising concerns that may be noted, would help in avoiding rework at site.

Lastly, what is done to a building at the end of its useful service life is critical. As many materials as can be reused or recycled need to be reused or recycled. Assessment of reusability and identification would be a much-needed activity in the coming years.

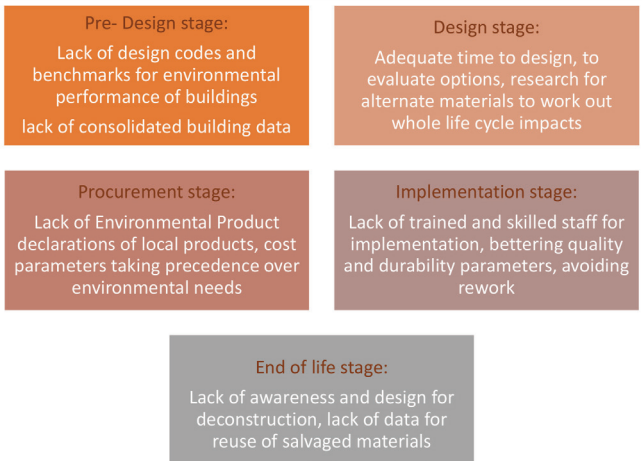

Figure-5: Challenges at different stages of a project

Creating awareness, and education of everyone in the Construction industry is thus the need of the hour. Many times, the data regarding low carbon alternatives are not known. There thus needs to be a country-wide database for India of all materials, products, etc. with comprehensive information, CAD details, BIM objects, specifications, green product information, sourcing options, cost, etc., that would help in identifying the right material or product for use. It would be akin to what is available in other countries, like Sweets Catalogue in USA.

Research for alternate materials and radical new processes should be encouraged to bring immediate changes to the current industry norms. While some such materials may have scalability and applicability issues, identification and implementation in suitable projects should be encouraged.

Adoption of 3D and 5D engineering software providing Building Information Modelling can help in maintaining all database related to the building. Information regarding all material used in the construction of the building can be stored for use during the operating phase and during the end-of-life phase for effective operations and disposal or reuse of the facility for some other purpose.

Cost is always a driving factor in making any of the decisions related to sustainability. While life cycle assessments provide a better idea of the cost advantage, often it is seen that reduction in capital cost is the main motive, especially when the developer has no advantage from the other phases of the building use. It is imperative that to provide the required push to the sustainability agenda, different strategies like green loans, bonds, cheaper capital availability, and providing sops for the developers can play a vital role in the adoption of change making decisions.

Partnering with other nations for developing and implementing frameworks for emission standards would help India leverage global research and speed up implementation. National Australian Built Environment Ratings System (NABERS) is the embodied emissions initiative in Australia which is funding the development of a world-leading framework for measuring, benchmarking and certifying emissions from construction and building materials. There are a lot of advances in research and strategies in other countries like the US, Canada and Europe which can be partnered with.

Conclusions

With the increase in population and the ever-increasing need for infrastructure, construction activity with the use of concrete and steel would go on. Hence, their impact on the environment has to be controlled by way of small improvements in the existing processes and materials. While the design phase is the most important and has a major impact, improvements at all stages of a construction project are required to achieve the intended targets. Creating awareness by way of education, encouraging research, mandating carbon declarations and integration with ESG goals, setting emission targets for new buildings, encouraging reuse and retrofit of buildings, etc. are some of the ways to bring about a positive change.

Reduction of carbon emissions is a combined effort and cannot be achieved by one section of the construction industry. Architects, Engineers, Execution teams, Authorities, Local Bodies, Policy makers, Educators, Owners, Builders, Users/ Consumers, et al. have to play an important role in India for achieving its targets.

References

1. Alice Moncaster - 'Design comment, Design for Sustainability, The impact of the built environment on climate change – and of climate change on the built environment'
2. 'Aligning Buildings with the Paris Climate Agreement: Insights and Developments from the Green Bond Market' – www.climatebonds.net
3. Cornelia Glees – 'Concrete: a game changer in Climate technology' - NZZ's Sustainable Switzerland
4. Global status report 2021 - UNEP
5. Mike White – 'Engineering in the Climate emergency: doing less, better' - Vol 100, Issue 10, 2022, The Structural Engineer
6. Shirish Bharadwaj and Deepak Tewari: 'Tackling embodied carbon from India's building sector' – Alliance for an energy efficient economy
7. 'Structural material and Global climate: A primer on Carbon Emissions for Structural Engineers', ASCE SEI Sustainability Committee
8. 'The Science of Climate Change – The world is warming' – Wisconsin DNR
9. Tom Newby – 'Engineering climate justice: how can we contribute to equitable global decarbonisation' – Vol 100, Issue 6, 2022, The Structural Engineer
10. United Nations – Climate Action: The Science

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20creativeways(andcounting)thatAmsterdam is pushing to make its economy circular

Amsterdam has an ambitious goal to be fully circular by the middle of the century. Now, it's figuring out how to get there.

16

Sustainable Engineering and Circular Economy for Roads & Highways – Case Studies

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Abstract

As countries emerge from the pandemic, they are gearing up to accelerate the economy. India has also adopted a proactive approach but with emphasis on local production and consumptions plus exports. Radical changes and initiatives have been taken by the Government of India in that direction, with The PM Gati-Shakti being an initiative to become a $20 trillion economy by the year 2040. Gati-Shakti has incorporated various Infrastructure schemes such as Bharatmala, Sagarmala, Inland waterways, Ports and Udan, etc.

The Bharatmala project envisages a network of 83,677 kms of roads at a total investment estimated to be Rs. 10.63 lakh crores. It is planned giving due consideration to social, environmental issues in addition to the economic concerns. The intensive development in the road sector involves land-use, human resources, material and energy. Hence success of the development initiative depends upon optimum utilisation of finite resources and completing the projects within prescribed schedules in a sustainable manner by shifting from a Linear to a Circular Economy. In the latter concept waste management is key to shift from the path of unsustainable material development and mismanagement of resources to one of minimising requirement of new material, which is very large, by recycling construction waste. Circular Economy (CE) when looked at holistically needs to encompass not only naturally occurring materials but also the flora and fauna. Thus, with due consideration of sustainability, this paper

also looks at ways to minimise road induced impacts on wildlife. Sustainable engineering solutions need to be considered while finalising the alignment, designing and operating a roadway especially through forest areas and protected areas such as a Wildlife Sanctuary/ National Park or its Eco Sensitive Zone (ESZ). The Ministry of Road Transport and Highways have already come up with number of new policies and innovations in that direction. This paper presents three Case Studies as the efforts in the direction of use of circular economy approach for sustainable development by incorporating the policy level changes, innovations and eco-effective measures in alignment planning and detailed engineering of highway project.

Introduction

The CE concept has become the order of the day in academic, nongovernmental, private sector and policy circles. That is evident from the improved partnerships between environmental organisations, governments, and between programme makers and researchers, with particular effort on research, innovation, and exchange of knowledge (Bao et. al. 2019). There have been global calls to find new ways to use existing natural resources more efficiently and reuse of existing materials of construction when the design life of a final product is over but the life of the individual ingredients of the product still exist.

The CE concept closes the entire loop of the production cycle by maximising recycling and reuse of material throughout their lifecycle as against a linear economy that promotes the use of raw materials for production and consumption, and throwing away of the resulting waste or disposing or destroying it (Lag-Brotons 2020).

CE stimulates reuse of waste materials as different to the dumping of used material surplus which is more commonly related with the linear economy (Kirchherr et. al. 2017). The Ellen MacArthur Foundation (2013), (EMF) has observed that the CE is the best step towards minimising material waste, reducing environmental degradation, and mitigating climate change. Hartley, et. al. (2020) recommended a few policies for a better CE. They advocate policy-induced expansion of circular procurement, tax relief for circular products, liberalisation of waste trading, and awareness campaigns. CE is thus one that emphasises product, component and material reuse, remanufacturing, refurbishment, repair, cascading, and upgrading as well as waste-derived energy utilisation throughout the value chain of a product.

Transportation involves traversing the undeveloped areas hence development in the road sector must also consider the impact on forests and wildlife since it tends to fragment the natural landscapes on account of it severing the habitat connectivity which is vital for the demographic and genetic viability of several endangered species. Some stretches or sections in about 100 National Highways are falling in or passing through forest areas declared as Wildlife Sanctuary/ National Park or its Eco Sensitive Zone (ESZ). Development of roads and highways in forest areas often create barriers or breaks in habitat, which cause great damage to the long term conservation of wildlife and ecosystem.

Wild animals killed in road accidents in India in recent years

Eighty-three leopard deaths in train and road accidents were recorded in 2019, which is the highest in a decade, according to data collated by Delhi-based Wildlife Protection Society of India (WPSI). While 73 leopards were killed in road accidents, 10 were run over by trains. For the second consecutive year, Maharashtra recorded the highest number of leopard deaths in accidents among all states with 22 cases (19 in road, 3 in train accidents) in 2019 - Published in Hindustan Times on December 31, 2019

An RTI reply has revealed that a total of 29 wild animals were killed in road accidents on the stretch of Coimbatore – Bengaluru National Highway 948 that passes through Sathyamangalam Forest Range in Sathyamangalam Tiger Reserve (STR) between 2012 and 2021 - Published in The Hindu on March 02, 2022

In Maharashtra, one leopard is dying every two days. Officially, in the last 140 days, 87 leopards have died in the state. Of the 87 deaths, 47 are claimed to be natural and 33 due to road accidents. Road hits continue to be a major cause for concern - Published in The Times of India on May 24, 2021

Wild Animals killed in Road Accidents

A road project either through or close to a forest area or protected areas or eco-sensitive zone of protected areas would lead to loss of habitat that would finally result in a reduction of that area to sustain the wildlife therein. The magnitude of the impact is likely to be proportional to the proposed Right of Way (RoW) and the length of the road in the forest area. Hence, it is necessary that mitigation measures be incorporated right from the start of the project.

Planning and design of roads and highways right from the initial stages are an important part of road development. Adopting CE in early stages of development streamlines the further processes and helps in identifying any constructability issues well in advance. The concept of CE in road design and planning is characterised by the following.

- Effective reconnaissance, data collection and investigations using latest technology for the maximum efficiency and accuracy;
- Comparative analysis of alignment options with consideration of social, environment impact, ecology, traffic, cost, length of structures, etc;
- Optimisation of selected alignment (vertical geometry) option in feasibility design stage;
- Selection of material for pavement, earthworks and structures with consideration of Reuse-Recycle-Repair approach;
- Social, environmental and economic uncertainties in project influence area.

Issues and Challenges in Adoption of Circular Economy

Today's major concern is to conserve the planet by conserving the environment and for that CE is a boon which enables development in a sustainable manner. However, there are a few issues which need to be addressed.

- Lack of Researches and previous exposure in this area,
- Lack of coordination among different stakeholder departments,
- Little knowledge of Circular Economy principles and strategies among Consultants, Institutes and Contractors,
- Haulage, stacking and allied costs for the waste material,
- Lack of incentives and fragmented nature of construction industry,
- Poor land records and Utilities database to assess the social and economic impact, and
- Political interferences.

The above issues could be dealt with by proper planning, and taking initiatives for adopting guidelines, and adopting new practices

Despite the issues and challenges, there are examples wherein the CE approach has been effectively and demonstrated and successfully executed. These are presented in this paper.

Case Study I: Sanchore Ahmedabad Expressway

NHAI is constructing a Six Lane Access Controlled Greenfield Highway from Amritsar to Jamnagar under the Bharatmala Pariyojana (Phase-I). That economic

corridor passes through India's most agricultural and industrial potential states like Punjab, Haryana, Rajasthan and Gujarat. The project is already in an advance stage of implementation.

While Ahmedabad and Vadodara are already connected by Expressway (NE1) and the Vadodara Mumbai Expressway including the spur to JNPT is also under construction. Hence, it was necessary to connect the Amritsar - Jamnagar economic corridor by a Greenfield Expressway to Ahmedabad so that eventually there would be an expressway connectivity between Amritsar and Mumbai. Considering the economic importance of the corridor NHAI looked at finalizing an optimal greenfield alignment connecting the Amritsar - Jamnagar economic corridor near Sanchore in Rajasthan to Ahmedabad in Gujarat considering that it would provide alternate and shorter route to traffic between Amritsar and Mumbai.

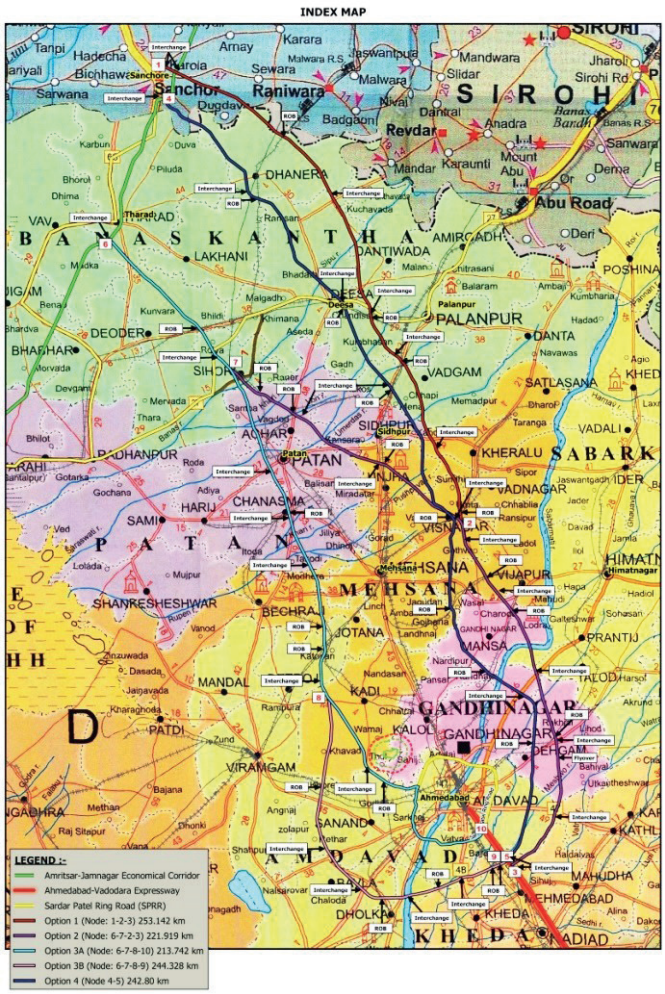


Figure-1:Alignment Option Map

Due consideration was given sustainability, value engineering and circular economy for the project.

1. Alignment Selection and Optimisation

Five alignment option were created and studied. The recommendation was for Option 2 (Node number: 6-7-2-3) refer Alignment option Map in Figure-1. The alignment of approximate length of 213 km, passes through Banaskantha, Patan, Mehsana, Gandhinagar and Ahmedabad districts for connectivity between the Amritsar Jamnagar Economic Corridor and the Vadodara Mumbai Expressway for following reasons;

Length of Option 2 Alignment is around 30 km shorter as compared to Option 1 and approximately 22 km shorter than Option 3B and 4.

- Shorter alignment length also means lesser land acquisition and also correspondingly lesser land acquisition cost.
- The alignment also minimise construction cost and the associated implementation costs which include monitoring cost during construction, implementation cost, minimised resettlement cost, etc.
- The preferred Option-2 alignment starts at the proposed Tharad Bypass under the Amritsar - Jamnagar Economic Corridor would also mean economic prosperity in the region especially between Tharad and Mehsana which is less developed, compared to later stretch from Mehsana towards Ahmedabad.

2. Use of Waste Material

Flyash/ Pond ash is a proven material for embankment/ subgrade layer construction. Hence, an inventory of such material was made at the feasibility study stage.

Two sources of pond ash were identified in the vicinity of the proposed alignment. Representative samples of the pond ash were collected from those sources for testing. The location and the approximate distance from the Power Plant to the nearest point on the project road are given in Table-1.

Table-1: Details of Pond Ash Sources

S. No	Chainage of Proposed Alignment (Km)	Side	Name / Location	Lead from Proposed Alignment (Km)	Approximate Production per day in tonne
1	Ch. - 183+000	R/S	Gandhinagar Thermal Power Station, Gandhinagar	20	25
2	Ch. – 205+000	R/S	Wanakbori Thermal Power Station, Kheda	75	250
3	Ch. 0+000	R/S	JSW Energy, Barmer	190	450

Test conducted on the samples of pond ash samples showed that its gradation as well as MDD conformed to the requirements as specified in IRC: SP: 58 and thus could be used in embankment construction.

3. Perpetual Pavement Design

A pavement having a service life of fifty (50) years or longer is termed as a long life pavement or perpetual pavement. The long life pavement considered as one of the options comprised of the following layers

(a) Prepared roadbed soil, i.e., subgrade,

(b) Aggregate sub-base courses (GSB),

(c) Aggregate base courses (WMM),

(d) Dense graded Bituminous Macadam (DBM), and

(e) Bituminous Concrete (BC) surface course.

Expressways should preferably be designed as long-life pavements, or in any case for a minimum period of 30 years. The project road being an Expressway hence due consideration of very low maintenance with only functional overlay is important, therefore a long life pavement (perpetual) was recommended. A high modulus DBM layer in a perpetual pavement makes it easy to reuse and recycle in the future.

4. Spaces for Way Side Amenities

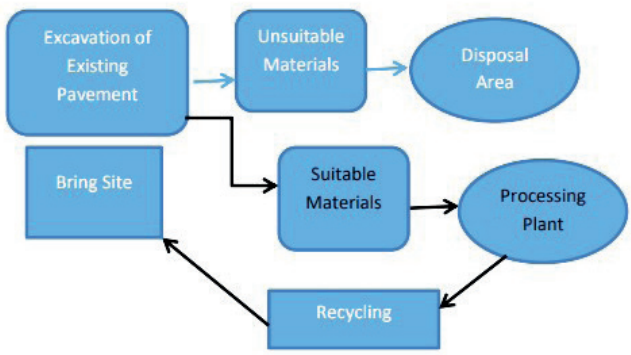
The Land parcel owned by the government were identified along the alignment for way side amenities so that land acquisition could be reduced and i reduce the negative social impact.

5. Use of Glass /Carbon/ Aramid Fibre Reinforced Polymer Rebar

Fibre Reinforced Polymer (FRP) rebars have been considered in the design of structures, since they are a proven and successful alternative to steel reinforcement and would give structures a longer service life and reduce the demand of conventional reinforcement for highway projects.

Case Study II: Design Review of Jeshore - Jhenaidah Project (48 km) and Feasibility Study and Detail Engineering of Navaron – Satkhira - Bhomra Section (55km) from Two lanes to Four Lanes Divided Highways, Bangladesh

CE principles were used for the project. Normally the sub base, base course and bituminous mixes are made using sand, aggregate, bitumen and other materials. In most of the cases the flexible pavement deteriorates and becomes unserviceable in 15 – 20 years which is the design service life of pavement and thereafter there is a need for reconstruction right from the subgrade level. However, the individual life of the aggregate, sand and other ingredients are more than 20 years. Hence, the individual materials can be reused. Flow Chart_1 shows a typical system of recycling of existing pavement layers.



Flow Chart-1: Recycling of Existing Pavement Layers

The Jeshore - Jhenaidah Project (48 km) and the Navaron – Satkhira - Bhomra Section (55km) highways are in

Bangladesh.The major problem in Bangladesh is the availability of good stone / aggregate for bituminous works due to limited aggregate sources namely Madhya Para, Sylhet, and Panchgarh. The quantities from other sources are very small and they do not meet the quantity required for construction of highways and roads. Hence, aggregates are brought from India, Dubai, Viet Nam and other countries. Because of that the rate of concrete and bituminous works there are more than 2.5 - 3 times more than that in India. The cost of road construction in Bangladesh is 600-650 million Taka per km a for four lane divided carriageway with Intermediate Service Road on both sides.

This case study deals with the Satkhira - Bhomra Section. Pavement and material investigation along with those for construction material including the Benkelman Beam Deflection Test (BBD) were carried out for the road. The compositions of the existing pavement are given in Table-2.

Table-2: Existing Pavement Compositions

Description	Range of Thickness (mm)	Average(mm)
Bituminous Course	55 - 160	105
Base Course	70 - 540	260
Sub Base Course	50-490	250
Total	310-1090	640

From the BBD Test deflection data analysis, it was observed that the characteristic deflection varied from 1.72 mm to 2.72 mm and the remaining service life varied from 0.4 Million Standard Axle (MSA) to 1 MSA i.e., pavement life was nearing its end and as per the overlay design it needed an overlay thicknesses which varied from 145 mm to 160 mm. The existing embankment height was low and it varied from 0.3 m 0.9 m which did not fulfil the minimum freeboard above HFL criteria. It was thus decided that the existing pavement be dismantled since the existing road had to be raised. A large quantity of bituminous and granular materials were to be available from dismantling of the existing pavement. It was therefore proposed that the the dismantled materials be reused for the granular sub base and for Recycling Asphalt Pavement (RAP). However, the Government of Bangladesh present policy is for reusing only the granular material in the sub base. It has therefore been suggested by the consultants that RAP be also adopted. Accordingly, the pavement design using RAP has been proposed. The conventional Pavement thickness and that using RAP are presented in Table-3. Use of 100 % recycling was not possible and hence, 70 % of the excavated materials were proposed for reusing based on past experience of similar projects.

Table-3: Flexible Pavement with RAP

HS*	Design Traffic (MSA)	Effective CBR	Pavement Thickness (mm)					
			Wearing Course	Binder Course	RAP	Granular Base	Cement Treated Sub-base	Total
HS I	85	8	50	70	115	300	300	835
HS II II	85	8	50	70	115	300	300	835

Note: HS 1is Navaron – Satkhira, 35 km and HS II is Satkhira - Bhomra, 17 km

The cost was determined based on reusing of existing pavement materials. It was calculated that the available quantity of bituminous material would be 27,100 m^3. The cost of excavating of the existing material and taking it to the plant and re-processing it were also considered. 13,050 m^3 of RAP could be used and 200 million Takas would be saved. Similarly, the quantity of existing granular material was found to be 65,500 m^3. Considering the cost of excavation, carting of the material to the plant and processing, the total cost saving would be around 201 million Takas. Similarly, for 67100 m^3 of the existing base course material the cost saving would be around

260 million Takas. The total saving would be around 660 million Takas. The cost saving per km would thus be around 12 million Takas approximately (around 2 % of the project cost, 650 million Takas per km).

Besides, the construction cost saving, identification of proper places for the safe disposal of the huge quantity was not required; land in anyway is not easily available along the project road and if required in case reuse of waste material would not be possible then the extra cost for land accusation would get added to the project cost. The reuse of existing pavement material minimises the environmental hazard and also helps in conserving the natural material/ resources for future use.

Economic analysis was carried out to find out viability of the project without using waste pavement layers and with using waste pavement layer. Economic Internal Rate of Return (EIRR) was found to be 13.0 % for base case and 13.3% for using waste pavement layers i.e., increase in EIRR.

This case study shows an example of circular economy for road construction industry in pavement construction. There are several examples of circular economy. These are using waste product from power sector, steel sector. These are pond ash, fly ash which may be used in replacement of cement, steel slag as a replacement aggregate.

Case Study III: Vadodara – Mumbai Expressway in the State of Maharashtra

The Vadodara Mumbai Expressway (VME) is an 8-lane access-controlled green-field expressway between Vadodara and Mumbai (main alignment and spur). In Maharashtra, the length of the main expressway is 86.269 km (design chainage 112+851 to 26+582) and length of the spur is 79.783 km (design chainage 0+000 to 79+783). The alignment passes through Palghar, Thane and Raigad districts of Maharashtra State.

The expressway will provide smooth, safe and uninterrupted traffic movement between Vadodara to Mumbai as an alternative to NH 48. The spur will connect the main expressway with the Jawaharlal Nehru Port, Mumbai - Nagpur Expressway and Mumbai - Pune Expressway. Therefore, the traffic bound for Jawaharlal Nehru Port, Nagpur and Pune will ply on the spur and will not enter Mumbai city. That will reduce both traffic congestion and pollution in the city. The proposed spur of VME will be linking Vadodara – Mumbai Expressway, Ahmedabad - Vadodara Expressway, Mumbai – Nagpur Expressway and Mumbai - Pune Expressway and will thus provide expressway connectivity for the Delhi – Ahmedabad – Mumbai – Nagpur - Pune.

The alignment of the expressway in Maharashtra does not pass through any Protected Areas declared under the Wildlife (Protection) Act, 1972 and it's Eco-Sensitive Zone. However, the alignment crosses the Dahanu Taluka and the Matheran Eco-Sensitive Zone; which are declared as ecologically fragile areas under the Environment (Protection) Act, 1986 and thus involves diversion of 357.3903 ha of forest land.

A total of 24 Schedule-I species are noted in the study area (i.e., within 10 km radius of the alignment). They comprise 4 mammals; *Panthera pardus* (Leopard), *Prionailurus rubiginosus* (Rusty spotted Cat), *Tragulus merrima* (Mouse deer) and *Tetracerus quadricornis* (Four horned antelope); 2 reptiles; *Crocodylus palustris* (Mugger) and *Pythus molurus* (Indian python); and 18 avian species.

Engineering Solutions

To minimise the impacts on the wildlife, the engineering solutions proposed for the section of the Vadodara - Mumbai Expressway in the State of Maharashtra are given below.

Eco-duct/ Animal Overpass

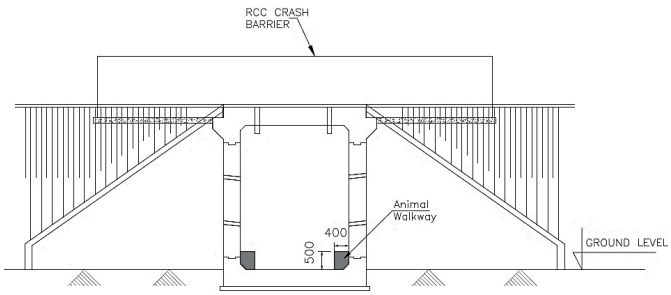
4 eco-duct/ animal overpasses have been proposed along the expressway alignment, out of which 2 are proposed along the main alignment and 2 are along the spur alignment. The animal overpasses will allow natural movement of wild animals as they are less confining, quieter and have natural conditions and climate and can be used by a wide range of fauna. The design considerations for the animal overpasses are:

Typical view of Eco-duct / Animal Overpass

- 30 m wide bridge
- Minimum human activities and disturbance
- RCC guardrail and boundary wall to be provided to funnel the animals towards the structure and away from the expressway
- Plantation of native species and their maintenance.

Dedicated Animal Underpass

105 dedicated animal crossings (box structure) have been proposed along the expressway. The minimum size of the animal crossing is 4m x 3m and the maximum is 6m x 4m.



Typical Layout of Animal Underpass including Animal Walkway

Animal walkway of 0.4 m x 0.5 m has been proposed on either side of the structure to facilitate the crossing of wild animals during the rainy season.

Small Vehicular/ Cattle Underpasses

Apart from dedicated animal underpass, 85 small vehicular/ cattle underpasses, 7m x 4m, have been proposed along the expressway.

Compliance with Government of Maharashtra Circular

The Circular issued by the Principle Chief Conservator of Forest, Maharashtra State vide letter dated 24th September 2020 has been complied with. All underpass and animal crossing are proposed to have a minimum width of 4.00 m and height 3.00 m and the distance between such structures is to be less than 1 km.

Civil Cost of Structures

The cost of construction of the animal overpass, dedicated animal crossing and Small Vehicular/ Cattle Underpasses is Rs. 381.6 crores, which is part of the mitigation cost.

Proposed Tunnel in Matheran Area

The proposed spur alignment crosses the Matheran Eco Sensitive Zone at two locations i.e., from km 71.532 to 75.426 (buffer & ESZ) and from km 77.115 to km 77.691 (online buffer zone). To preserve the ecology of the Matheran ESZ, a 4.160 km long tunnel is proposed which will go under the Matheran Eco-Sensitive Zone. The start point and end point of the tunnel are outside the buffer zone.

Boundary Wall

Visual barrier in the form of a boundary wall has been proposed along the sides of the expressway to reduce the number of accidents due to collisions between large mammals and vehicular traffic and also to reduce the number of smaller animals killed on the expressway.

Summary of Total Structures Proposed

A total of 687 structures which comprise major and minor bridges, interchanges, flyovers, rail over bridges, culverts, dedicated animal underpasses, vehicular underpasses, vehicular overpasses, eco ducts/ animal overpasses, light vehicular/ pedestrian underpasses, small vehicular/ cattle underpasses, and tunnels have been proposed along the main expressway and spur of the Vadodara - Mumbai Expressway in the State of Maharashtra (166.05 km). 4 structures per km have been proposed for crossing.

Mitigation Measures other than Engineering Solutions

Apart from engineering solutions, various non-structural solutions have been proposed for wildlife conservation and are summarized below:

- Design modification to save trees standing outside the construction zone on the edge of the RoW.
- Design of the expressway has been revised to reduce the right of way from 100m to 70 m in the forest stretches to minimize the diversion of the forest land.
- Avenue plantation (3/2 rows) on either side of the expressway and median plantation under greenbelt development plan. This will provide canopy connectivity.
- Plantation of approximately 7,14,780 trees in double degraded forest land under CA Scheme by the Maharashtra Forest Department against felling of 54,913 trees in the forest area.
- To compensate the loss of medicinal plants, development of herbal garden is proposed through the Forest Department.
- Preparation of site specific conservation plan for 10 years with budgetary provision covering the following items:
  - ✓ Creation of new waterholes at multiple locations in the forest area.
  - ✓ Deepening and removal of silt of existing waterholes under forest area.
  - ✓ Construction of watch tower at multiple locations in the forest area.
  - ✓ Purchasing of cage for wounded wildlife, caging them and releasing them after treatment into their natural habitat.
  - ✓ Wildlife Rescue Vehicle and Patrolling Vehicle for the Forest Department.
  - ✓ Camera Trap for inspection migratory path of wildlife.
  - ✓ 15% cost towards construction of administrative building at Transit Treatment Centre at Dahanu in Palghar District of Maharashtra.
  - ✓ Monkey Catching Net, Snake Catcher Kit, Snake Catching Box, Leopard Trap, GPS, Hunter Shoes, Search Light, etc.

The site specific wildlife conservation plan for the Main Expressway (Phase-I and Phase-II) and spur in the State of Maharashtra has been approved by the Principle Chief Conservator of Forests (Wildlife) cum Chief Wildlife Warden, Government of Maharashtra.

Conclusions

Most of the roads, in India, are built based on the concept of Linear Economy with focus on product based non-conventional approach with least consideration for reuse and recycling of materials and value engineering. The Circular Economy concept transforms grey infrastructure into green infrastructure, it is the need for sustainable development. There are many challenges which can be overcome by policy changes, stakeholder engagement, improving supply chains, resource management, proactive researches, radical innovations and various incentive programs at different levels.

The Government has already started working on principles of Circular Economy and brought number changes in current policies, issuance of new guidelines, great initiatives and radical schemes. The Case Studies, presented in this paper, highlight the need for alignment planning and value engineering proposals to make sustainable development an integral part of the road sector as per the policy documents of the Ministry of Road Transport & Highways (MoRT&H) to be in with of sustainability and circular economy requirements.

Going forward, the Engineering Consultants need to explore the use of industrial waste, slag, waste from mines, for earthworks of roads and highways. The document by MoRT&H on value engineering recommends that to reduce the Green House Gas emission and cost of transportation, use of industrial waste, slag, waste of mines have to be evaluated. It is necessary that the DPR must contain recommendations for improvement measures to modify locally available material, industrial and mines waste to acceptable road building materials in the proximity of the Project Road.

Acknowledgement

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References

1. "Bharatmala Pariyojana - A Stepping Stone towards New India | National Portal of India". www.india.gov.in . Retrieved 11 Nov 2022.
2. "PM Gati Shakti National Master Plan Multi Modal Connectivity". https://www.india.gov.in/spotlight/ Retrieved 11 Nov 2022.
3. Ministry of Road Transport and Highways, GoI, circular no. RW/NH-33044/01/2019-S&R(P&B)RSCE-Pt 1 dated 18th April 2022, subject: Use of fly ash in Road/Flyover embankment construction of National Highway works.
4. Ministry of Road Transport and Highways, GoI, circular no. RW/NH-33044/18/2020-S&R(P&B) dated 14th December 2020, subject: Use of new/ alternative material and technology in construction of Highway.\
5. Ministry of Road Transport and Highways, GoI, circular no. RW/NH-34049/01/2020-S&R(P&B)pt. dated 30th August 2022, subject: Value Engineering Practices for the Design, Construction & Maintenance of National Highways Projects
6. Dr. Chetan Hazaree, Envisioning Circular Economy for Indian Road Sector. https://info.cecr.in/envisioning-circular-economy-for-indian-road-sector/ Retrieved 11 Nov 2022.
7. Mantalovas, K., Mino, G. D., Jimenez, A., Carrion, D. B., Keijzer, E., Kalman, B., …Lo Presti, D. (2020). European National Road Authorities and Circular Economy: An Insight into Their Approaches. Sustainability, 12(17), Article 7160.
8. Kirchherr J, Reike D, Hekkert M (2017) Conceptualizing the circular economy: an analysis of 114 definitions. Resour Conserv Recycl 127:221–232
9. EMF (2013) Towards the circular economy. Ellen MacArthur Foundation, London .
10. Hartley K, van Santen R, Kirchherr J (2020) Policies for transitioning towards a circular economy: expectations from the European Union (EU). Resour Conserv Recycle 155:104634.
11. Sauvé S, Bernard S, Sloan P (2016) Environmental sciences, sustainable development and circular economy: alternative concepts for trans-disciplinary research. Environ Develop 17:48–56.
12. Lag-Brotons AJ, Velenturf AP, Crane R, Head IM, Purnell P, Semple KT (2020) Resource recovery from waste. Front Environ Sci 8:35.
13. Eco-friendly Measures to Mitigate Impacts of Linear Infrastructure on Wildlife – Wildlife Institute of India, Dehradun
14. Connecting Tiger Populations for Long-Term Conservation - Wildlife Institute of India
15. Circular of Ministry of Road Transport and Highways, Government of India dated 29th May 2019, 2nd August 2019
16. National Highways Authority of Indian, MO dated 2nd September, 2019
17. Circulars and Office Memorandum of Ministry of Environment, Forest and Climate Change, Government of India
18. DPR and Environmental Impact Assessment Report of Vadodara Mumbai Expressway - Intercontinental Consultants and Technocrats Private Limited, Green Park, New Delhi
19. Wildlife Conservation Plan for Development of 8-lane SPUR Starting from Km 26.582 of Vadodara - Mumbai Expressway Main Alignment (Design Ch. 0+000) and terminating at proposed Junction with the Multi-Modal Corridor of MMRDA (Design Ch. 79+783) in the state of Maharashtra - Intercontinental Consultants and Technocrats Private Limited, Green Park, New Delhi
20. Wildlife Conservation Plan for Development of Vadodara - Mumbai Expressway (Phase-II) from Km 26+320 to Km 104+700 (Km 390+846 of NH-8) of main Expressway in the State of Maharashtra - Intercontinental Consultants and Technocrats Private Limited, Green Park, New Delhi
21. Wildlife Conservation Plan for Diversion of 52.4805 ha of forest land for Development of Vadodara-Mumbai Expressway (Phase-l) from Km 104+700 to Km 112+851 in Palghar District in the state of Maharashtra - Intercontinental Consultants and Technocrats Private Limited, Green Park, New Delhi
22. Relevance of Mainstreaming Biodiversity in Planning and Implementation of Development Projects – Ms. Asha Rajvanshi, Senior Professional Fellow, Wildlife Institute of India, Dehradun
23. Good practice guidance for infrastructure assessment and design - Ms. Asha Rajvanshi, Senior Professional Fellow, Wildlife Institute of India, Dehradun
24. Mitigation of road related impacts on wildlife – David Magintan, Wildlife Officer, Department of Wildlife and National Parks Peninsular Malaysia, December 2012

17

Reducing Transportation Costs by Optimal Utilisation of National Highway Capacity

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India's transportation cost is 14% of the GDP which is only 7-8% in developed countries. It is a goal that both the MORTH and the Commerce Ministry want to move towards; hence, the thrust towards better road infrastructure. For better utilisation of the road infrastructure, the permissible axle loads of trucks have also been recently increased so that the roads can carry more at lesser transportation costs. However, an area that has received less attention, but is adding to transportation costs is that many NHs are utilised to barely 25% of their designated capacity for various reasons. It affects the overall transportation costs and with it the cost and time for building new infrastructure - a double-whammy, affecting both commerce and development. That needs to be addressed urgently.

Understanding Cost of Transportation

A brief discussion on how NHs affect transportation costs would help better understand how to optimise utilisation of existing NHs.

Improved road infrastructure allows for heavier loads to be carried quicker and with minimum disruptions, to their destination. It directly reduces Fuel Consumption/ Tonne and running time (and so the over-heads). The maintenance cost is also reduced with better roads, a fact

Ser	Axle Type	Max Safe Axle Weight (Tonnes)
1	**Single Axle**	
1.1	Single Tyre	**3**
1.2	Two Tyres	**7.5**
1.3	Four Tyres	**11.5***
2	**Tandem Axles** (Two axles -distance < 1.8 Mtr)	
2.1	For rigid vehicles, trailers and semi-trailers	**21***
2.2	For Puller tractors for hydraulic and pneumatic trailers.	**28.5**
3	**Tri–axles** (3 axles - distance between outer axles < 3 Mtr) For rigid vehicles, trailers and semi-trailers	**27**
4	**Axle Row** (Two axles with four tyres each in Modular Hydraulic trailers.) 9 tonnes load permissible for single axle.	**18**
* Note: If the vehicle is fitted with pneumatic suspension, 1 tonne extra load is permitted for each axle.		

Table 1: MORTH Notification: Increase in Truck Axle Loads - 18 Jul 2018 (extract)

that is not hard to perceive. The increase in permissible axle loads notified by MORTH in June 2018 (Table-1), allows for an increase of loads on trucks by 20-25%. It is aimed at lowering logistic costs by 2% as per the Government Notification.

Few realise the kind of savings possible by using larger trucks for transportation. In December 2020, the State of Bihar, banned use of 14-wheel trucks and above by a notification, because a few bridges did not allow their movement. A road construction agency immediately claimed a compensation of nearly Rs 58 crores as the additional cost of transportation of sand and aggregate due to the 'Change in Law'. Their claim was upheld in the arbitration that followed and awarded. It came as a surprise to many.

Table-2 shows the Effect on Cost of Transportation due to the Truck size. If a 6-wheel truck is used instead of a 12-wheel truck, the cost of transportation of aggregate can go up by 71% as per the SSR, of the Bihar State government. In actual practise, the cost almost doubles due to increased handling charges when using smaller trucks.

	Type of Truck	Gross (tonnes)	Carrying Capacity (tonnes)	Rate Rs/Ton for 10 Km lead	% Increase wrt 12 Wheel trucks	Remarks
Rates as per SSR Bihar State wef 01 Apr 22 for Tpt of Aggregate	6 Wheel	18.5	10	137	71.3%	
	10 Wheel	28	18	99	23.8%	
	12 Wheel	35	25	80	0.0%	Taken as Standard
	14 Wheel	42	32	70	-12.5%	

Table - 2: Effect of Truck size on Transportation cost

While the State of Bihar had temporarily restricted use of vehicles that were over 14 wheels, the J&K Government issued a notification which has existed for some time now, restricting movement to twin axle, 6-wheel trucks with stipulations to use bigger trucks. That has restricted transportation to mostly 6-wheel trucks. During an interaction with some truckers, it was found that a petroleum truck with 12K litres capacity was only loaded to 10K because of local restrictions, making 20% capacity go waste. The truckers felt, that had bigger trucks been permitted, the cost of transportation of goods could be halved. Considering the wonderful infrastructure being created at great costs in these areas, the matter is a cause for concern. It is happening to various degrees in all States, more along the hilly border-states and a little less in the other states. The effect on cost of transportation due to this is huge and the resultant losses in commerce and burden on the taxpayer add up exponentially.

The underutilisation does not directly affect the road construction agencies – the contractor or the government agencies such as the NHIDCL, NHAI or the BRO. While common sense tells you it affects the Nation, there is no ownership to this underutilisation and for very long, this has been neglected. The Ministry of Commerce needs to study the losses due to the underutilisation, an 'economic analysis' of the road net-work.

Why Such Under-Utilisation of NHs?

NHs are designed for double lane of Class A traffic or higher, however, it requires only one bottleneck to reduce the capacity of the entire NH. Bridges can be such bottlenecks when they are weak or narrow, restricting loads and traffic.

A typical example is shown in Figure-3. The bridge had to be replaced in 2012 when the original bridge collapsed during floods. Since the only option was to launch a Bailey bridge, the capacity remained that of single lane with Load Class 24 since then. Hence, the load carried on the entire NH is limited to only 6-wheel trucks with a gross weight of 18.5 Tons Besides, reducing the load to 25% of the specified Load Class 70R, only one vehicle at a time can cross the bridge, thus adding to vehicle idling time and increasing the total travel time. Carriage of construction materials or heavy machinery is also restricted. Such bridges need to be urgently up-graded.

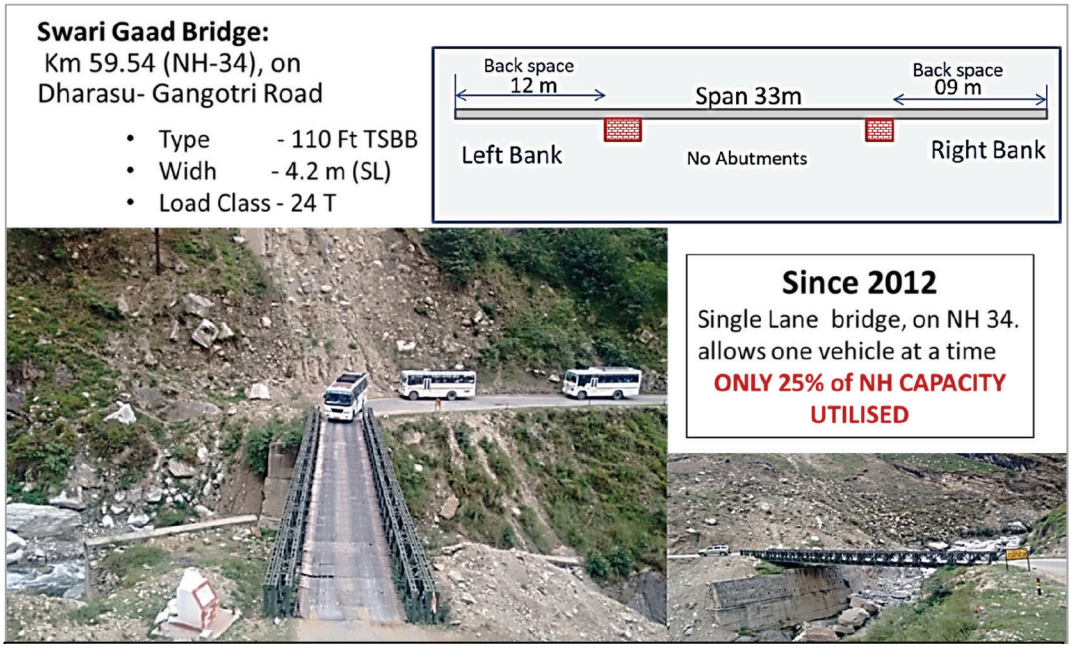

Figure-3: A bottleneck due to a weak bridge for a long time

Swari Gaad is not an isolated example of a weak bridge that has remained for so long. On NH 37 the Irang Bridge which is of Load Class 18 is a more recent example. The bridge collapsed due to overloading on 01 November 2020. It was replaced by a similar Bailey bridge by NHIDCL, with the help of the Army. That was again washed away on 12 May 2022. The option was still a Bailey bridge. In the mean while the two other major bottlenecks at Barak and Makru have been upgraded at great cost, but the utilisation of the highway remains at 25% because of the Irang Bridge. The situation is likely to continue for another 2 years or so.

NHAI is also facing such situations. The Shillong bypass is a typical example where a bridge was declared distressed when cracks were noticed on the girders.

Figure-4: NH 37 is underutilized even after upgrade of two major bridges

Figure-3: A bottleneck due to a weak bridge for a long time

Heavy ore carrying vehicles had to be diverted through Shillong city in October 2020. A temporary solution using a single lane Bailey bridge now allows limited loads. The bridge also needs to be closed regularly for repairs. Construction of a new bridge is yet to start. With better modular bridges, the distressed bridge could have been refurbished in four months to full capacity and restricted traffic over such a prolonged time could have been avoided. However, the NHAI is not equipped for such an urgent response.

Examples of underutilisation continue to increase by the day, because of poor response to such emergencies and the nation bears the cost for the losses due to increase in transportation costs. One reason for the poor response is not being better prepared. Using better modular bridges for emergencies, rather than relying on out dated Bailey bridges, would make the critical difference here. With the build-up along the LAC, operational logistics will also get the desired boost with better modular bridges at their disposal.

The Way Forward

Today construction agencies, the world over, have graduated from Bailey bridges to 3rd Generation Modular Bridges. These are as fast in construction as the Bailey bridge and able to provide a permanent bridges of spans up to 65m with double lane width and 70 R loading (refer ViewPoint, December 2021 page 91 for a detailed article on this where ICT[1] helped launch one such 3rd Gen Modular Bridge in the Kedarnath Valley).

Instead of relying on the Bailey bridge of World War II vintage and reacting to bridge emergencies by requisitioning the Army or calling the BRO, *it is time construction agencies developed their own capability to deal with such situations and took responsibility to utilise the highway to full capacity*. For this they need to have the right bridging equipment within easy reach.

The 3rd Generation Bridges would no doubt cost more than the old Bailey bridges, but the value earned is much more, since the bridges can carry four times the load and have a life of 100 years as against 25 years for the Bailey bridge while being as fast to launch. The effect of reduction in transportation cost due to deployment of 3rd Generation Bridges has also to be factored in and the economic value earned by using these bridges must be pragmatically worked out. It would be seen that the savings are multiple times the total cost of the bridge. *Decision making must shift from just looking at the 'cost' to ascertaining the 'value earned' by the overall impact*.

However, just understanding the value is also not enough. The response must change *from being reactive to being proactive*. It implies that better modular bridges must be stocked in anticipation by the various construction agencies, so as to be available on the site, within 2-3 days of the emergency. Only then would it be possible to ensure the NHs are utilised to full capacity for the maximum time.

MORTH seems to be seriously looking at better Modular Bridges and have also formulated an IRC Committee to evolve guidelines, which will take time. While that happens, the way forward is to get a feel for the 3rd Generation Modular Bridges by stocking a few to address emergency situations. Simultaneously, with these bridges in stock, one could address critical problems such as the Irang Bridge, which can be upgraded in a matter of a week to allow larger trucks on NH 37. The positive effect on the transportation costs would be immediate. The effect on commerce would follow the very next week. The State of Manipur would celebrate for it is their lifeline which has never functioned to full capacity.

It is time that optimal utilisation of NHs is considered as an important factor affecting transportation costs, and agencies are made accountable for low utilisation. There is need to have a time bound policy to restore traffic in emergencies and be proactive by being equipped with reserves to act in a timely manner, with the best available equipment in the world. It is too important to settle for anything less if the adverse effect on commerce and the growth of the country are to be checked, especially along the Northern and NE Borders.

Notes: ICT: Intercontinental Consultants and Technocrats, an infrastructure consultancy company based in New Delhi was as a part of the UDRP Bridge Consultancy Project to design over 70 washed away Bridges in the floods in Kedarnath Valley. They helped design and construct a 3rd Generation Modular Bridge, of 60m span and 70 R loading at Sonprayag. For details see ViewPoint, Dec 2021, Page 91, 'Modular Steel Bridges for Speedy and Quality Construction'.

18

Environmental Benefits and Challenges of EVs in India: Key Findings from LCA Analysis

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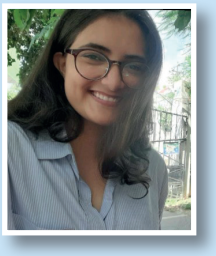

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Electric Vehicles' Emergence in India

With rising carbon footprint and emissions of fuel-based vehicles, the world has developed strong affinity towards electrification of vehicles. That has prodded the policymakers around the globe to actively consider electric vehicles (EVs) as an usherer for the future of the automobile sector. The Indian automotive industry, as of today, is the fifth largest in the world and is envisaged to be the third largest by 2030, and it won't stay behind in this initiative. Huge demand for conventional modes of fuel intensive vehicles, increasing burden of oil imports, rising emissions, and international commitments to combat global climate change are among other key motivating factors for India's speedy transition to e-mobility. In India, the concept of electric vehicles started in the late 90s but the country's first substantial steps to incentivize EVs was in 2010, and since then persisting efforts have been made to adopt, develop and encourage the e-mobility market in India. One of the significant initiatives in that regard is the National Electric Mobility Mission Plan (NEMMP) 2020. It was launched in 2013 as a mission to provide vision and the roadmap for the faster adoption of electric vehicles and their manufacturing in the country.

As part of the NEMMP 2020, the Department of Heavy Industry formulated a Scheme viz. Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME India) in the year 2015 to promote manufacturing of electric and hybrid vehicle technology and to ensure sustainable growth of the same. In 2019, the second phase of the scheme was launched and is on the running. Financial support from the government is a significant booster for these schemes and 86 percent of funds has been allocated for demand side incentives to create a sustainable market for EVs in the country. The aim is to create demand for 7000 e-Buses, 5 lakh e-3 Wheelers, 55000 e-4 Wheeler Passenger Cars (including Strong Hybrid) and 10 lakh e-2 Wheelers and also set up the charging infrastructure. More recently, the production linked incentive (PLI) scheme for the automotive sector was launched to encourage domestic production of batteries to support the EV industry with requisite infrastructure and reduction in costs. While there is 100% FDI in the auto sector, the domestic policies seem to be clearly partisan towards EVs.

To further improve the environmental credibility of EVs, the government has come up with associated policies

for holistic electrification of the transport sector. The attempt is to make EVs beneficial through conservation of precious resources and eventually channeling the economy to become circular in nature. The Vehicle Scrappage Policy, launched on August 13, 2021, by the Ministry of Road Transport and Highways (MORTH) is an example. The aim of that policy is to support the 'Green India' mission, as it creates space for a cleaner fleet of vehicles by replacing older ones and elevating the circular economy approach by encouraging the usage of scrap in different sectors.

Although EV is expected to revolutionise the transport sector in the coming years, in selected segments there are debates on the environmental performance of EVs over their ICE (internal combustion engine) counterparts. While EVs are preferred for their on road reduced emissions, they involve usage of critical minerals that are highly energy intensive at the time of extraction and manufacturing. Additionally, the electricity used for charging the batteries has a high share of thermal based generation as in India, the grid constitutes a major portion of coal-based electricity. If the environmental footprints of these factors are to be considered, the benefits envisaged from EVs may not be as high as perceived.

Apart from its environmental concerns, another challenge arising due to faster adoption of EV is related to increasing economic and societal burden. EV adoption is hindered by unavailability of charging infrastructure. Due to cost and weight dynamics of battery packs in an EV it becomes crucial to charge them at regular intervals. The driving range anxiety distracts people from adopting EV even in urban areas. In the case of rural and remote areas, the accessibility to electricity is itself a blockage in EV sustainability.

The powertrain components of EV viz., motor and battery are based on advanced technologies and their critical mineral intensity is higher compared to ICE based vehicles. Due to its nature, India's EV transition is highly dependent on other countries' component manufacturers and suppliers that creates an excess burden on its own trade balance. The maximum value addition margin is available in production of battery cells and magnet manufacturing.

Thus, as EVs gain momentum in the Indian market, there is a need for having a comprehensive environmental performance assessment of EVs in India based on accepted environmental parameters and understanding the hotspots areas for improving their sustainability competitiveness.

Environmental Sustainability of EVs

A number of studies have been undertaken in developed and developing markets where environmental impacts along their life cycle stages have been measured and reported. For example, the European Environment Agency (2018) assessed EVs from a systems perspective. Unlike most of the studies where only the Global Warming Potential (GWP) or the emissions categories and impacts are estimated and reported, the EU study adopted a holistic approach where impact categories like human toxicity impacts, climate change impacts and ecosystem impacts were analyzed, beyond Greenhouse Gas (GHG) emissions, using the Life Cycle Assessment (LCA) tool. LCA is a technique for assessing environmental impacts of any product across its entire life cycle; thereby going beyond just the manufacturing or use phase that usually concerns producers and consumers respectively.

Based on the carbon intensity of the EU electricity mix in 2015, the well to wheel emissions of a mid-sized BEV (Battery Electric Vehicle) was estimated at 60 and 76 gCO2e/km. That is between 47 % and 58 % lower than the emissions of an average mid-sized passenger ICEV in 2015, at 143 gCO2e/km. Such results provide valuable insights when comparing the Indian scenario where there exists significant difference between EU and Indian electricity grid mix. A study by Abdul-Manan et al. (2022) has found India's GHG reduction potential of electric 4-wheelers principally depends on the time and location where they are charged. It has been observed that a 40% reduction in the north-eastern states and 15% increase in the western/ eastern states are seen with more overall GHGs emission when charged in summer overnight, owing to their respective regional electricity grid mix. They suggested that India's 4W BEV potential lies in decarbonizing the power sector

by phasing out the coal-based generation. The end-of-life scenario has been presented using secondary data already built in the LCA software.

End of life management of EVs have strong sustainability implications as well. A number of studies have addressed the environmental effects of battery recycling (Dunn et al., 2012; Amarakoon et al., 2013; Hendrickson et al., 2015; Ciez and Whitacre, 2019; Gaines, 2018). However, much uncertainty still remains about the end-of-life phase. Ciez et al. (2019) estimated that while no significant mitigation is possible through hydrometallurgical and pyrometallurgical methods, direct recycling could be viable for materials like lithium, nickel, manganese, cobalt oxide (NMC) and lithium nickel cobalt aluminum oxide (NCA) chemistries. There are other studies like Hendrickson et al. (2015) which concluded that both pyrometallurgical and hydrometallurgical recycling methods lead to decreased environmental impacts in most categories in comparison to the use of virgin raw materials. Amarakoon et al. (2013) modeled different recycling technologies and found that the GHG savings obtained by recycling were only 3.6% on an average compared to primary production, depending on the battery chemistry. The results calculated by Gaines (2018), on the other hand, suggest that increasing the amount of recycled material in battery cells decreases the overall energy consumption significantly, especially when aluminum is also recovered. The idea behind gathering this information and sharing it is to communicate that there is no single narrative or established conclusion about the importance of recycling and technology involved in it. Therefore, as India fully adopts EVs, incorporation of circularity in its value chain would need much scrutinisation before implementation.

Key Findings from LCA of EVs and ICEs in India

In the absence of a comprehensive assessment of impacts of EVs along the production consumption value chain in India, the authors carried out a detailed comparative LCA between EV and ICE powertrain of a comparable compact SUV, using India specific data. A cradle-to-cradle approach was adopted for the study. Such an exercise would help in assessing the environmental positioning of EVs in India while enhancing understanding of numerous dimensions of sustainability associated with different fuel type vehicle powertrains.

The study only considers the powertrain of the vehicles and not the glider components. That is because glider components are not the key to the current transition. Hence their environmental impacts are not relevant to the study's objectives and are moreover assumed to cancel out one another in both vehicle technologies. Considering policies like the Vehicle Scrappage policy, Battery Waste Management rules, which require focus on end-of-life management of vehicles; quantification of the change in environmental impact based on end-of-life streams was done. Delhi was considered as the case study location largely to capture the use phase data based on primary surveys conducted at traffic points and parking lots. The average life of the vehicles has been assumed at 1,60,000 kms. Factors like road conditions and driving behavior are not part of the study' scope.

The results were analyzed across 18 environmental impact categories including Global Warming Potential (GWP), water consumption, acidification, eco toxicity, ozone depletion, eutrophication, mineral and fossil resource consumption, etc. It is found that EVs perform better than ICE vehicles in a few categories including GHG impact, ionizing radiation, stratospheric ozone depletion, and water eco toxicity. The total GHG emission for EVs using the current grid has been estimated at 24 tonnes of CO2 eq., during the entire life, followed by diesel vehicles at 27.1 tonnes of CO2 eq., and petrol at 30.2 tonnes of CO2 eq. This indicates that EVs have 21% and 12% reduced emissions in comparison to petrol and diesel engines respectively.

In categories of water consumption, eutrophication, and mineral and fossil resource consumption, the performance of EVs is not consequential compared to ICE vehicles. It is noteworthy that most of the impacts for water consumption and fossil resource scarcity for EVs arise from electricity used for battery recharging

in the use phase. It is expected that with the increasing share of renewable energy, the emission and other impact categories would provide favorable results for EV adoption. Sensitivities including changes in renewable contribution to grid, different ethanol blending proportions to petrol are discussed here.

Increased renewable installed capacity to 50% would reduce GHG emission by 22%. To achieve at least 20% reduction in overall GHG emission of EVs, the carbon intensity of grid electricity has to come down from its current level of 800 gCO2eg/kWh to 500 gCO2eq/kW. Further achievement of 50% is possible when the emission intensity is brought down to around 340 gCO2eq/kWh.

In regard to aggressive promotion of ethanol blending in India, sensitivity analysis with blending of 5% and 20% ethanol has been envisaged. The results reveal that this proposition could lead to GHG emissions reduction between 4% to 6% which is largely attributed to the production phase. Further, local pollutant reduction potential in the form of particulates during use phase could be to the tune of 20%.

Majority of the resources that go into manufacturing assemblies in EVs are scarce and available in limited geographies. For example, more than 60% of the production of lithium from brines comes from Chile followed by China and Argentina. Cobalt, in particular, is associated with resource scarcity challenges. Nearly 70% of the cobalt mining in DR Congo is based on artisanal mining with low scale operations, leading to hazardous tailings and slags. The study has estimated that recycling of EV powertrain components, especially electric battery, could lead to avoiding almost 7.5% to 8% of the total GHG emission that may arise in the stages of minerals' mining and processing from virgin sources. However, the emission reduction associated with recycling varies on the basis of selected recycling methods and minerals recovery ratios.

Many of the resources required in EV batteries and motors are highly concentrated and limited to a few regions like South America, China, Australia and Central Africa; hence recovery from vehicle end of life could promote mineral security. But EVs have been just rolled out on Indian streets, and accordingly only a few vehicles would reach the end of life in the coming years, causing continued import dependence for inputs. Also lack of adequate facilities and absence of technical know-how leading to lesser materials recovery from end-of-life EVs is another hurdle in the process. Thus, focus on environmentally sustainable recycling of EV components, particularly batteries, needs focus from multiple aspects of skills, technology, infrastructure and finance.

Limitation of LCA

The comparative study of LCA of ICE vehicles and EV has its limitations in terms of data availability. The data related to battery chemistry and its manufacturing is derived from literature of that field. The material composition and manufacturing technology of battery and motor is assumed considering the latest trends towards efficient components applications. Similarly for end-of-life and recycling phases, commercially viable technologies and input-output ratios of minerals and metals are computed through available literature. In case of non-availability of data points, the inbuilt values of the Ecoinvent database used in LCA software have been used.

Conclusions

The above assessment reveals that electrification of road transport can reduce local NOx, PM2.5, that are imperative for improving ambient air quality of Indian cities. Further reduction is possible as India moves away from coal-based power generation to renewable electricity sources.

Meanwhile, the higher share of the transport sector in carbon emission requires immediate policy intervention for inclusion of alternate fuels technology in the road vehicles fleet. The CNG fueled ICE vehicle and hybrid electric vehicles are expected to be better performing alternatives for short term decarbonizing strategy. Further considering India's potential of biomass-based

fuel generation, exploring that technology could also help in faster reduction of GHG emission and other local air pollutants.

As for electric battery recycling, most recyclers claim material recovery efficiency from spent batteries of above 95% which needs further investigation and there is a need for recycling technology standardisation. The recently announced Battery Waste Management and Handling Rules 2022, covers all types of batteries, including that of EVs, portable batteries, automotive batteries and industrial batteries. The rules are based on the concept of Extended Producer Responsibility (EPR) where the producers (including importers) of batteries are responsible for collection and recycling/ refurbishment of waste batteries and use of recovered materials from wastes into new batteries. Mandating the minimum percentage of recovery of materials from waste batteries under the rules would bring new technologies and investment in the recycling and refurbishment industry and create new business opportunities.

Given that there is substantial life (to the tune of 70 to 80%) after an EV battery reaches end of life, promoting second life, through stationary application is an option that needs further investigation and mainstreaming in policy support. However, reusing lithium-ion batteries would require extensive testing and upgrades to ensure better and reliable performance. Further upgradation of the International Centre for Automotive Technology (ICAT) to undertake such assessments for testing and certification of used batteries needs to be explored. Finally, a sustainable transport policy that incentivises the right technology mix at the right time and in the right location for providing clear signals to key stakeholders will be the need of the hour.

References

1. Abdul-Manan, A.F.N., Gordillo Zavaleta, V., Agarwal, A.K. *et al.* 2022. Electrifying passenger road transport in India requires near-term electricity grid decarbonisation. *Nat Commun* **13**, 2095. https://doi.org/10.1038/s41467-022-29620-x
2. Amarakoon, S.; Smith, J.; Segal, B. 2013. Application of Life-Cycle Assessment to Nanoscale Technology: Lithium-Ion Batteries for Electric Vehicles; No. EPA 744-R-12-001; Environmental Protection Agency: Washington, DC, USA.
3. Battery Waste Management Rules 2022. Ministry of Environment, Forest and Climate Change, Government of India. https://pib.gov.in/PressReleasePage.aspx?PRID=1854433#:~:text=EPR%20mandates%20that%20all%20waste,or%20refurbishment%20of%20waste%20batteries.
4. Ciez, R.E and Whitacre, J.F. 2016. Comparison between cylindrical and prismatic lithium-ion cell costs using a process-based cost model. Journal of Power Sources. 340, 273-281. doi.org/10.1016/j.jpowsour.2016.11.054
5. Dunn, J.B., Gaines, L., Sullivan, J. and Wang, M.Q. 2012. Impact of recycling on cradle-to-gate energy consumption and greenhouse gas emissions of automotive lithium-ion batteries Environ. Sci. Technol. 46 12704–10. doi.org/10.1021/es302420z
6. European Environment Agency Report. 2018. Electric vehicles from life cycle and circular economy perspectives. TERM 2018: Transport and Environment Reporting Mechanism (TERM) report. ISSN 1977-8449. doi:10.2800/77428
7. FAME India Scheme Phase II. Ministry of Heavy Industries. Government of India. https://fame2.heavyindustries.gov.in/
8. Gaines Linda. 2018. Lithium-ion battery recycling processes: Research towards a sustainable course. Sustainable Materials and Technologies. Volume 17. https://doi.org/10.1016/j.susmat.2018.e00068
9. Hendrickson, T.P., Kavvada, O., Shah, N., Sathre, R. and Scown, C.D. 2015. Life-cycle implications and supply chain logistics of electric vehicle battery recycling in California. *Environ. Res. Lett.* **10** 014011. https://iopscience.iop.org/article/10.1088/1748-9326/10/1/014011
10. https://archive.epa.gov/epa/sites/production/files/2014-01/documents/lithium_batteries_lca.pdf
11. National Electric Mobility Mission Plan 2020. Department of Heavy Industry. Ministry of Heavy Industries and Public Enterprises, Government of India. https://heavyindustries.gov.in/writereaddata/Content/NEMMP2020.pdf
12. Vehicle Scrapping Policy. Ministry of Road Transport and Highways, Government of India. https://morth.nic.in/Circulars-Notifications-related-to-Vehicle-Scrapping-Policy

19 Websites for Circular Economy

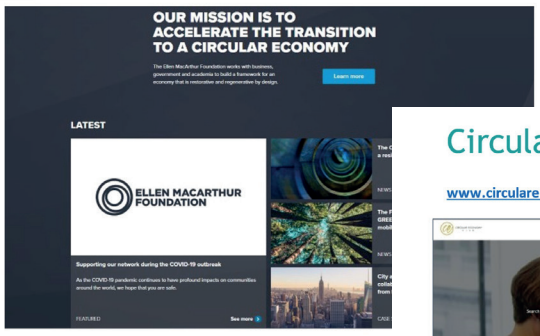
Websites for Circular Economy

Ellen MacArthur Foundation

www.ellenmacarthurfoundation.org

Resources:

- Read: Case studies, Circulate news, Publications
- Learn: Learning hub, Courses, Higher education resources, Kumu resource map, Schools & colleges resources
- Apply: Circular design guide, Circulytics - measuring circularity, ResCoM, Toolkit for policymakers



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Disruptive Innovation Festival - DIF

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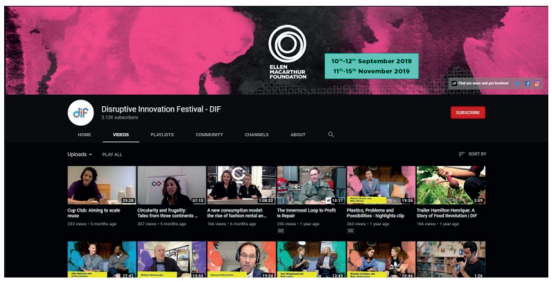

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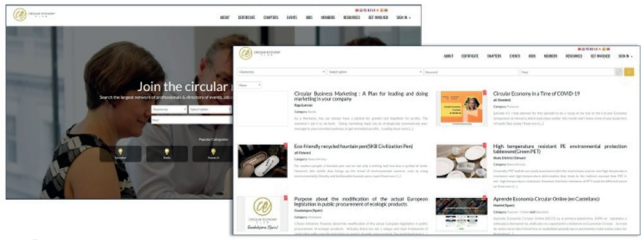

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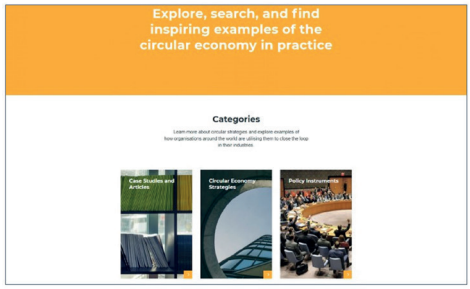
Circle Lab



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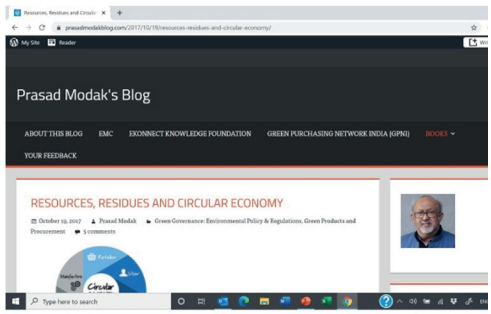


20

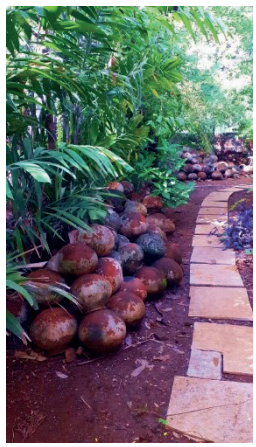
Environment Friendly House- Living with Nature

Dileep Halbe
Architect

The single storey house, on the Deccan Plateau, was planned *ab initio* with the aim to make it sync with nature and use as much natural material as possible. That was way back in the mid 1980s.

Cooling System: The summers are hot and hence a natural cooling system, albeit a long lasting one which would require minimum care was thought of. The waterproofing of the roof was done by the traditional method of laying brickbat coba and a 25 mm layer of screed laid level with no slope. The idea was to create a 25 mm of water pond on the roof. The water level was maintained by providing a sump and a ballcock. The rain water outlets were kept 25 mm above the water level.

The system gave an equivalent of 11 ton of Air Conditioning by evaporative cooling method. The indoor temperature remained at 23 deg. C even in the midst of summer even when the windows were kept open. The system worked very well without failing even once for three decades. The moss and the guppy fish in the water pond on the roof kept the mosquitoes away, thus creating a natural habitat for birds. Water used was supplied from a recharged tube well. Rain water harvesting ensured ground water recharging, thus the tube well supplies water throughout the year.



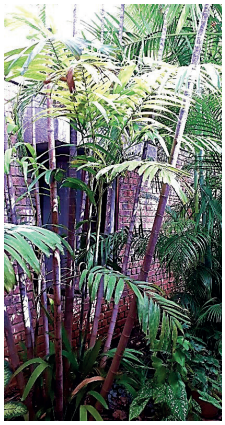
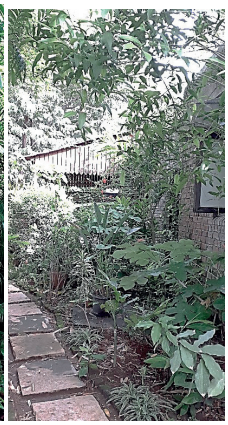
Over the years as water became a scarce resource it was decided to adopt another solution, again using natural materials. The solution lay in using earthen pots dipped in white lime wash, to cover the whole roof. The village potter was enthusiastic and sourced the pots from nearby

areas. The system brought down the temperature by 10 deg. C. At any moment the sun rays hit the pot at one point only. The white wash reflected the heat. It's a practice used in Rajasthan. The system worked well for around a decade. Every three years the pots were whitewashed. However, in areas like walkways, where the pots could not be placed, the waterproofing started to crack and that led to leakage. Hence, around three years ago the pots were removed and a layer of resinous coating applied. It has worked well so far.

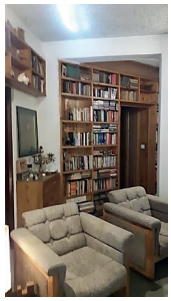
Solar Panels for Electricity & Hot Water System: There are two houses side by side, hence it was found beneficial to install 3kWh and 5kWh solar panels to generate electricity. The excess power is fed into the MSEB grid. Other solar panels for heating water provide hot water throughout the year.

Ceiling Plaster was done with stone grit and painted with white cement; that also was way back in 1986. That has helped to create an acoustical ceiling which is ideal for good musical sound.

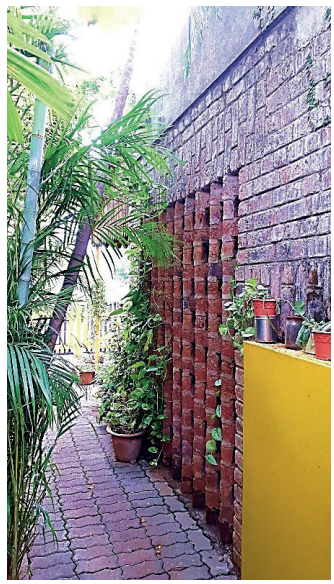
Gardening - the pots from the roof were not thrown away, 400 pots were reused by Rashid Ali (Dr. Salim Ali's grand nephew), an environmentalist and snake catcher. From the rest, many pots were used by people as 'Ola' pots, buried near trees and filled with water to recharge the ground. The water for the garden has created greenery akin to a rain forest around the house.

Woodwork – for all interior work was done with recycled Pine wood that was oiled with linseed oil and turpentine. The look is natural and pleasing. No wood varnishes, primers or paints have been used.



Brickwork was given two coats of sodium methyl siliconate in 1986 and has lasted well since then. It has protected the brickwork from moss, etc.

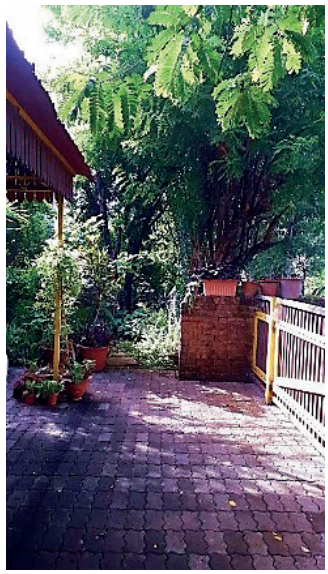


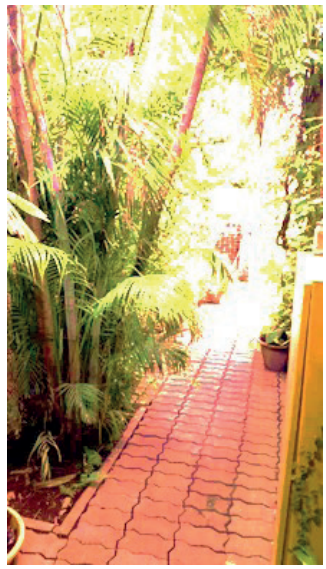
Macrame Screen made from ship rope has stood the test of time.

Watercolour painting of the Entrance area by Suhita Shirodkar

Wintry sun in green environs

Drive way and Walkways are made of fly ash paver blocks to allow water to seep through into the ground.





CEAI NEWS

CEAI's GOVERNING COUNCIL ELECTION FOR THE TERM 2023-2024

The process for CEAI's Governing Council Election for the term 2023-2024 was initiated in October 2022 and the results were declared on 29th November 2022.

No nominations were received for the category of Member (EPC), AFMO and AFMI.

The Members listed below stand elected:

Sl. No.	Member (Organisation)
1	Aarvee Associates Architects Engineers & Consultants Pvt. Ltd.
2	Aeon Integrated Building Design Consultants LLP
3	B&S Engineering Consultants Pvt. Ltd.
4	Civtech Consultants Pvt. Ltd.
5	Consulting Engineers Group Limited
6	Dhrumataru Consultants and Constructions
7	Holtec Consulting Private Limited
8	Intercontinental Consultants and Technocrats Pvt. Ltd.
9	Lion Engineering Consultants Private Limited
10	Mantec Consultants Pvt. Ltd.
11	Saviram Engineering Consultants Pvt. Ltd.
12	Swach Environment Pvt. Ltd.
13	Tata Consulting Engineers Limited
14	Theme Engineering Services Pvt. Ltd.

Sl. No.	Member (Individual)
1	Shri K K Kapila
2	Shri Rama Shankar Sharma
3	Dr. Samarjit Chatterjee
4	Shri Saurabh Khanna
5	Shri Somenath Ghosh
6	Shri Sudhir Dhawan

Sl. No.	Young Professional (Individual)
1	Shri Aseem Rastogi
2	Shri Mihir Kumar Singha

President of CEAI for 2023-2024

The first meeting of the Governing Council members elected for the term of 2 calendar years 2023-2024 was held on 24th December 2022 primarily to elect a new President.

Mr Rama Shankar Sharma was elected as the President for the term 2023 - 2024.

Mr. R S Sharma received his Civil Engineering degree in 1971 and a Post Graduate degree in Civil Engineering (Structures) with Honours in 1978, both from the University of Delhi.

He joined the Central Engineering Service (Roads) Group 'A' of the Ministry of Shipping and Transport, Government of India in 1972 as an Assistant Executive Engineer. He worked in various posts in the Ministry both at the Head Quarters and at the Regional Office, Jaipur. In

June 1997 he joined the National Highways Authority of India as General Manager. In July 2000 he was elevated to the post of Chief General Manager. During his 6 years tenure at NHAI, he managed the prestigious 1400 km long 4-laning of the Mumbai-Chennai Corridor as part of the Golden Quadrilateral project from conceptualisation to implementation. On his return from NHAI in February 2003 he worked as Chief Engineer (Special Zone) in the Ministry of Road Transport and Highways and was assigned the job of implementing of National Highways Development Project involving the widening of 10,000 km of National Highways to the 4-lane dual carriageway. The Detailed Project Reports pending with the Ministry on those sections were concluded, and Bidders shortlisted.

ANNUAL GENERAL MEETING 2022

The 26th Annual General Meeting of the members of the Consulting Engineers Association of India was held on 24th December 2022 and transacted the following business:

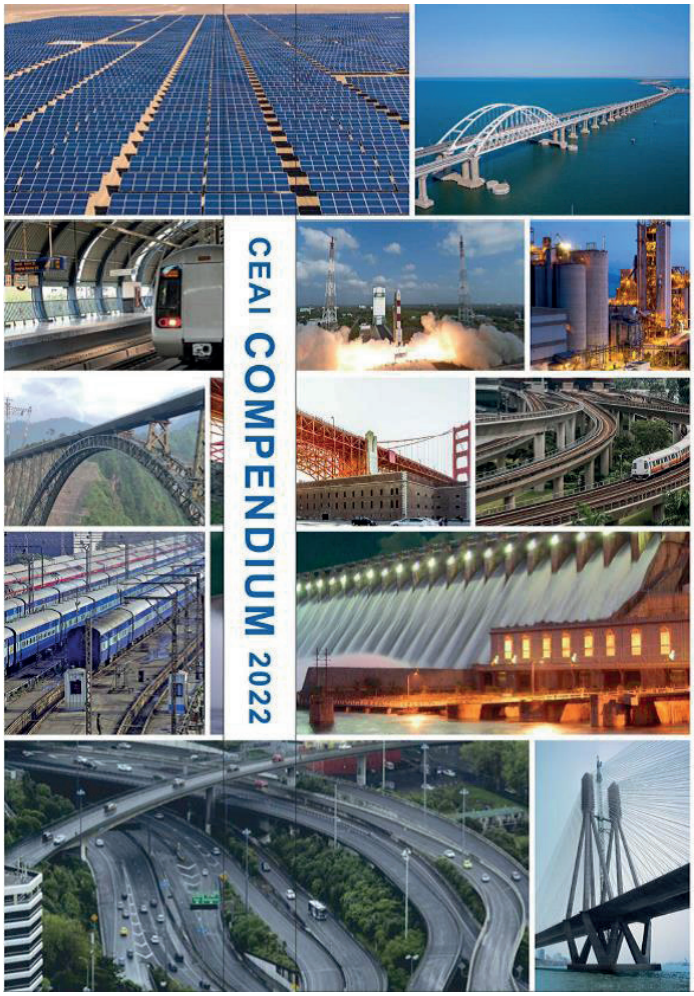
- Confirmation of the Minutes of the 25th Annual General meeting held on 17th December 2021.
- Adoption of the Annual Report of the Association for the year ended 31st March 2022.
- Passing of the Audited Accounts of the Association for the year ended 31st March 2022.
- Appointment of the Auditors for the Financial Year 2022-2023.

After transacting the business of the Annual General Meeting, the outgoing President, Dr. Ajay Pradhan welcomed Mr. R S Sharma as the President and handed over the charge to the newly elected President Mr. R S Sharma.

CEAI COMPENDIUM ON 'AZADI KA AMRIT MAHOTSAV'

CEAI is proud to join in 'Azadi Ka Amrit Mahotsav' to celebrate 75 years of India's Independence and has brought out a Compendium to mark the occasion, showcasing the tremendous progress and achievements that India has made in Engineering, Technology and Construction by showcasing some of the projects executed by Indian Engineers since attaining Independence in 1947.

The compendium was released during the Annual General Meeting held on 2



Azadi Ka Amrit Mahotsav

CEAI Consulting Engineers Association of India

COMPENDIUM

on

Engineering Accomplishments and the Future Engineering Consultancy in India

SEMINAR ON "CONTRACTS FOR INFRASTRUCTURE WORKS"

The CEAI Western Region Centre organized a seminar on ***"Contracts for Infrastructure Works"*** on 15th October 2022 at Taj President, Cuffe Parade, Colaba, Mumbai, to analyse and examine the changes over the last two years and more that the pandemic had thrust upon the judicial thinking, processes and procedures for contracts, especially those related to the extensive infrastructure developed in the Country. The term 'Infrastructure' was used to imply all sectors - Roads & Highways, Railways & Metros, Shipping & Water transport, Airports, Water, Wastewater & Solid Waste, Power, Irrigation & Flood Control, Townships, Smart Cities, Buildings, Hospitals & HealthCare, Industrial, etc.

The seminar which covered six current issues in the legal eco-system was made possible by the whole hearted support of the members of the CEAI-WRC event team. The speakers and panellists comprised eminent professionals from the legal sector, construction and engineering who have their finger on the pulse. They shared their views, experience and the recent pronouncements on legal matters and their impact on the Works. Participants comprised Corporate Legal Heads, VP/ GM Contracts, Commercial Managers, Project Managers, Engineers & Quantity Surveyors, Construction Professionals, Consultants, Lawyers & Arbitrators, Insurance Professionals and others who have a professional interest in the handling of contracts. Ample opportunities were planned to give the participants time to exchange their experiences and views with the speakers, panellists and amongst themselves.

Dr. Harshavardhan Subbarao, Member Governing Council CEAI and Chairman, CEAI-Western Region Centre, welcomed everyone and requested the Chief Guest, **Vice Admiral Rajaram Swaminathan, AVSM, NM,** Director General Naval Projects (Mumbai) for lighting the lamp. Other dignitaries also joined for that. Thereafter Dr. Subbarao invited the Chief Guest to deliver the **Keynote address**.

Vice Admiral Rajaram Swaminathan, AVSM, NM at the outstep clarified that the Navy "also deal with creation of infrastructure through the home-grown Military Engineer Service or through EPC/ PMC contracts. Techno-legal issues faced by us are much the same and I'm sure there will be learnings today for us too." He went to dwell on the link between infrastructure and the country's economy and "India is the third largest construction market in the world today." He talked of the National Infrastructure Pipeline which envisages investment of USD 1.4 Trillion and all that would help India achieve its "Sustainable Developments Goals 2030 for improving living standards of people and inclusive growth."

He then spelt out the initiatives and the drastic improvements in the speed of execution of projects due to new materials, technologies and processes for construction. He went on to add that "Technology can also enable project and contract management by way of remote monitoring, remote inspection of stage works, basic adjudication on claims, preparation of monthly progress reports, physical and financial progress and monitoring of projects. The potential to reduce decision making/ reporting delays, especially on issues like extension of time or cost is enormous. Similarly, Systems for capability, capacity and performance rating of vendors can be generated which would facilitate ease of selection based on PQC thereby reducing contracting time."

He went to say that despite all that "bottlenecks and pain points that remain are delays in resolution of techno-legal issues" and that in most cases the starting point of the discord was accuracy of site data and pacing the onus on the contractor could be unfair. Hence there was need to provide more accurate site data using better technology and also incorporate fair clauses in the contracts with respect to extension of time and monetary compensation for deviations. They help to reduce litigations due to "unforeseeable conditions".

To do that he clarified required proper drafting of contracts. He suggested that the Employers need to work towards project partnership to "Transforming employer-contractor relationships into a mutually beneficial partnership with the sole aim of moving projects ahead and curbing delays."

Vice Admiral Rajaram Swaminathan, then gave examples of "conflicts and inconsistencies of contractual clauses vis- a-vis law of the land which led to delays adjudication." He gave examples of the concept of extension of time in contracts and its ramifications. He also mentioned about the provision in Code of Civil Procedure - Order 2, Rule 2 Res Judicata, which is not recognised by Arbitration tribunals and thus leads to multiple claims. Then he went on to point out the disconnect between infrastructure contracts and the Indian legal framework.

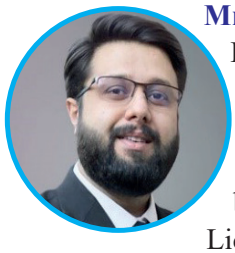
He next said that faster resolution of disputes is a sine qua non for ensuring regular cash flows and physical progress of projects. He mentioned that a former CJI had advocated that "arbitration awards must be binding and escalation to higher courts must be avoided to reduce load on the courts as also speed up contractual dispute resolution." Vice Admiral Rajaram Swaminathan therefore advocated that the techno-legal aspects be ironed out and efforts taken to draw up Infra Vision 2025. He suggested that steps need to be taken to make the Engineers determination "final and binding" in the interest of the project. He wished the sessions good deliberations.

Dr. Subbarao thanked Vice Admiral Rajaram Swaminathan for his enlightening address and putting across the disconnects between the contracts, the law of the land and the practices. He then **invited the expert speakers to make their presentation.**

Mr. Aditya Gupte, Partner, Tuli & Co. Advocates and Solicitors, Insolvency & Arbitration dealt with the ***"Current Judicial trend and issues in Limitation of Interest clauses in Contracts".*** He covered the provisions of Interest as per the Interest Act 1978 – the power of the court to allow interest, and also what the Code of Civil Procedure 1908 stipulates vide Section 34(1) which envisages three categories viz. Pre lite interest, Pendente lite interest and Post lite interest. He then dealt with Section 29 of the Arbitration Act 1940 and also the Arbitration & Conciliation Act 1996.

With that background he discussed various judgements which had been passed by courts in respect of interest such as the Ambica Principles (2016) and interest barring clauses being binding on the arbitrator. He then moved on to the issues created by the current position of law and as a closure presented the case where the constitutional validity of Section 31(7)(a) of the 1996 Act and Section 3(3)(a))ii) of the Interest Act 1978 has been challenged.

Mr. Rajat Taimni, Partner, Tuli and Co., Advocates and Solicitors, Head of Practice-Dispute Resolution went on to elaborate on the matter of interest and the limitation of interest clauses in contracts and summed up that in all fairness and interest of justice there is a need for a solution to the issue of interest.



Mr. Suvigya Awasthy, Associate Partner, PSL Advocates & Solicitors took up the matter of ***"Recent Judicial Pronouncements on Liquidated Damages".*** He set off by expanding on understanding Liquidated Damages and what and how they are in construction contracts. To elucidate that he presented some sample LD clauses. He clarified the difference between Liquidated Damages and Penalty clauses vis-à-vis enforceability, statutory provisions, the two-pronged test and the test for determination whether LD or Penalty. He presented landmark judgements from India, Singapore and the UK.

Moving on to the Guiding Principles he talked of computation of LD, no guess work to be done, and the types of recoverable damages. Regarding Evidentiary Threshold he explained the First Test – Named Sum v Formula, Second Test - Aggrieved party under an obligation to plead and prove the loss suffered on

account of breach, and the Third Test – leading evidence. He presented the case wherein the legitimate interest of the innocent parties was an issue. Mr. Awasthy thereafter presented five more recent judgements and summed up with a note for the contracting parties.

Mr. Vikas Kumar Sinha, IRAS, DFCCIL took up the matter regarding the ***"Right to Claim variations and acceleration/ damages and time extension in Contract Execution – What to watch out for"***. He represented the public organisation with great conviction and explained the matter from the perspective of the working of a government organisation and the right to claim by a contractor. He clarified as to what one needs to look out for with regards to procedural aspects; contemporaneous managing the contract; what is theoretical and what is as per the contract and the law.

Mr. Sinha explained the clause on Variations which covers additions, omissions, substitutions or alteration from a contractual perspective. Thereafter he moved on to discuss Value Engineering that could be done by a contractor to benefit the client/ project. He next dealt with damages form a legal perspective. He concluded by emphasising that the Project is supreme.

Mr. Ashutosh M Kulkarni, Advocate speaking on ***"What the Future outlook would be vis-à-vis Operation and Interpretation of Force Majeure clauses in Covid-19"*** clarified as to what Force Majeure is and gave its definition as per Black's Law dictionary.

He spelt out the statutory provisions which deal with Force Majeure and then moved on to judicial interpretations of the term and also its jurisprudentical evolution.

Mr. Kulkarni related some pertinent judgements and went on to discuss the broad principles associated with Force Majeure. While concluding he clarified how it would apply to the pandemic created issues.

Dr. Subbarao invited the Distinguished Guest, to share his views.

Dr. Ramnath Sonawane, Secretary, Maharashtra Water Resource Regulatory Authority, while addressing the gathering spoke about contracts based on his experience of dealing with many of them on varied projects. He drew attention to certain practices, especially during preparation of DPRs which led to issues during the execution of the project and consequently led to disputes. The sum of his address was that there needs to fair dealing by all parties to a contract so that the project is done smoothly and interest of all is addressed.

Mr. Kirindeep Singh, Senior Partner, Dentons Rodyk & Davidson LLP, Litigation & Arbitration Practice took up the issue of ***"Design Liability in Design and Build Contracts"***. He commenced by lucidly explaining the responsibilities of contractors under a design and build contract and then the design liabilities. With that background he covered fitness for purpose and presented a judgment on the same.

He next took up the matter of variation orders under design and build contracts and presented a judgment on that and moved on to analysing the FIDIC and the JCT forms for design and build contracts. While concluding he stressed that contractor needs to take extreme care under such contracts and gave some suggestions.

Mr. Sachin Mishra, Head Legal & Company Secretary, TATA Consulting Engineers Limited touched on the issue of "***Engineers Determination Clause : Final & Binding Effects - How can this be challenged with reference to Indian Contract Act?"***. He commenced with presenting global data on the construction disputes – their value, length, cause, method of resolution, important factors in mitigation/ early resolution and claim avoidance techniques.

With that background he took up the clause on Engineer's

Determination as per FIDICs rainbow suite of contracts and also the Indian contract law. He mentioned that the Engineer's determination could still be challenged on many grounds and presented some judgements and the learnings from them. On the way forward to save time and cost he made some suggestions.

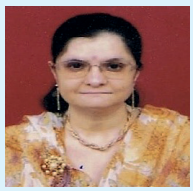
Mr. A P Mull, Past President CEAI and Former MD& CEO Tata Consulting Engineers Limited spoke on ***"Ethics & Quality"*** with reference to the Code of Ethics of the Consulting Engineers Association of India (CEAI) which is mandatory for all members to adopt and abide by. He explained all the clauses with reference to that Code.

He next, delt with Quality and what is means and implies for the purpose of engineering. Emphasising that Engineers are the backbone of development and must therefore be particular regarding quality, he mentioned that Green Engineering and Sustainable Development must be the aim. He showed how ethics and quality are interlinked and also essential to fulfil contractual requirements. Mr. Mull summed up that planning & design must be integrated and holistic.

Panel Discussions

Experts shared their experience during two Panel discussions moderated by Mr. Rajat Taimni. During those sessions, the Speakers and members from the audience also participated and spoke of their experience and offered suggestions.

The experts were:



Dr. Vandana Bhatt
PRO CARE
Contract Administration Consultant

Mr. Chetan Kavdia
Founder
Secure Legal & Associates

Mr. Uttam Sengupta
Fmr Corporate Advisor
Contracts & Risks
Voltas Ltd.

Dr. Milind Wankhede
Legal Advisor
Construction Contracts & Arbitration Law

Dr. Vandana Bhatt very eloquently summed up the day long deliberations and echoed the need of knowledge regarding Construction Law for engineers. For that she informed that CEAI was planning to have a short-term course for the working professionals. The dates would be announced later on.

Mr. Jeffrey Nambiar, Hon. Secretary & Treasurer, CEAI – Western Region Centre thanked all the Chief Guest, the Distinguished Guest, the Speakers, the Panellists and the Participants for their wide but

incisive talks and presentations, to all the participants for the extensive interaction which was the goal; all that made the event a big success. He also thanked the sponsors Tuli & Co and PSL Advocates & Solicitors, the Supporting Organisations and the Media Partners. A special thank was to Dr. Vandana Bhatt for generously providing, for the kit bag, the book "Law for Engineers" co-authored by her. He thanked the members of CEAI -WRC's Core Committee Seminars-for their unstinted help in organising the seminar; Taj President Hotel for the excellent arrangements, Soundtrek for the projection and sound systems, the staff at Chempro Expertise, Tuli & Co. and Secure Legal for being the backbone; and Dr. Harshavardhan Subbarao for his excellent compering of the seminar and Mr. Rajat Taimni for the panel discussions.

WEBINAR ON QUALITY IN CONSTRUCTION - ITS IMPACT ON NATION BUILDING

The webinar on ***"Quality in Construction – Its Impact on Nation Building"*** on 4th November 2022, received excellent participant response, with over 100 attending. It was supported by the India Chapter of the International Road Federation.

Mr. Somenath Ghosh, Chairman – Quality Sub-committee of CEAI, moderated the proceedings. He welcomed all the speakers and the participants and to set the tone invited Dr. Ajay Pradhan, President CEAI to give the opening remarks.

Dr. Ajay Pradhan, President CEAI, set the context to the webinar while highlighting the criticality of construction quality in the current day environment of hectic construction activity all over the country. He provided the background of CEAI and the commendable work it has been doing in the field of projects in different sectors in India. He pointed out the major factors that influence quality in the lifecycle of a project, namely quality of engineering & design and the supervision provided by engineers, the clarity and transparency in tender specifications and the contractor's clear understanding of the same, quality of human resources, sharing of necessary data with contractors, selection of best qualified contractor and not based on lowest price, contractor's track record in safety and quality.

Mr. R. K. Pandey, Member Projects, NHAI Dwarka, gave the Keynote Address. Complimenting CEAI for selecting the important topic of Construction Quality for the webinar Mr. Pande highlighted the critical aspects pertaining to the Highways and Roads sector in India which has the second largest road network in the world. He briefed the participants about the prestigious National Highway program of the Government of India, known as Bharatmala, with a plan to develop about 65,000 kms of National Highways with a budget of Rs. 200,000 crores per annum. However, he also drew attention to the fact that India has the maximum number of fatalities on roads and therefore it was critical to cover road safety also in addition to the quality in road construction. He also highlighted the peculiarities of Roads and Highways which are required to be kept operational all the time, even when construction work is in progress. The construction quality of roads is critical since the road conditions can affect a multitude of aspects such as vehicle maintenance, human resources and several other factors.

He also dwelt on the lifecycle of the road projects covering pre-construction, construction and post construction phases where high quality has to be ensured during all these phases. Although the processes followed by the National Highways Authority of India (NHAI) in implementing projects during various stages starting from DPR, all the way to engineering and construction adhered to established practices and quality-based criteria, there had been instances of quality not matching the standards. Therefore, NHAI have often engaged the services of external experienced people to undertake independent review of reports and documents as well as to conduct work inspection at various stages followed by

a detailed process of approval of their recommendations and implementation of the same. The process incorporates multiple levels of checks and inspections with the objective to ensure high level of quality in the construction work.

Mr. Pande also explained the methodologies for two types of projects executed by NHAI namely Concession Projects and EPC Projects. They had been enhancing the mechanisation element in their projects which ensures better and consistent quality, and they were also considering deployment of Digital technologies (such as sensors, drone videography, etc.) to improve that further. He however, stated that despite the strict process followed to select contractors, the results were not always encouraging. He therefore looks forward to support from CEAI to play a role in the entire process, which would go a long way to enhance road construction quality.

Mr. D. U. Ramakrishnan, Head QCS, L&T Energy Hydrocarbon Limited (LTEH) made a comprehensive presentation on ***'Construction Quality – A Critical Success Factor in Large Scale Hydrocarbon Projects'*** highlighting the importance of construction quality as a Critical Success Factor in large scale Hydrocarbon projects. He started his talk explaining the challenges faced by the Construction industry, especially in the hydrocarbon sector, which in turn had the potential to impact the construction quality. Process quality and Product quality are the two important aspects of Construction quality and are the key factors that contribute to the project success. Process quality pertains to the operations processes through the lifecycle of the project from Engineering phase through Procurement, and Construction, which calls for due attention to be given to aspects such as client specifications, interface engineering, constructability, drawing revision control, vendor's quality management, logistics, storage and preservation and strict quality assurance and inspection at various stages of construction. Product quality on the other hand is influenced by quality enablers such as production technology, measures to improve productivity, deployment of digital technologies and so on.

Mr. Ramakrishnan, in order to explain and drive the point, screened a few videos of modern technology-based tools deployed by LTEH for processes such as CNC enabled based piping fabrication, Orbital Welding, special machinery for LNG tank construction work involving 9% Ni steel, latest NDT techniques such as Digital Radiography and PAUT, Electrostatic painting, Auto-plastering and Robotic wall painting, CNC based Automated rebar cutting / bending etc. He also highlighted the effectiveness of modern quality assessment tools such as CPQR and EIPQR respectively for Civil and E&I quality assessment without subjectivity. All these advanced technologies facilitate the process of achieving high construction quality, ensuring work being done right the first time, also leading to high productivity.

Mr. Sathish Rao, Head PMC Business Unit, TATA Consulting Engineers Limited (TCE) elaborated on ***'Quality in Construction – A Project Manager's Perspective'*** of Quality aspects in large scale construction projects. He began by stating that the construction quality has to address both the stated needs as well as the implied needs for a project to be successfully completed. The PAF model for the cost of achieving the requisite project quality consists of two components namely Failure Cost and Prevention Cost. It was critical to minimise the failure cost which could adversely affect the project outcome. Quality Assurance and Quality Control are both critical. Quality Assurance calls for implementation of training and reward schemes which can help ensure high motivation levels in employees to achieve high quality. Quality Control on the other hand addresses the adherence to standards, implementing corrective measures while ensuring continuous improvement. He also dwelt with the multiple factors which affect construction quality such as material quality, changes in documents, design complexities, scope creep and so on. He drew attention to the fact that the cost of poor quality had far reaching impact on the project outcome. He compared it to an iceberg where several costs resulting from poor quality are hidden costs which appear in a variety of forms such as impact on schedule, higher OPEX cost, lost sales, loss

of client confidence, etc. Emphasising on the importance of training, he presented statistics on training cost vs rework costs under different situations. Mr. Satish Rao while concluding stressed on the need to move away from the traditional L1 to a Quality cum Cost Based System (QCBS) for contracts.

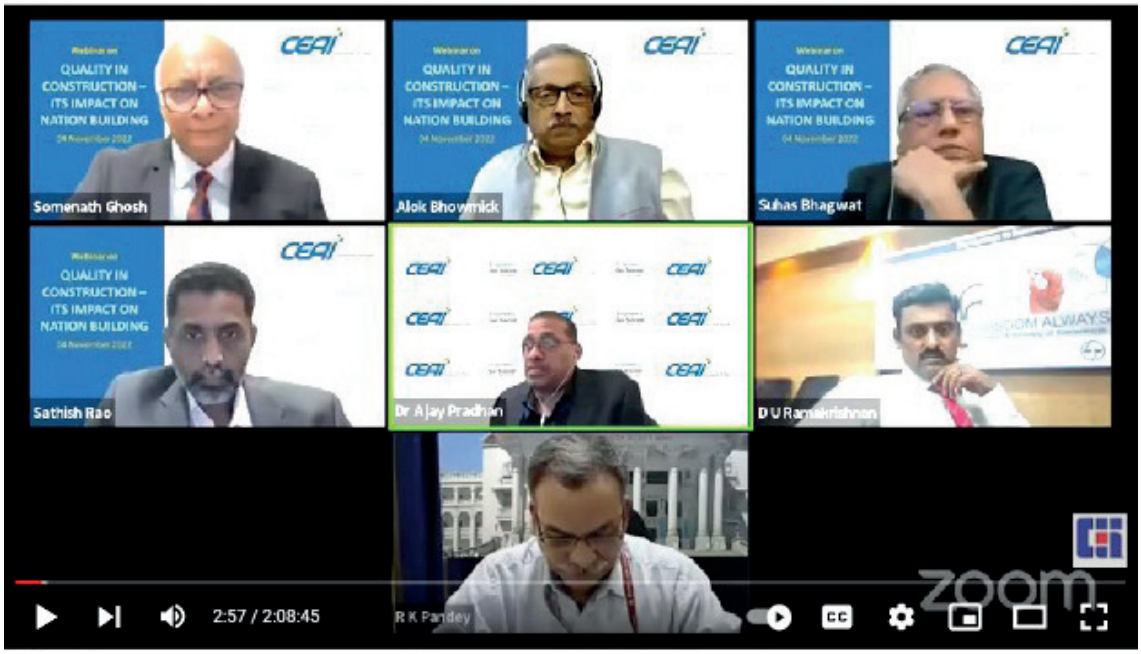
Mr. Alok Bhowmick, Manging Director, B&S Engineering Consultants touched upon ***'Myths of Quality Assurance in Construction Projects'***. He drew attention to the fact that quality observed in several construction projects was not up to the mark, plus accidents and near misses were occurring at a worrisome frequency. He presented details of several accidents caused by various factors such as wrong design by inexperienced and incompetent designers, quality policy not being followed, work done by un-qualified contractors, usage of poor-quality material, absence of work supervision and so on. He went on to add that it was necessary to learn lessons from accidents and near misses based on investigation reports, however that was not seen happening and that such mistakes were in fact being repeated.

Mr. Bhowmick further highlighted the misconceptions regarding Construction Engineers and Construction Quality such as construction is thought to be a low-profile job, designers are not required to visit sites, and the impact of such misconceptions on the fate of the projects. He also stressed that the costs of such thoughts were a reason contributing to construction errors are very significant. He then went on to suggest guidelines for the way forward for Owners' and Clients' Engineers as well the Structural Engineers of Consultants with the objective that everyone concerned adheres strictly to the quality requirements and avoid accidents and failures.

The presentations were followed by a Question-Answer session in which there was an enthusiastic response from the participants.

Mr. Suhas P. Bhagwat, Member – Quality Sub-committee, CEAI, thanked the speakers for putting across the message so succinctly. He thanked all the participants for joining and interacting with the speakers. He acknowledged the efforts of CEAI Secretariat in organising and helping in conducting the webinar efficiently.

Link for the webinar: https://youtu.be/Sj9k4RNdTTc



FIDIC TRAINING PROGRAMMES

a. CEAI organised FIDIC Trainings (Open house) in November 2022 at Shriram Hall, PHD Chamber of Commerce and Industry, New Delhi, on two Modules.

Module 1: ***"Practical Use of FIDIC Conditions of Contract"*** on 14-15 November 2022

Module 2: ***"Management of Claims and Disputes Resolution"*** on 16-17 November 2022

b. An In house Training Programme was organised for the NHSRCL and TCAP PMC officials.

All the Training programmes were conducted by Mr. Bogdan Oprea, FIDIC Accredited Trainer, who clarified the matters raised by the participants.

MEMBER NEWS

5th Russian Energy Week International Forum 2022

The 5th Russian Energy Week International Forum 2022 was held at the Manege Central Exhibition Hall, Moscow. on 13th October 2022 Mr. Manek Ghoshal, Secretary & Organizing Committee Member-Consulting Engineering Association of India -Eastern & North Eastern Region Centre, was a Panellist (online) for the topic of **'Ecology and Climate Agenda'**; Sub Topic – ***'Ash and Slag Wastes at Thermal Power Plants: How Can Energy Become the Solution?"***

IRC Lifetime Achievement Award

The **Lifetime Achievement Award of Indian Roads Congress (IRC)** for the year 2022 was conferred on **Mr. R S Sharma** for his outstanding contributions to the Highway Engineering profession. The award was given during the Inaugural function of the 81st Annual Session of IRC held on 8th October 2022 at Lucknow.

FIDIC Certified Consulting Practitioner

FIDIC Credentialing Limited, (FCL) the Certification Body for Global Consulting Professionals have declared Mr. Alok Bhowmick, to have successfully participated in the **FIDIC Certified Consulting Practitioner** Exam which was held on the 25th November 2022 and had obtained a score of 80% which is higher than the pass mark which was set at 65%. FCL while congratulating him have said "on your efforts to enforcing and improving industry standards as well as equipping yourself with the most relevant tools for success". Mr. Bhowmick is Vice President, CEAI. He is the Managing Director, B&S Engineering Consultants Pvt. Ltd.

IEI Industry Excellence Award 2022

B&S Engineering Consultants Pvt. Ltd. received the ***IEI Industry Excellence Award 2022*** from the Institution of Engineers (India) by virtue of demonstrating outstanding performance with a high order of business excellence. The award was given at the 37th Indian Engineering Congress held in Chennai on 16th December 2022. The award was received by Mr. Alok Bhowmick, Managing Director, B&S Engineering Consultants Pvt. Ltd.

CEAI FOUNDATION PROJECT

CEAI Foundation has been actively following up various social projects in Delhi and other Regional Centres.

CEAI Foundation was approached by PVR Nest to help them in the design and construction supervision of a Community Complex for Women in one of the slum areas of Delhi.

CEAI Foundation did the design work of the complex comprising computer training centre and facility for training women in stitching plus 16 toilets/ wash rooms. CEAI Foundation coordinated the construction work and assisted in selection of major finishing items. The Center is now operational.

Features

• Computer Center cum Library	• Stitching room
• Counselling room	• Meeting Hall
• Children Play Area	• Toilets (16 nos.) + 1 for physically challenged persons

ViewPoint

The themes for the quarterly issue CEAI's magazine ***"ViewPoint"*** for 2023-2024 will be decided by the Publication Committee 2023-2024.

The articles for an issue need to reach CEAI at least 3 weeks prior to the end of the month of the ViewPoint issue.

Articles need to be in Times New Roman 12 with single line spacing with before and after 6 pt and normal margin, on A4 size. A recent clear and bright passport size photograph of the author(s) is to be sent along with the article. For details of formatting please refer to *"Format for Articles for CEAI Viewpoint"* on CEAI's website, under *'Publications'*.

Advertisement in ViewPoint

ViewPoint is circulated to all CEAI Members, FIDIC, Ministries of the Government of India, Public & Private Sector Undertakings, Construction Firms, Contractors, Consultants, Foreign Missions and Funding Institutions in India and other organisations related to or dealing with the engineering profession. Thus, all stakeholders partnering development and progress are its readers.

Catch the Customers Eye

Get Wide Exposure → VIEWPOINT

Improve Visibility

Support from CEAI members and stakeholders are sought for increasing the number of advertisements, so that ViewPoint gains in its stature as a unique Technical Publication for the fraternity and the public at large to spread information of how Consulting Engineers are helping society for improving the quality of life and doing so sustainably.

The rates for advertisements in ***VIEWPOINT*** which will be booked on or after 1st January 2023 are given below:

Item	Revised Rate Per issue* (Rs)	Discounted rate at 10% for 2 consecutive issues* (Rs)	Discounted rate at 20% for 4 consecutive issues* (Rs)
Back Cover	**25,000.00**	**45,000.00**	**80,000.00**
Inside Front Cover	**18,000.00**	**32,400.00**	**57,600.00**
Inside Back Cover	**18,000.00**	**32,400.00**	**57,600.00**
Full Page (Colour)	**12,000.00**	**21,600.00**	**38,400.00**
Full Page (Colour), if a specific page position is required.	**14,000.00**	**25,200.00**	**44,800.00**
Full Page (B&W) (such advertisements will be taken up for printing only when there are 4 or multiple of 4 advertisements for an issue)	**8,000.00**	**14,400.00**	**25,600.00**

Notes:

*GST @ 5% or as prescribed will be added to the above rates.

**Inside Front Cover booked till June 2023

***Inside Back Cover booked till Sept 2023

Tech Quiz

1. **Which of the following is the reason that makes plastics difficult to recycle?**
   a. It is light weight
   b. It comes in different sizes
   c. It cannot be melted
   d. It contains different types of polymer resins

2. **What do the three key Rs in Circular Economy stand for?**
   a. Reduce, Reuse and Revive
   b. Reduce, Reuse and Recycle
   c. Reduce, Reset and Retain
   d. Reduce, Revive and Reset

3. **Which of the following is NOT true of Circular Economy**
   a. Circular economy wastes resources.
   b. Circular economy implies the reduction of waste to a minimum.
   c. Circular economy promotes recycling.
   d. Circular economy enables meeting SDG goals

4. **Which international standard is followed in LCA?**
   a. ISO 14045
   b. ISO 14046
   c. ISO 14440
   d. ISO 14040

5. **Which is the First Asian Country to Launch a Plastics Pact?**
   a. China
   b. Singapore
   c. India
   d. Japan

6. **Which of these ideas does not form part of a circular economy?**
   a. Manufacturing Products
   b. Consuming Products
   c. Recycling Waste Products
   d. Mining of Raw Materials

7. **Where does the microplastics in the oceans primarily come from?**
   a. Primarily from Plastic Pellets
   b. Primarily from tyres, city dust and synthetic textiles
   c. Primarily from Plastic Bags
   d. Primary from ordinary consumer products

8. **Under Extended Producer Responsibility, a producer should be responsible for:**
   a. waste management instead of municipalities.
   b. nothing as unavoidable costs could be incorporated into the product pricing.
   c. the eco-design of products.
   d. the eco-design of products, and the management and financing of products' end-of-life.

9. **What is eco-design?**
   a. Creating inexpensive economical products
   b. Using a production method that makes it possible to reduce environmental impacts
   c. Reducing the quantity of materials and eliminating hazardous/toxic substances
   d. Designing products from waste only

10. **What does a Product-as-a-service Model lead to?**
    a. Developing the multifunctionality and multi-use of products
    b. Limiting obsolescence
    c. Transitioning from selling a product to selling its use
    d. Creating essential products only

The first person who mails the correct answers to CEAI *info@ceai.org.in* will get a congratulatory mail and will be acknowledged by publishing the persons photograph in the next issue.

Contributed by Environmental Management Centre Pvt. Ltd.

Answers to Tech Quiz of September 2022 issue

Answers:
1. (d) 2. (b) 3. (a) 4. (d) 5. (c) 6. (d) 7. (d) 8. (d) 9. (c) 10. (c)

Consulting Engineers Association of India
Western Regional Centre

Workshop

Steel - for Sustainable Development

Block Date

4th February 2023, 9:30 am to 6pm

Victor Menezes Convention Centre

Indian Institute of Technology Bombay, Mumbai

Green Engineering → *Sustainability* → *Climate Change*

Take A Close Look At Challenges For Engineers

- Steel Intensive Structures - Sustainability Aspect
- Steel Intensive Buildings – LCA & Sustainability Framework
- Steel Composite Technology in High-rises
- Cold Formed Steel Buildings
- Steel in Bridges– Various Aspects
- Steel Framed Buildings – with Case Studies
- Reuse of Steel for Sustainability

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- Design of over 4,200 Bridges and other Structures.
- Transaction & Financial Advisory for Projects of Capital Value over USD 7 Billion
- EIA / SIA for over 600 Projects.
- Nearly 27,000 km of Road Construction Supervision and Project Management.
- Over 60 Airport Projects Involving Planning, Design & Supervision
- Road Safety Audit/ Black Spots Improvement/ Awareness Campaigns in over 200 Assignments
- Water Supply Schemes for over 500 Towns and Villages
- Design of over 4200 Bridges, Tunnels and other Structures
- Over 45 Projects of Railways and Metro Rails
- Master Plan and Development Plans for over 77 Cities/Towns
- Irrigation Planning & Design of over 8,00,000 ha. Gross Command Area

KEY BUSINESS VERTICALS

Expressways and Highways

Tunnels

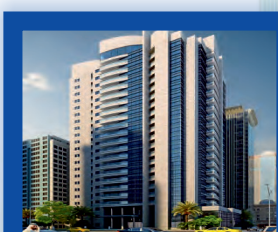
Bridges and Other Structures

Railways and Metro Rails

Airports and Aviation System

Urban Regional Planning and Smart City Solutions

Traffic Transportation and Road Safety



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CEAI CENTRE