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RESEARCH ARTICLE

ASSESSMENT OF CIRCULAR ECONOMY AND REDUCTION OF EMBODIED CARBON DRIVE FOR SUSTAINABLE CONSTRUCTION

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Abstract

According to United Nations Environment Program 2020, construction industry uses almost 35 % of global energyand is responsible for 38 % of greenhouse gas emissions. Buildings areoe of the largest end-use sector and their contributioncontinues to be a source of that energy demand in the future. In this paper, a brief overview of assessment of circular economy and reduction of embodied carbon drive for sustainable construction is explained. The aim of the study is to analyze circular economy principal in construction industry for sustainable development. A brief introduction about circular economy (CE), need of study, problem statement, aim of study, and objectives of project are discussed in the paper.Theuse of timber as a structural element is slightly promoted concrete, minimize carbon footprints produced by use of steel and concrete.Majority of the buildings hasa mixture of compounds which are very difficult to filter/ separate, it makes the material reuse/ recycling process less easy, so new technologies to be used for separation of used building materials needs to be focused on.

Introduction:-

The traditional economic paradigm of "make-use-dispose," which has been shown to be a successful and widely accepted method of conducting business, has come under scrutiny recently for a number of reasons. The term Circular Economy (CE) first developed as an alternative to the traditional economic paradigm in the final decade of the 20th century. The laws of thermodynamics serve as its foundation.However, the term remained in obscurity until following the turn of the twenty-first century, and the Chinese government first put it into practise with the Circular Economy Promotion Law of the People's Republic of China. [1]

Embodied Carbon Drive

The building and construction industry is very significant since it makes a significant contribution to a country's economic development. This industry, which is closely related to natural resources, has a long history of being one of the main drivers of climate change. 40 percent of the world's energy, 30 percent of raw materials, 25 percent of solid waste, 12 percent of land use, and 33 percent of greenhouse gas emissions are attributed to the building sector. Embodied Carbon (EC) and Operational Carbon are two different categories of life-related carbon emissions (OC). The carbon released during the final material's extraction, production, and transportation to the assembly site is known as embedded carbon. Embodied carbon is related to greenhouse gas emissions from production, transportation, installation, and maintenance processes.

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Objectives:-

1) To study available literature on application of circular economy in construction industry.
2) To find out scope, uses, problems, limitations for application of circular economy.
3) To find out circular economic design strategies which is useful to reduce embodies carbon-drive towards sustainable development.
4) To prepare questionnaire and get responses from construction industry professionals.

Literature Review:-

The study by Catherine De Wolf et al. discusses the software, resources, and databases that may be used to determine the environmental impact of construction materials and structures while exhibiting the various approaches, boundary conditions, and geographical areas. The academic and professional literature on the state of the art in the construction industry, as well as qualitative research with practitioners, were consulted to determine how embodied CO2 is estimated in practise. [2]

In the article, Francesco Pomponi et al. conducted a thorough evaluation of the vast body of scholarly literature on embodied carbon mitigation and reduction in the built environment as well as life cycle assessments of buildings. [3]

The four design techniques discussed in this chapter by Danielle Densely Tingley et al. are crucial to a circular economic approach to the built environment because they all work to preserve the value of material assets, either now or in the future. [4]

In this article, Antonin Lupisek describes ways for designing buildings that reduce embodied energy and carbon emissions and illustrates them with five real-world examples of design improvements to individual building components, subsystems, and the entire structure. [5]

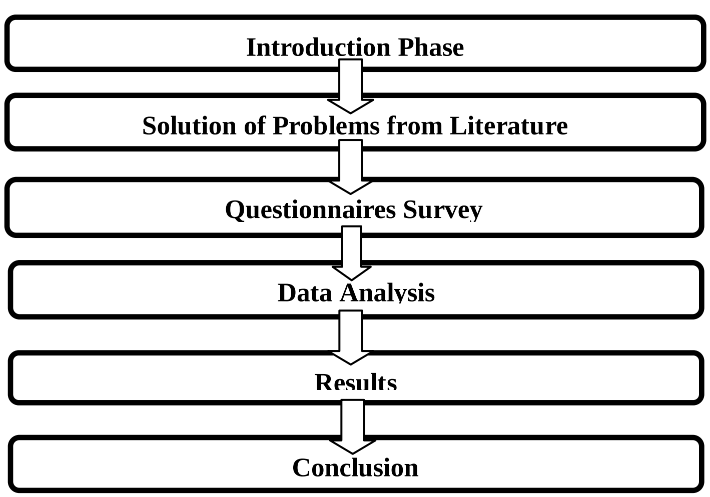
The goal of the systematic literature review was to uncover new advancements of the circular economy in the construction industry, as stated by Gabriel Luiz Fritz Benachio et al. in their article. [6]

The paper by Ali Reza Afshari et al. provides a summary of the literature on theoretical Circular Economy methods, techniquesand implementation cases in construction sector. It also discusses proposals for future development. [7]

In this article, Mangos Sparrevik et al. describe a number of techniques for evaluating the environmental performance of the built environment. The majority of these techniques use a life cycle perspective that corresponds to the three distinct stages of a building's life cycle: construction, use, and end of life. Methods frequently overlap and are weaved together. [8]

Additionally, Manish K. Dixit sought to thoroughly evaluate the possibility of MSW-derived power generation using an integrated solid waste management system. Developed nations have put sustainable material management plans in place to address these issues. [9]

Methodology:-



Data Collection

We separate key principles into two categories: those relevant to R frameworks and those relating to the systems approach. For many years, both academics and professionals have employed a variety of R frameworks. Many authors consider the multiple R frameworks to be a fundamental element of CE and the "how-to" of CE. The 3R framework was our first choice because it is the most well-known R framework and forms the foundation of the People's Republic of China's Circular Economy Promotion Law from 2008. The key characteristic of all R framework variations is hierarchy, with the first R (which in the 4R framework would be "reduce") being prioritised over the second R, and so on.

The seven techniques, how they might be used to construct buildings, and the obstacles posed by conventional structures that prevent their use.

The 3Rs principle of reduce, reuse, and recycle is frequently linked to the CE framework. We determined the seven most prevalent tactics after reviewing the literature on the CE and its use. We list these tactics in Table No. 1 and explain how they apply to construction.

Table no 1:- Seven stratergies and barriers of traditional buildings.

	Strategy	Appling the Strategy to Prefabricated and Traditional Buildings	Barriers of Traditional Buildings
1.	Reduction of construction waste and the lean production chain	Adopt the lean production chain to reduce construction waste	TB degree of complexity and variable measures are a barrier toward lean production
2.	Integration of scrap, waste, and by-products into new components	Use of by-products in concrete	No barriers were found in the literature
3.	Reuse of replacement parts or entire components	Use of second-life components	Technically complex, elevated time, and cost requested
4.	Design toward adaptability (reduction through life extension) during operational stages	Adaptability during the operational phase	Low adaptability of components due to monolithic nature of the TB; knowledge gap on space adaptability
5.	Design toward disassembly of goods into components to be reused	Reusability at the EoL	Monolithic structures with chemically bonded connections
6.	Design for recycling of construction materials	Recyclability at the EoL	Concrete is intensively used in TBs; however, in the recycling process, its characteristics decrease with scarce saving of CO_2 emissions
7.	Systems to track materials and components within their supply chain	Tracking the components	Practicable only when component can be disassembled and reused

Source: Roberto Minunno (2018)

4.2 Strategies for Embodied Carbon Reduction

Many studies have been done to look into different methods of lowering the embodied carbon in buildings. Five criteria can be used to categorise these techniques:

(1) Low-carbon materials
(2) Strategies for material minimization and reduction
(3) Strategies for material reuse and recycling
(4) Strategies for sourcing materials and components locally
(5) Local sourcing and minimising of transportation.

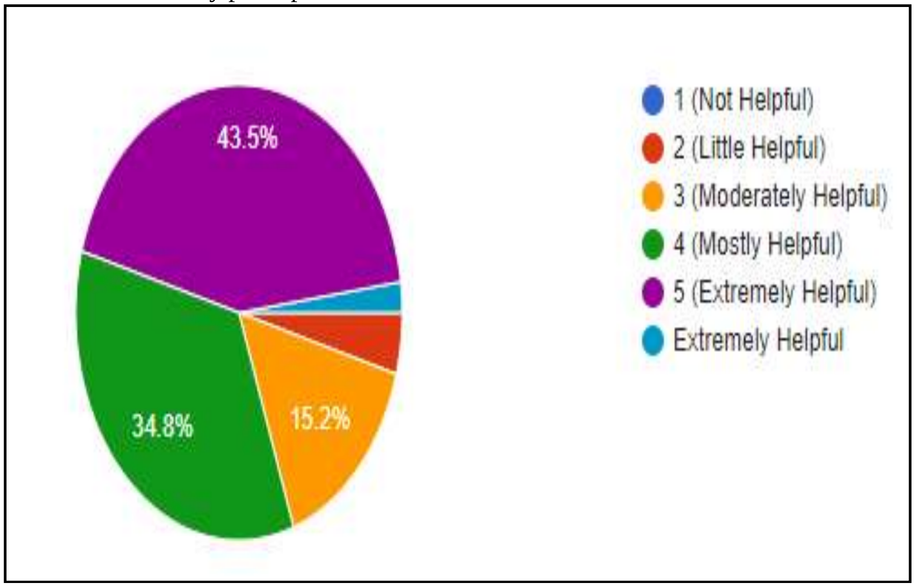
Analysis

The survey was done with the help of Google form. The survey link was shared with 100 people in total. The actual number of people who responded to the survey were 46. Thus, the response rate was 46%. Below are the pie charts of survey responses.

Primary Analysis

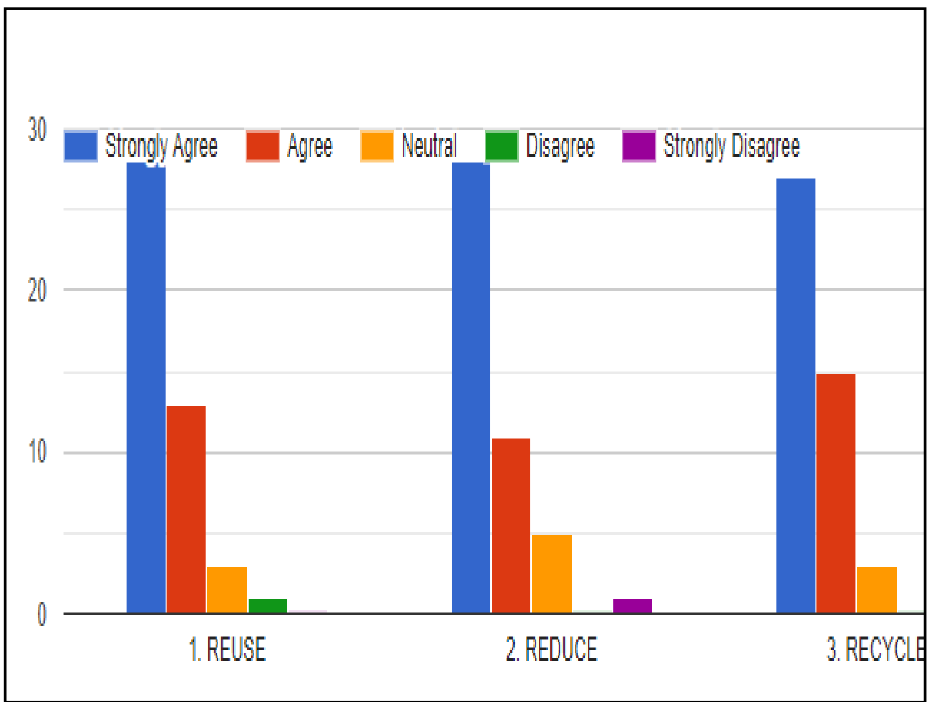
Importance of circular economy in construction industry.

How helpful is the circular economy principles in construction sector?



Give Rankings to following circular economy principals as per their importance.

1] Reuse
2] Reduce
3] Recycle



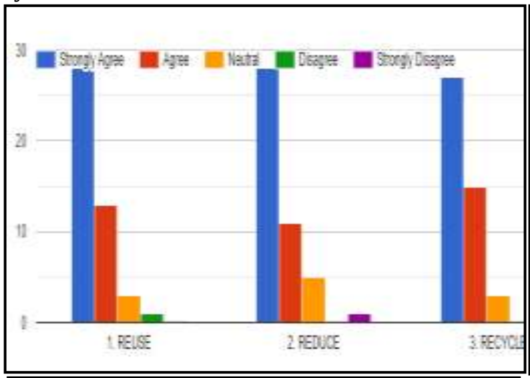
5.1.3 Barriers in implementations of circular economy in construction industry.

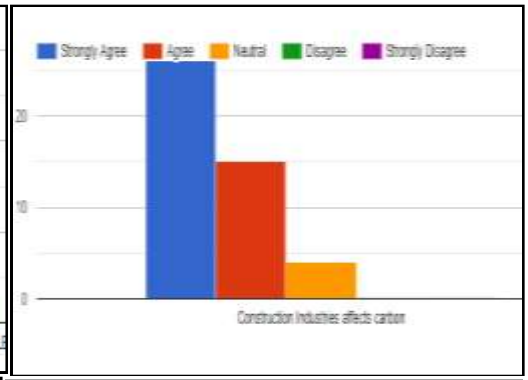
1) Give Rankings to the following circular economy principles as per their implementation Barriers.

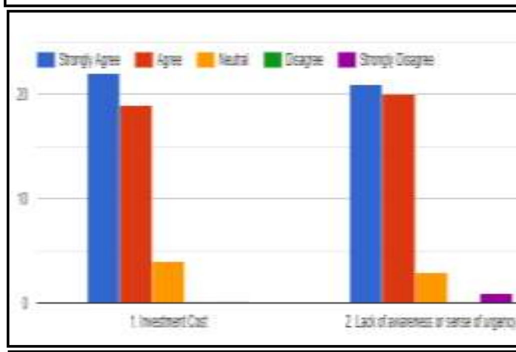
1] Reuse-

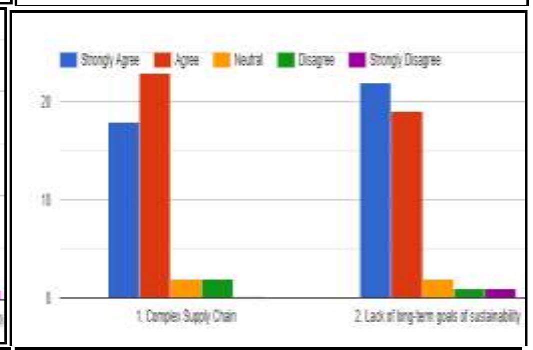
2] Reduce-

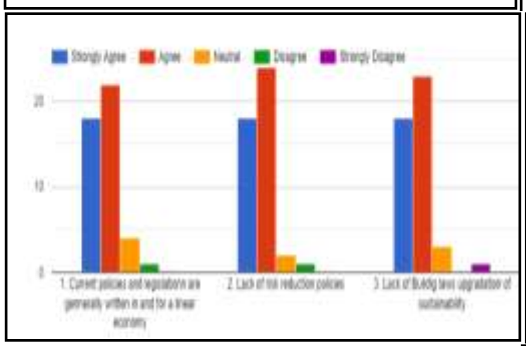
3] Recycle-

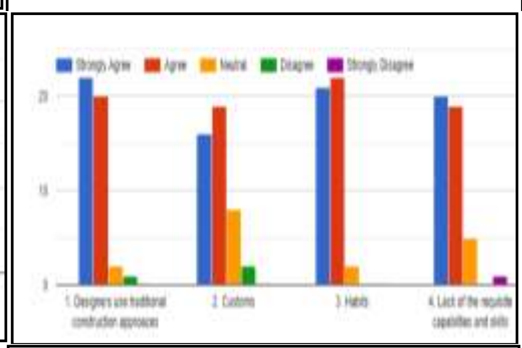


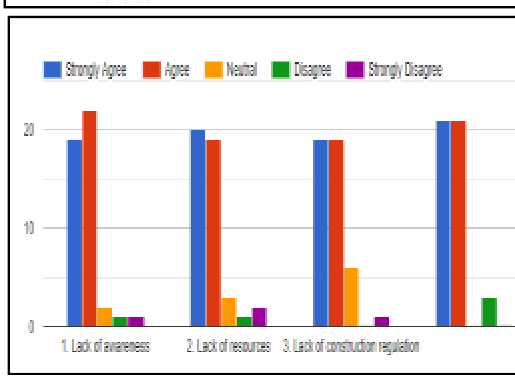


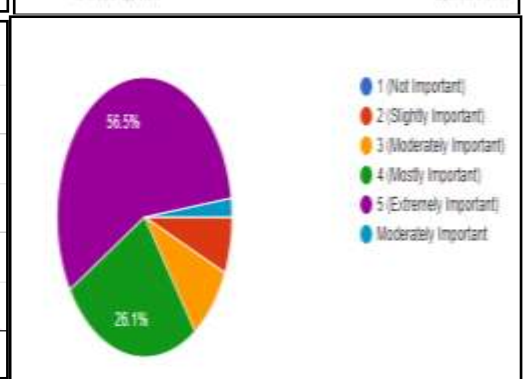




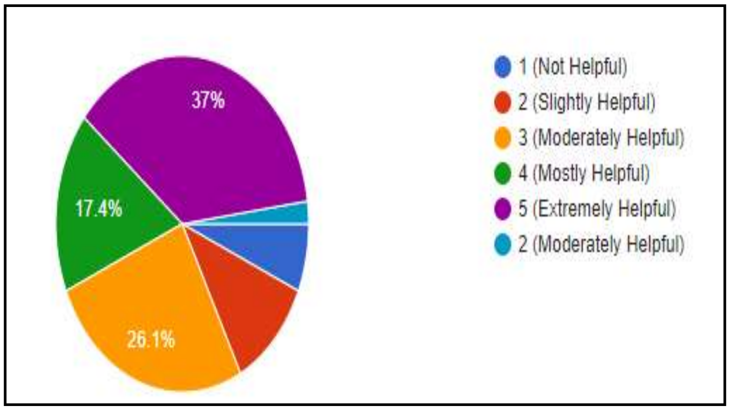




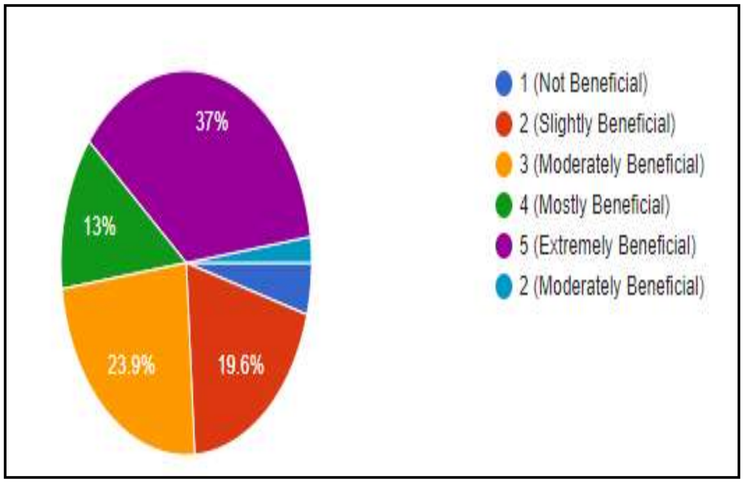




Q. How helpful is it to reduce the use of steel and concrete in building materials?



Q. Is it beneficial to use of timber as the structural material instead of Steel?



Survey Analysis Method (RII – Relative Importance Index)

Relative Importance Index (RII) has been calculated for each of the questionnair**e**. Below is the sanple calculation for a questionnaire:

$$\textbf{RII} = \frac{(5*n5) + (4*n4) + (3*n3) + (2*n2) + (1*n1)}{A*N}$$

where,

n1 = Highly Disagree
n2 = Disagree
n3= Moderate/Neutral
n4 = Agree
n5 = Highly Agree
A = Highest weight (5)
N =Total number in the sample/ observations (46)

Sample Calculation:

Q1)How helpful is the circular economy principles in construction sector?

- Data: Extremely Helpful – n5= 21
Mostly Helpful – n4= 16
Moderately Helpful – n3 = 7
Little Helpful – n2 = 2
Not Helpful – n1 = 0

$$\textbf{RII} = \frac{(5*n5) + (4*n4) + (3*n3) + (2*n2) + (1*n1)}{A*N}$$

RII = $\frac{(5*21)+(4*16)+(3*7)+(2*2)+(1*0)}{5*46}$

$$\text{RII} = \frac{\mathbf{194}}{\mathbf{230}}$$

RII = 0.843

Calculated RII for Questionnaire:

No.	Questionnaire	Calculated RII
1.	Importance of circular economy in construction industry.	
1.1	How helpful is the circular economy principles in construction sector?	0.843
1.2	Give Rankings to following circular economy principals as per their importance.	
	Reuse	0.882
	Reduce	0.869
	Recycle	0.886
2	Barriers in implementations of circular economy in construction industry.	
2.1	Give Rankings to the following circular economy principles as per their implementation Barriers.	
	Reuse	0.830
	Reduce	0.856
	Recycle	0.830
2.2	Economic barriers.	
	Significant investment cost	0.808
	Lack of awareness or sense of urgency	0.847
2.3	Collaboration barriers	
	Complex supply chains	0.826
	Lack of long-term goals of sustainability	0.843
2.4	Policies barriers	
	Current policies and legislation are generally written in and for a linear economy	0.834
	Lack of risk reduction policies	0.843
	Lack of Building laws up gradation of sustainability	0.834

2.5	Social barriers	
	Designers use traditional construction approaches	0.860
	Customs	0.800
	Habits	0.865
	Lack of the requisite capabilities and skills	0.834
2.6	Technical barriers	
	Buildings traditionally contain a complex mixture of compounds that are often difficult to separate, making material reuse and recycling difficult.	0.878
	Technical performance of components/materials not designed for reuse/recycling	0.837
	Lack of stringent legislation and policies	0.826
	Lack of adequate information at the design stage	0.826
	Lack of large enough market for recovered components	0.800
	Difficulty in developing a business case	0.834
	Lack of effective tool	0.826
3	Today's scenario about CO2 footprints due to construction industry	
	How much construction industries affect carbon cycle	0.878
4	Implementation of circular economy to reduce footprint.	
4.1	How important is it to highlighting the life cycle CO2 emissions reduction	0.878
4.2	Give Rankings to following circular economy principals as per their usefulness to reduce CO2 footprints?	0.817
	Reuse	0.817
	Reduce	0.826
	Recycle	0.865
4.3	How helpful is it to reduce the use of steel and concrete in building materials	0.747
4.4	According to you is it beneficial to use of timber as the structural material instead of Steel	0.704

Results & Conclusion:-

A brief overview of assessment of circular economy and reduction of embodied carbon drive for sustainable construction has been discussed in the paper. The analysis of the survey/analysis was done using RII (Relative Importance Index). RII ranges from 0.704 to 0.886 depending on the various set of the questions. There is very less difference in different Relative importance index circular economy questionnaire.

As construction industries have huge effect on carbon cycle,
1. There is need to implement the circular economy principles.
2. There is need to overcome the different implementation barriers of circular economy in construction industry.
3. There is high need to highlighting the life cycle CO_2 emissions reduction in construction industry.
4. Use of steel and concrete in construction should be reduced to minimize carbon footprints.
5. Use of timber as structural element is slightly promoted.
6. There is need to make risk reduction policies in construction industry.
7. Use of recycle materials in construction helps to reduce carbon footprints.
8. Buildings contain a complex mixture of compounds that are frequently challenging to separate, making it challenging to reuse and recycle resources, necessitating the use of innovative technologies for the separation of spent building materials.

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