Experimental Research on Green Concrete

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Abstract:
Concrete is a predominant material in global construction due to its versatility and essential role in various infrastructure projects. However, its production is responsible for approximately 8 to 10 % of global CO2 emissions, primarily attributed to the manufacturing of cement. Consequently, there is a critical need to reduce concrete usage and seek eco-friendly alternatives to conventional cement. Green concrete refers to concrete produced by incorporating waste materials such as fly ash, slag, by-products from power plants, recycled concrete aggregate, and waste glass, this approach aims to reduce carbon dioxide emissions associated with traditional concrete production.
This study presents experimental work conducted on both conventional and green concrete samples of M40 mix design. The green concrete samples incorporated fly ash as a partial replacement for cement at 20%, 25%, and 30% levels, and used recycled concrete aggregate (RCA) to replace 50% of both fine and coarse aggregates. The primary objectives were to design a concrete mix that maintains properties comparable to conventional concrete, reduces environmental impact by substituting waste materials for cement, and achieves cost efficiency.

Keywords: Green concrete, Fly ash, Recycle Concrete Aggregate.

INTRODUCTION

Concrete is the second most widely used material in the world after water, contributing approximately 8 to 10 percent of global CO2 emissions [1]. This significant environmental impact underscores the necessity of reducing cement consumption and exploring more sustainable alternatives. Green concrete, introduced in Denmark in 1998, represents a pivotal development in concrete technology. Despite its name, green concrete is not related to colour rather, it is designed to address environmental concerns by minimizing pollution and reducing the carbon footprint of concrete production.

Green concrete is a highly advantageous material for construction due to its superior thermal and fire resistance properties. It also enhances the damping resistance of structural elements. When compared to conventional concrete, green concrete can achieve higher compressive strength with an appropriate water-to-cement ratio while maintaining similar flexural strength. Furthermore, green concrete generally demands less maintenance and repair over its lifespan. In this research, we explored the use of fly ash as a partial replacement for cement at levels of 0%, 20%, 25%, and 30%, and replaced 50% of both fine and coarse aggregates with recycled concrete aggregate, through various parameters such as slump, compressive strength, flexural strength, and cost-effectiveness.

LITERATURE REVIEW

Concrete is increasingly utilized in the construction of buildings and other infrastructure worldwide. However, cement, a critical component of concrete, poses significant environmental challenges due to its production processes. To address this issue and mitigate environmental impact, extensive research has focused on improving concrete's constituent materials without compromising its performance. One promising solution is the development of green concrete, which incorporates eco-friendly materials by partially substituting traditional cement with waste-derived resources. This approach offers a viable strategy for enhancing the sustainability of concrete while maintaining its essential properties. Gauri Aglave et al. (2020) investigated the cost-effectiveness and performance characteristics of conventional versus green concrete. Their study involved partially replacing cement with fly ash and substituting fine aggregate with a blend of 50% glass powder and 50% crushed debris. The findings indicated that the properties of green concrete were comparable to those of conventional concrete. Notably, green concrete demonstrated a lower economic cost, highlighting its potential as a more sustainable and cost-effective alternative in construction applications. Building on this, Neeraj Agarwal et al. (2018) examined the compressive strength and economic implications of partially replacing cement with glass powder and fly ash. Their research demonstrated that cement can be effectively substituted with these materials up to a replacement level of 45% without compromising concrete quality. However, they noted that exceeding this threshold could negatively impact the performance of the concrete, thus establishing a practical limit for such substitutions. Further expanding on alternative materials, Ronak Malpani et al. (2014) explored the effects of replacing fine aggregate with marble sludge powder and quarry dust. Their study found that using substantial amounts of marble powder and quarry dust resulted in lower slump values, which in turn decreased the workability of the concrete. The authors suggested that the use of admixtures could mitigate this issue. Despite the reduced workability, the study highlighted the cost-saving benefits of incorporating quarry rock dust and marble sludge powder as fine aggregates in concrete production, reinforcing the viability of these materials as sustainable alternatives.

METHODOLOGY

The concrete mix design **Fig. 1** for both conventional and green concrete was performed in accordance with the specifications outlined in IS: 10262-2009. The design focused on achieving an M40 grade of concrete. The mix proportions for both types of concrete are detailed in **Table_1.** For the experimental investigation, concrete samples were prepared as follows:

Conventional Concrete: Six cubes of dimensions 150 mm× 150 mm × 150 mm and six beams of dimensions 100 mm × 100 mm × 500 mm were cast for conventional concrete.

Green Concrete: Six cubes of dimensions 150 mm × 150 mm × 150 mm were prepared with cement replaced by fly ash at 20%, 25%, and 30% levels. Additionally, 50% of both fine and coarse aggregates were replaced with recycled concrete aggregate, and six beams of dimensions 100 mm × 100 mm × 500 mm were cast with 20% of the cement replaced by fly ash and 50% of both fine and coarse aggregates replaced with recycled concrete aggregate.

Fig 1: Process of maxing and casting of specimens

Table_1: Mix design portion

Concrete Type	Material (kg)						
	Cement	Fly ash	Water	Coarse (Fresh)	Fine (Fresh)	Coarse (RCA)	Fine (RCA)
0%	400	0	152	1158	718	0	0
20%	320	80	122	596	346	596	346
25%	300	100	124	600	349	600	349
30%	280	120	106	604	351	604	351

RESULT

The workability of the concrete mixtures was evaluated prior to hardening. The results of these assessments, including slump measurements for all concrete samples, are presented in **Fig 2**. This table provides a comparative analysis of workability between conventional and green concrete mixes. Following the curing period, compressive and flexural strength tests were conducted to evaluate the structural performance of the concrete samples. The results of these tests provide insight into the mechanical properties and durability of both conventional and green concrete formulations.

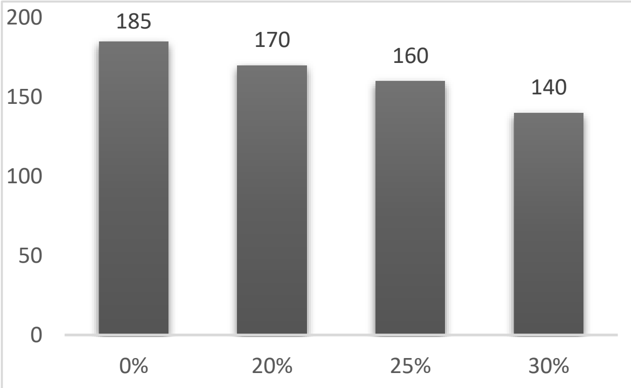

Fig 2: Slump result

Table_2: Compressive strength

Sample	Compressive Strength in 7 Days (N/mm²)			
	0%	**20%**	**25%**	**30%**
N1	38.49	39.30	38.49	33.40
N2	41.29	41.40	41.29	35.20
N3	39.00	41.10	39.00	35.50
Average	**39.60**	**40.69**	**39.60**	**34.70**

Sample	Compressive Strength in 28 Days (N/mm²)			
	0%	**20%**	**25%**	**30%**
N4	54.80	58.00	54.80	48.89
N5	56.30	50.10	56.30	50.18
N6	59.60	55.80	59.60	48.49
Average	**56.90**	**54.70**	**56.90**	**49.19**

Table_3: Flexure strength of concrete beams.

Samples	Conventional Concrete		Green Concrete	
	7 Days (N/mm²)	**28 Days (N/mm²)**	**7 Days (N/mm²)**	**28 Days (N/mm²)**
N1	3.40	-	3.40	-
N2	4.10	-	4.10	-
N3	3.80	-	3.80	-
N4	-	5.30	-	5.30
N5	-	4.80	-	4.80
N6	-	5.10	-	5.10
Average	**3.80**	**5.10**	**3.80**	**5.10**

Table_4: Cost compression of conventional and green concrete.

Material	Conventional Concrete		Green Concrete	
	Amount (Kg)	Price (INR)	Amount (Kg)	Price (INR)
Cement	400	2600	320	2080
Coarse Aggregate (Fresh)	1158	46321	596	23840

Fine Aggregate (Fresh)	718	32310	346	15570
RCA Aggregate	0	0	942	376
Fly ash	0	0	80	104
Total	**2432**	**81230**	**2284**	**41970**

CONCLUSION

The experimental results indicate that green concrete, which incorporates environmentally friendly materials, presents a viable option for reducing the ecological impact of construction activities.

The compressive strength of green concrete was found to be comparable to that of conventional concrete, with no significant differences observed. Additionally, as illustrated in **Table_3** green concrete demonstrated superior flexural strength compared to its conventional counterpart. Notably, green concrete also offers considerable economic advantages as shown in **Table_4**, with a cost reduction of approximately 52% per cubic meter compared to conventional concrete.

Moreover, green concrete utilizes waste materials such as glass powder, fly ash, and recycled concrete aggregate, which are environmentally benign and do not require additional industrial processes for their production. The use of these materials contributes to reducing carbon dioxide emissions, as each kilogram of cement produced generates approximately 900 kilograms of CO2, representing 8 to 10% of global pollution. By substituting traditional cement with green alternatives, we can significantly reduce CO2 emissions, with an estimated savings of 1 kilogram of CO2 per kilogram of cement replaced.

In conclusion, green concrete not only addresses environmental concerns by utilizing waste materials but also offers economic and performance benefits, making it a promising alternative to conventional concrete.

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