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COMPARATIVE STUDY of GREEN CONCRETE and PCC BLOCK with FERROCEMENT JACKETING

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Abstract: Concrete structures tend to deteriorate with time and exposure due to faulty construction, cracking and even may collapse due to increase in service load. Ferrocement Jacketing is an old technology, which is widely used as a construction material with modern technology in developed and developing countries. It is one of the cost-effective materials for strengthening of concrete structures due to its improved structural properties. Today the worldwide consumption of concrete is around 30 billion which directly or indirectly leads to natural hazard. For a feasible and sustainable approach green concrete will be more considerable. In this experimental based study green concrete is designed by replacing river sand by manufactured sand which will be strengthened with the help of Ferro cement jacketing technique under the same environment conditions and same mix design composition in order to study the comparison between the strength of green concrete and conventional concrete separately and with or without jacketing.

Keywords: Ferrocement jacketing, Cost-effective, Green concrete, Manufacture sand/ M-sand, Natural hazard

I. INTRODUCTION

The CO2 emission due to the daily production of concrete holds up to 5% of the total world CO2 emission. [1]. The greater need to study and analyse green concrete with a cautious prospect arises from the fact that green concrete has lesser negative environmental effect when compared to the conventional plane cement concrete (PCC) [2]. This positive front of green concrete formulated a dominant effect over generally used PCC or the conventional concrete, which eventually lead engineers to study, adopt and apply green concrete more often. Green cement concrete or GCC is a term given to the concrete which has one or more than one of its constituents as a green material. Broadly the concrete whose production is sustainable and has less carbon emission, having a positive or neutral effect on environment than those of normal plane cement concrete (PCC) is recognized as green concrete . [2]Green material, a term used to refer the material which emits less carbon from the events of its production till its application, destruction and even at a further stage of reusability which is also environmentally sustainable. The central goal of green concrete is to reduce the environmental impact. To provide external strength to the already existing structure is called as retrofitting technique, the use of ferrocement for the retrofitting is considered to be better and successful than the use of carbon fibre and steel jacketed strengthening methods. [3]. With extensive and large-scale use of green concrete it would be of knowledge to study its compressive strength under a retrofitted technique. Thus, this study was conducted conforming to the IS codes discusses and compares the compressive strength between plane cement concrete (PCC) cubes with green cement concrete cubes (GCC) at 3, 7 and 28 days of curing and PCC having ferrocement jacketing with GCC having ferrocement jacketing each at 28 days of curing period.

II. RELATED WORK

Ferrocement has been acknowledged as a great retrofitting method which has been studied by researchers in different aspects. Some related works are identified, Stress and strain studied on column when jacketed by ferrocement having multiple layers of wire mesh, showing that the strength increases with the increase in the number of layers of wire mesh. [4]. The use of finite element analysis to investigate the behaviour of the reinforced concrete beams with different inner angle and orientation of the wire mesh has also been studied. [5]. Combined replacement of cement by % weight of cement with silica fume and manufactured sand has been studied. [6] In this study an initiative is taken to present a

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comparative strength study between green concrete and plane cement concrete, green concrete and plane cement concrete both when jacketed with ferrocement having single wire mesh of interior angle 90° or square type wire mesh.

III. MATERIAL

To assess the study between PCC and GCC cubes, material used for PCC and GCC are as follows, pozzolana Portland cement grade 53 (PPC conforming to IS 1489 part 1), natural sand of zone 2 conforming to table 4 of IS 383 as fine aggregate and coarse aggregate of nominal size 20mm were used for PCC cubes. For GCC cubes the material and quality used for coarse aggregate and cement was identical to that of PCC cubes except for natural sand which was altered with manufactured sand or M-sand belonging to the zone 2 conforming to table 4 of IS 383. The specific gravity for river sand was 2.46, for manufactured sand it was 2.73 and 2.74 for coarse aggregate

A. **MANUFACTURED SAND (A sustainable and green material).**

Manufactured sand is produced by crushing stones/rocks (hard granite stone) with the help of vertical shaft impact (VSI) crusher. The sand acquired from this process is often found with very less surface roughness and with improved particle shape due to the process of attrition which is a result of the use of (VSI).

The total global consumption of natural sand annually is around 40 to 50 billion tons of sand. The ascending shortage of natural sand directly results to the increase in the value and cost of the natural sand. Significant major issue to be pondered upon are related to the harm full environmental effect due to excessive consumption of sand, such as decrease in water bed level, erosion of nearby land and disruption of flora and fauna. Hence M sand providing as a sustainable replacement of natural sand is the need of future. [7].

Materials used for ferrocement jacketing were sand cement mortar, PPC, natural sand and GI wire mesh of 90° internal angle, having 15mm internal spacing and diameter of wire 1.5mm

Moulds used for PCC and GCC cubes without ferrocement jacketing were of metal having inner dimension dimensions 150mm×150mm×150mm. Custom moulds were made for the cubes on which ferrocement jacketing was to be applied, these moulds were constructed of plywood having dimension of the Moulds as 300mm in length, 300mm wide and height of 175mm. A gap of 10mm from bottom of the mould at the inner side was provided with the use of a wooden stub of dimension 25mm×25mm×10mm as seen in the figure no. 1. The dimension of cube itself with jacketing after demoulding came out to be 200mm×200mm×150mm (since 10 mm gap was provided from top and bottom). This clear gap was provided so that the load is directly applied on the cube's surface to neglect the load to be applied on the jacketing since the load is directly carried out by the members of the structure and not by the jacketing provided in any structure.

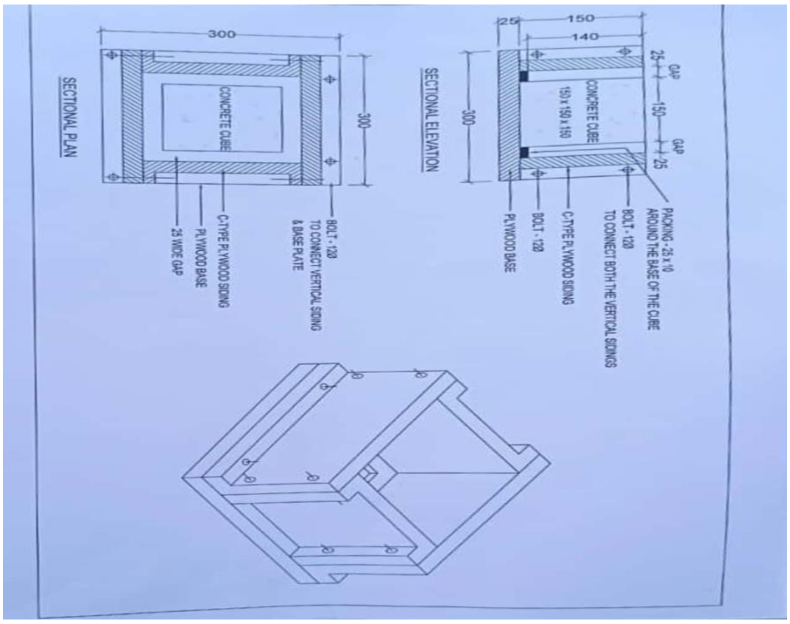

Fig 1. Design of mould

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Fig. 2. Mould for ferrocement.

IV. MIX DESIGN

The mix design for grade of concrete M20 was prepared conforming to IS 10262 2019. Mix design for PCC and GCC was identical having a water cement ratio of 0.5. The design strength for the proposed mix design was 20 MPa and target strength was 26.6 MPa. 10262:2019). Specific gravity of aggregate plays important role in mix design. As strength of concrete varies with respect to the specific gravity of coarse and fine aggregates. The cement sand and coarse aggregate ratio of 1:1.5:3 was maintained uniform for both PCC and GCC. The sand cement and water ratio for cement mortar used for the jacketing of the cubes was 2:1:0.5 with water cement ratio of 0.45.
The water cement ratio and cement sand and aggregate ratio was kept similar between PCC and GCC to obtain results which allows us to compare them since the mix design, design strength and target strength are all equal in the designing part of the study.

V. TEST PERFORMED

The following preliminary tests were performed;
Sieve analysis test following IS-2386 –1963 part-1. From this test the particle size distribution curve was formulated, it was determined that both the type of sand belonged to zone 2 of table number 9 of IS code 383:2016. Further it was determined that M-sand was well graded and river sand was gap graded sand.
Slump cone tests were performed during the casting of cubes results were as such
For batch A (Plain Cement Concrete) = 80 mm for batch B (Plain cement Concrete) =75 mm For batch C (Green cement Concrete) =75 mm For batch D (Green Cement Concrete) = 85 mm.

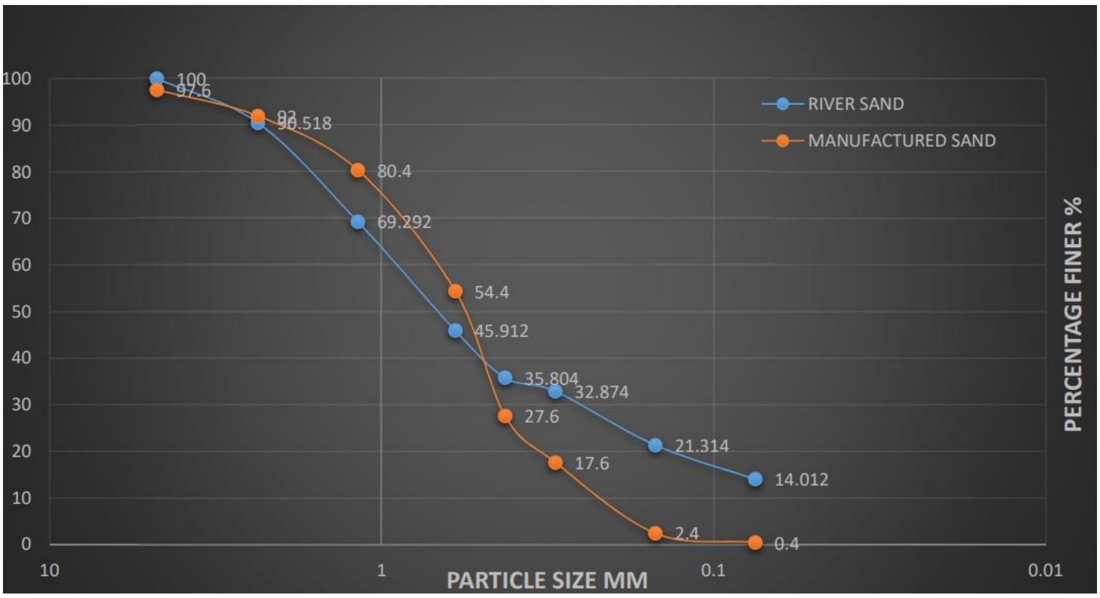

Fig. 3. Particle size distribution curve.

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Determination of specific gravity was done through IS code 2386-1963 part-3.
Specific gravity for M-sand, natural sand and coarse aggregate were 2.73, 2.46 and 2.74 respectively.
Crushing value test and Impact value test according to the IS code 2386- 1963 part-4 was performed.
Compressive strength of concrete was determined by IS-4031-part-8.
Determination of consistency of standard cement paste was found out following the IS code 4031-1988 part-1. The consistency was found to be 34%.

VI. METHODOLOGY

A total of 36 cubes were casted, which were divided into 2 Halves as 18 cubes belonged to the PCC and 18 to the GCC out of which the 18 cubes under PCC were further divided into 2 parts, 9 for non-jacketed PCC cubes termed as batch A and 9 for ferrocement jacketed PCC cubes termed as batch B. Similarly, the division of 18 cubes for GCC was further followed by 9 for GCC non-jacketed cubes termed as batch C and 9 cubes for GCC ferrocement jacketed cubes termed as batch D.

TABLE I. Distribution of Cubes.

PCC (18 cubes)		GCC (18 cubes)	
Non jacketed Batch A	Jacketed ferrocement cubes Batch B	Non jacketed cubes Batch C	Jacketed ferrocement cubes Batch D
9 cubes	9 cubes	9 cubes	9 cubes

A. Procedure.

The concrete mix was prepared by first dry mixing of all materials. Then adding water to it and mixing it properly. All the moulds were properly cleaned and greased. Moulds were filled with the concrete mix in 3 layers, each layer was tamped by using the tamping rod before putting the next layer. The demoulding was done after 24 hours. The batches of cube made were:
Batch A and Batch C, these cubes were cured in water tank and tested on an interval of 3, 7 and 28 days from their date of casting.

Fig. 4. Casted Concrete cubes batch A and C respectively.

Batch B and Batch D, these cubes were prepared for the testing of ferrocement jacketing these were cured in water tank for 28 days. After 28 days the ferrocement jacketing of these cubes was conducted.

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Fig. 5. Casted Concrete cubes batch B and D respectively.

For Jacketing of batches B and D, mesh was cut in the shape of a rectangle of dimension 700mm X 150mm and folded around the concrete cubes for jacketing. Corner of the cubes were rounded and the sharp edges were made blunt with the help of signature paper. Hacking of cubes were done to in order to make the surface of the cube rough so that the new concrete mortar that is used for jacketing can properly get a hold of the surface of cubes. The concrete mix was made by first mixing the dry mix i.e., cement and sand and then water was added to it and cement mortar was prepared. The properly chiselled cubes were then kept in the moulds. The mesh was then placed in the mould, around the cube. Concrete mortar was filled in the cube and levelled so that the top surface of the cube is not covered by the new cement mortar. Table vibrator was used to compact all the cubes so that no voids are left in the cube. Cubes were demoulded after 24 hours of jacketing and then the cubes were submerged in the water tank for curing.

Fig. 6. Ferrocement jacketed PCC cubes

Fig.7. Wire mesh.

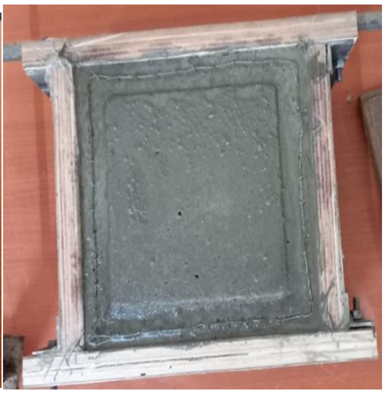

Fig. 8. Top view for jacketed cubes.

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These jacketed cubes of Batch B and D were then cured in water tank for 28 days so as to gain strength mainly for the Jacketing provided. These cubes were tested after 28 days of curing of the ferrocement jacketing. Thus, getting cured for a total of 56 days.

Fig. 9. Ferrocement jacketed GCC cubes.

VII. RESULTS

TABLE II. Compressive strength of blocks from batch A (PCC), 3rd day of testing.

CUBE NUMBER	STRENGTH N/mm²
1	13.83
2	14.44
3	13.37

Average: 13.88 N/mm²

TABLE III. Compressive strength of blocks from batch C (GCC), 3rd day of testing.

CUBE NUMBER	STRENGTH N/mm²
1	10.4
2	11.184
3	10.438

Average: 10.67N/mm²

TABLE IV. Compressive strength of blocks from batch A (PCC), 7th day of testing.

CUBE NUMBER	STRENGTH N/mm²
4	17.21
5	17.42
6	14.62

Average: 16.41 N/mm²

TABLE V. Compressive strength of blocks from batch C (GCC), 7th day of testing.

CUBE NUMBER	STRENGTH N/mm²
4	13.55
5	17.06
6	13.33

Average: 14.65 N/mm²

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TABLE VI. Compressive strength of blocks from batch A (PCC), 28th day of testing.

CUBE NUMBER	STRENGTH N/mm²
7	26.85
8	27.20
9	31.02

Average: 28.35 N/mm²

TABLE VII. Compressive strength of blocks from batch C (GCC). on 28th day of testing.

CUBE NUMBER	STRENGTH N/mm²
7	27.68
8	22.35
9	23.73

Average: 24.58 N/mm²

For the calculation of strength, the surface area considered is the one on which load is applied directly which will be 150mm×150mm.

TABLE VIII. Compressive strength of blocks from batch B (PCC with ferrocement jacketing). 28th day of testing.

CUBE NUMBER	STRENGTH N/mm²
1	58.66
2	62.04
3	58.31
4	60.93
5	62.08
6	58.35

Average:60.06 N/mm²

TABLE IX. Compressive strength of blocks from batch D (GCC with ferrocement jacketing). 28th day of testing.

CUBE NUMBER	STRENGTH N/mm²
1	53.77
2	49.68
3	52.84
4	55.11
5	50.57
6	56.17

Average: 53.19 N/mm².

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Fig. 10. Cracks in PCC ferrocement jacketed cubes.

Fig. 11. Cracks in GCC ferrocement jacketed cubes.

By the experimental based study, it is clearly visible that PCC had gained 69% strength after 3 days of curing and GCC had gained 53% strength of designed strength

After 7 days of testing PCC had gained 82% of strength and GCC had gained 73% times of designed strength.

After 28 days of testing PCC had gained 141% of strength and GCC had gained 122% of designed strength.

It can be seen that ultimate strength of PCC is still greater than GCC but the GCC has also yield the resultsupto the mix designed.

28 days compressive strength of jacketed cubes has given surprising gain of 211% for PCC & 216% for GCC.

VIII. DISCUSSION

The addition of the M-sand results in the reduction of workability. [8] this could be adjusted with the use of water reducing admixture such as superplasticizer. This study did not include the addition of any admixture.

When 20% of M-sand is replaced with fine aggregate (natural sand) in the mix, performs most economical and provides higher compressive strength in presence of admixtures. [9]. In this study 100% replacement of M-sand with natural sand was conducted for the GCC cubes with no addition of admixtures.

Vertical cracks are visible, no significant pattern is found which would suggest that cracks were formed only at the part of the jacketing where wire mesh was connected (overlap of wire mesh). In some cubes a fine gap could be observed between the jacketing and the cube which might be due to lack of bonding although proper hacking was insured, this might be a result due to the hoop stress provided by the cube on the jacketing when under load.

IX. FUTURE SCOPE.

This study has been conducted with the main significance of sustainability, green material and green environment it is an effort to gain knowledge in this domain of study for reference towards the future work. The following are a few methodologies and techniques with which the study can be modified.

The use of nano materials in the concrete mix.

Use of sisal fibres, extracted from sisal plants.

Use of green materials in the mortar used for ferrocement jacketing.

Addition of admixtures for workability adjustments of the concrete consisting M-sand.

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Mixture of fibres and mesh which is often termed as fibrous ferrocement.
Study of various other elements of a structure such as Strength of RCC column made up of green concrete and when jacketed with ferrocement

X. CONCLUSION

From the study it can be concluded that use of M-sand with 100% replacement of the natural sand levels up and matches designed strength according to the mix designed for the concrete cubes. The addition of ferrocement jacketing with single layer of wire mesh improves the strength of the concrete by almost doubling the initial strength of the cubes.

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