Experimental study on compressive strength of concrete cubes with internal ferrocement jacketing using *single- and double-layer* reinforcement.

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Abstract—**Concrete is one of the most widely used construction materials in the world due to its compressive strength and durability. However, over time concrete structures may experience deterioration due to environmental effects, overloading, poor construction practices, and aging. This reduction in strength affects strengthening and retrofitting techniques.**

In this research paper the flexural and compressive strength of normal concrete cube and the cube with internal steel mesh confinement with square opening size and cube with the combination of two layers of meshes and that steel mesh confinement on cube is compared, in previous research paper we have seen use of wire mesh, steel plate, epoxy resin with beam show measure enhancement in ductility.

Ferrocement jacketing is an effective technique used for strengthening concrete structures. In this study, the effect of ferrocement jacket on the compressive strength if concrete cubes have been investigated. Ferrocement jackets have a simple, economical, and efficient method for improving the strength and performance of concrete structures.

In this experimental study, the compressive strength of cubes with internal ferrocement jacket is investigated and compared with plain concrete cubes. 36 specimens were prepared including plain concrete cubes, single reinforcement cubes, and double reinforcement cubes.

Three types of specimens were prepared, namely plain concrete cubes, single layer ferrocement jacketing, and double layer ferrocement jacketing. The cubes were cast using the M30 design mix ratio and cured for 7, 14 and 28 days. Ferrocement jacketing was applied using square shape wire mesh. After curing, all specimens were tested under a compression testing machine (CTM). The results obtained show that the compressive strength of ferrocement jacketed cubes was higher than that of plain concrete cubes. Moreover, double layer reinforcement provided greater strength enhance11ment compared to single layer reinforcement. The study concludes that ferrocement jacketing is a simple, economical, and effective method for improving the strength of concrete elements.

The study concludes that internal ferrocement jacketing enhances the loading carrying capacity of concrete cubes and can be effectively used as strengthening techniques in structural application.

I. INTRODUCTION

Concrete is one of the most widely used construction materials due to its high compressive strength and durability. However, over time, concrete structures may suffer from deterioration due to environmental effects, overloading, poor construction practices, and aging. This leads to a reduction in strength and performance of the structure. Therefore, strengthening and rehabilitation techniques are required to enhance structural performance.

The demand of durable and sustainable construction materials is continuously increasing day by day, despite its advantages, concrete structures loss its strength due to environmental exposure, corrosion of reinforcement, overloading, poor workmanship and aging. These factors lead the cracks and reduction in strength. Therefore, it becomes essential to adopt effective strengthening techniques to enhance the

performance of concrete structures.
For improving the behavior of concrete, various methods are used such as epoxy resin fiber reinforcement, steel reinforcement, glass fiber reinforcement, and different layers of wire in horizontal direction, steel plate, polymer material etc.
Ferrocement is a type of reinforced concrete in which layers of wire mesh are embedded in a cement mortar to improve strength and ductility. It was first introduced by P.L. Nervi, who explained its potential in constructing lightweight but strong structure elements.

Ferrocement is widely used in thin shell structures, water tanks, repair works and strengthen application due to its excellent crack resistance property. One of the most effective applications of ferrocement is jacketing.
Use of steel mesh with cubes is an economical method to improve the strength of cubes.
Internal ferrocement jacketing is a method in which we used layers of meshes internally. This improves the load carrying capacity and strength of structure. It is an economical and efficient method of strengthening.

The main objective of this study is to investigate the effect of internal jacketing on the compressive strength of concrete cubes. The study also compares the strength of plain concrete cubes reinforced with a single and double layer of ferrocement mesh. The study also aims to highlight the effectiveness of ferrocement as an economical and efficient strengthening technique for civil engineering.
This research will contribute to the understanding of internal reinforcement techniques and provide useful insights for engineers and researchers working in the field of structural strengthening and retrofitting.

II. LITERATURE REVIEW

Ferrocement has been widely studied as a strengthening and retrofitting material due to its high tensile strength, crack resistance, and cost effectiveness.
Many researchers have worked on this ferrocement reinforcement to improve its mechanical properties, compressive and flexural strength. here are some of them are:

2.1. Nervi *(1943)*, who is considered the pioneer of ferrocement technology, demonstrated the use of wire mesh reinforcement in thin structural elements. His work shows that ferrocement structure possesses high strength to weight ratio and improves durability. This laid the foundation for further research in the field of ferrocement and its application.

2.2. Comparative study on strength of ferrocement panels and normal cement mortar panels (N. Jayaram Appa), in this they apply wire mesh ,8mm steel bar and normal cement mortar panels, they get strength ratio in increasing by order from plain to wire mesh and from wire mesh to steel bar with wire mesh.

The result of this study is the specimen are tested for ultimate loads. The failure loads of normal cement mortar cubes and ferrocement cubes for compression test and for normal cement mortar panels and ferrocement panels for bending and they compare between these two and the result proves that ferrocement can take higher ultimate loads than normal cement mortar.

The conclusion of this study is the compressive strength of ferrocement cubes is higher than the normal cement mortar cube at the age of 28 days and also the flexural strength of ferrocement panels is higher than the normal cement mortar panels at the age of 28 days.

2.3. To increase compressive strength of ferro Crete block (*prof. Nikhil H. Pitale)*, they use different types of meshes such as square woven wire mesh, square welded wire mesh, hexagonal wire and expanded metal, in this study they apply meshes horizontally, vertically and spiral reinforcement.

In this experimental study, when meshes are oriented horizontally, the compressive strength of blocks is increased by 47.45% when three meshes are laid if compared with non-reinforced blocks. And when 6 meshes are laid, a 67.10% increase in strength can be achieved if compared with a non-reinforced block.
So, we can say that ferrocement is constituted in a long way optimized material, it can be expected that

the material will evolve and the requirements for improvements will be used as light weight better utilization material it prevents cracking and improved impact resistance

2.4. Effect of wire mesh type on strengthen reinforced concrete beam (Basil S. Al Shathr), in this they also use different type of meshes but there is a different they tighten the mesh with the help of screw, and they got the square mesh have best strengthen capacity.

In this, they noticed that there was no debonding between any of the three types of ferrocement layers from reinforced concrete beams due to the applied loading.

III. MATERIAL USED

The selection of materials plays a crucial role in determining the strength and durability of concrete. In this experiment study, all materials were carefully as per our mix design.
The materials used for preparation of concrete cubes are followings:

3.1. Cement

Ordinary Portland Cement (OPC 43 Grade) was used. The cement was fresh, free from lumps, and stored in dry condition. “The cement is a binding material that holds the aggregates and sand together and contribute significantly to compressive strength of concrete.”

Table No. 3.1 Chemical composition of OPC

OXIDE	PERCENTAGE CONTENT
CaO	60-67
SO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	O.1-4
ALKALIES (K_2OM, NA_2O)	0.4-1.3
SO_3	1-3

Fig. Collecting materials

3.2. Fine Aggregate

Clean River Sand, which is clean and free from impurities such as silt, clay, and organic matter. The sand conformed to the requirements of IS 383. “The proper grading of fine aggregate ensures better workability and reduce voids in concrete.”

3.3. Coarse Aggregate

Crushed stone of maximum size 20mm were used as coarse aggregate. The aggregates were angular in shape, clean and free from dust. “The use of well graded coarse aggregate improves the strength and reduce the cement requirement.”

3.4. Water

Clean and portable water was used for both mixing and curing concrete. The water was free from harmful substances such as oils, acids, alkalis, and salts. “A water cement ratio of 0.45 was maintained throughout the experiment to achieve the desire workability and strength.”

3.5. Wire Mesh

Galvanized square shape iron mesh. (Reinforcement), The mesh was selected due to its good tensile strength, corrosion resistance and easy availability.

Two types of reinforcement were used:

3.5.1. Single layer mesh reinforcement

3.5.2. Double layer mesh reinforcement

“The mesh provides confinement to the concrete, which enhances its compressive strength and also control cracks.”

IV. METHODOLOGY

The methodology adopted in this experimental study involves the systematic preparation, casting, curing, and testing of concrete cube specimens with and without reinforcement.

The concrete mix is prepared with fine aggregate (sand), coarse aggregate, cement, and steel wire mesh with water cement ratio of 0.45.

Fig. During Molding

The experimental methods and term we used firstly we divide the molding types in three different way the first one is plain cubes without reinforcement we say G1, the second one is single layer reinforcement cube in this we use only one surrounded layer in cubes we say G2 and the third one is double layer reinforcement in cube in this we use two layers of meshes in cubes we say G3.
We mold a total of twenty-seven cubes in this. There are nine plain cubes, nine single layer reinforcement cubes, and double layer reinforcement cubes.

4.1. Mix Design

We design M30 as per IS10262:2019 on MS Excel with that also it can design any design mix by just mentioning the input it calculates the ratio automatically, The M30 design mix ratio is 1:1.5.3

4.2. Preparation of Specimens

The cube specimen size is 150mm*150mm*150 mm, before casting the cube there should be no cement mortar attached with mold that obstruct the mold, set all the bolt should be tight, the inner surface of the mold should be lubricated with oil to avoid concrete sticking.

All the cube mold is cleaned before casting, the size of steel mesh is 100mm*100mm*100mm and 50mm*50mm*50mm from all side provided; after preparing the concrete mix it is placed in mold in three layer and it is compacted with tamping rod for 35 times, tamping rod height is 300 mm and 16 mm diameter.

4.3. Types of Specimens

Three types of specimens were prepared:

4.3.1. Plain concrete cube (without reinforcement)

4.3.2. Concrete cubes with single layer mesh reinforcement

4.3.3. Concrete cubes with double layer mesh reinforcement

Each category consisted of specimens tested at 7,14 and 28 days of curing.

Fig. After Molding & during molding

4.4. Internal Ferrocement Jacketing

For reinforced specimens, ferrocement jacketing was provided internally using galvanized steel mesh.
A hollow 3D rectangular shape mesh was prepared with two different spacings. The first one is a 25 mm cover provided, and another 50 mm cover provided.
The purpose of providing an internal mesh was to confine the concrete and improve its load carrying capacity. The mesh helps in distributing stress uniformly and prevents cracks.

4.5. Curing

After casting the cube is allowed to set for 24 hours and then it is taken out of mold and placed in immersion for 7, 14 and 28 days, the temperature of water should be 27+2 degrees.

4.6. Workability Test

The workability of fresh concrete was measured using slump cone test, the true slump obtains and the value was 80mm, which indicates medium workability suitable for normal reinforced concrete work

4.7. Testing Procedure

After the completion of curing periods, the specimen was removed from the water tank and allowed to dry for some time. The surface of the cubes was cleaned to remove excess moisture and dust.

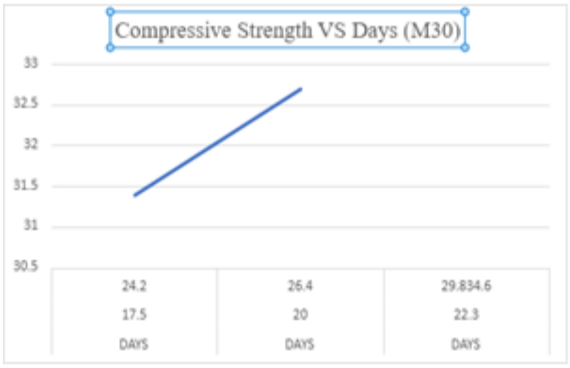
After curing, the cubes were tested for compressive strength using a Compression Testing Machine (CTM). The load was applied gradually until failure (crack) occurred, and the maximum load was recorded.

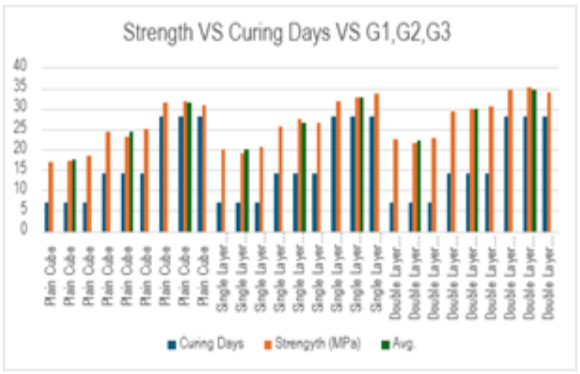
"Compressive strength is the ratio of load and cross-sectional area."

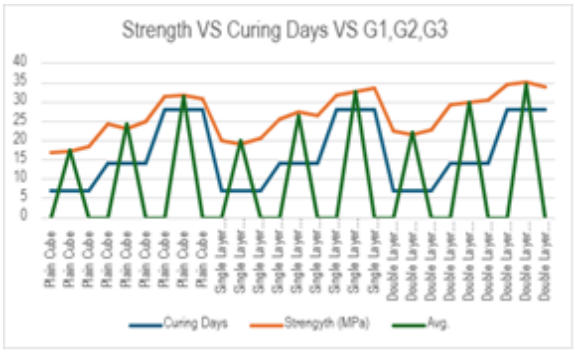
V. RESULTS

After the curing, the cube specimen is taken out from the water tank and held for some time and removes water from the surface of the cube and cleaned with cloth to remove unwanted particles from the cube.

To check its compressive strength, we use a compressive testing machine, and cubes are placed in two plates, and the load is gradually increasing on cubes. Compressive strength is the ratio of maximum load and area of specimen.







Specimen	Curing Days	Strength (MPa)	Avg
Plain cube	7	16.8	
Plain cube	7	17.3	17.5
Plain cube	7	18.4	
Plain cube	14	24.5	
Plain cube	14	23	24.2
Plain cube	14	25.1	
Plain cube	28	31.4	
Plain cube	28	31.8	31.4
Plain cube	28	31	
Single Layer Reinforcement	7	20.1	

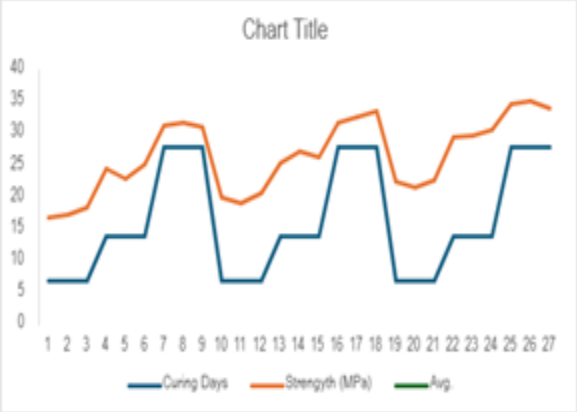
Single Layer Reinforcement	7	19.2	20
Single Layer Reinforcement	7	20.7	
Single Layer Reinforcement	14	25.5	
Single Layer Reinforcement	14	27.3	26.4
Single Layer Reinforcement	14	26.4	
Single Layer Reinforcement	28	31.8	
Single Layer Reinforcement	28	32.7	32.7
Single Layer Reinforcement	28	33.6	
Double Layer Reinforcement	7	22.4	
Double Layer Reinforcement	7	21.7	22.3
Double Layer Reinforcement	7	22.8	
Double Layer Reinforcement	14	29.4	
Double Layer Reinforcement	14	29.8	29.8
Double Layer Reinforcement	14	30.6	
Double Layer Reinforcement	28	34.6	
Double Layer Reinforcement	28	35.2	34.6
Double Layer Reinforcement	28	34	

Strength Comparison table 1.1

VI. CONCLUSION

The experimental results obtained from the compressive strength test clearly show the internal ferrocement jacketing performance of concrete cubes. The plain concrete cube has normal strength while the cube with mesh shows the improved higher strength. That means the result also indicates that the effectiveness of jacketing depends on mesh layers, spacing, and positioning with concrete.

Overall, the findings of this study are consistent with previous research, which shows that ferrocement reinforcement enhances compressive strength and structural performance.



VII. FUTURE SCOPE

- Study can be extended to beams and columns.
- Different mesh sizes and layers can be investigated.
- Long term durability studies can be conducted.

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