STRUCTURAL BEHAVIOUR OF RCC MEMBER USING STEEL MESH SUBJECTED TO IMPACT AND DYNAMIC LOADS

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ABSTRACT

The modern problem in structural engineering that involves reinforcing preexisting elements with easily accessible materials, especially RC columns. Some of the more conventional and cutting-edge approaches to reinforcing RC columns' strength have included the use of steel plates, GFRP, and CFRP. Nevertheless, wire mesh is the main focus of this study because it is a possibly cheaper alternative that can be used for strengthening.This study employs an experimental approach to examine the effects of reinforcing RC columns with wire mesh on their structural characteristics. All three of the RC columns that were cast have reinforcement running both longitudinally and transversely. Welded steel wire mesh was used to further reinforce two of these columns; the lateral reinforcement arrangements of the other columns were varied. Later on, the axial compression tests were performed on the columns.The trial results showed that wire mesh is an appropriate material for reinforcing RC columns because it greatly increases the concrete's load-bearing capacity. Wire mesh is comparatively more cost-effective than other rehabilitation approaches like GFRP and CFRP, and it also improves the structural performance of columns under compression, according to the study.Ultimately, the study's findings imply that wire mesh, rather than more costly materials, would be an attractive and economical option for reinforcing RC columns during structural rehabilitation.
The current research problem of utilizing easily accessible materials to reinforce preexisting structural parts, especially reinforced concrete (RC) columns. Some of the more conventional and cutting-edge approaches to reinforcing RC columns' strength have included the use of steel plates, GFRP, and CFRP. Nevertheless, wire mesh is the main focus of this study because it is a possibly cheaper alternative that can be used for strengthening.This study employs an experimental approach to examine the effects of reinforcing RC columns with wire mesh on their structural characteristics. All three of the RC columns that were cast have reinforcement running both

longitudinally and transversely. Welded steel wire mesh was used to further reinforce two of these columns; the lateral reinforcement arrangements of the other columns were varied. Later on, the axial compression tests were performed on the columns.The trial results showed that wire mesh is an appropriate material for reinforcing RC columns because it greatly increases the concrete's load-bearing capacity. Wire mesh is comparatively more cost-effective than other rehabilitation approaches like GFRP and CFRP, and it also improves the structural performance of columns under compression, according to the study.

GENERAL

Infrastructure, which includes things like buildings and transportation, is crucial to a country's economic development. Structural components can fail for a variety of reasons, including poor design or environmental causes, even if structures are engineered with a certain lifespan in mind. Early detection of load-carrying defects and application of suitable strengthening measures can frequently prevent structural failure.This background highlights ferro-cement, a material with enormous promise that was invented in 1940 by Italian architect and engineer P. L. Nervi. Strong, robust, water-resistant, lightweight, ductile, and environmentally stable are just a few of its desirable qualities that have contributed to its rising popularity. The ability to shape ferro-cement into any desired shape, even without formwork, makes it a versatile construction material, distinguishing it from traditional materials like masonry, reinforced concrete, or steel. The ductile behavior is imparted by ferro-cement's high surface area, despite the mortar's lack of ductility, and the thickness usually falls between 10 mm and 25 mm.Reinforced concrete structures are ideal candidates for ferro-cement repairs and reinforcements when it comes to structural restoration. It has a number of benefits over conventional repair methods, including making the building lighter while increasing crack resistance and doing away with the requirement for formwork. Rehabilitative and non-rehabilitative uses alike can benefit from this material's low price tag. In addition, masonry walls and columns can have ferro-cement overlays placed to them to make them more ductile, which improves their performance under stress and makes them last longer.As a whole, the paragraph highlights ferro-cement as a great material for building and repair since it is a practical and affordable choice for reinforcing and restoring structures.

BACKGROUNDANDHISTORY

The paragraph highlights the composition and history of ferro-cement as it examines its features and benefits as a building material. Using hydraulic cement mortar and continuous layers of small wire mesh, ferro-cement is essentially a thin reinforced concrete laminate. The narrow diameter and continuous character of this mesh, which can be formed of metallic or other appropriate materials, enhance its bonding capacity and structural integrity. The term "ferrocement" was first used by Shah (1974) to describe a composite material that combines mortar with fine mesh reinforcement. The mesh adds strength to the mix and improves the bond strength of the mortar by increasing the surface area per unit of mortar.Masood (2003) noted that traditional building materials, such as steel and concrete, exhibit signs of degradation with time, especially when subjected to harmful environmental factors or natural disasters like earthquakes or fires. On the other hand, ferro-cement is a great alternative to traditional cement for building in areas where these problems are common because of its increased durability and resilience.

Ferrocement is a good option in developing nations like Nigeria because the raw components are readily available and building it requires only basic skills. Shell roofs, swimming pools, tunnel linings, silos, tanks, and prefabricated houses—typically with a thickness of less than 25-30 mm—are all possible with this material because of its higher strength capabilities compared to traditional reinforced concrete. One reason ferro-cement is so good is that it's prefabricated, which means it's cheaper, easier to build with, and requires less maintenance than alternatives like wood and steel. Its improved resistance to rot and corrosion makes it ideal for use in saltwater settings.A significant benefit of ferro-cement is its load-bearing capacity, which is comparable to that of reinforced concrete. But the high alkalinity of the cement-rich mortar and the finer mesh reinforcement work together to delay crack growth by spreading small cracks over a large region. The fact that ferro-cement isn't very light doesn't diminish its usefulness or potential, however its weight does restrict its use in particular contexts.The first documented use of ferro-cement dates back to 1848, when Frenchman Jean Louis Lambot built a rowing boat out of the material. The boat is still in excellent shape and is on display at a museum in France. In the 1960s, ferro-cement became popular in many nations, including Australia, New Zealand, and the UK (Biggs, 1968). The material's adaptability and longevity keep it a top choice for numerous building endeavors.There are a number of important reasons why ferro-cement is ideal for developing countries:

Raw Material Availability: Cement and wire mesh, the two main ingredients of ferro-cement, are easily accessible in the majority of developing nations. Because of this, it is an easily accessible and practical building material.

Design Versatility: Ferro-cement's malleability allows it to be formed into practically any shape, satisfying a wide range of building requirements. Using ferro-cement, it is possible to replicate and even enhance traditional architectural patterns. Ferocement is a more economical and long-lasting substitute for materials such as imported steel or wood. This lessens the need for costly imports and makes it a practical alternative to these materials in numerous building applications.The skills needed to build with ferro-cement are easy to pick up and put to use right away. It is typically straightforward to adopt ferro-cement building in developing regions since these abilities often overlap with existing local competence.The use of ferro-cement

in building does not necessitate complex or large pieces of machinery. The low cost of labor in poor nations makes the procedure feasible, despite its labor-intensive nature. Complex designs, such deepwater vessels, may necessitate more sophisticated methods and tools.tresses like twisting, bending, and hammering can induce cracks and fractures in ferro-cement constructions, but they are easy to repair. If sufficient steel reinforcement is added to ferro-cement, the material may absorb these pressures, making it easy to repair. By reducing the likelihood of breaking, this reinforcement ensures that the structure will last.
Durability and Toughness: Compared to other types of concrete, ferro-cement has much higher levels of toughness and crack resistance. An improvement over traditional reinforced concrete, these characteristics can be attained with constructions as thin as 25-30 mm. Structural Integrity: According to Hago's (2005) research, the reinforcement's specific surface area determines both the stress at which the first crack emerges and the spacing of the cracks. When the mortar breaks, the reinforcing takes the brunt of the weight, which is equivalent to the reinforcement's own load capacity. The stress-resistance of ferro-cement is enhanced by this.In areas where resources are scarce, ferro-cement is the material of choice for infrastructure construction due to its versatility, affordability, and durability.

STEEL WIRE MESH

A grid that is prefabricated using electric fusion welding is called welded mesh. The wires run parallel to one another and are welded to the cross wires at the specified intervals. To make welded mesh, the material is usually stainless steel wire or low-carbon steel wire, which makes it long-lasting and corrosion-proof. Depending on the application, welded mesh can be found in a wide range of sizes and shapes.

ADVANTAGES OF USING STEEL MESH:-

Welded wire mesh, made from high-quality low-carbon iron wire using automated machines, offers several advantages, which are outlined below:

1. **Improved Efficiency**: It speeds up construction and reduces the need for large on-site labor teams.
2. **Precision Bending**: Bending machines bend the entire mesh as a single unit, reducing errors from manual bending.
3. **Exact Reinforcement**: Mesh allows for precise reinforcement with adjustable bar size and spacing.
4. **Faster Installation**: Placing welded mesh is quicker than tying individual bars, reducing slab casting time.
5. **Cost Savings**: Faster construction means lower overall costs.
6. **Better Stress Transfer**: Thinner bars can be placed closer together, improving stress distribution and minimizing cracks for a better surface finish.

7. **Less Material Wastage**: Mesh is produced from rolls, which reduces leftover material.
8. **Smaller Storage Space**: It takes up less room at the construction site.
9. **Off-Site Preparation**: Cutting and bending are done in the factory, so there's no need for an on-site rebar yard.
10. **Safer Production**: Working in a controlled factory environment is safer than bending rebar on-site.
11. **Quicker Erection**: The mesh can be quickly placed into position.
12. **Stays in Place**: Once installed, the mesh stays in position and adheres well to concrete.
13. **Easy Handling**: It is easy to unload and install at the worksite, improving overall efficiency.

Building with welded wire mesh is more precise, quicker, and cheaper. In addition to enhancing site safety and quality, it is easy to handle and requires less room when not in use.

APPLICATION OF WELDED WIRE MESH:

There are many more applications for welded wire mesh than building. It is commonly used for things like:When inserted in poured concrete forms, such as slabs and foundations, reinforcing concrete adds strength to the concrete and makes its usage widespread.

Frames: Welded mesh is a versatile material that may be used to make strong frames for a variety of applications.The road strengthening mesh grid is used to strengthen road surfaces and parking lots so they last longer.

- Fencing: Its strength and pliability make it an ideal material for fence construction.Masonry Support: It's a masonry mesh that holds bricks in place.Its primary application is as a supporting mesh to fortify and steady the mine roadways in coal mines.
- Welded wire mesh is an adaptable material that has numerous real-world applications in many fields.

Here are the key benefits of ferro-cement:

Its multi-use in the building industry ranges from simple agricultural structures and self-help dwellings to complex industrial processes involving precast house panels, pipelines, channels, and curtain walls.

Materials Availability: In the majority of countries, the raw materials required to make ferro-cement are readily available. It is perfect for low-tech building because it involves basic labor skills and minimum technology. Heavy machinery is also unnecessary due to its lightweight nature.

The lightweight characteristics of ferro-cement are advantageous in industrial construction, particularly in prefabricated construction, and this material offers several industrial benefits.

Compared to regular reinforced concrete, it weighs significantly less.

- The malleability of ferro-cement makes it an ideal material for intricate and curving structures such as domes, boats, homes, and sculptures.
- Reduced Pollution and Encouragement of Sustainable Resource Use Make Ferro-cement an Eco-Friendly Material.
- When compared to its predecessors, this technology improves upon waste management by recycling more materials and dealing with remaining materials more effectively
- Structures made of ferro-cement are simple to maintain and fix in the event of damage.
- Affordable and long-lasting, it is a great choice for those on a tight budget.
- When considering a variety of building projects, ferro-cement stands out as a practical, ecological, and budget-friendly material.

OBJECTIVES

1. **Increase ductility** in the reinforced concrete column.
2. **Determine maximum strain** using load-deflection analysis.
3. **Determine maximum deflection** for the applied load.
4. **Calculate Young's modulus, ductility, and strain energy** using the stress-strain diagram.
5. **Reduce self-weight of the building** by using mesh, which is lighter than steel bars.
6. **Decrease buckling failure** and compression failure rates in columns.

LITERATURE REVIEW

Results from multiple investigations on ferro-cement's impact on reinforced concrete structures are summarized here, with an emphasis on how it improves the ductility, strength, and performance of slab panels and columns. Using ferro-cement to increase stiffness, dissipate energy, and change failure modes from brittle to ductile flexural failure, Katsuki Takigu chu and Abdullah investigated how steel mesh in columns enhances strength and ductility. Reinforcement kinds and configurations were investigated by M.A. Mansur and P. Paramasivam, who focused on the usage of mesh in a closed cage shape to improve column structural integrity.

After 21 days, M. Pavan Kumar and S. Sandeep showed that ferro-cement columns reinforced with steel welded mesh increased the ultimate strength by 13.3%, reaching a compressive strength of 37.4 N/mm². Shibivarghese and Anagha A.R. verified that ferro-cement confinement increases ductility and load-carrying capacity, with rounded-corner columns exceeding sharp-edged ones. By incorporating ferro-cement formwork, beam specimens were found to have substantially enhanced structural performance, as demonstrated by Anisha G. Krishnan and Allzi Abraham (2016).

This improvement was particularly noticeable when skeletal reinforcement and mesh layers were combined.In their 2015 study, Drs. P. Srichandana and Kamanuru Naga Deepika examined ferro-cement slabs using self-compacting mortar (SCM). They found that SCM improves construction efficiency by doing away with the need for external vibration. These results highlight the versatility, affordability, and enhanced strength of ferro-cement in a variety of building applications, including structural and maintenance work.

EXPERIMENTAL ANALYSIS & DESIGN

MATERIALS USED:-

1. CEMENT

Buildings rely on cement, more especially 53-grade RAMCO ordinary Portland cement, as a binding agent. Particles are so small that they can be passed through a 90-micron IS sieve, which is one of its defining features. The increased surface area for hydration, brought about by the tiny particle size, is one factor that contributes to the development of strength and durability in concrete structures. During building, a smooth and workable mix is achieved in part by the fineness of the cement.

Upon completion of the curing process, 53-grade cement achieves a compressive strength of 53 MPa, which is measured in megapascals. Construction of tall structures, bridges, and other heavy-duty infrastructure projects necessitates concrete with a high compressive strength. Additionally, it is lastingly stable under a variety of loads and pressures because to its strength characteristics.

The setting time of cement is another crucial characteristic. You'll have plenty of time to mix, pour, and complete the concrete with RAMCO regular Portland cement because its initial setting time is about 30 minutes. With a final setting time of 600 minutes, the cement will firm gradually, lowering the risk of early-stage building issues such shrinkage cracks.Another important consideration is the cement's soundness, which guarantees that the material will maintain its dimensions after setting. Cracks or structural problems caused by variations in volume are less likely to occur when expansion is low. Finally, this cement has a moderate heat of hydration, which implies it cures with an even distribution of heat. This is particularly important when pouring large quantities of concrete because it reduces the likelihood of thermal cracking caused by an accumulation of heat. Taken together, these qualities make 53-grade RAMCO cement an excellent and flexible material for a wide range of buildin jobs.

2. FINE AGGREGATE

For cement mortar, the fine aggregate must be devoid of hazardous substances like chloride, silt, and clay, and its grading must be such that void ratios are minimized. If the concrete's water requirement is too high, it could compromise its strength and longevity, so accurate grading is crucial. The fine cementitious particles will be able to fill the maximum number of voids created by the fine aggregate. Because of its role in creating a strong and workable concrete mix, a coarser type of fine aggregate with a high fineness modulus is preferred.

3. COARSEAGGREGATE

In this investigation, coarse aggregate, which is a type of natural shattered stone, had a maximum size of 20 mm. Particles of a size more than 4.75 mm are considered coarse aggregates, and they are essential for the concrete mix because they add bulk and strength. The concrete's strength and longevity are enhanced by the inclusion of these larger-sized particles.

4. WELDED STEEL MESH

There are many dependable uses for stainless steel welded wire due to its strength and longevity. It can withstand long periods of exposure to severe environments without rusting, corrosion, or chemical exposure, so it can keep working. Due to its resistance to corrosion and chemicals, stainless steel welded wire is a great material for long-term applications.

5. REINFORCINGSTEEL

Grade 415 of steel, an extremely durable and strong iron-carbon alloy, finds extensive application in construction and manufacturing. Three columns with different steel combinations were cast for this study.

The first column was cast without the addition of steel mesh as part of the preparation of the column specimens using steel. The main reinforcement consisted of four 16 mm diameter reinforcement bars. To further guarantee structural stability, four 8 mm diameter lateral ties were also supplied. The concrete was effectively contained and the column's load-bearing capability was enhanced by placing the lateral ties 200 mm apart. By removing the steel mesh reinforcement, this design made it possible to test the column's performance.

WATER:

The principal component responsible for the strength of concrete, calcium silicate hydrate (C-S-H) gel, is formed when water chemically reacts with cement, making water an essential component of concrete. Because of its binding activity, this hydrated cement paste is a major contributor to cement mortar's strength. Nevertheless, the strength, durability, and water-tightness of the concrete, among other crucial attributes, might be adversely affected by an excessive water-to-cement (w/c) ratio.

The water that is added to cement should be precisely the right amount to start the chemical hydration reaction. When the cement paste hardens, any surplus of water weakens the structure by creating holes, or capillaries, in it. Too much water weakens the cement paste because its strength is inversely proportional to how much water is added to it. As a result, you need to keep the water content low while yet making sure it's workable and that the cement and additives react completely. Strong, long-lasting, high-quality concrete requires this equilibrium.

STRUCTURAL BEHAVIOR OF CONCRETE

In comparison to a regular beam, the ferro-cement-reinforced column performs better, showing increased cracking and ultimate loads and decreased deflection. A universal testing equipment was used to assess the reinforced concrete column's structural behavior. Deflection was measured at the column's mid-span after subjecting it to axial compression. A dial gauge installed at the center span measured the load and deflection as it was applied to the column's surface. A number of important metrics were determined from the data on load deflection, such as strain, stress, modulus of elasticity, and strain energy. These computations show how ferro-cement improves structural strength and stability, and they shed light on the column's mechanical characteristics and performance under axial compression.

1. WORKABILITYOFCONCRETE

A battery of workability tests was run on the concrete utilized for the columns to determine its workability. Due to the incorporation of wire mesh, the concrete had to be more workable to guarantee proper flow through the mesh apertures. It may be challenging to achieve the desired level of compaction and coverage within the mesh if ordinary workable concrete is used.

This is what the workability tests turned out to be:

A real slump of 126 mm was observed in the concrete during the slump test, which is indicative of acceptable workability and is appropriate for the mesh-reinforced columns.The concrete was able to flow well and fill the areas surrounding the wire mesh during placement because the compaction factor was 0.95, which is a high level of workability.It is clear from these findings that the concrete mixture was adequately workable to fulfill the needs of the reinforced assembly.

2. COMPRESSIVE STRENGTH TEST

The column's design adhered to the specifications of an M20 concrete mix. After 28 days of curing, concrete cubes measuring 15 cm in diameter were used to measure the compressive strength of the mixture using the calculated mix proportion. The mix met expectations, with an average compressive strength of 26.86 MPa measured after seven cubes had cured for 28 days.

ENERGY ABSORPTION

The energy absorption capacity was learned from the load-deflection curves of columns C1, C2, and C3. The area under each curve shows the energy absorbed by the columns during deformation, and these curves show how the columns behave under load. The next figure displays the energy absorption values for each reinforced column; it is clear that reinforced columns, especially those with steel mesh reinforcement, are much better at absorbing energy. Understanding the columns' structural robustness under applied loads is aided by this data.

This is the breakdown of the figure's three columns' energy absorption values: The energy absorbed by Column 1, which did not contain steel mesh, was 829.3 kN/m. The energy absorption rose to 1289.0 kN/m for the steel mesh-reinforced column 2. Column 3, which featured extra steel mesh reinforcing, had the greatest energy absorption, measuring 1612 kN/m. The remarkable improvement in energy absorption for steel mesh columns demonstrates the material's superior load-dissipation capabilities, which in turn make the structure more robust and stress-tolerant.

DUCTILITY

The ability of a material to sustain large plastic deformations before rupturing or breaking is called its ductility. Deflection behavior under load is a good indicator of ductility in concrete columns. This metric is useful for determining the maximum allowable column stress before failure. The material's structural resilience and its capacity to withstand deformation can be shown by representing the results of ductility calculations for various columns. In order to find out how effectively the concrete columns handle tension before they break, this examination is essential.

STIFFNESS

The resistance of an object to deformation under the influence of a force is its stiffness. The structural study of a material is based on the load-deflection curve's slope to find the stiffness. The relationship between a structure's displacement and the force acting upon it is depicted by it. With a steeper slope, the material is more rigid and resists deformation under a given weight to a larger extent. You may find the stiffness from the load-deflection curve by dividing the applied force by the corresponding deflection. A structure's resistance to bending or compression under stress can be measured in this way is determined and represented in following figure

STRESS-STRAIN BEHAVIOUR OF COLUMN

Analyzed is the load-deflection relationship derived from the results of the universal testing machine tests. We use the applied loads to determine the appropriate stresses and an indirect method with a specific formulation to estimate the strains from the deflections. After then, the data is visually shown with strain on the horizontal axis and stress on the vertical axis. The image below shows a graph that shows the stress-strain behavior for several types of columns that were examined in the study.

STRAIN ENERGY

One way to find the amount of strain energy stored in a column is to look at the area under the stress-strain curve. The area here stands for the strain energy, which is basically the amount of energy that the column absorbs when it deforms. The toughness or strain energy of a material is a measure of its capacity to absorb stress before breaking.Using steel mesh considerably raises the strain energy in the columns, according to this study. According to the results, the strain energy for column 1 was 20.73 kN/m². With the addition of reinforcement to column 2, the strain energy reached 32.22 kN/m². Column 3, which was the mesh-strengthened area, had the greatest strain energy at 40.3 kN/m². These findings show that the columns' ability to absorb energy is improved when steel mesh is used. In the given figure, the values are shown.

MODULUS OF ELASTICITY

By utilizing the stress-strain curve and the offset method, one can ascertain the modulus of elasticity. The first step is to draw an offset line parallel to the starting linear component of the stress-strain curve, which is situated 0.2% of the proof stress. The straight line is finally intersected by the curve when the material starts to yield, which veers off course. The modulus of elasticity is given by the slope of this offset line, which stays parallel to the initial linear component of the curve. The stiffness of the material is shown by this value, which is computed as the slope of the offset line. The related figure displays the values of the modulus of elasticity.

CONCLUSIONS

Based on practical and technical observations, the following conclusions can be drawn:

1. The ultimate load-carrying capacity of column C2 increased by 24.3% compared to the control specimen, while for column C3, it increased by 38%. This demonstrates that lateral ties, combined with welded steel mesh, effectively increase the load-carrying capacity.
2. The highest compressive strength was observed in column C3, where the first crack appeared at 118 kN, and the ultimate load reached 252 kN.
3. The maximum lateral deflection for column C1 was 6.21 mm, while for columns C2 and C3, the deflections were 7.82 mm and 8.84 mm, respectively.
4. Energy absorption capacity significantly improved in columns reinforced with steel wire mesh.
5. The ductility of columns C2 and C3 increased as the amount of steel reinforcement was higher in these columns.
6. Column C3 absorbed 1612 kN/m of energy.
7. There was no significant difference in the increase in stiffness, as the load at the first crack was observed to occur at nearly equal intervals across all columns. The stiffness values were 23.427 kN/m for column C1, 24.587 kN/m for column C2, and 25.669 kN/m for column C3.
8. The toughness of column C2 increased by 50.2%, while column C3 showed an increase of about 70% compared to column C1.
9. The modulus of elasticity increased by approximately 4.7% for column C2 and 9.57% for column C3, indicating an improvement in structural performance.
10. The study confirms that the ductility and load-carrying capacity of ferro-cement elements can be enhanced by adding layers of wire mesh.

11. Increasing the number of mesh layers improves the shear load-carrying capacity of ferro-cement elements.
12. Ferro-cement confinement increases the ultimate load-carrying capacity of columns, making them more robust and effective under load conditions.

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