A Review on the Performance of Concrete Beams reinforced with GFRP Bars and Internally reinforced with Different Meshes

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ABSTRACT

The incorporation of geogrid or Glass-Fiber Reinforced Polymer (GFRP) mesh into concrete structures presents a novel approach to leveraging the geosynthetics and Fiber Reinforced Polymer (FRP) composites in structural components. Geogrid, steel, and GFRP mesh can enhance the post-cracking ductility and load-bearing capacity of Reinforced Concrete (RC) beams, depending on the specific type and properties of the mesh utilized. The use of reinforcing meshes offers the advantage of reducing the size of structural elements due to their lower weight compared to steel bars, thereby decreasing the overall weight of the structure.

Keywords-steel mesh; geogrid mesh; internally reinforced concrete beams; GFRP mesh; flexural strength

I. INTRODUCTION

This study aims to provide a review of the existing knowledge regarding the behavior of concrete beams internally reinforced with various mesh configurations, the advancement of the associated theories, and the application of finite element nonlinear analysis for the assessment of RC beams reinforced internally with meshes. An option that has demonstrated several advantages is the use of welded wire mesh in the form of ferrocement laminates. Ferrocement exhibits exceptional durability, ductility, and toughness. Furthermore, ferrocement can be easily cast into any desired shape to match the geometries of the components that require repair [1-3].

In recent years, several researchers have reinforced RC structures utilizing geogrid, a type of geosynthetic material with excellent ductile properties, and the results have been rather satisfying [4-6].

II. GFRP BARS REINFORCED CONCRETE BEAMS

Glass fibers are primarily manufactured from silica sand and are available in a variety of grades within the commercial sector. The three predominant glass types are electrical (E-glass), high-strength (S-glass), and alkali-resistant (AR-glass). E-glass exhibits superior mechanical characteristics, minimal moisture absorption, and exceptional electrical insulation capabilities. S-glass is less preferable than the E-glass due to its higher cost, yet it possesses a superior tensile strength and elasticity modulus. While AR-glass exhibits remarkable resistance to the alkali attack in cement-based matrices, there is currently a lack of suitable sizing for the thermoset resins commonly used to pultrude the FRP bars. Glass fiber composites show robust thermal and electrical insulation properties. By providing creative and sustainable solutions, GFRP composites are transforming the construction industry and are utilized in structural components, such as bars, grids, and profiles, effectively replacing the steel rebars in concrete construction [7].

One of the key advantages of GFRP is its resistance to corrosion, resulting in durable structures. GFRP also exhibits tensile strength more than double that of steel. Additionally, it is resistant to chemical attacks from chloride ions and low pH environments, and it is electrically non-conductive. However, GFRP does have some significant drawbacks, such as an erratic plastic behavior and reduced ductility, making it more brittle and prone to cracking or breaking under sudden impacts. Lastly, GFRP comes at a higher price point compared to traditional steel reinforcement [8].

The main differences between steel and GFRP bars are that GFRP is linear elastic to failure, GFRP bars have a lower creep-rupture threshold than steel, due to their lower elasticity modulus steel expands and leads to a collapse of the member while GFRP bars' degradation mechanisms are benign to the nearby concrete if they degrade [8, 9].

The expected and measured load-deflection relationships of 12 concrete beams reinforced with either steel or GFRP bars has been investigated [10]. The quantitative analysis employed three models: a computer model integrating the unique properties of the composite constituents, the ACI load-deflection model, and a modified load-deflection model from the existing literature for the FRP-reinforced beams. The preceding two models were implemented with a spreadsheet. The deflection limit and ultimate strength of concrete were the primary design parameters evaluated. The computer model accurately predicted the observed service and full load-deflection curves, with inaccuracies of less than 10% and 1% for the service load deflection and ultimate flexural strength, respectively. For the GFRP-reinforced beams, the ACI model overestimated the service load deflection by 70%, whereas the updated model had an inaccuracy of less than 15%.

Ten beams reinforced with GFRP bars, designed using limit state principles, were evaluated in terms of strength and serviceability flexure performance [11]. GFRP reinforced beams exhibited a block-type rotational failure mode, in contrast to the flexural failure observed in steel reinforced control beams. An analytical model has been proposed to quantify the strength of GFRP reinforced beams, accounting for the observed failure mechanism. The design of the GFRP reinforced beams is predominantly governed by the maximum permissible crack width, which serves as the serviceability criterion. An empirical model has been suggested to estimate the maximum crack width. The deflection of the GFRP reinforced beams has been predicted using a previously published model. The analytical model's findings demonstrate a strong correlation with the experimental data.

The performance of concrete beams strengthened with GFRP bars was investigated [12]. The study examined the influence of the quantity of GFRP reinforcement on the behavior of both simply supported and continuously supported concrete beams. In the simply supported beams, GFRP reinforcement was used both underneath and above the concrete. The continuous concrete beams were tested with three unique configurations of GFRP reinforcement, featuring different ratios of over and under reinforcement in the upper and lower layers. Additionally, an RC continuous beam was included for comparison. The experimental results demonstrated that excessive strengthening of the lower layer in either the simply supported or continuously supported GFRP beams was a crucial factor in regulating the crack width and distribution, enhancing the load-bearing capacity, and reducing deflection. Furthermore, the equations proposed in [13] were found to accurately predict the load capacity and deflection of the tested simply supported or continuously GFRP-RC samples, as corroborated by comparisons with experimental data and simpler methods recommended by the ACI 440 Committee.

An extensive experimental study was conducted at Salerno University that investigated the structural behavior of concrete beams reinforced with GFRP and Carbon-Fiber Reinforced Polymer (CFRP) bars and stirrups under service conditions [14]. The experimental program involved forty beams, varying concrete strength and reinforcement percentages. The key objectives were to examine midpoint displacements and crack widths, as well as the final failure behavior. This paper focuses on a portion of the study, specifically ten prototypes strengthened with GFRP bars. The findings suggest that the predictive formula proposed in [15] for estimating the shear failure load significantly overestimates the true strength of the FRP-reinforced components. This distinction necessitates further scrutiny to improve the reliability of the design methodology.

The flexural strength and serviceability performance of Geo-Polymer Concrete (GPC) beams reinforced with GFRP bars was assessed using a two-point static load test [16]. The study examined the impact of the nominal bar diameter, reinforcement ratio, and anchoring mechanism. The test results indicated that the bar diameter did not significantly affect the bending strength of the samples. Generally, the serviceability of a beam improves with an increase in the reinforcement ratio. The mechanical interlocking and frictional forces of the sand covering were sufficient to establish a robust bond between the GFRP bars and the GPC. Overall, the prediction equations of [13] tend to underestimate the strength of the tested beams, which exhibited a greater bending-moment capacity compared to the previously studied FRP-RC beams.

The structural performance of regular and high-strength concrete beams reinforced with distorted GFRP bars was investigated [17]. The study focused on evaluating the flexural properties of these concrete beams under bending loads. Examining the behavior of concrete beams strengthened with distorted GFRP bars, using both normal and high-strength concrete, would expand the existing knowledge and provide crucial insights for the potential use of distorted GFRP bars as internal reinforcement in concrete building components. Eight beams, all with a cross-sectional width of 200 mm, height of 300 mm, and a clear span of 2700 mm, were tested under two-point flexural loading until failure occurred. Four samples were constructed using Normal-Strength Concrete (NSC) with a compressive strength of 35 MPa, while the other four beams were made with High-Strength Concrete (HSC) with a compressive strength of 65 MPa. Each beam was reinforced at the bottom with two GFRP bars for tensile strength. The study utilized four different GFRP bar diameters, 12 mm, 16 mm, 20 mm, and 25 mm in diameter, resulting in a range of reinforcement ratios from 0.380% to 1.630%. Seven samples experienced concrete compression failure, while the eighth sample suffered tensile failure due to the rupture of the GFRP. The test results showed that increasing the GFRP reinforcement ratio had a greater influence on the service moment than on the resistance moment.

An investigation was conducted on six concrete beams strengthened using a combination of GFRP and steel bars [18]. Additionally, three concrete beams were developed and tested with only steel reinforcement. The study analyzed and compared the flexural behaviors of the tested beams to theoretical models. The analytical and experimental results revealed that, under the specified service load, the GFRP-steel RC beams exhibited more rapid growth in the crack width and deflection compared to the steel-RC beams. Despite having the same total reinforcing quantity of GFRP and steel bars, the

GFRP-steel RC beams achieved an ultimate flexural capacity between 91.0% and 97.0% of that of the steel-RC beams.

Twelve concrete beams reinforced with GFRP and CFRP bars were tested for their bending characteristics [19]. The beam dimensions were 130 × 220 × 2200 mm, and the beams were strengthened with varying diameters of GFRP and CFRP. The reinforcing ratio and concrete strength had a significant impact on the behavior of the GFRP, CFRP, and RC beams, leading to a reduction in the deflection and fracture width.

The flexural capacity of the structural members reinforced with GFRP bars was explored [20]. A nonlinear stress-strain relationship was used to account for the behavior of concrete under compression. The theoretical calculations were validated by comparison with a previous experiment, and the findings were also contrasted with [21] code. The results indicated that the predicted failure modes in the analytical assessment were consistent with those observed in the experiment. Additionally, the average ratio of flexural capacity, computed using Todeschini's nonlinear curve, ranged from 0.78 to 0.86 when compared to the experimental data. Furthermore, the flexural capacity obtained by employing Todeschini's nonlinear stress-strain curve for specimens with reinforcement ratios beyond the balanced reinforcement ratio demonstrated superior performance compared to the flexural capacity acquired using the ACI code.

Authors in [22] performed the investigation of the flexural behavior of T-beams constructed with GPC and reinforced longitudinally with GFRP bars was performed. Six T-beams with simple supports were manufactured and tested. One beam utilized conventional concrete, while the remaining five were made of GPC. The G-GPC2 beam was specifically designed to achieve an equivalent theoretical moment capacity to the reference beam. The primary parameters examined were the reinforcement ratios (ρf/ρb) of 0.75, 1.05, 1.12, 1.34, and 1.34 for G-GPC1, G-GPC2, G-GPC3, G-GPC4, and G-GPC5, respectively. These ratios were analyzed in relation to the compressive strength of the GPC. The experimental results indicated that the ultimate strain behavior of the GPC beams differed from the control beam, which influenced the failure mode. The prediction equations in [23] overestimated the beam capacity and underestimated the deflection.

Authors in [24] examined the performance of unbonded post-tensioned concrete elements exhibiting partial strand damage and reinforced with CFRP laminates employing a near-surface mounted method, both with and without U-wrap anchorages. The experimental findings indicated that the application of CFRP laminates considerably influences the strand strain, particularly when anchors are utilized. In comparison to the undamaged girder, the Near Surface Mounted (NSM) CFRP laminates improved the flexural capacity by 11% and 7.7% for strand damage levels of 14.3% and 28.6%, respectively.

The efficacy of the flexural reinforcement in concrete elements was examined when subjected to partially unbonded prestressing, focusing specifically on the proportions 0%, 14.2%, and 28.5% of severed strands, considering both symmetrical and asymmetrical damage [25]. The EB-CFRP laminates enhanced the flexural capacity by around 13%, correlating to a strand damage of 14.28% and roughly 9.5% for 28.57% strand damage, which is a notable discovery in this domain. Furthermore, semi-empirical equations for predicting the real strain of unbonded tendons were introduced. The proposed equations are straightforward to resolve and yield accurate outcomes.

III. CONCRETE WITH MESH REINFORCEMENT

The use of geogrid or GFRP mesh in concrete structures offers a novel approach in utilizing geosynthetics and FRP composites in structural components. Geogrids are employed to strengthen the asphalt concrete layers, stabilize and limit the soil retaining structures, and mitigate the progressive cracking in pavements. Integrating a biaxial geogrid into infrastructures is an innovative advancement in the concrete technology. Geogrid is a type of geosynthetic, which is mostly composed of polymeric substances. The materials often used in geotechnical constructions for providing tensile reinforcement include polypropylene, polyethylene, polyester, polyamide, polyvinyl chloride, and polystyrene. Geogrids are flat polymeric structures composed of a network of linked tensile components called ribs. The ribs are connected deploying extrusion, glueing, or interlacing methods, utilizing perforations or apertures.

Geogrids are classified in two categories: uniaxial and biaxial. Uniaxial geogrids are predominantly used for the construction of retaining walls and the separation of steep slopes. In contrast, biaxial geogrids are employed in highway projects due to their exceptional tensile strength in both horizontal and vertical directions. Fiber and wire mesh are often interchangeable components in concrete members. Fiber mesh is more suitable for delicate concrete forms and thin concrete layers, while wire mesh is typically used for thicker concrete applications [26-29]. Uniaxial geogrids have exceptionally strong tensile capacity in their unidirectional ribs, while biaxial geogrids have tensile strength in all directions. Biaxial geogrids are engineered to evenly distribute stress resistance in two perpendicular directions, which is why they are called bi-axial. This geogrid is created by stretching ridges in the transversal and machine axes, resulting in high tensile strength along both directions and commonly seen square aperture forms. Compared to typical geogrids, biaxial geogrids can more evenly distribute loads across larger regions, enhancing their capacity for base stabilization. Although biaxial geogrids are suitable for wall and slope applications, their intricate design requires a more expensive production process, making them a costlier option than the uniaxial designs for those specific purposes. However, biaxial geogrids are highly suitable for base stabilization applications, including car park construction, transport route foundations, roadways, unpaved roads, railway truck beds, and airport runways [30].

Researchers in [29] explored the application of geogrid mesh as a means of confinement in concrete samples. This research examines the relationship between geogrid and concrete. Additionally, it explores the influence of using geogrid in combination with Steel Fiber-Reinforced Concrete (SFRC). The experimental findings suggest that the geogrid may serve as a viable alternative material for confining concrete, compared to the traditional confinement methods. The utilization of SFRC enhances the axial stress-strain characteristics of concrete specimens confined with geogrid. The performance of cylindrical specimens subjected to splitting tensile testing underscores the importance of geogrid confinement, with and without the presence of steel fibers. The flexural testing of the beam specimens indicates that the strength of the geogrid and the number of layers it possesses significantly affect the enhancement of the load-deformation behavior and crack propagation. The stress transmission mechanism of a geogrid under flexure suggests that it may serve as a viable substitute for tensile reinforcement in RC applications. The peak flexural load capacity of the specimens confined with geogrid improves by a factor of 5 to 6 compared to the specimens without geogrid confinement.

Fiberglass Mesh (FM) has exceptional durability, possesses outstanding insulating characteristics, high tensile strength, demonstrates remarkable resistance to chemicals, and can withstand elevated temperatures of up to 600 °C without sustaining any harm. By utilizing this specialized fabric, it becomes feasible to create glass fiber mesh that possesses both alkali resistance and non-combustibility. Consequently, they are well-suited for many applications, such as soil stabilization and reinforcing concrete structures [31].

Authors in [32] conducted an examination of the mechanical characteristics and failure patterns of a combination of mortar slurry and stable foam or Foam Concrete (FC) that was reinforced with FM. The study evaluated the flexural, compressive, and tensile splitting strengths of FC with a density of 1100 kg/m³. The FC was confined using several layers of FM weighing 145 g/m². The mechanical properties of the FC were significantly enhanced by employing a three-layer jacketing technique. After 28 days, notable gains in compressive strength, flexural strength, and splitting tensile strength were observed when compared to the control samples reaching 108.0%, 254.0%, and 349.0%, respectively. The FC samples that were not confined failed in a brittle manner when tested under compressive, flexural, and tensile stresses. The tensile stress failure mechanism of the FC, which was reinforced with one to three layers of FM jacketing, exhibits a minor top-side fracture and a vertical mark on the lateral section. Therefore, the use of FM in the FC jacketing system improves the performance and structural strength of FC by effectively inhibiting crack development.

IV. CONCRETE BEAMS REINFORCED WITH MESH

Authors in [33] conducted an investigation on the properties of thin composite materials made of ferrocement. They examined the effects of different reinforcing meshes on their flexural behavior. The criteria of this study encompass the investigation of the impact of several types of reinforcement meshes, namely stainless steel meshes and E-FMs. Additionally, the study explored the influence of the mesh layer number and the diversity of mesh variations. The sizes included the opening size and different types of mortar components, such as cement grout mortars and polymers, which served as the matrix. The findings demonstrated that incorporating stainless steel meshes of stainless steel as a reinforcement method in the ferrocement narrow composite members greatly enhances their bending properties. This includes improvements in the first crack load, bending stiffness, ultimate flexural load, energy absorption until failure, as well as the presence of numerous fine and evenly distributed fractures with a narrower width compared to using FMs.

The efficacy of the Steel Wire Mesh (SWM) and polymer mortar in enhancing the flexural strengths of concrete beams was investigated in [34]. Additionally, the building techniques associated with these materials were explored for future advancements. The primary test parameters consisted of the quantity of longitudinal SWM reinforcement and the history of the load. The findings illustrated the practicality of rehabilitating and reinforcing RC elements using SWM composites. They also suggested that the maximum strength of the RC T-beams, when strengthened with SWM composites, remains consistent independent of the load history throughout the reinforcement process. The purpose of this study is to provide a design approach that can accurately forecast the flexural strength of T-beams reinforced with SWM composites. A high level of concordance was attained between the experimental results and the projected values.

The flexural characteristics of epoxy syntactic foams that were strengthened by the use of FM were studied in [35]. The flexural test findings demonstrated that the inclusion of FM resulted in higher strength and modulus values in syntactic foams, compared to the syntactic foams without reinforcement. FM was discovered to be much more effective. The flexural strength and elasticity modulus of the glass fiber reinforced syntactic foams were significantly enhanced by using a two-layer FM. The flexural strength rose by about 2.5 times, while the elasticity modulus increased by around 2 times. The density of the reinforced foam only saw a modest rise of 9.3%. Furthermore, it was discovered that the placement and number of FM sheets had a substantial impact on the flexural characteristics.

Authors in [36] delivered a presentation on an ongoing research project that explores the application of novel composites to enhance the behavior of concrete beams. The wire mesh epoxy composite was used to externally attach one to five layers onto a simple concrete beam. The flexural performance of the beam specimens was evaluated between those bonded with wire mesh layers, those bonded with carbon fiber, and those bonded with a wire mesh, epoxy, and carbon fiber composites. The test findings indicate that incorporating wire mesh via epoxy is a highly effective method for enhancing the flexural behavior of the concrete samples. The addition of more wire mesh layers greatly improves the cracking categories, flexural capacity, and energy absorption. The wire mesh epoxy composite has a superior flexural strength and ductility when compared to the carbon fiber.

The flexural characteristics of bidirectional geogrids were examined, both with and without steel fibers, to assess the feasibility of utilizing biaxial geogrids with steel fibers as an alternative to shear reinforcement [37]. This study investigated two categories of beam specimens including different arrangements of transversal reinforcements. The geogrid specimens and conventional concrete specimens underwent three-point monolithic loading to investigate and contrast their load-deflection performance. The experimental test reveals a significant improvement in flexural strength, reduction in stiffness, energy dissipation capacity, displacement ductility, and the maximum load together with its associated deflection.

Authors in [38] conducted an investigation to determine the efficacy of geogrid as shear reinforcement in shear deficit RC beams by experimental observations and non-linear finite element calculations. The RC beam specimens were internally constrained using a geogrid material to reduce the shear deficiency. ANSYS is used to conduct comprehensive 3D non-linear finite element studies on RC beams that are constrained by geogrid. The purpose of these analyses is to accurately mimic the behavior of beams that are lacking in shear strength. The experimental analysis revealed that the load bearing capability of the geogrid bonded beam increased by 24.35% compared to the control beam. Similarly, there was a significant enhancement in the ultimate failure displacement, ductility, and energy dissipation capabilities of the reinforced beam compared to the control beam. The failure mode of the RC beam changed from shear-flexural to flexural when it was restricted with geogrid. The load-displacement behavior and damage predicted the by finite element analysis closely corresponded to the experimental results.

The load tests performed on 7 fully-scale RC beam samples were documented in [39]. This research aimed to assess the viability of utilizing a new and environmentally friendly material, Basalt Fiber Reinforced Polymer (BFRP) composite, for the purpose of enhancing the flexural strength and restoring the RC beams. The flexural reinforcement ratio, corrosion level, BFRP composite layer count, and cross-strapping technique are the test variables having been utilized in this investigation. The study concluded that the use of the externally bonded BFRP composite is an effective method for strengthening and rehabilitating the RC beams. This is because it significantly increases the strength of the beams, particularly if the risk of premature debonding-induced failure is minimized through the carrying out of a suitable cross strapping technique. Researchers also found that RC beams' ductility can be reduced by 29.9% when BFRP flexural strengthening and rehabilitation is used, however this reduction is far from catastrophic.

The performance of Light-Weight Concrete (LWC) beams was investigated in [40]. In comparison to conventional concrete beams, LWC beams demonstrated superior load-deflection, energy absorption, and ductility index performance. Incorporating internal mesh reinforcing into the LWC beam increased its load-carrying capability without making it bulkier or heavier. Specifically, this reinforcement was built up of four layers of Welded Wire Mesh (WWM) spaced 15 mm apart, then four layers of WWM spaced 10 mm apart, and lastly four layers of mesh that alternated between distances of 15 and 10 mm. The beam, which was internally strengthened with WWM, demonstrated a greater ability to bear loads and endured more substantial deflection without experiencing rapid collapse. WWM incorporates internal reinforcement to produce steel rebars, and it functions as a monolithic structure under load. Reinforcing the structure from the inside using WWM increased its load-carrying capability by 25%. The reduced strain on tension bars and increased load capacity are the results of this design element.

Authors in [41] used the idea of dual-layer concrete to study the flexural behavior of beams with high-strength concrete reinforced with mesh of steel wire in different shapes, including hexagonal, square, and diamond wire mesh. To create 500 × 100 × 100 mm beams, three groups of 450 ×50 × 50 mm beams were first cast. The beams were then surrounded by three distinct mesh configurations and filled with concrete. According to the study, enclosing beams with steel wire meshes improves both the overall flexural strength and the way the failure mechanism of the beam behaves under two-point loads. The flexural strength of hexagonal, square, and diamond meshes has been enhanced by 10%, 23%, and 35%, respectively. However, when comparing the specimens with square and hexagon wraps over the core, the one with the diamond mesh confinement performs better in terms of stress-strain curves and Young's modulus.

To determine the internal reinforcing effect, the impact of various material meshes on the flexural strength of concrete beams was assessed [5]. In order to achieve this objective, a total of eleven RC beams were subjected to testing using a four-point bending method. The beams were constructed using standard concrete, with a rectangular cross-section of 150 × 200 mm and a length of 1200 mm.

The reinforcement of flexure and shear used in all eleven beams were similar. The control beam was constructed without any interior mesh reinforcement, whilst the remaining beams were strengthened with three distinct kinds of mesh components. Different numbers of layers and combinations of these substances were used. Geogrid, GFRP, and steel meshes were utilized. A single beam was constructed using a U-shaped mesh for each material. The mesh was utilized to encase the stirrups and extended vertically by 50 mm. The experimental program focused on investigating the major features of the failure mechanism, load capacities, load-deflection relations, and ductility.

The test findings indicated that the failure load capacities of the composite beams had a percentage increase of approximately 3.0% to 25.0% compared to the control beam. Furthermore, the composite beams with a U-shaped mesh design demonstrated a 17% higher load capacity compared to their straight mesh equivalents. Similarly, the ductility ratio exhibited a significant rise of roughly 82% to 136% as the number of layers increased from 1 to 3. This suggests that the use of composite materials and various mesh designs can enhance the structural performance and load-bearing capabilities of the beams.

V. RC BEAMS WITH MESH REINFORCEMENT

Table I provides a comparative analysis of the research on RC beams strengthened with mesh reinforcement. It includes detailed information on the number of specimens studied, concrete mix design, mesh type and arrangement, strengthening techniques employed, and the corresponding percentage increase in the failure load of the beams (Pu).

TABLE I. COMPARISON OF RC BEAMS WITH MESH REINFORCEMENT

Ref.	No. of Samples	Concrete Type	Mesh Type	Type of Strengthening	Failure Type	Mesh Arrangement	Pu Enhancement (%)
[5]	11	Normal	Steel, geogrid, or GFRP	Flexural	Flexural	U or straight	3-25
[37]	6	Stell fiber	Geogrid	Shear	Shear	Full wrapping	11
[38]	2	Normal	Geogrid	Shear	Shear	Full wrapping	24.4
[42]	15	Normal or propylene fiber	Geogrid	Shear	Shear or flexural	Full wrapping	30.6
[36]	10	Normal	Steel	Flexural	Sudden Failure	Straight	124
[34]	5	Normal	Steel	Shear	Flexural or region peeling	U	14.9
[40]	5	Light weight	Steel	Flexural	Flexural	Straight	33.3
[43]	9	Normal	Geogrid	Flexural	Flexural	Straight	38.2
[44]	8	Normal	Geogrid	Flexural	Shear	Straight	80
[45]	13	Steel fiber	Geogrid	Flexural	Flexural	U or straight	86.6

VI. CONCLUSIONS

- Previous studies have primarily focused on utilizing steel mesh and geogrid to reinforce concrete members, while the application of Glass-Fiber Reinforced Polymer (GFRP) mesh has received less attention.
- In a simple supported beam, it is economically advantageous to place the flexural reinforcement mesh solely in the central region of the beam.
- The existing literature has typically examined the use of mesh for shear reinforcement, rather than flexural reinforcement.
- Prior research has investigated the impact of steel mesh on ferrocement. However, these meshes can also serve as an alternative reinforcement method for concrete.
- The use of mesh reinforcement is more cost-effective than traditional steel bars, leading to a decreased overall cost of the building.
- The implementation of reinforcing meshes reduces the size of the structural element due to their lower weight compared to steel bars, thereby decreasing the overall weight of the structure.

As a future research direction, the investigation of the effect of mesh reinforcement on concrete beams reinforced with GFRP bars is proposed.

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