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Review on Flexural Behavior of Slabs Reinforced with FRP Bars Subjected to Static and Cyclic Loads

Ramani K[1] and Dr.S. Sidhardhan[2]

[1]Post Graduate Student, Department of Civil Engineering, GovernmentCollege of Engineering Tirunelveli, Tamilnadu, India.

[2]Post Graduate Student, Department of Civil Engineering, GovernmentCollege of Engineering Tirunelveli, Tamilnadu, India.

[3]Research Scholar, Department of Civil Engineering, Government College ofEngineering Tirunelveli, Tamilnadu, India.

[4]Assistant Professor, Department of Civil Engineering, Government Collegeof Engineering Tirunelveli, Tamilnadu, India.

Abstract: *One of the main issues that reduces the lifetime serviceability of concrete buildings is the corrosion of steel reinforcing. The degradation of concrete buildings caused by the corrosion of steel reinforcing can be prevented, delayed, or repaired using a variety of currently available techniques. Fiber reinforced polymer bars are an effective and affordable solution to the corrosion issues that steel rebars in severe settings are prone to. Steel alternatives that are robust and extremely corrosion resistant include fiber reinforced polymers. The fiber reinforced polymer bars have a high strength, a low center of gravity, are simple to handle, and require little maintenance. Glass fiber reinforced polymer bars are among the most widely used composite rebars, mostly because of their reasonable price and high performance. The Glass Fiber Reinforced Plastic's mechanical characteristics Steel bars were inferior to polymer bars in a number of respects. This study examines how glass fiber reinforced polymer slabs behave under flexure under static and cyclic loads.*

Keywords: GFRP bars, Steel.

1. INTRODUCTION

The most promising and discerning material now accessible has been discovered to be composites. As the market grows in need for lightweight materials with high strength for particular purposes, composites reinforced with fibres of synthetic or natural materials are becoming more important.In addition to having a high strength to weight ratio, fiber reinforced polymer composites also exhibit excellent qualities such great durability, stiffness, damping property, flexural strength, and resistance to corrosion, wear, impact, and fire. Composite materials have found uses in a wide range of manufacturing sectors, including mechanical, construction, aerospace, automotive, biomedical, marine, and many more.Functional qualities of the various fibers are therefore important because performance of composite materials mostly depends on their constituent constituents and manufacturing procedures.

2. REVIEW OF LITERATURE

Tarek Alkhrdaji et al. (2000) studied the An analysis of the flexural behavior of FRP reinforced concrete one-way slabs is described in the study. Theoretically and empirically, cracking and deflection of FRP reinforced concrete structures are analyzed. For the purpose of predicting cracking and deflections, a generic non-linear method based on slip and bond stresses is used, whereas the experimental study involves deformed one-way slabs of GFRP-reinforced concrete.(C-BARTM) rebars. The reinforcement ratio, rebar diameter, and rebar spacing of four one-way slabs—three reinforced with GFRP rebars and one with conventional steel rebars—have all been tested to failure. Comparing GFRP reinforced slab deflections, fracture shapes, and crack breadth to those of steel reinforced concrete slabs is done.

T.Kanie et al. (2000) discussed the application of FRP composites Three silanized or unsilanized woven glass fibers were used, and specimens with four different thicknesses and five different types were created by heating the denture cure resin dough incorporating the glass fibers, which were sheathed in the dough. Three-point flexural tests and flywheel type impact tests were used to determine the flexural properties and impact strength. The longitudinal tensile strength of glass fiber N is 382/25.

H.A. Abdalla (2002) investigated the performance evaluation of Over the past ten years, there has been a sharp growth in the usage of fibre reinforced polymer (FRP) reinforcements in concrete constructions because of their superior non-magnetization qualities, strong tensile strength, and exceptional corrosion resistance. The low modulus of elasticity of FRP reinforced structures experience significant bending and extensive fractures due to the elasticity of the FRP materials and their non-yielding qualities.composed of concrete. As a result, serviceability needs may frequently dictate how such members are designed. The development of straightforward methods for calculating the deflection of FRP reinforced concrete components exposed to Flexible strains. The experimental findings from testing seven prototypes are contrasted with the expectations of these methodologies.glass fiber reinforced polymer (GFRP) and carbon fiber reinforced polymer (CFRP) bars used to strengthen concrete beams. The test findings from eight concrete slabs reinforced with conventional steel, GFRP, and CFRP bars are documented in the literature and provide additional support for the analytical methodologies that have been provided.

Burong Zhang et al. (2004) approached the Structures Research Group, Currently, fiber reinforced polymer (FRP) composites are employed as reinforcement for concrete constructions when magnetic permeability or durability are the determining factors. In some concrete structural elements exposed to harsh climatic circumstances that speed up corrosion of the steel reinforcements and worsen the structures, carbon fiber reinforced polymer (CFRP) grid reinforcement stands in as a viable substitute for steel rebars. This study compares the flexural behavior of three one-way concrete slabs reinforced with CFRP grids to a single slab reinforced with steel rebars. The slabs were identical in size (33001000250 mm) but had various reinforcement ratios. To examine their flexural and shear limit states, including pre-cracking behavior, cracking pattern and breadth, deflections, ultimate capacities and stresses, and mechanism of failure, they were simply supported and tested in the lab under static and cyclic loading conditions. The transverse bars in the grid's are shown to have an impact on cracking and cracking moment. Design principles and recommendations are put forward in light of this study.

R. Sivagamasundari et al. (2008)experimentally investigated about In order to lower the entire life-cycle costs of structures, interest in adopting cutting-edge high performance materials in the construction sector has been growing over the past few decades. As a result, several studies have been conducted to develop novel materials that offer comparative advantages over traditional steel reinforcements. Fibre Reinforced Polymer (FRP) reinforcements are regarded as modern, high-tech, and excellent building materials that are ebulliently employed in many nations, particularly in the construction of bridge deck slabs. Numerous studies have been conducted to evaluate the flexural and shear behaviors of FRP reinforced structural components under static or monotonic loads, as well as the mechanical characteristics of FRP reinforcements.

Mark Adom-Asamoah et al. (2009) experimentally investigated the Twelve simply supported one-way concrete slabs that were strengthened with steel bars cut from waste metals underwent testing in the lab. At the third locations, the slabs were exposed to intense line loads. Flexural yielding of the tension bar or flexural crushing of the concrete were projected to be two separate failure scenarios. However, the observed failure types were either a single form of tension failure, concrete crushing, diagonal shear, or shear bond failures, or a combination of these modes. The experimental results provided an average short-term factor of safety of about 1.3 against cracking and 0.94 against collapse for one-way slabs with span-to-effective depth ratios varying between 14 and 24.37 and shear span-to-effective depth ratios varying between 4.6 and 8.12. According to the analysis of the trial findings, it is recommended that steel bars milled in Ghana have an average steel strength of around 370 N/mm2 be used in reinforced concrete design instead of the typical value of 250 N/mm2 typically recommended by BS8110 for mild steel.

M. S. Ahmadi et al. (2009) conducted a study on strengthening of RCC slabs Shear modulus is improved when the braid roving linear density is increased, but tensile modulus and flexural stiffness are decreased. Higher braid roving linear density rods showed superior torsional qualities but less favorable tensile and flexural characteristics. In order to create glass fiber reinforced composite rods using the braiding-pultrusion technology, a regular textile braiding machine was modified and attached to a pultrusion line. There were three distinct braid angles and three different braid roving linear densities used to manufacture braid-pultruded (BP) rods. Unidirectional (UD) rods without braided fabric were also created in order to evaluate the effects of overbraiding on the mechanical characteristics of pultruded rods. Tests for tensile strength, bending, and torsion were performed on all rod varieties. The experiment's findings revealed.

L. Michel et al. (2009) investigated the effects of GFRP The behavior of reinforced concrete slabs that have been strengthened and slabs that have not been strengthened under the same, local load at their centers is discussed in this study. During the experimental phase, the effect of the reinforcement on the different slabs tested was evaluated by analyzing the bending stiffness of the slabs and their behavior at failure. A model was built to estimate the value of the bending stiffness, the mid-span displacements, and the strain on each material making up the slabs in order to forecast the mechanical behavior of the slab. There was a fair deal of agreement when the experimental and model findings were compared. The predetermined criteria of modeling the behavior of a slab in reinforced concrete in the simplified model created using Calculus's technique is satisfied.

HH Xin et al. (2013) conducted the experimental study on RC beams were strengthened with GFRP In this work, a sort of economically advantageous hybrid GFRP/Concrete deck system was suggested. A fullscale specimen was subjected to a fatigue test, and a number of static tests were also performed following normal loading cycles.In order to assess long-term performance, the failure modes, deflections, stresses, and fractures of concrete and GFRP plates were measured during the fatigue test. According to the findings of the fatigue test, the hybrid deck still performs well even after 3.1 million cycles. A three-dimensional finite element model was also developed to assess the fatigue behavior of the material. The strength and stiffness of the findings of the finite element analysis agreed with those of the tests, and the fatigue failure cycle was computed using the associated S-N curve.

Mahfoud Benzerzour et al. (2014) This study examines the source and size of internal stresses at the junction of an overlay and a supporting reinforced concrete slab that has been subjected to cyclic flexural pressure. Two configurations of reinforced concrete slab panels measuring 3.3, 1.0, and 0.2 m were examined for internal stresses using finite-element modeling: an unaltered reference slab and a repaired slab with a 40-mm-thick bonded overlay. Two slab panels with the same configuration and dimensions were tested experimentally to determine how the structural capacity and cracking behavior changed over time. The panel of the overlaid slab revealed several small horizontal fractures advancing at the contact between the overlay and the substrate slab during laboratory cyclic pressure. The flexural fracture pattern dramatically increased, according to the finite-element modeling.

Chris P. Pantelides et al. (2015) focused the study on two-way RC slabs,These connections obtained capacities from 105 to 109 kn (23.5 to 24.5 kip) or 0.95 to 0.99 times that of the as-is welded connection using GFRP composite bond length that was the same as the repaired field samples. Additionally, a desired life-safety feature was retained in the connection even after the gfrp composite's glue failed. Since the early 1960s, transportation authorities have used aluminum overhead sign structures. It is generally known that fatigue loads from slender members' vibration caused by wind cause fractures to form in the welds connecting diagonal and chord members.

Yu Zheng et al. (2017) experimentally investigated the study on RC slab An experimental and analytical analysis of the structural behavior of concrete bridge deck slabs without reinforcement is presented in this work. A revolutionary load-carrying mechanism is added to the proposed deck construction to do away with the necessity for internal steel reinforcing. This technique combines the use of deck slabs that arch and fiber reinforced polymer (FRP) rods to connect the supporting beams. The size of the supporting beams, the kind of edge beams, and the spacing between the FRP restraint rods were only a few of the structural characteristics that were varied in this study's one-third scale deck specimens before they were tested to failure. In this sort of lateral constrained concrete deck, punching failure and arching action were anticipated as the failure modes of concrete deck slabs under concentrated wheel loads.

Jayaramappa et al. (2017) evaluated the behavior of RC slabs retrofitted with different composite materials under static load. The first crack load for 0.30% steel reinforcement was 240 kN in both normal RC and RC + mesh slabs. The ultimate loads for 0.30%, 0.50%, and 0.70% of steel reinforcement were 440 kN, 500 kN, and 540 kN, respectively, in normal RC slabs. The addition of SBR latex increased the first crack load and ultimate load. However, in RC + mesh slabs, the first crack load remained the same, but the ultimate load decreased. The study highlights the effectiveness of SBR latex in enhancing load-carrying capacity and the limitations of mesh reinforcement affecting the overall behavior of the slabs.

V. Jeyanthi Vineetha et al.(2018) In this study, Such RC slab retrofitting is necessary to solve design or construction flaws, withstand increasing loads brought on by changes in the structure's use, or both. Fibre Reinforced Polymer (FRP) jacketing has gained popularity recently for retrofitting the existing defective slabs. FRPs were ideally suited for retrofitting the old, inadequate structures because of their light weight, high strength, and resistance to corrosion. The effectiveness of the FRP retrofitted RC slabs was examined in this study. This study's major goal is to assess the viability of retrofitting RC slabs with FRP. The effectiveness of RC slabs with FRP retrofits under static vertical stresses is demonstrated in this experimental investigation. To analyze the behavior of RC, RC slabs were produced with the identical reinforcing features.

S.Dhipanaravind and R.Sivagamasundari (2018) studied the The primary focus of this work is on the flexural behavior of glass- and carbon-fiber reinforced concrete one-way slabs. In order to design hybrid FRP slabs that meet ultimate strength and serviceability requirements using the ACI 440.1R-03 Guide, it is important to consider how design factors interact with one another. A key barrier to the widespread use of fiber-reinforced polymers (FRPs) in reinforced concrete (RC) is the lack of design guidelines. This paper's entire focus is on the characteristics of concrete and reinforcement from various angles, and it concludes with an experimental and analytical analysis of the flexural behavior of the slabs.

Mohamed Abo Elyazed et al.(2019) studied the steel hybrid bar with a core of steel wires is introduced in this study. Three variants of the hybrid cross section with three distinct steel ratios of 6.25%,12.5%, and 22% are taken into consideration. Tensile tests show that the elastic modulus of FRP Hybrid Bars is higher than that of regular GFRP Bars by 3.66% to 24.4%. The bars are produced locally utilizing a double parts die pattern and local raw materials. Five slabs with dimensions of 800 mm in width, 150 mm in thickness, and 2400 mm in length are evaluated in the lab under static four-line loading circumstances to ascertain their flexural limit states, including the behavior before cracking, cracking, and ultimate flexural failure.

Ali S. Shanour et al. (2020) investigated the effect of strengthening techniques on Adding woven laminates and glass fiber ropes as reinforcement will increase the suggested composite material's ability to bend. The outcome demonstrated that the suggested composite sleeper material has adequate strength to maintain mechanical connections.In order to assess the strength and behavior of the fiber composite sleeper, this work gives further findings of experimental testing and analytical analysis.The suggested composite sleepers were made using a mixture of recycled high density polyethylene, iron slag, calcium carbonate, styrene, and polyester resin in varying proportions. On a full-scale sleeper, negative bending at the center and positive rail seat compression were carried out. Under a negative bending test, two full-scale sleepers were proof loaded up to 72, 82 KN without producing any cracks. A positive rail seat is also underneath.

S. Indira Prasanth et al. (2020) investigated the study of the comparative orientational research of glass fibers utilizing sophisticated simulation, where the same repeated angles are only chosen as fiber orientated angles, is another topic covered in this work. When it comes to structural simulations and material optimization for tensile stress situations, ANSYS-based structural tools play a major role. Because of their high resistivity and cheap cost, composites based on glass fiber reinforced polymer (GFRP) are the material most frequently used in difficult engineering applications.

A. Kheyroddin et al.(2021) conducted an experimental study on the performance of FRP Fiber reinforced polymers (FRP) to enhance concrete construction impact behavior. In this study, 52 concrete samples with varying compressive strengths (20, 30, and 40 MPa) and polypropylene fibers were built (half of which were covered with GFRP, or glass fiber-reinforced polymers). These samples (46.7 kg and 66.8 kg) underwent weight reduction. It was noted how many people lost weight after losing 30% of their body weight. Results showed that utilizing stronger concrete, greater polypropylene ratios, or GFRP wrapping, both independently and in combination with one another, enhanced the impact resistance of the concrete samples,which corresponded to the number of weight droppings. Experimental research was done on the effects of GFRP on concrete sample impact resistance.

Wit Derkowski et al.(2021) conducted a study on the pilling-off failure mechanism, only 35% of externally bonded fiber-reinforced polymer (FRP) composites are used in the reinforcement of reinforced concrete (RC) structures. Pre-tensioned composite laminates can be used to overcome this issue.Using this method, a previously harmed RC beam was repaired and shielded against brittle failure. The disadvantage of brittle and quick failure of the concrete-FRP composite junction may be eliminated by the cooperation of stiff and flexible adhesive layers in the reinforcement of concrete structures employing FRP composite. The results of the provided special tests showed that the restored structure's ductility greatly improved, boosting safety reserve—even for the seriously damaged beam. The additional labor required by parallel bonding CFRP laminates to stiff and flexible adhesive layers.

Thong M. Pham et al. (2021) investigated the lateral impact response of the columns, the influence of longitudinal FRP ratio and concrete strength (50 MPa vs. 100 MPa) was examined. The experimental findings revealed that the longitudinal reinforcement ratio had a significant impact on the failure modes and capacity to withstand impacts, whereas using high strength concrete (HSC) did not significantly enhance the performance of the columns and may have even led to spalling failure because of its brittleness.

Rabe Galal et al.(2021) examined the GFRP Numerous applications in the realm of construction engineering include the usage of fiber-reinforced polymers. Commonly utilized to support and rebuild different reinforced concrete components including slabs, beams, and columns are fiber- reinforced polymers. There are several strengthening methods accessible right now. The type of weakness in the concrete element, the cost of the suggested technique, the environmental conditions the concrete element is subjected to, and the readiness of the technology to be chosen are some of the elements that influence the selection of the right strengthening method. This research refers to the strengthening of two-way reinforced concrete slabs utilizing the approach of using a lower layer of reinforced concrete because reinforced concrete slabs are elements that are exposed to rebar rust, lack of body, and low resistance to bending.

Liu Jin et al. (2021) examined the response of Rebar's cross-sectional area and the link between it and the concrete are reduced by corrosion, which decreases a structure's structural endurance. In order to investigate the effects of localized corrosion on the behavior of single-way RC slabs, a three-dimensional mesoscopic numerical analytical model was developed. As a three-phase composite made up of coarse aggregate particles, mortar matrix, and interface transition zones (ITZs), concrete was modeled. By lowering the cross-sectional area of the rebar and bond, the impact of corrosion was mimicked. In order to characterize the interaction between concrete and reinforcement, localized corrosion of the reinforcement was taken into consideration and a non-linear spring element was used. In terms of ultimate flexural capacity and displacement, the modeling findings for the corrosion-resistant concrete slab are in good agreement with the test results.

Yaseen ali salih et al.(2022) studied the GFRP slabs are under 25% strain.Additionally, the time interval was 37.5% shorter than it was for the slab with steel bars. In comparison to other directions, the short direction has a higher strain value. In addition to long-term static stresses, concrete buildings are frequently exposed to short-term dynamic loads. Tensile. As long as the concrete is incapable of bearing these stresses, strength and energy dissipation qualities are diminished. impact weights. This study examines the behavior of glass fiber-reinforced polymer-reinforced one-way concrete slabs.(GFRP) under a load of impact. One-way concrete slabs with GFRP reinforcement and conventional steel have been compared.

hossein Esmaeilkhanian et al.(2022) studied The ultimate strength, bond strength, and structural stiffness of the resin in the post-curing process decrease as the temperature rises, especially as the resin's glass transition temperature (Tg) is approached and exceeded. However, during post-curing, resin seems to retain its mechanical characteristics at high temperatures. As a consequence, FRP-reinforced/-strengthened parts behave structurally appropriately at high temperatures that are below the resin decomposition temperature Td. For example, a 90% reduction in bond strength at temperatures between 100 and 200 C results in the loss of FRP-concrete interaction. This is generally observed to happen when the mechanical characteristics of the resin degrade at temperatures above Tg.

3. LITERATURE SUMMARY

- The mid-span deflection was reduced by 21% when the concrete strength was increased for a greater reinforcement ratio (2.0%) as opposed to just 7.0% for a reinforcement ratio of 1.0%.
- Regardless of the reinforcing ratio, increasing the concrete's strength from normal to high strength had no impact on the experimental moment capacity.
- For reinforcement ratios of 1.0% and 2.0%, respectively, post cracking bending stiffness rose by 25% and 23% for a concrete strength increase from 40 to 80 MPa.
- Under static stress, it was demonstrated that the GFRP RC slabs were flexural critical.
- The dynamic amplification factor for the GFRP RC slabs during impact loading was found to be, on average, 15% greater than that under static loading.

4.CONCLUSION

The techniques provide a highly effective and versatile bars for strengthening of slabs and other structural elements. By applying GFRP bars on existing slabs, their load carrying capacity, durability and overall structural performance can be significantly improved. The lightweight, non-corrosive and adaptable nature of FRP composites allows for rapid installation with minimal disruption, making it cost-effective long-term solution. However, proper design, installation and quality control are essential to ensure optimal results and to continue advancing the effectiveness of FRP technology for future projects.

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