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

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Abstract- Presently, fiber reinforced polymers are gaining more importance in the market for their lightweight, high strength to weight ratio, high durability, stiffness, damping property, flexural strength, wear, impact, and fire resistance. They have been used as a substitute for traditional steel reinforcing bars as they have excellent electrochemical corrosion resistant property. These polymers have become essential materials for maintaining and strengthening existing infrastructures. FRP bars are stronger material than steel .This paper presents an overview of the flexural behaviour of slabs reinforced with FRP bars subjected to static and impact loads.

***Key Words*:** FRP Bars, Flexural Strength.

1.INTRODUCTION

Fiber reinforced polymer composite offers not only high strength to weight ratio, but also reveals exceptional properties such as high durability, stiffness, damping property, flexural strength, and resistance to corrosion, wear, impact, and fire. FRP has been used extensively for strengthening structural components including the application of sheets or plates as external reinforcement to the exterior surface of beams and slabs. The primary function of fibre reinforcement is to carry the load along the length of the fibre and to provide strength and stiffness in one direction. It replaces metallic materials in many structural applications where load-carrying capacity is important.

Their exceptional performance in the numerous fields of applications have made fibre reinforced composite materials a promising alternative over solitary metals or alloys. The use of FRP in engineering applications enables engineers to obtain significant achievements in the functionality, safety and economy of construction because of their mechanical properties. Although the initial cost of FRP reinforcement is higher than steel reinforcement, the total life cycle cost of the structure or structural components reinforced with FRP is lower, as significantly less maintenance costs are required for structures or structural components reinforced with FRP. It is noted that, for conventional steel RC structures, exposure to harsh environments including moisture and temperature reduces the alkalinity of the concrete and causes corrosion of the steel reinforcement and ultimately results in the loss of serviceability and strength. Increasing the FRP tensile stress ratio is also key a factor that increases load capacity and controls deflection.

2. REVIEW OF LITERATURE

Mohd Zamin Jumaat and M.A. Al-Kubaisy (2000) conducted the study on flexural conduct of reinforced concrete with ferrocement pressure zone cover. The primary crack increased within the rate of work support and the ferrocement layer thickness. Significant decrease in splits width and dispersing (64–84%) was watched for examples with a ferrocement layer. The nearness of a cold joint between the reinforced concrete and the ferrocement layer brought down the extreme flexural stack by 34%, be that as it may, splits width and dispersing were decreased. The avoidances at benefit stack and close extreme stack were littler for examples with ferrocement layer. The ferrocement layer thickness and the association sort impacted the decrease in avoidance.

Luciano Ombres et.al (2000) investigated that the flexural behavior of FRP reinforced concrete unidirectional slabs is presented. Cracking and deflection of FRP reinforced concrete structures are analyzed both theoretically and experimentally. A comparison of the deflections, crack configurations, and crack widths of GFRP reinforced concrete slabs is made, and the different behaviors are analyzed and discussed. Finally, experimental results and theoretical predictions are compared.

Zineddin and Krauthammer (2007) investigated the large number of slabs designed and built, the effect of their details on their behavior under impact loads are not always appreciated or properly taken into account. This experimental study was aimed at understanding the dynamic behavior of structural concrete slabs under impact loading to improve the state of the art of protective design. This study investigated the effects of different types of slab reinforcements and the applied impact loads on the dynamic response and behavior of reinforced concrete slabs.

AntonioNannietal (2009)experimentally investigated the flexural behavior and design of RC members using FRP reinforcement. Since reinforced plastic reinforcement does not yield, there should be an express condition that damage can be controlled by crushing the concrete and not by crushing the reinforcement. In the design of FRP reinforced concrete structures, flexural control can become as important as flexural strength. The main reasons are that the predicted torque capacity represents a highly variable state that can only be reached at high deformation and cracking and that it strictly depends on the concrete ultimate stress.

Gavami K (2011) studied about the corrosion of steel reinforcement embedded in a concrete bridge deck, which was the cause of significant structural deterioration and high repair and maintenance costs. They did on a unidirectional concrete slab strip under static load, with hybrid steel and glass fiber reinforced polymer (GFRP) reinforcement and all steel or almost all GFRP reinforcement and the effect of reinforcement ratio and hybrid reinforcement method. An elementary analysis of the bending behavior of the plates was also carried out to determine the final bearing capacity of the investigated plates, and it was compared with the results of the experimental test. GFRP bars offer a promising alternative reinforcement with high resistance combined with high strength and lightness. They appreciate the superior strength and performance of the compression member.

Sathishkumaret.al (2012) experimentally investigated that the GFRP composites were equal to steel, their stiffness was higher than aluminum and their specific gravity was one-fourth that of steel. The yield stress of GFRP bars is less than 5% of the initial value after 10,000 hours of continuous tensile loading. This value is obtained at a high stress of 30% of the guaranteed tensile strength. The elongation of the GFRP plates is 25% less than that of the steel bar plate, and the span was also 37.5% less. The value of strains is greater in the short direction than in the other directions.

Kara and Ashour (2012) studied about a numerical method to evaluate the curvature, deflection and moment resistance of FRP reinforced concrete beams. The moment curve ratio is obtained by considering force balance and strain compatibility. The proposed change also takes into account the experimentally observed wide cracks on the span of continuous FRP reinforced concrete beams in terms of mid-span flexural stiffness. Comparison with experimental results shows that the proposed numerical technique can accurately predict the moment capacity, bending and deflection of FRP reinforced concrete beams. The deflection of the beam is then calculated based on the curvature of the central plane 15. A large increase in FRP reinforcement was found to slightly increase the moment capacity of the FRB with respect to the reinforced concrete beam, but to significantly reduce the deflection after the first crack.

Sunna et al (2012) studied about the flexural response of FRP members. The flexural response of RC members is investigated by load-deflection tests on 24 RC beams and slabs with glass-FRP and carbon-FRRP reinforcement covering a wide range of reinforcement ratios. The stresses in the reinforcement and concrete around the crack initiator are used to determine the moment curvature ratio and to estimate the shear and flexural components of the mean deflections. It is concluded that the contribution of shear and bond strains can be very important for FRP RC members with moderate to high reinforcement ratios. Existing equations for calculating the short-term deflection of FRP RC members are discussed and compared with experimental values.

Baturay (2013) experimentally investigated the static and impact behavior of identical specimens, plates were cast in three identical pairs, so that one of the specimens was tested under impact loading, while its identical specimen was tested under static loading. To test the slabs under simply supported conditions, an innovative impact test system was developed and manufactured that supports the specimens at 20 points around the perimeter and holds the specimens during impact. Impact loads were applied to the specimens with a free-falling drop weight that struck the specimens in the center. The results obtained from these tests showed that the impact behavior of the plates is significantly different from their static behavior. Displacement profiles and force distribution are strongly influenced by large inertial forces during impact.

Ashraf et al., (2013) conducted the study on variation of flexural stiffness of cracked FRP reinforced concrete elements was evaluated using different existing effective moments of inertia models. The reduced shear stiffness model was also used to account for differences in shear stiffness in the cracked regions. Comparison of the results obtained with the proposed analytical procedure and the effect of shear deformation in simply and continuously supported tests was found to affect continuous FRP reinforced concrete beams more than simply supported beams. The proposed analysis method is the basis for the analysis of concrete frames reinforced with FRP concrete elements**.**

Gudonis et al (2014) experimentally investigated that the fiber reinforced polymers are considered promising alternatives to steel reinforcement. Long-term deterioration of properties, depending on the type of FRP reinforcement, can reduce the long-term strength by a factor of two to three. The largest reduction in strength is associated with GFRP. The designer must be aware of the increase in deformation of FRP-reinforced concrete elements over time.

Trevor and Frank (2014) investigated the slabs that contained longitudinal reinforcing bars and were manufactured with steel fiber content ranging from zero to 1.50% by volume. The test results showed that the addition of steel fibers effectively increased the capacity of the plate and reduced the crack width and gap and localized effect. Although the plates must be flexurally critical under static loading conditions, the development of inertial forces caused the reactions and shear modes observed under impact loading conditions.

Zhicheng et al (2016) experimentally investigated that the structural behavior of reinforced concrete (RC) slabs subjected to accelerated corrosion. Some test specimens developed transverse cracks when a controlled amount of static load was applied. A constant load was maintained during the corrosion process. The results show that the stainless reinforced concrete slabs have multiple flexural cracks perpendicular to the steel reinforcement in the ductile failure mode. Etched specimens have fewer but wider transverse cracks under flexural loading and the failure mode is a brittle fracture mode. The initial pre-crack condition and continuous loading during the corrosion process significantly affect the corrosion behavior of RC plates. These conditions cause a greater drop in the maximum load capacity of such plates compared to corroded plates when there are no cracks and the load cannot be sustained in nature during the corrosion process. Ignoring this harmful activity can lead to a dangerous fitness assessment.

Honghao et al. (2017) investigated how longitudinal GFRP bars significantly affected column capacity, where the maximum compressive and tensile stresses for longitudinal GFRP bars were approximately 910 MPa (98% failure strength) and 125 MPa (14% failure strength). The maximum tensile stress of the GFRP base was 300 MPa. The stress-strain curves of coir rope are obtained. Empirical equations are proposed for tensile strength and bond strength. Higher tensile and bond strength is achieved by boiling.

Valter Carvelli et al (2017) studied about the reinforcing material, glass fiber reinforced polymers (GFRP) are increasingly used in reinforced concrete structure. The main advantages of using GFRP reinforcement instead of steel are: non-corrosive and non-conductive properties and a high strength-to-weight ratio, as well as their magnetic transparency and good fatigue. Although much research has been done to understand the properties of the FRP bar/concrete connection, this area still receives considerable attention. DIC analysis provided a better understanding of the crack development pattern, which indicates crack initiation.

Shahad and Adheem (2018) investigated the mechanical characterizations of concrete with GFRP rebars are performed and compared with those of steel bars. The preparation of concrete samples with a fixed material ratio (unreinforced concrete, smooth GFRP reinforced concrete, sand-coated GFRP reinforced concrete and reinforced concrete) was carried out with two curing times of 7 and 28 days at ambient temperature. The value of the volume fraction of GFRP and steel rods in reinforced concrete was distributed equally at the distances prescribed in the form. The results show that the tensile strength of the GFRP rebar is 593 MPa and the flexural strength is 760 MPa. The compressive strength of the concrete was within an acceptable range of 25.67 MPa. Unreinforced concrete has a flexural strength of 3 MPa and GFRP reinforced concrete, especially sand-coated GFRP RC, has a flexural strength of 13.5 MPa, which increases the adhesion of concrete and a higher stress of 10.5 MPa in 28 days than reinforced concrete at the expense of the flexural modulus.

Hamid Sadraie et al (2019) investigated the dynamic performances of concrete slabs reinforced with steel and GFRP bars under impact loading. In this work, the influence of reinforcement material, number and arrangement of reinforcements, concrete strength and slab thickness on the dynamic behaviour of reinforced concrete slabs was investigated both by laboratory experiments and numerical simulations. The experimental and numerical model results are in good agreement and show that increasing the reinforcement ratio or plate thickness improves the behaviour of RC plates under impact loading. By controlling the amount and placement of GFRP in GFRP plates, it is possible to achieve better performance than steel-reinforced plates, which allows choosing the appropriate reinforcing material considering the corrosion resistance of the material.

Allan Manalo et.al (2020) investigated on Flexural behaviour of concrete slabs reinforced with GFRP bars. This study investigated the flexural behaviour of concrete slabs reinforced with GFRP bars were tested under four-point static bending to observe the propagation of failure, load-deflection, and the load-strain behaviour.

Maher A. Adam et.al (2021) investigated the Structural Behavior of High-Strength Concrete Slabs Reinforced with GFRP Bars. They investigate the behavior of such specimens when reinforced with a locally produced GFRP reinforcement. The structural behaviour of the tested slabs was investigated in terms of ultimate load, ultimate deflection, load–deflection relationship, and crack pattern. The outcomes showed that the contribution of GFRP rebars in concrete slabs improved slab ductility and exhibited higher deflection when compared with traditional steel rebars.

Hajiloo et al (2019) investigated the thickness of the concrete cover to achieve sufficient fire resistance, which lowers the efficiency and increases the cost of glass fiber reinforced polymer (GFRP) reinforcement compared to conventional steel reinforcement. This paper investigates the fire resistance of two full-scale GFRP-RC slabs with only 40 mm clear concrete cover at the ends and a 200 mm unexposed (cool) anchorage zone. Both plates lasted 3 hours under normal fire. The plates were subjected to a continuous load that produced a moment corresponding to 45% of its ultimate bending strength. The focus was to investigate the bond behaviour of GFRP bars by thoroughly examining the temperature distribution, especially in the exposed anchor zones at the ends of the plates. The temperature drops significantly in the unexposed zones, providing adequate support for the bars, while almost all of the GFRP-concrete connection was weakened in the exposed zone. Analysis of the test results showed that the increase in tensile strength of GFRP bars during a standard fire is less than 50% of the existing permanent strength. In the new model, bond weakening predicts the fire resistance of GFRP-reinforced slabs. The results allow the efficient, economical and fire-safe use of GFRP reinforcement in concrete construction by reducing the concrete cover.

YaseenaliSalih et.al (2022) investigated that the elongation of GFRP plates is 25% less than steel bar plate, and the span was also 37.5% less. The value of strains is greater in the short direction than in the other directions. The GFRP elements resisted mostly axial forces, which was in good agreement with the axial mechanical properties of unidirectional pultruded GFRP composites. The flexural behavior of such a unique bridge can be predicted with sufficient accuracy using validated numerical and simplified analytical models, including the total deformation of the entire structure and the axial force of the GFRP under strings and tongue ties.

Samad Khaksar et al. (2022) investigated that the case of minor resin in the post-curing process, as fracture strength, bond strength and structural stiffness decrease with increasing temperature, especially when approaching and exceeding the glass transition temperature Tg of the resin. After curing, the resin appears to retain its mechanical properties at high temperatures, resulting in adequate structural performance of FRP-reinforced parts at high temperatures. They modified the GFRP surface using coarse aggregate to improve bond strength with concrete. The yield strength of GFRP rebar is about 30% higher than that of steel rebar. The strength of smooth GFRP has reached 70-82% of the flexural strength of RC steel.

AbdulMuttalib and Enas (2022) investigated that the concrete slabs under high mass and low velocity repeated impact loading. The observed damage and crack formation were found to be typical among RC slabs. For the slab group that initially investigated the effect of increasing the steel reinforcement ratio, the slab with the highest reinforcement ratio was more resistant to local damage, and the crack pattern on the bottom surface of the slab consisted mainly of discontinuous hairline cracks. For all plates, the development of inertial forces led to the observed responses and failure modes under impact loading conditions,which were controlled by the shear force.

Yaseen Ali and Aziz (2022) investigated that the concrete structures are usually exposed to short-term dynamic loads in addition to long-term static loads. The tensile strength and energy loss properties are reduced as a result of these loads until the concrete is poorly resistant to impact loads. This paper investigates the behavior of unidirectional concrete slabs reinforced with glass fiber reinforced polymer (GFRP) under impact loading. A comparison of unidirectional concrete slabs reinforced with GFRP and plain steel was made. A simple device is made mainly to apply an impact load by applying a load of 7 kg falling on the center of the plate from two different heights, 1000 mm and 2000 mm. Elongation of concrete at different locations is measured over a period of time. The results showed that plates reinforced with GFRP bars behave better than plates reinforced with plain steel. The elongation of the GFRP plates is 25% less than that of the steel bar plate, and the span was also 37.5% less. The value of strains is greater in the short direction than in the other directions.

Renbo Zheang et al (2023) studied a model of GFRP reinforced concrete slabs with different impact mass and velocity. Using the available experimental data, a numerical model was established and validated to investigate the impact behavior of Glass FRP (GFRP) reinforced concrete slabs with different impact masses and velocities. The characteristic history of central displacement and impact force was found.

3. LITERATURE SUMMARY

- The elongation of the GFRP plates is 25% less than that of the steel bar plate, and the span was also 37.5% less. The value of strains is greater in the short direction than in the other directions.
- By controlling the amount and placement of GFRP in GFRP plates, it is possible to achieve better performance than steel-reinforced plates, which allows choosing the appropriate reinforcing material considering the corrosion resistance of the material.
- The yield strength of GFRP rebar is about 30% higher than that of steel rebar. The strength of smooth GFRP has reached 70-82% of the flexural strength of RC steel.
- The results obtained from these tests showed that the impact behavior of the plates is significantly different from their static behavior.

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