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Review on Steel Reinforcements Replaced by Bamboo and GFRP Rods in Concrete Slab

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Abstract:

Currently fiber-reinforced polymers are increasing in importance in the market due to their lightness, high strength-to-weight ratio, high durability, stiffness, damping properties, flexural strength, abrasion, impact and fire resistance. They have been used as a replacement for traditional steel bars due to their excellent electrochemical corrosion resistance properties. These polymers have become important materials for maintaining and strengthening existing infrastructures. In recent decades, there has been a growing interest in the use of bamboo in construction, mainly due to its durability. The mechanical properties of bamboo, its availability in developing regions, low cost, lightness and short growth cycle have led to its empirical use as reinforcement in concrete structures. This article provides an overview of the behaviour of GFRP and bamboo reinforced plates, their advantages and applications.

Keywords —**GFRP rods, Bamboo, Structural Performance of slabs.**

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I. INTRODUCTION

1.1 BAMBOO

Concrete is a popular construction material due to its low cost, fire resistance, and availability. However, its low tensile strength makes it unsuitable for all applications. Steel, with its high tensile strength, is commonly used to reinforce concrete. Bamboo, with a tensile strength of 370 MPa, is an attractive substitute for steel in tension load applications. This study aims to investigate bamboo's properties for concrete reinforcement performance, its ductility, and compare it with steel reinforcement for low-cost housing.

1.2 FIBER REINFORCED POLYMER

Fiber-reinforced composites, made from synthetic or natural materials, are gaining importance due to their lightweight and strong properties. The performance of these materials depends on their components and manufacturing techniques. Studying the functional properties of various fibers, their classifications, and manufacturing techniques is crucial to optimize these materials for various applications. Fiber-reinforced composites offer a promising alternative to single metals or metal alloys.

II. LITERATURE REVIEW

Ghavami (2005) stated that the construction industry is a significant consumer of energy and materials. Recent studies on bamboo's microstructure and composite behavior have shown that bamboo can replace steel satisfactorily. Bamboo concrete adhesion can be improved by over 100% when treated, demonstrating its potential in various matrices like soil and cement compounds.

Rahman et al (2011) preferred bamboo as a reinforcement, evaluating its performance through tensile and beam bending strength tests. They used 1 m bamboo sticks with different cross-sections and compared bamboo-reinforced beams with concrete beams, comparing length, width, and depth.

Terai and Minami (2012) studied the mechanical behavior of bamboo reinforced concrete blocks, revealing differences in structural properties compared to reinforced concrete. They found that bamboo's tensile strength increases with aging, and its pull-out test behavior is similar to that of ordinary steel bars, with a higher value of 1.2-1.35 MPa. This confirms the use of bamboo and concrete construction.

Nayak et al (2013) explored the use of bamboo rebar instead of steel rebar due to its high strength, ease of processing, and environmental friendliness. They chose advanced bamboo reinforcement technology for an affordable financial structure, using it in main and distribution reinforcement. Bamboo is three times cheaper than steel reinforcement, especially in single-layer construction, making it a more cost-effective option.

Subramaniam and Venugopal (2015) explore the use of bamboo reinforced concrete slabs as a reinforcement for garden walls in rural South India. Currently, garden walls are constructed from cast-in-situ reinforced concrete (SRC) slabs without specification. BRC tiles are 25-30% cheaper and fail at 50% of the load taken at failure. The cost analysis suggests using BRC boards for garden walls, allowing more bamboo to grow from the environment, as they are 25-30% cheaper.

Gupta et al (2015) study bamboo's structural properties, focusing on its flexural and tensile strength and high strength to weight ratio. They conduct laboratory tests to assess its applicability and reliability as a reinforcement material in low-cost housing concrete structural parts, and select suitable bamboo specimens for use in concrete elements.

Maruthupandian et al (2016) conducted a study on bamboo rebar with three compositions (40, 30, and 25%) and epoxy and hardener. The 25% bamboo reinforcement composite had the highest tensile strength, making it suitable for minimal stress applications like kitchen tops and book tops. Steel concrete slab was slightly better than bamboo concrete slab, but both plates exhibited the same deflection under a 40 KN load.

Al Mamun and Bakar Siddique (2017) found that bamboo rebar has significantly higher flexural strength than ordinary cement concrete and is comparable to reinforced concrete beams. Bamboo reinforced beams and columns showed the best strength-to-cost ratio.

Bashir et al (2018) explored bamboo as a sustainable alternative to reinforcing bars in concrete, considering non-special issues like economy and social sustainability. Bamboo fiber concrete can increase compressive strength while reducing flexural strength. The study found that increasing bamboo percentage increases concrete's compressive strength, while decreasing flexural strength. This makes bamboo a promising alternative for sustainable civil engineering development.

SeethalakshmiThangaraj and MadasamyMurugan(2023)studied the cementitious composite slab panel with nano-basalt powder (nBP) modified epoxy-coated bamboo as reinforcement. The panel showed improved flexural performance and bonding characteristics, with 32% increase in bond strength compared to uncoated bamboo. The nBGS slab also showed an 89% increase in load-carrying capability compared to conventional cement concrete.

2.2 GFRP

Matthys and Taerwe(2000) studied FRP grid strengthening of concrete slabs found a strong interaction between shear and bending effects. FRP-reinforced slabs with higher reinforcement ratios or depths had similar impact strength to steel-reinforced reference slabs. However, bar slip occurred in most slabs, causing larger deflections at failure. The study highlights the importance of considering load modes and reinforcement ratios when strengthening concrete slabs.

Razaqpur et al (2006) studied reinforced concrete slabs with externally bonded GFRP laminates found that retrofitted panels performed better than non-retrofitted panels. However, there was no consistent trend in residual strength, making it difficult to determine blast attenuation. The study suggests that GFRP retrofitting may not be suitable in every situation and that quantifying its strengthening effect requires actual shock wave testing, rather than theoretical modeling or pseudodynamic testing.

Zheng et al (2011) investigated the corrosion of steel reinforcement in concrete bridge decks, highlighting the high repair and maintenance costs. They conducted a study on unidirectional concrete slab strips with hybrid steel and glass fiber reinforced polymer (GFRP) reinforcement, comparing their bending behavior and bearing capacity. The study found that GFRP bars offer a promising alternative with high resistance, strength, and lightness, enhancing the compression film's performance.

Kara and Ashour (2012) developed a numerical method to estimate the curvature, deflection, and moment capacity of FRP reinforced concrete beams. The method considers force balance, stress compatibility, and wide cracks on the span. The technique accurately predicts moment capacity, bending, and deflection. A large increase in FRP reinforcement slightly increases moment capacity but reduces deflection after the first crack.

Sunna et al (2012) investigated the flexural response of FRP members using load-deflection tests on 24 RC beams and slabs with various reinforcement ratios. They found that shear and bond strains are crucial for FRP RC members with moderate to high reinforcement ratios. Existing equations for calculating short-term deflection were discussed and compared with experimental values.

M. V. Venkateshwara Rao et al (2012) studied glass fiber reinforced polymer (GFRP) bars, finding an optimal fiber/resin ratio of 7:3. GFRP bars have comparable tensile strength to mild steel but a 25-30% modulus of elasticity.

Experimental studies were conducted on small slabs with an effective span of 0.9 m × 0.45 m, comparing them with plate panels reinforced with ordinary mild steel bars.

Noel and Soudki (2013) examined the corrosion of steel reinforcement in reinforced concrete structures, a major issue affecting infrastructure safety. They used FRP as an alternative, evaluating the bond's impact on workability and efficiency of slabs, particularly in terms of deformations.

Gudonis et al (2013) found fiber reinforced polymers as a promising alternative to steel reinforcement. However, long-term properties can deteriorate, reducing strength by two to three, with GFRP being the most significant. Designers should consider deformation increase over time.

Piriyakootorn et al (2015) found that the amount of glass fiber reinforced plastic rods (GFRP) in concrete columns slightly affects their strength. Lateral reinforcement affects confining pressure and inelastic deformation, increasing with the GFRP reinforcement ratio. However, it has limited effect on compressive strength. The concrete cover mainly affects the early closure effect, not maximum load capacity or late phase deformation.

Ali et al (2015) conducted an experimental study on replacing steel with reinforced plastic to address corrosion issues. They found that concrete slabs reinforced with square GFRB bars showed improved behavior and flexural loads compared to those reinforced with round GFRP bars. Nine full-scale GFR Pre-forced concrete unidirectional slabs were constructed, tested, and analyzed, with the square GFRP plate showing improved bending, cracking, and maximum load.

III. CONCLUSIONS

The list of literatures for both bamboo and FRP has been collected, analyzed and the summary of the litrature has beem obtained. From literature review, it is concluded that bamboo reinforced concrete slabs have less load withstanding capacity than steel reinforced concrete slabs, with high tensile stress and equal deflection. Considering the ultimate load capacity as a measurement, bamboo reinforced sections have less load carrying capacity when used as a main reinforcement on doubly reinforced beam, compared with RC beams but still can withstand the design load. The GFRP bars shows less deflection, cracks and better bond strength when compared to circular bars. The effect of the lateral reinforcement on deformability is more influenced than that on the column strength. The strengthening technique of GFRP helps in increasing the shear capacity and bond strength of beams and it is most economical.

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