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A study on Steel Rebars Replacement with GFRP Rebars in Coastal Concrete Structure- A Review

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Abstract- Reinforced concrete structures are widely used in infrastructure development due to their strength and durability. However, corrosion of steel reinforcement in aggressive environments such as coastal regions significantly reduces the service life of structures and increases maintenance costs. In recent years, Glass Fiber Reinforced Polymer (GFRP) rebars have emerged as a promising alternative to conventional steel reinforcement due to their non-corrosive nature, high tensile strength, and lightweight properties. This review paper presents a comprehensive study of 20 research works focusing on the replacement of steel rebars with GFRP in concrete structures. The paper evaluates mechanical performance, durability, bond behavior, sustainability, and field applications of GFRP reinforcement. It is observed that GFRP rebars provide superior corrosion resistance and durability, although they exhibit lower stiffness and brittle behavior compared to steel. The study also identifies key research gaps related to long-term performance, design standards, and ductility improvement. The findings suggest that GFRP is a suitable alternative for coastal and aggressive environments, and further research is required to enhance its structural performance and practical implementation.

Keywords- GFRP Rebars, Steel Reinforcement, Coastal Structures, Durability, Corrosion Resistance, Sustainable Construction.

I. INTRODUCTION

Reinforced concrete (RC) has been one of the most widely used construction materials in civil engineering due to its ability to combine the high compressive strength of concrete with the tensile strength of steel reinforcement. It is extensively used in buildings, bridges, pavements, water retaining structures, and marine infrastructure. Steel reinforcement plays a vital role in resisting tensile stresses, controlling cracks, and ensuring structural stability. However, despite its widespread use, steel reinforcement suffers from a major drawback—corrosion. This issue becomes more severe in aggressive environments such as coastal regions, marine structures, chemical industries, and wastewater treatment plants, where exposure to chloride ions, moisture, and harsh chemicals accelerates the corrosion process. Corrosion of steel reinforcement leads to expansion of steel due to rust formation, which in turn causes cracking, spalling, and delamination of concrete. This not only reduces the strength and serviceability of structures but also increases maintenance and repair costs significantly. In coastal areas, the problem is even more critical due to continuous exposure to seawater and high humidity. Studies have shown that a large percentage of infrastructure deterioration worldwide is directly related to corrosion of steel reinforcement. Therefore, there is an urgent need to find alternative materials that can enhance the durability and service life of reinforced concrete structures while reducing maintenance costs.

In recent years, Fiber Reinforced Polymer (FRP) materials have emerged as a promising alternative to conventional steel reinforcement. Among the different types of FRP, Glass Fiber Reinforced Polymer (GFRP) has gained considerable attention due to its relatively low cost, high tensile strength, corrosion resistance, and lightweight nature. GFRP rebars are non-metallic and do not rust, making them highly suitable for use in aggressive environments such as coastal and marine structures. Additionally, GFRP materials are non-magnetic and non-conductive, which makes them ideal for special applications such as hospitals, research facilities, and structures requiring electromagnetic neutrality.

One of the major advantages of GFRP rebars is their high strength-to-weight ratio, which facilitates easier handling, transportation, and installation at construction sites. This can lead to increased construction efficiency and reduced labor costs. Furthermore, the use of GFRP contributes to sustainable construction practices, as it reduces the need for frequent repairs and maintenance, thereby lowering the overall lifecycle cost of structures. From an environmental perspective, GFRP also has the potential to reduce carbon emissions associated with steel production. Despite these advantages, GFRP rebars exhibit certain limitations that must be carefully considered. One of the primary concerns is their lower modulus of elasticity compared to steel, which results in higher deflection and wider crack widths in structural members. Unlike steel, which exhibits ductile behavior and provides warning before failure, GFRP behaves in a linear elastic manner up to failure, leading to brittle fracture. This lack of ductility poses challenges in structural design, particularly in critical load-bearing elements. Additionally, the bond behavior between GFRP and concrete differs from that of steel, which may affect load transfer and crack distribution. Another challenge associated with GFRP reinforcement is the lack of standardized design codes and guidelines. Although some international standards exist, their application is still limited, and engineers often face difficulties in designing GFRP-reinforced structures with confidence. Moreover, long-term performance aspects such as creep, fatigue, temperature effects, and durability under sustained loading conditions require further investigation.

To address some of these limitations, researchers have explored hybrid reinforcement systems that combine steel and GFRP to take advantage of both materials. Such systems aim to provide improved ductility, strength, and durability while minimizing the disadvantages of each material. However, these approaches are still under research and require further validation through experimental and field studies. In this context, the present review paper aims to study the feasibility of replacing conventional steel reinforcement with GFRP rebars in coastal concrete structures. A detailed analysis of 20 research studies has been carried out to evaluate the mechanical performance, durability, bond behavior, and sustainability aspects of GFRP reinforcement. The paper also identifies key research gaps and provides insights into future research directions for the effective implementation of GFRP in reinforced concrete structures. Overall, this study contributes to understanding the potential of GFRP as a durable and sustainable alternative to steel reinforcement in modern construction practices.

II. LITERATURE REVIEW

The literature review plays an important role in understanding the existing research related to the use of GFRP rebars as a replacement for conventional steel reinforcement in concrete structures. Various researchers have studied the mechanical behavior, durability, bond characteristics, and sustainability aspects of GFRP in different structural applications. The following section presents a comprehensive review of 20 research studies to analyze the performance of GFRP reinforcement, especially in coastal and aggressive environmental conditions.

[1] Flexural Behavior of GFRP Rebars and Steel Rebars with Polypropylene Fibers and Fly Ash-Based Concrete (2025) by Vudata Harsha Sai et al. studied flexural performance of beams using GFRP and steel reinforcement. The results showed that steel beams have higher load capacity, while GFRP beams exhibit higher deflection due to lower stiffness. However, GFRP provided good corrosion resistance and durability. The study concluded that GFRP is suitable for aggressive environments where durability is important.

[2] Construction and Field Tests of Jointed Reinforced Concrete Pavement (2025) by Xi Wu et al. analyzed GFRP use in sea sand concrete pavement. The study showed that GFRP performs well in marine conditions and reduces corrosion issues. Field tests confirmed satisfactory structural behavior under loading. It was concluded that GFRP is a reliable option for coastal infrastructure.

[3] Comparative Study on Structural Performance of GFRP and TMT Bars (2025) by Piyush Ghagi et al. compared GFRP and TMT reinforcement. The results showed GFRP has better corrosion resistance and durability, while TMT provides higher ductility. The study suggested hybrid reinforcement for better performance. It concluded that material selection depends on environmental conditions.

[4] Experimental Study of Comparison between GFRP and Steel Bars (2025) by Tejas Suresh Tayade et al. evaluated mechanical properties of GFRP and steel. The study found GFRP has comparable strength and better durability than steel. Bond strength was also satisfactory. It concluded that GFRP is a sustainable alternative to steel.

[5] Integrating Smart Technologies for Sustainable GFRP Rebar Solutions (2025) by Prakhar Singh et al. focused on improving GFRP performance. The study highlighted issues like low ductility and bond strength. Advanced techniques were suggested to enhance performance. It concluded that GFRP needs further optimization for wider use.

[6] Assessing GFRP as a Sustainable Alternative to Steel Reinforcement (2025) by Tanmoy Ghosh et al. reviewed sustainability aspects of GFRP. The study showed GFRP reduces maintenance and improves durability. It also has lower lifecycle cost despite higher initial cost. The study concluded that GFRP is suitable for sustainable construction.

[7] Comparative Study of GFRP and Steel Rebar Bonding in Concrete (2024) by Ahlem Sdiri et al. investigated bond behavior of GFRP and steel. The study showed GFRP has weaker bonding and wider cracks compared to steel. However, it provides good durability. It concluded that surface treatment is important for performance.

[8] Comparative Life-Cycle Assessment of Steel and GFRP Rebars (2024) by Saad Al Omar et al. analyzed environmental impact of GFRP and steel. The results showed GFRP significantly reduces CO₂ emissions. It also reduces lifecycle cost and maintenance. The study concluded that GFRP is more sustainable than steel.

[9] Replacement of Steel with GFRP for Sustainable Reinforced Concrete (2024) by Shaikh Ahad Shabbir et al. studied structural and environmental performance of GFRP. The study showed GFRP improves durability but increases deflection. It also leads to brittle failure. The study recommended hybrid systems for better performance.

[10] Replacement of Steel Bar with GFRP Bar (2024) by Mohan Pidurkar et al. analyzed GFRP as an alternative to steel. The study showed GFRP has high strength and corrosion resistance. However, it has lower stiffness than steel. The study concluded that further research is required for long-term behavior.

[11] Hybrid GFRP-Steel Reinforcement System in Concrete Beams (2023) by Rajeev Devaraj et al. reviewed hybrid reinforcement systems. The study showed hybrid systems improve ductility and durability. It reduces drawbacks of pure GFRP. The study concluded that hybrid reinforcement is an effective solution.

[12] GFRP Reinforced Concrete Boat-Approach Slab (2022) by Allan Manalo et al. studied GFRP slabs in marine conditions. The study showed improved durability and performance. It also improved construction efficiency due to lightweight nature. The study concluded GFRP is suitable for coastal structures.

[13] Replacement of Steel Bars with FRP Bars (2020) by Vishwal Deshmukh et al. conducted experimental analysis using FRP bars. The results showed high tensile strength and good flexural performance. Surface treatment improved bonding. The study concluded FRP can replace steel in aggressive environments.

[14] Structural Performance of Columns using GFRP Rebar (2020) by V. Manjari Blessing et al. studied GFRP in columns. The results showed improved load capacity and crack control. GFRP columns showed better recovery after loading. The study concluded GFRP enhances durability of columns.

[15] Feasibility and Utilization of GFRP in Concrete Structures (2020) by Chandan Kumar et al. analyzed GFRP as alternative material. The study showed improved durability and reduced environmental impact. However, brittle failure is a concern. The study concluded GFRP is a feasible alternative.

[16] Comparative Study of Steel and GFRP Bars in RC Members (2019) by Rifat Resatoglu et al. compared steel and GFRP beams. Steel showed higher strength, while GFRP showed better durability. GFRP had more cracks and deflection. The study concluded GFRP is suitable for corrosive environments.

[17] Flexural Strength of GFRP and Steel Reinforced Beams (2018) by Shilpi Bhuniyan et al. studied flexural performance of beams. The results showed GFRP beams have adequate strength and corrosion resistance. Steel showed better stiffness. The study concluded GFRP is a good alternative in harsh environments.

[18] FRP Reinforced Concrete Slabs (2017) by Valerio Stuart et al. compared different design methods. The study showed variation in code predictions. FRP slabs performed well but require better design guidelines. The study concluded that more research is needed.

[19] Structural Frames Reinforced with GFRP Grid (2004) by Aly M. Said et al. studied seismic performance of GFRP frames. The study showed good strength but low ductility. Energy dissipation was limited. The study concluded design improvements are required for seismic use.

[20] Application of FRP Bars in Civil Engineering Structures (2002) by R.V. Balendran et al. reviewed applications of FRP in structures. The study showed FRP improves durability and reduces corrosion problems. It is suitable for harsh environments. The study concluded FRP has strong future potential.

III. RESEARCH GAP

Based on the detailed review of 20 research studies, it is observed that although GFRP rebars have shown promising performance as an alternative to steel reinforcement, several important research gaps still exist. One of the major gaps identified is the lack of comprehensive long-term performance studies of GFRP-reinforced concrete structures. Most of the existing research focuses on short-term experimental results such as flexural strength and load-carrying capacity, while aspects like creep behavior, fatigue performance, thermal effects, and long-term durability under real environmental conditions are not adequately explored. Another significant gap is related to the lower modulus of elasticity of GFRP compared to steel, which results in higher deflection and wider crack widths in structural members. Although these issues are frequently reported, there is still a lack of effective design solutions and guidelines to control serviceability criteria in GFRP-reinforced structures. The brittle nature of GFRP is also a major concern, as it does not exhibit ductile behavior like steel, leading to sudden failure without warning. Research on improving ductility through hybrid reinforcement or material modification is still limited.

Bond behavior between GFRP rebars and concrete is another area that requires further investigation. The performance of GFRP largely depends on surface treatment and bonding characteristics, but there is insufficient data on bond behavior under varying conditions such as cyclic loading, high temperatures, and long-term exposure. Additionally, there is a lack of reliable analytical models for predicting crack behavior and bond-slip relationships. From a practical perspective, the absence of widely accepted and standardized design codes for GFRP reinforcement is a major limitation. Engineers face challenges in adopting GFRP in real projects due to unclear design procedures, especially for complex structures and seismic conditions. Furthermore, large-scale field applications and real-life case studies are limited, particularly in coastal regions where GFRP is most beneficial. Sustainability aspects such as recyclability, disposal, and environmental impact of GFRP at the end of its lifecycle are also not well studied. Economic feasibility studies considering initial cost, lifecycle cost, and large-scale implementation are still inadequate. Therefore, further research is required to address these gaps and promote the practical use of GFRP in construction.

CONCLUSION

This review paper presents a comprehensive analysis of 20 research studies related to the replacement of steel rebars with GFRP rebars in concrete structures, particularly in coastal environments. The study highlights that corrosion of steel reinforcement is a major challenge affecting the durability and service life of reinforced concrete structures. GFRP rebars, due to their non-corrosive nature, high tensile strength, lightweight properties, and durability, offer a promising alternative to conventional steel reinforcement. The literature review indicates that GFRP-reinforced concrete structures perform satisfactorily under various loading conditions and exhibit superior resistance to environmental degradation.

GFRP is particularly suitable for marine and coastal structures where corrosion is a critical issue. Additionally, the use of GFRP contributes to sustainable construction by reducing maintenance requirements and lifecycle costs. However, GFRP rebars also have certain limitations, including lower stiffness, higher deflection, wider crack widths, and brittle failure behavior compared to steel. These limitations require careful consideration during design and analysis. The study also highlights the need for improved bond characteristics, better understanding of long-term behavior, and development of standardized design codes.

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REFERENCES

- [1] V. H. Sai, N. Lingeshwaran, P. K. Prasanna, et al., "Flexural Behavior of GFRP Rebars and Steel Rebars with Polypropylene Fibers and Fly Ash-Based Concrete," *Research on Engineering Structures & Materials*, 2025. DOI: <http://dx.doi.org/10.17515/resm2025-686me0214rs>
- [2] X. Wu, L. Huang, H. Yang, et al., "Construction and Field Tests of Jointed Reinforced Concrete Pavement Made of Sea Sand Concrete and GFRP Reinforcement," *Case Studies in Construction Materials*, vol. 23, 2025. DOI: <https://doi.org/10.1016/j.cscm.2025.e04974>
- [3] P. Ghagi, N. Chavhan, Y. Raut, et al., "Comparative Study on the Structural Performance and Durability of GFRP and TMT Reinforcement Bars," *International Journal of Novel Research and Development (IJNRD)*, vol. 10, no. 12, 2025.
- [4] T. S. Tayade and B. H. Shinde, "Experimental Study of Comparison between GFRP and Steel Bars," *International Journal for Research in Applied Science & Engineering Technology (IJRASET)*, vol. 13, no. 6, 2025.
- [5] P. Singh and N. Soni, "Integrating Smart Technologies for Sustainable GFRP Rebar Solutions," *Journal of Ravishankar University*, vol. 38, no. 1, pp. 129–142, 2025.
- [6] T. Ghosh, S. Sharma, and B. Mukherjee, "Assessing GFRP as a Sustainable Alternative to Conventional Steel Reinforcement in Beams and Columns," *International Journal of Creative Research Thoughts (IJCRT)*, vol. 13, no. 1, 2025.
- [7] A. Sdiri, N. Meddeb, E. Ghorbel, et al., "Comparative Study of GFRP and Steel Rebar Bonding in Concrete," *Revue des Composites et des Matériaux Avancés*, vol. 34, no. 2, pp. 233–245, 2024. DOI: <https://doi.org/10.18280/rcma.340213>
- [8] S. Al Omar and A. Abdelhadi, "Comparative Life-Cycle Assessment of Steel and GFRP Rebars," *Sustainability*, vol. 16, no. 10, 2024. DOI: <https://doi.org/10.3390/su16103899>
- [9] S. A. Shabbir, K. V. Tupsakhare, A. Surve, et al., "Replacement of Steel with GFRP for Sustainable Reinforced Concrete," *International Journal of Enhanced Research in Science, Technology & Engineering*, vol. 13, no. 3, 2024.
- [10] M. Pidurkar, M. Ninawe, S. Talmale, et al., "Replacement of Steel Bar with GFRP Bar as a Reinforcing Material in Concrete Structure," *International Journal of Research Publication and Reviews*, vol. 5, no. 4, pp. 5602–5605, 2024.
- [11] R. Devaraj, A. Olofinjana, and C. Gerber, "Making a Case for Hybrid GFRP-Steel Reinforcement System in Concrete Beams," *Applied Sciences*, vol. 13, no. 3, 2023. DOI: <https://doi.org/10.3390/app13031463>
- [12] A. Manalo, O. Alajarmeh, X. Yang, et al., "Development and Mechanical Performance Evaluation of a GFRP-Reinforced Concrete Boat-Approach Slab," *Structures*, vol. 46, pp. 73–87, 2022. DOI: <https://doi.org/10.1016/j.istruc.2022.10.040>
- [13] V. Deshmukh and N. P. Phadatare, "Experimental Study of Replacement of Steel Bars with FRP Bars," *International Research Journal of Engineering and Technology (IRJET)*, vol. 7, no. 8, 2020.
- [14] V. M. Blessing and S. Vignesh, "Enhancing the Structural Performance of Column using GFRP Rebar and Hybrid Fiber," *International Journal of Engineering Research & Technology (IJERT)*, vol. 9, no. 5, 2020. DOI: 10.17577/IJERTV9IS050827
- [15] C. Kumar, A. R. Sinha, S. Prakash, et al., "Feasibility and Utilization of GFRP in Concrete Structures," *International Journal of Engineering Research & Technology (IJERT)*, vol. 9, no. 8, 2020. DOI: <https://doi.org/10.5281/zenodo.18952015>

- [16] R. Resatoglu and M. S. Muhammad, “Comparative Study of Steel and GFRP Bars in RC Members,” ARPN Journal of Engineering and Applied Sciences, vol. 14, no. 16, 2019.
- [17] S. Bhuniyan, N. Memon, S. Katariya, et al., “Comparative Study of Flexural Strength of GFRP and Steel Reinforced Beams,” International Journal of Innovative Research in Technology (IJIRT), vol. 5, no. 1, 2018.
- [18] V. Stuart and L. S. Cunningham, “FRP Reinforced-Concrete Slabs: A Comparative Design Study,” Proceedings of the Institution of Civil Engineers – Structures and Buildings, vol. 170, no. 8, pp. 581–602, 2017. DOI: <https://doi.org/10.1680/jstbu.16.00055>
- [19] A. M. Said and M. L. Nehdi, “Performance of Structural Concrete Frames Reinforced with GFRP Grid,” 13th World Conference on Earthquake Engineering, Vancouver, Canada, 2004.
- [20] R. V. Balendran, T. M. Rana, T. Maqsood, and W. C. Tang, “Application of FRP Bars as Reinforcement in Civil Engineering Structures,” Structural Survey, vol. 20, no. 2, pp. 62–72, 2002. DOI: <https://doi.org/10.1108/02630800210433837>



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