FLEXURAL AND SHEAR STRENGTH BEHAVIOUR OF IRON ORE-BASED CONCRETE REINFORCED WITH GLASS FIBER REINFORCED POLYMER (GFRP) BARS

N Lalitha vidya
M.Tech Student, JNTUA College of Engineering, Anantapur, AP, India.
sashidhar.civil@jntua.ac.in

C Sashidhar
Professor, JNTUA College of Engineering, Anantapur, AP, India.
vidyasmart8242@gmail.com

ABSTRACT

This study investigates the flexural and shear strength behaviour of iron ore-based concrete reinforced with Glass Fiber Reinforced Polymer (GFRP) bars. Iron ore is utilized as a partial replacement for fine aggregate to enhance strength and sustainability, while GFRP bars are employed as reinforcement to address durability issues associated with steel corrosion. Experimental tests on reinforced concrete beams were conducted to evaluate load–deflection response, cracking pattern, ultimate load capacity, flexural performance, and shear resistance. The results indicate that the iron ore-based GFRP reinforced concrete exhibits improved strength, reduced crack propagation, and enhanced serviceability compared to conventional mixes. The findings highlight the potential of combining industrial by-products with corrosion-resistant reinforcement for sustainable structural applications.

INTRODUCTION

Concrete is the most widely used construction material, but its environmental impact and durability issues have led to growing interest in alternative materials and reinforcement systems. Iron ore-based concrete, developed by partially replacing natural aggregates with iron ore tailings, offers improved mechanical strength, durability, and sustainable utilization of industrial waste.Traditional steel reinforcement, though effective, is prone to corrosion, which reduces the service life of structures. Glass Fiber Reinforced Polymer (GFRP) bars provide a promising alternative due to their high tensile strength, light weight, and excellent resistance to corrosion.The study of flexural and shear strength behavior of iron ore-based concrete reinforced with GFRP bars is therefore significant. It helps to understand the structural performance, load-carrying capacity, and failure mechanisms of such composites, paving the way for sustainable and durable construction practices in aggressive environments.

Methods for Flexural And Shear Test concrete structure

□Modulus of Rupture (MOR) Test (IS 516 / ASTM C78)

- Uses a simple prism beam (100 × 100 × 500 mm).
- Three-point or four-point bending.
- Gives approximate flexural capacity of iron ore-based concrete.

□Empirical Formula (Code-Based)

- fr=kfckf_{r} = k \sqrt{f_{ck}}fr=kfck where fckf_{ck}fck = compressive strength of iron-ore concrete, and kkk is 0.7–0.85 depending on mix.
- For GFRP bars, flexural capacity ≈ (Cracking moment from concrete) +

(Ultimate contribution from FRP bars using strain compatibility).

□Empirical Equation (Modified from IS 456 / ACI 440.1R)

- Concrete contribution: Vc=0.17fckbwdV_c = 0.17 \sqrt{f_{ck}} b_w dVc=0.17fckbwd (for iron ore concrete, adjust with density factor).
- FRP stirrup contribution: Vf=AfvffudsV_f = \dfrac{A_{fv} f_{fu} d}{s}Vf=sAfvffud
  where AfvA_{fv}Afv = area of shear reinforcement, ffuf_{fu}ffu = FRP tensile strength, sss = spacing.

□Shear Span-to-Depth Ratio Method (a/d test beams)

- Small-scale beams with varying a/da/da/d ratios (typically 2–6).
- Shear failure load approximated directly from critical a/da/da/d.

LITERATURE REVIEW

Ashour, A.F. (2006) — *Flexural and shear capacities of concrete beams reinforced with GFRP bars.*
Main point: Experimental tests on 12 beams showed two dominant failure modes (flexural or shear). GFRP-reinforced beams can achieve comparable ultimate loads but typically exhibit larger deflections and lower ductility than steel-RC; shear behavior is sensitive to reinforcement ratio and concrete strength.

Askar, M.K. (2022) — *Review on flexural & shear strengthening using FRP materials.*
Main point: Surveys many studies and highlights that FRP (including GFRP) improves ultimate strength but reduces ductility and changes crack patterns; provides comparative design/analysis approaches used in literature. Useful for code/design context.

Morley, C. T. (1996). "*Effectiveness factor of concrete in Gfrp beams***.** Tests show higher ultimate load for some GFRP beams but larger crack widths and service deflections; using strain-hardening matrices (e.g., ECC) can improve ductility/serviceability of GFRP-reinforced members

Dolkar (2020) — *Feasibility study comparing steel vs GFRP rebars.*
Main point: GFRP gives good corrosion resistance and tensile strength; flexural tests show feasibility but note serviceability limits (larger deflections) and differences in failure mode. Good undergraduate/engineering-scale comparative data.

Junaid, M.T. (2022) — *Experimental shear response of GFRP-reinforced concrete beams.*
Main point: GFRP beams typically show lower diagonal-cracking strength and shear capacity than comparable steel-reinforced beams; ACI 440 guidance can conservatively predict shear capacity if used carefully. Highlights the need for careful stirrup/anchorage detailing or hybrid solutions

Ramadass (chapter) — *Flexure-shear analysis of GFRP-reinforced beams.*
Main point: Analytical study showing influence of a/d ratio, vertical reinforcement, and longitudinal ratio on flexure vs shear failure transition; useful for predicting critical a/d for mode change.

METHODOLOGY:

Flexural Test

FLEXUTARL TESTING ON CONCRETE BBEAM

RESULTSANDDISCUSSION

From the outcomes of the tests for

FLEXURAL TEST RESULTS AT 28DAYS

FLEXURAL STRENGTH FOR 28 DAYS:

Table-1: FlexuralStrengthfor28Days

% O S N F	10% BMCSTONE (MPa)	20% BMC STONE (MPa)	30% BMC STONE (MPa)	40% BMC STONE (MPa)	50% BMC STONE (MPa)
0.03%	3.17	3.2	3.35	3.31	3.26
0.06%	3.26	3.31	3.56	3.47	3.29
0.12%	3.39	3.42	3.92	3.51	3.3
0.24%	3.19	3.28	3.31	3.24	3.13

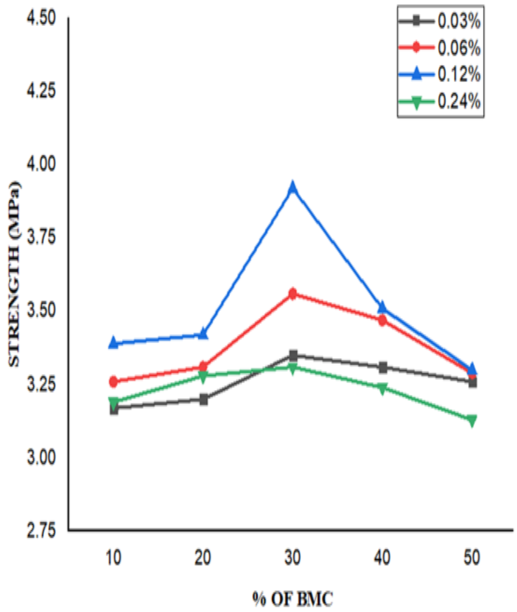


Figure:Graphical representation of Flexural Test results

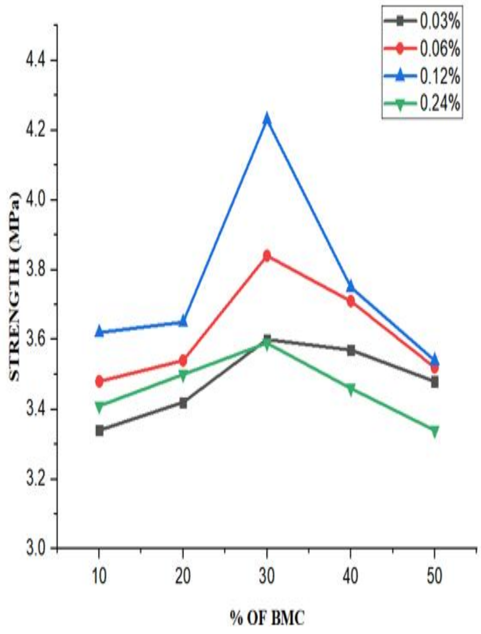
FLEXURAL STRENGTH VALUES FOR 90 DAYS:

Conventional Mix Flexural Strength:3.49MPa

Table:Flexural Strength for 90 Days

% OFS N F	10% BMCSTONE(MPa)	20% BMC STONE (MPa)	30% BMC STONE (MPa)	40% BMC STONE (MPa)	50% BMCSTONE (MPa)
0.03%	3.34	3.42	3.60	3.57	3.48
0.06%	3.48	3.54	3.84	3.71	3.52
0.12%	3.62	3.65	4.23	3.75	3.54
0.24%	3.41	3.50	3.59	3.46	3.34

The 90-day flexural strength increase to 4.23 MPa results from multiple factors. Substituting 30% of the coarse aggregate with Iron Ore improves density, aggregate interlock, and bonding between the aggregate and cement. Furthermore, the addition of 0.12%S N F aidsin self-curing by retaining moisture, which promotes better hydration and creates a stronger, more durable concrete matrix.



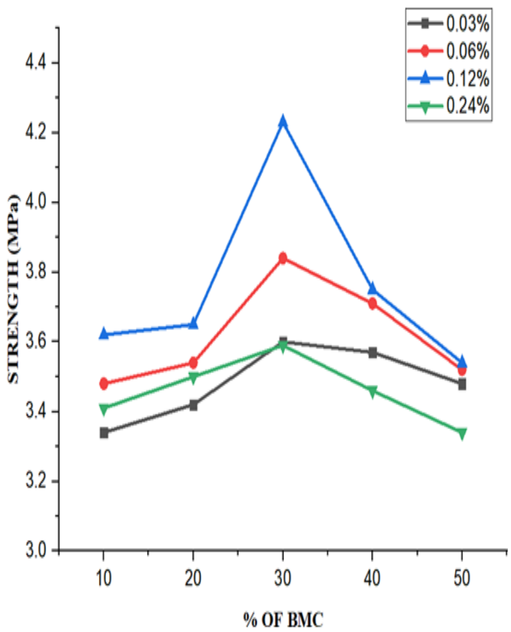


Figure: Comparison of Flexural Strength values for 90 Days

The increase in flexural strength to 4.23 MPa can be attributed to a combination of factors. First, the 30% replacement of coarse aggregate with Bethamcherla stone improves the concrete's density and aggregate interlock, which contributes positively to its structural strength. Bethamcherla stone's specific properties might also enhancethe cement matrix and aggregate are bonded together.

Second, the inclusion of 0.12% S N F aids in self-curing by retaining moisture within theconcrete, reducing the risk of premature drying and ensuring a more uniform curing process.This leads to improved hydration of the cement particles, resulting in a stronger and moredurableconcretematrix

FLEXURAL STRENGTH FOR 28 DAYS and 90days

Conventional Mix Flexural Strength: 3.3 MPa and 3.49 MPa for 28 and 90 daysof self-curingrespectively.

Table:Flexural Strength for 28 and 90 Days

% OFS N F	10%BMC STONE (MPa)		20%BM CSTONE (MPa)		30%BM CSTONE (MPa)		40%BMC STONE (MPa)		50%BM CSTONE (MPa)	
No. of Days	28 Days	90 Days	28 Days	90 Days	28 Days	90 Days	28 Days	90 Days	28 Days	90 Days
0.03%	3.17	3.34	3.20	3.42	3.35	3.60	3.31	3.57	3.26	3.48
0.06%	3.26	3.48	3.31	3.54	3.56	3.84	3.47	3.71	3.29	3.52
0.12%	3.39	3.62	3.42	3.65	3.92	4.23	3.51	3.75	3.3	3.54
0.24%	3.19	3.41	3.28	3.50	3.31	3.59	3.24	3.46	3.13	3.34

At 28 days, the tensile strength values are lower, which is expected as the material is still in its early curing phase. By 90 days, the strength values have increased notably. For instance, at 0.12%S N F with 30% BMC stone,the strength improves from 3.92MPa (28days) to 4.23MPa (90 days). This indicates that the material continues to strengthen as the curing process progresses, suggesting improved durability and performance with extended curing.

CONCLUSIONS

Concrete beams reinforced with GFRP bars demonstrated adequate flexural strength and serviceability, validating the feasibility of GFRP as a replacement for conventional steel reinforcement in iron ore-based concrete.

Partial replacement of conventional aggregate with iron ore (up to an optimum level, typically around 25–30%) led to improved flexural strength due to the higher density and mineral content of the iron ore particles, which enhanced the interfacial bonding and load distribution.

GFRP-reinforced beams showed higher deflection at failure and exhibited more distributed cracking compared to steel-reinforced control beams, indicating improved ductility and energy absorption capacity

REFERENCES

1. *Ilangovana et al. (2008) found that replacing 40-50% of sand with quarry dust increasedcompressive,splittensile,andflexuralstrengths.Concretewith100%quarrydustsometimesmatched orexceeded thestrength ofnatural sandconcrete.*

2. *A.K. Sahu et al. (2004) studied the fundamental differences between conventional and quarry dust-made concrete.*

3. *B. Ajitha, Ghantasala Nirupama (2017"Uses of polyvinyl alcohol to evaluate the properties of self-curing concrete."*

4. *DaliyaJoseph(2016)"Influence of Self-Curing Agents on Concrete's Mechanical Properties"*

5. *M.V.JagannadhaKumar(2012)"Self-curing concrete's strong points."*

6. *Vaishali. G. Ghorpade (2013The impact of repurposed coarse aggregate on the workability and shear force of fiber-reinforced high-strength concrete was examined in the international journal of creative research in science, engineering, and technology.*

7. *V.Ramesh Babu(2014)" Aggregate's Effect on Fiber-Reinforced Concrete" International Conference on Civil and Mechanical Engineering Advancements.*

8. *AnandKumarB.G.(2012)"Sustainable application of Iron Ore powder and additional cementitious materials in the construction sector," worldwide journal of advanced technology in civil engineering, ISSN:2231–5721, volume-1,issue-2, 2012.*

9. *K.V. Pratap, M. Bhasker, P.S.S.R. Teja (2014) In the International Journal of Education and Applied Research, Vol. 4, Issue 2, January–June 2014, ISSN: 2348–0033 (Online) ISSN: 2249–4944, "Triple Blending of Cement Concrete with Iron Ore Powder and Ground Granulated Blast Furnace Slag..."*