International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 13 Issue: 07 | Jul 2026 www.irjet.net p-ISSN: 2395-0072

BOND STRENGTH OF GFRP BARS AND REINFORCEMENT BARS EMBEDDED IN FLY ASH BASED CONCRETE.

R. Mohamed iqbal[1], P. Senthil[2]

[1]Assistant professor, Dept.of civil Engineering, M.A.M College of Engineering and Technology, Tiruchirappalli, Tamilnadu, India
[2]PG Student, Dept.of civil Engineering, M.A.M College of Engineering and Technology, Tiruchirappalli, Tamilnadu, India

---***---

Abstract - *Reinforced concrete structures rely heavily on the bond between reinforcement and concrete for effective load transfer and durability. Conventional steel reinforcement, although widely used, is susceptible to corrosion in aggressive environments. Glass Fiber Reinforced Polymer (GFRP) bars have emerged as a corrosion-resistant alternative. This study investigates and compares the bond strength of GFRP bars and steel reinforcement embedded in fly ash-based concrete. Experimental tests such as pull-out tests were conducted with varying fly ash replacement levels (0%, 10%, 20%, and 30%). The results indicate that while steel bars exhibit higher bond strength due to mechanical interlocking, GFRP bars demonstrate satisfactory performance with improved durability. The inclusion of fly ash enhances long-term strength but slightly affects early bond performance. This study highlights the feasibility of GFRP bars as a sustainable alternative in reinforced concrete structures.*

Key Words: GFRP bars Bond strength, Fly ash concrete, Pull-out test, Reinforcement, Sustainability.

1. INTRODUCTION

Reinforced concrete (RC) is a fundamental material in modern construction due to its ability to combine compressive strength of concrete with tensile strength of reinforcement. The bond between reinforcement and concrete plays a critical role in stress transfer, crack control, and structural performance.

Steel reinforcement is widely used but suffers from corrosion, especially in coastal and industrial environments. This leads to durability issues and increased maintenance costs. To overcome these limitations, Fiber Reinforced Polymer (FRP) bars, particularly Glass Fiber Reinforced Polymer (GFRP), are being explored.

GFRP bars offer advantages such as corrosion resistance, lightweight nature, and high tensile strength. However, their bond behavior differs from steel due to lack of yielding and different մակ surface characteristics.

Additionally, the use of fly ash as a supplementary cementitious material improves sustainability by reducing CO_2 emissions and enhancing long-term properties of concrete. This study focuses on evaluating the bond performance of steel and GFRP bars in fly ash-based concrete.

2. OBJECTIVES

Previous studies indicate that bond strength of GFRP bars depends on factors such as surface treatment, concrete strength, and embedment length.

- Fiber addition improves bond strength and toughness.
- Rib geometry significantly influences bond behavior.
- GFRP bars exhibit pull-out failure unlike steel yielding.
- High-strength concrete increases bond strength.
- Fly ash and geopolymer concrete enhance durability.

Overall, GFRP bars show comparable bond performance but require careful design considerations.

3. LITERATURE REVIEW

Previous studies indicate that bond strength of GFRP bars depends on factors such as surface treatment, concrete strength, and embedment length.

- Fiber addition improves bond strength and toughness.
- Rib geometry significantly influences bond behavior.
- GFRP bars exhibit pull-out failure unlike steel yielding.
- High-strength concrete increases bond strength.
- Fly ash and geopolymer concrete enhance durability.

Overall, GFRP bars show comparable bond performance but require careful design considerations.

4. MATERIALS AND METHODOLOGY

4.1 Materials Used

- Cement: OPC 53 Grade.
- Fly Ash: Class C.
- Fine Aggregate: M-Sand (Zone II.)
- Coarse Aggregate: 20 mm crushed granite.
- Reinforcement: Steel bars (10mm & 12mm).

- GFRP Bars: 10mm & 12mm.

4.2 Mix Proportions

Fly ash replacement levels:

- Nominal mix (Control mix)
- 10%
- 20%
- 30%

4.3 Testing Methods

- Fineness, consistency, and setting time tests.
- Specific gravity and water absorption tests.
- Pull-out test to determine bond strength.
- Load vs slip behavior analysis.

5. EXPERIMENTAL RESULTS AND DISCUSSION

5.1 Material Properties

- Cement fineness: 4.27% (within IS limits).
- Specific gravity: Cement (3.13), Fly ash (2.28).
- M-Sand fineness modulus: 2.69 (Zone II).
- Aggregate absorption: 1.96%.

5.2 Bond Behavior

Steel bars showed higher bond strength due to ribbed surface. GFRP bars showed linear elastic behavior until failure.. Failure in GFRP: Pull-out. Failure in steel: Splitting cracks or yielding.

5.3 Effect of Fly Ash

Increased fly ash reduces early bond strength. Improves long-term strength and durability. Optimum performance observed around 20% replacement.

5.4 Load-Slip Relationship

- Steel: Gradual slip with ductile behavior.
- GFRP: Sudden failure after peak load.

5.5 Test results

Table – 1: Mix Design for M30 Grade Concrete

Sl. No	Fly ash %	Cement (kg)	Fly ash (kg)	Water (Lit/ M³)	M. Sand (kg)	Course Aggregate 20mm (kg)
1	0%	427	0	192	640	993
2	10%	384	43	192	634	984
3	20%	342	85	192	629	977
4	30%	299	128	192	623	969

Table – 2: Compressive Strength Test on concrete - (M30 mix) Overall results

Fly ash %	7 days	14days	28 days
Nomina1 mix	20.8	27.5	31.1
10%	18.2	23.1	31.6
20%	16.4	22.2	31.6
30%	14.7	20.0	30.7

Chart -1: Compressive Strength Test on concrete - (M30 mix) with add fly ash Overall results

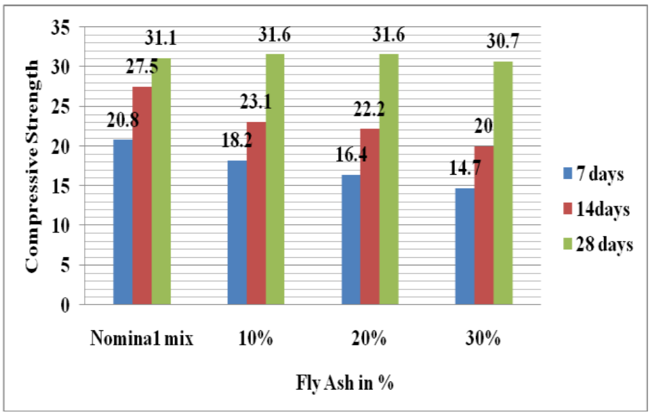

Fig -1: Compressive Strength Test on concrete - (M30 mix)

Table – 3: Split Tensile Strength Test on Concrete (M30 mix) Overall Results

Fly ash %	7 days	14days	28 days
nominal mix	1.96	2.48	2.97
10%	1.84	1.29	2.99
20%	1.10	2.40	2.80
30%	1.4	1.78	2.55

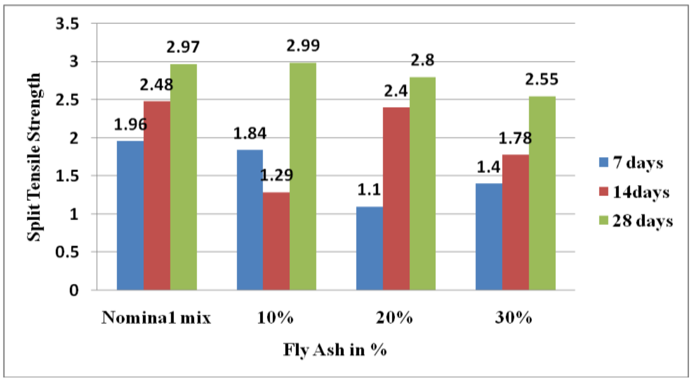

Chart -2: Split Tensile Strength Test on Concrete (M30 mix) Overall Results

Fig -2: Split Tensile Strength Test on Concrete (M30 mix)

Table- 4: Overall Comparison Table-Bond Strength (Pull-Out Test) for Steel Bars & GFRP Bars

Sl.No	Diameter of Steel & GFRP Bars (mm)	Bond Strength of Steel Bars (MPa)	Bond Strength of GFRP Bars (MPa)
1	10	8.0	7.35
2	12	8.43	7.49

Chart -3: Bond Strength Test (Pull-Out Test) for Steel Bar

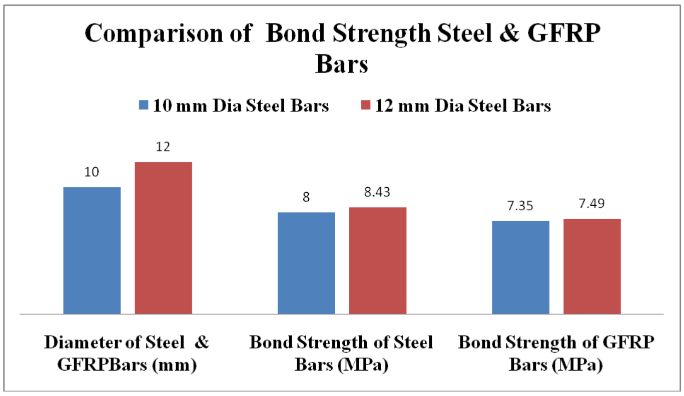

Fig -3: Bond Strength Test (Pull-Out Test) for Steel Bar

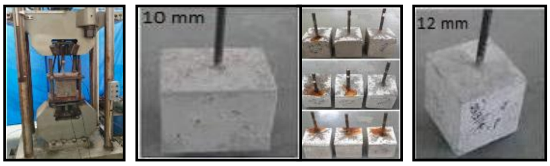

Fig -4: Bond Strength (Pull-Out Test) for GFRP Bars

6. CONCLUSION

Steel reinforcement exhibits higher bond strength compared to GFRP bars .GFRP bars provide excellent corrosion resistance and durability. Fly ash improves sustainability and long-term performance. Optimum fly ash replacement is around 20%. GFRP bars are suitable for aggressive environments.

7. FUTURE SCOPE

Study long-term durability under environmental exposure. Investigate different surface treatments of GFRP bars. Explore hybrid reinforcement systems .Conduct large-scale structural testing.

REFERENCES

1) Yining Ding, XiliangNing, Yulin Zhang, F.Pasheco-Torgal,J.B.Aguir 2013. .“Fibers for enhancing of bond capacity between GFRP rebar and concrete”,Construction and building materials, 51,303-312.

2) Qingduo Hao, YanleiWang, Zheng He, Jinping Ou.2009. “Bond strength of GFRP ribbed bars in normal strength concrete” Construction and Building materials.23.865-871.

3) Marta Baena, Lluis Torres, Albert Turon, Cristina Barris.2009. “Experimental study of bond behavior between concrete and FRP bars using a pull out test”,Composites:Part B 40 ,784-797.

4) Zenon Achillides and KyprosPilakoutas. 2004. “Bond behavior of fiber reinforced polymer bars under direct pullout conditions”, Journal of composites for concrete, 09(2), 173-181.

5) Malvar.L,J.,Cox. J,V.,Bergeron Cochran.2003.“Bond between carbon fiber reinforced polymer bars and concrete”,Journal of Composites for construction, 07(2)-154-163.

6) Hossian,K,M,A., Ametrano,D., Lachemi,M.2014. “Bond strength of strandrad high modulus GFRP bars in high strength concrete”,Journal of Materials in Civil Engineering,26(3),449-456.

7) Julio F. Davalos., Yi Chen, Indrajit Ray.2008**.** “Effect of FRP bar degradation on interface bond with high strength concrete”,Cement and Concrete Composites.30,722-730.

8) Lee.J.Y,,Kim.T.Y,. Yi.C.K.,Park.J.S. You.Y.C.2008. “Interfacial bond strength of GFRP bars in high strength concrete”,Composites:Part B, 39,258-270.

9) Emadaldin Mohammadi Golafshani, Alireza Rahai, Mohammad Hassan Sebt.2014. ”Bond behavior of steel and GFRP bars in self-compacting concrete”, Construction and Building Materials.61, 230-240.

10) Ginghis Maranan, Allan Manalo, Karu Karunasena and Brahim Benmokrane.2014. “Bond stress-slip behavior: Case of GFRP bars in geopolymer concrete” Journal of Materials in Civil Engineering, 16(9), 899-998.

11) Prabir Kumar Sarker.2010. “Bond strength of reinforcing steel embedded in fly ash based geopoymerconcrete”, Materials and Science 44:1021-1030.

12) Tang,W.C., Lo,T.Y., Balendran.R,V.2008.“Bond performance of polystyrene aggregate concrete (PAC) reinforced with GFRP bars, Building and Environment, Building and Environment .43,98-107.

13) M. S. Shetty, Concrete Technology: Theory and Practice*,* New Delhi, India: Khanna Publishers, 2012.

14) P. K. Mehta and P. J. M. Monteiro**,** *Concrete:* Microstructure, Properties, and Materials*,* 4th ed., New York, USA: McGraw Hill, 2014.

15) A. R. Santhakumar, Concrete Technology, New Delhi, India: Oxford University Press, 2007.

16) IS 12269 – Ordinary Portland Cement (53 Grade) ,IS 3812 (Part 2) – Specification for Fly Ash for use as Admixture in Concrete

17) IS 383:2016**,** Coarse and Fine Aggregate for Concrete – Specification*,* Bureau of Indian Standards, New Delhi, India

18) IS 2386 (Part 1–8*),* Methods of Test for Aggregates for Concrete, Bureau of Indian Standards, New Delhi, India.

19) IS 456:2000, Plain and Reinforced Concrete – Code of Practice, Bureau of Indian Standards, New Delhi, India.

20) IS 10262:2019, Concrete Mix Proportioning– Guidelines*,* Bureau of Indian Standards, New Delhi, India.

21) IS 516 – Methods of Tests for Strength of Concrete.