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Research Paper

Investigative & Comparative Analysis of Reinforced Cement Concrete to the Fibre Reinforced Polymer Rebar in Concrete

Akshay Rajgopal Bangad[1] G.N. Shete[2]
[1]*MTech Student, Department of Civil Engineering, M.S. Bidve Engineering College, Latur, India*
[2] *Head of Department, Department of Civil Engineering, M.S. Bidve Engineering College, Latur, India*

ABSTRACT: *We are all familiar with tor steel(cast iron) used in RCC structure from a long time. It is all possible because many of its special properties. It includes high tensile strength, shear strength, torsional strength. Its yield strength as well as ductility is worthy. On site its practically easy to bend and carry. The thermal coefficient of concrete and steel bar are too close thus homogenous RCC structure is easily possible and steel and concrete hold each other firmly. Steel is non-renewable source of material and had been extracted from ores abundantly. A day will arise in near future when steel will become uneconomical. There must be an alternative material to steel, that must serve our purpose to give strength to concrete.*
KEYWORDS: FRP Fibre, reinforced concrete, compressive strength

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I. INTRODUCTION

There are various types of polymers discovered till date. Commonly used building polymers include polyethylene (PE), polyvinyl chloride (PVC), polymethyl methacrylate (PMMA), polyester resin (PR), polystyrene (PS), polypropylene (PP), phenolic resin (PF), and organic silicon resin (OSR). There are many studies stating usage of various polymers in concrete in a view to strengthen it.But, this study focus on polymer usage as a rebar in concrete.

So the main types of FRP(Fiber reinforced polymer)are CFRP (Carbon fiber reinforced polymer) , GFRP (Glass fiber reinforced polymer), AFRP (Armide fiber reinforced polymer) and BFRP (Basalt fiber reinforced polymer). There usage varies according to location.

II. AIMS AND OBJECTIVES

- To replace FRP rebar in concrete in place of steel in RCC.
- To conduct various tests on RCC element and FRP in concrete.
- To compare steel and FRP rebar on basis of general physical aspects such as weight, fire resistance, manual bending etc.
- Compare both materials in terms of rusting, labour cost and material cost.
- Comparing ductility, yield strength, ultimate strength, coefficient of thermal expansion etc.
- Thus, to make structure more stronger than RCC and more economical than RCC.
- Try to complete the study so as to introduce FRP bar based structure design in IS code if the tests succeeds.

Methodology (Tests) & Results

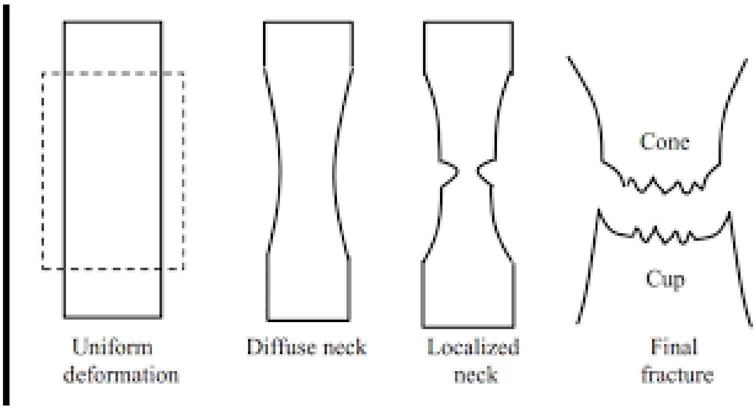
FRP: Its fiber reinforced polymer made of fibers which are too closely embedded in polymer (resign) matrix. So roughly 60-70% of the material is fiber while 30-40% is polymer binder. There are various types of fibers. They include glass, carbon, basalt, aramide etc. Polymer comprise mainly plastic viz. epoxy resin, vinyl ester, polyester etc.

There are various tests carried on RCC element and FRP bar in concrete. Also few tests would be carried solely on bars without concrete.

III. Tensile Test

Tensile testing, also known as tension testing, it is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young's modulus, Poisson's ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials.

The fracture pattern of cast iron after the tensile test is in the form of cup and cone as shown



Thus, we can say that the failure of FRP rebar was brittle unlike that of cast iron which gave cup and cone fracture pattern.

We know that the tensile strength of Tor steel Fe415,Fe500,Fe550 are 415MPa, 500MPa, 550MPa respectively. Thus, its necessary to check any other material's tensile strength if we want to replace the steel. Accordingly , we carried out tensile test over UTM for FRP and concluded with following results. FRP rebar is not ductile as that of steel. But for 6mm dia of rebar the breaking load was 2.12tonnes.

Thus, the calculation goes,

2.12*1000= 2120kg

2120 kg = 21200 KN

P= F/A

We have used 6mm diameter od FRP bar.

P= 21200 / πd*d/4

P= 21200/28.26

P= 750.17 MPa

Also, we have to consider the other observations occurred during the test. The elongation percent of FRP bar at the time of breaking point was 3%. We know the elongation of Fe500 steel bar is 12%.

So overall we can say tensile strength of FRP bar is more than steel bar which is good. But we need to consider the fact of elongation percent at breaking point.

- Coefficient of thermal expansion (α)

Steel and concrete are main two components of RCC element. There homogeneity or boinding with each other mainly remains strong due to the value of "α" which the share to vicinity.

α for steel is around 1.3 X 10^-5 / °C

α for concrete is around 1.0 X 10^-5 / °C

α for GFRP rebar is around 1.1 X 10^-5 / °C

This means that as steel and concrete can have good bonding strength , similar would be the case for FRP rebar and concrete as they too also share α value at very close difference.

Thus, we would cast few structural elements in RCC and FRP in concrete and then test them in lab .Finally we would compare and conclude there results.

- Concrete Mix Design

1) Grade designation is M30

- Maximum nominal Coarse Aggregate : 20mm
- Minimum cement content : 320 kg/m^3

- Maximum cement content : 450 kg/m^3

2) Data of materials

- Specific gravity of cement : 3.15
- Specific gravity of Coarse Aggregate : 2.68
- Specific gravity of Fine Aggregate : 2.63
- Water absorption of Coarse Aggregate : NIL
- Water absorption of Fine Aggregate : NIL
- Free surface moisture of Coarse Aggregate : NIL
- Free surface moisture of Fine Aggregate : NIL

3) Target mean strength

Characteristic strength f_{ck} = 30Mpa

Target mean strength= f_{ck} + (1.65 * S)
…(S is standard deviation as per IS456)

= 30 + (1.65 * 5)
= 38.25 N/mm^2

4) W/C ratio

Maximum w/c ratio is 0.45 as per IS 456.
Let us consider it 0.43
0.43 < 0.45 ……(Hence OK)

5) Selection of Water Content

Maximum water content for 20mm aggregate is 186 L
…[as per IS 10262 (2019)]

Now, 3% increase for every 25mm slump over and above 50mm slump

Estimated water content = 186 + [(6/100) * 186]
= 197.16 Litre
….(for 100mm slump)

6) Calculation of Cement Content

W/C ratio= 0.43
Water used = 197.16 Litre

Cement content = w/c = 197.16/ 0.43
= 458.51 kg/m^3

458.51 > 320 kg/m^3 …… (Hence OK)

Thus, we will take 450kg/m^3

7) Calculation of CA and FA content

Corresponding to 20mm size CA and FA of zone II for w/c ratio of 0.5 is found to be 0.62

We have w/c = 0.43 i.e it is less by 0.07

The CA is increased at the rate of 0.01 for every decrease in w/c ratio of 0.05

*Corresponding Author: Akshay Rajgopal Bangad

Thus, 0.01/0.05 - 0.07 = 0.014

Corrected proportion of volume
CA = 0.62 + 0.014
= 0.634
For Angular Aggregate the coarse aggregate can be reduced by 10%

Final volume of CA = 0.634 * 0.9
= 0.5706
~ 0.57
Final volume of FA = 1-0.57
= 0.43

8) Calculation of Mix proportion

Volume of concrete= 1m^3

Volume of cement= Mass of cement X 1
Sp. Gravity of cement 1000

= 0.45 X 1
3.15 X 1000
=0.142 m^3

Volume of water= Mass of water X 1
Sp. Gravity of water 1000

= 0.43 X 450
1 X 1000
= 0.197 m^3

Volume of Total Aggregate= 1 – [Vol. of cement + vol. of Water]
= 1 – [0.142 + 0.197]
= 1 – 0.339
= 0.66 m^3

Mass of CA = (Volume of total aggregate) X (Volume of CA) X (specific gravity) X 1000

= 0.66 X 0.57 X 2.68 X 1000
= 1008 kg/m^3

Mass of FA = (Volume of total aggregate) X (Volume of FA) X (specific gravity) X 1000
= 0.66 X 0.43 X 2.63 X 1000
= 746.39 kg/m^3

Hence,
Mix proportion [1 : 1.65 : 2.24]

- Cement = 450 kg/m^3
- Water = 197 kg/m^3
- Coarse Aggregate = 1008 kg/m^3
- Fine Aggregate = 746 kg/m^3
- w/c = 0.43

Fine aggregate

PPC [Birla A1 cement]

- **Specimen details**

1. **Casting of beam**: We would cast 4 beams (150mm x 150mm x 750mm). Two would contain 2 steel bars of 6mm diameter, while other would contain 2 FRP bars of 6mm diameter.M30 grade of concrete would be preferred and thus both beams would be casted and kept for curing for 7 and 28 days respectively.

2. **Casting of Panel (Slab):** We would cast 4 slab panels. The slab panel would be of 750mm x 500mm x 100mm. Thus 6mm bars at distance of 150mm in both direction would be tied for both slabs (6 and 4 in each direction). M30 grade of concrete would be preferred and thus both slabs would be casted and kept for curing for 7 days 28 days respectively.

- **NDT**

NDT or non-destructive test are of various types. But the test which we have performed on the specimens are Rebound Hammer Test. Where we use the hammer to determine the strength of specimen without breaking it

Casting of beam with FRP rebar in it

Panel (Slab) before casting

Test results of NDT

We have performed NDT (Rebound hammer test) on the various specimens and the outcomes are as follows.

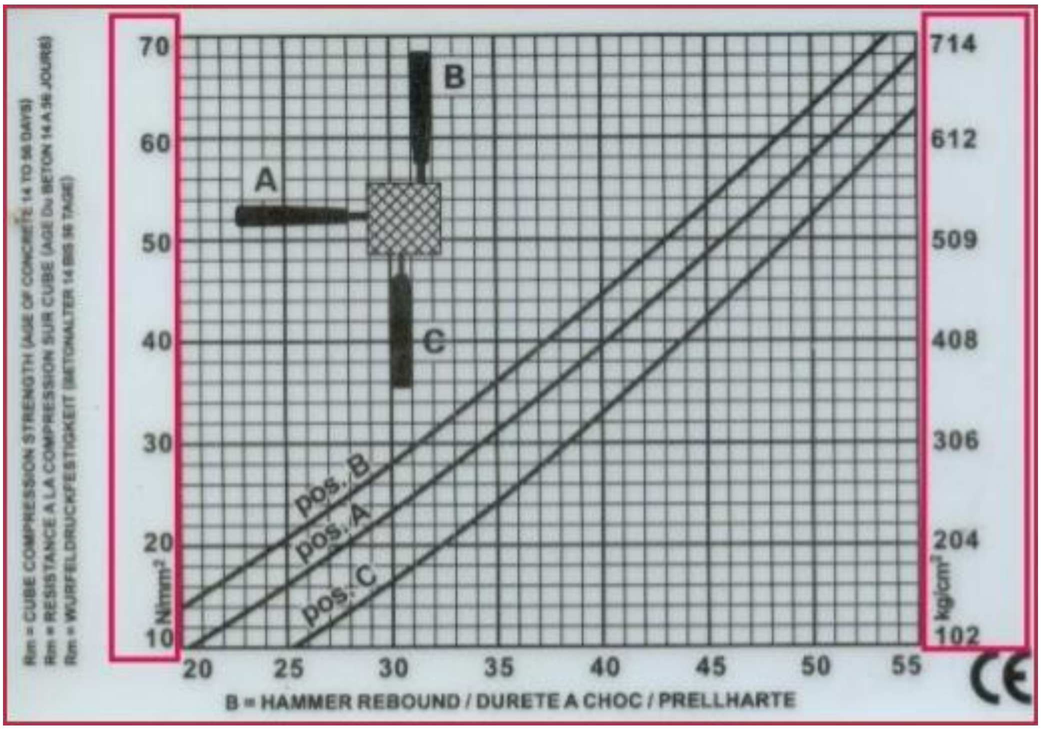
Test results after 7 days of curing. (Results in terms of rebound hammer number)

Beam (RCC)	Beam (FRP)	Slab (RCC)	Slab (FRP)
15	24	18	20
16	21	18	22
19	20	16	26
19	20	18	22
20	22	19	18
19	20	20	22
Average 18	Average 21.2	Average 18.2	Average 21.7

We have performed all the test by simply supporting the supports at two ends. The hammer hold was 90 degree with the specimen(position B as shown in diagram).

So results after rounding up the rebound numbers and convering it(with the help of graph) to MPa or N/mm2 are as follows…

RCC BEAM = 12MPa , FRP BEAM= 16MPa
RCC SLAB= 13MPa , FRP SLAB= 16MPa



Graph of Rebound number & strength relation

Test results after 28 days of curing. (Results in terms of rebound hammer number)

Beam (RCC)	Beam (FRP)	Slab (RCC)	Slab (FRP)
24	25	22	26
22	26	20	28
26	24	24	30
21	30	27	28
23	25	22	28
25	30	24	30
Average 23.5	Average 26.7	Average 23.2	Average 28.4

We have performed all the test by simply supporting the supports at two ends. The hammer hold was 90 degree with the specimen(position B as shown in diagram).

So results after rounding up the rebound numbers and convering it(with the help of graph) to MPa or N/mm2 are as follows…

RCC BEAM = 20MPa , FRP BEAM= 24MPa
RCC SLAB= 20MPa , FRP SLAB= 26MPa

- **Flexure Test**

We also conducted flexure test on beam specimen after 28 days of curing and the results were as follows….

RCC BEAM = 50.5MPa
FRP BEAM = 46 MPa

Conclusions

1) The tensile strength of FRP rebar is 750.17 MPa which is more than that of steel rebar 500 MPa. So surely we can use it in place of steel.

2) Elongation at the time of breaking point is 3% which is quite less than steel, as TOR steel has elongation of 12% at time of breaking point. But when we go by limit state of design method the strength consideration (yield point) occurs at 1.4% of steel rebar. Thus, by taking ample safety factor for FRP rebar we can use it.(especially for elastic design)

3) The thermal coefficient α of GFRP rebar is 1.1 X 10^-5 / °C and the thermal coefficient of concrete is1.0 X 10^-5 / °C . The both are close , so we get good bonding strength between them.

4) The weight of GFRP rebar is 55gram/metre for 6mm while that of TOR steel bar is 222gram/ metre for 6mm. The weight of FRP rebar is almost one fourth the weight of steel rebar. Thus, transportation and labour cost is reduced for FRP rebar.

5) In all rebound hammer test it has shown strength more the RCC specimen.

Average strength of FRP (slab) after 7 days of curing =16MPa
Average strength of RCC (slab) after 7 days of curing =13MPa
Average strength of FRP (slab) after 28 days of curing =26MPa
Average strength of RCC (slab) after 28 days of curing =20MPa
Average strength of FRP (beam) after 7 days of curing =16MPa
Average strength of RCC (beam) after 7 days of curing =12MPa
Average strength of FRP (beam) after 28 days of curing =24MPa
Average strength of RCC (beam) after 28 days of curing =20MPa

6) Flexure test result for FRP beam was 46MPa, that of RCC beam was 50.5MPa.

7) Currently, FRP it is uneconomical in India as we have steel in abundance. But the day steel will cross Rs. 115 per KG then FRP would become economical comparatively.

8) India government must release IS code over the material FRP rebar. Also IS code on structural design considerations and procedure details for FRP rebar must be released.

9) The FRP rebar is totally rust free unlike steel rebar, thus it increases the life of structure.

10) Experienced engineers should use this material in their mega-project work at least by partial replacing it with steel rebar.

References

[1]. ŢĂRANU NICOLAE , OPRIŞAN GABRIEL, ISOPESCU DORINA, ENŢUC IOANA, MUNTEANU VLAD and BANU CĂTĂLIN – "**FIBRE REINFORCED POLYMER COMPOSITES AS INTERNAL AND EXTERNAL REINFORCEMENTS FOR BUILDING ELEMENTS**". Bulletin of the Polytechnic Institute of Jassy, CONSTRUCTIONS. ARCHITECTURE Section · January 2008

[2]. CHRIS G. KARAYANNIS, PARTHENA-MARIA K. KOSMIDOU and CONSTANIN E. CHALIORIS-"**Reinforced Concrete Beams with Carbon-Fiber-Reinforced Polymer Bars—Experimental Study**". Reinforced Concrete and Seismic Design of Structures Laboratory, Civil Engineering Department, School of Engineering, Democritus University of Thrace, Xanthi 67100, Greece.

[3]. LAYTH MOHAMMED, M. N. M. ANSARI, GRACE PUA,MOHAMMAD JAWAID, and M.SAIFUL ISLAM-"**A Review on Natural Fiber Reinforced Polymer Composite and Its Applications**". International Journal of Polymer Science Volume 2015, Article ID 243947.

[4]. IMAD SHAKIR ABBOOD, SIEF ALDEEN ODAA,KAMALADIN F. HASAN, MOHAMMED A. JASMIN-"**Properties evaluation of fiber reinforced polymers and their constituent materials used in structures**". Materials Todays: Proceedings volume 43 (2021) 1003-1008.

[5]. **ACI 440.3R-04** – Guide test Methods for Fiber-Reinforced Polymers (FRPs) for reinforcing or Strengthening Concrete Structures

[6]. **IS 1608:2005**- Mechanical testing of metals-tensile testing

[7]. **ACI 440.6M-08** – Specifications for Carbon and Glass Fiber-Reinforced Polymer Bar Materials for Concrete Reinforcement.

[8]. **IS 456:2000** - Plain and Reinforced Concrete - Code of Practice

[9]. **IS 10262: 2019** – Concrete Mix Proportioning

[10]. **ASTM designation: D7957/D7957M-17** - Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement