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GLASS FIBER REINFORCED POLYMER (GFRP) USED IN CONCRETE BEAMS WITH REINFORCEMENT

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ABSTRACT

This thesis report involves the study of Glass Fiber Reinforced Polymer used in concrete beams with reinforcement. Generally, there are three major broad divisions in which the application of FRP in civil engineering can be classified: application for new construction, repair and rehabilitation applications, and architectural purposes. The other application is to strengthen the structurally deficient beams or columns with FRP sheets or plates. The polymer matrix can be either thermoset or thermoplastic resin such as polyester, isopolyester, vinyl ester, epoxy and phenolic that reinforced with fibers such as glass, carbon, aramid or other reinforcing materials. The characteristic of FRP includes high resistance to corrosion, lightweight, high strength-to-weight ratio, high tensile and impact strength, fatigue resistance, non-conductive and magnetically neutral. FRP could not be applied in all civil engineering projects and only the critical projects will be considered because the cost of manufacturing these products is quite high compared to the conventional materials. Concrete specimens are tested for various parameters such as compressive strength, split tensile strength, Flexural strength and modulus of elasticity.

Keywords *— Glass Fiber Reinforced Polymer, Compressive strength, Split Tensile strength.*

I. INTRODUCTION

1.1 Background Of Fiber Reinforced Polymer (Frp)

Fiber reinforced polymer (FRP) composites were first developed during the 1940's for the military and aerospace applications. Many researches and developments have been carried out in America, Canada, Britain and Japan. The past development of these advanced composite materials in the aerospace industry, military and chemical industry opens new doors for the application of these materials in civil engineering.

Generally, there are three major broad divisions in which the application of FRP in civil engineering can be classified: application for new construction, repair and rehabilitation applications, and architectural purposes. For structural applications, mostly FRP is used in two areas. The first area involved the replacement of steel reinforcing bars in the concrete structures or pre-stressing strands with variety types of FRP bars. The other application is to strengthen the structurally deficient beams or columns with FRP sheets or plates.

The characteristic of FRP includes high resistance to corrosion, lightweight, high strength-to-weight ratio, high tensile and impact strength, fatigue resistance, non-conductive and magnetically neutral. For these reasons, FRP is manufactured to be used in the construction that exposed to aggressive environments such as seawater, underground water and frost. As a result, FRP have been successfully used in many construction applications such as chemical and waste-water treatment plant, under water structures, bridges, substation reactor bases, airport runways, laboratories and water tanks.

Nowadays, applications of FRP in the construction industry have gained the increasing popularity in Malaysia. As proven, many construction projects are using FRP water tank to replace the conventional water tank that facing steel corrosion problems. Besides, road signboards are also constructed using the FRP plates since its lightweight and corrosion resistance properties.

II. LITERATURE REVIE

2.1 REVIEW OF LITERATURE

F. Matta et.al,.(2007) conducted a study about **size effect on shear strength of concrete beams reinforced with FRP bars.** The use of glass fiber reinforced polymer (GFRP) bars as internal reinforcement for portions of massive concrete retaining walls to be penetrated by tunnel boring machines (TBMs), commonly referred to as softeyes, is becoming mainstream. The low shear strength and inherent brittleness of GFRP bars greatly facilitate penetration of the TBM, preventing damage to the disc cutters, and eliminating the risk of costly delays. The safe shear design of softeyes and large members in general must account for the strength decrease due to size effect. To date, this phenomenon has not been documented for FRP reinforced concrete (RC). In this paper, the results of laboratory tests on four large-scale concrete beams reinforced with GFRP bars in flexure and shear are presented and discussed. Preliminary results are reported that indicate a decrease in concrete shear strength attributable to size effect, which is offset by an implicit under strength factor in the current ACI 440 design formula. Further experimental research is ongoing to better characterize the extent of size effect in FRP RC.

J. Sim et.al.,(2009) conducted a study on the **flexural behavior of concrete beams reinforced with GFRP rebars under fatigue.** Structural-member failure is largely classified into static failure and fatigue failure, which is caused by the damage accumulated in the structure with the lapse of time. The material fails at a stress that is much lower than the breaking stress under repeated stress or strain, and it generally shows rapid brittle failure. Bridges, concrete pavements, marine structures, railways, and high-speed railway structures are exposed to at least several-milliontimes repeated load during their lifetime and are likely to be affected by the fatigue failure caused by repeated loads rather than by static failure. As many studies have been conducted on the FRP rebar, which is a popular alternative to reinforcing steel bars, the CFRP, GFRP, and hybrid FRP rebars have been commercialized. Most of the studies on them involve static load, however, and few studies have thus far been conducted on their fatigue behavior. Therefore, to secure safety and availability against fatigue during the lifetime of a structure, the fatigue characteristics and S-N correlation must be applied to the design and analysis of the aforementioned rebars. In this study, static and fatigue bending tests were conducted, using three types of FRP rebars (CFRP, GFRP, and hybrid FRP), which have been commercialized. A static bending test was conducted to determine the fatigue load, and the fatigue characteristics of the concrete beam reinforced with FRP rebars, which can be used for fatigue examination, maintenance, and endurance limit estimation of the concrete structure built with FRP rebars, was identified. The use of the S-N correlation was also suggested for the estimation of the fatigue life.

Arivalagan. S (2012) studied about the **engineering performance of concrete beams**

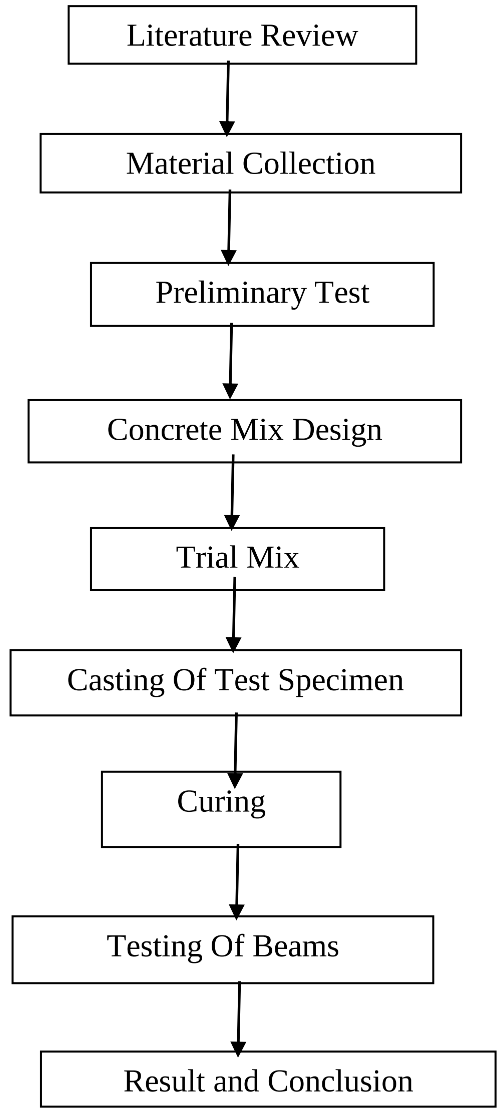
reinforced with GFRP bars and stainless steel. Corrosion of steel reinforcement is one of the main problems facing the construction industries throughout the world. Many methods have been used to minimize the problem but without success. Thus, more durable reinforcements are highly needed to replace conventional steel. Glass Fibre Reinforced Polymer (GFRP) bars provide a good alternative reinforcement due to its non-corrodible characteristic. This paper presents the flexural behaviour of concrete beams, each size is 150 x 150 x 900 mm and reinforced with GFRP and stainless steel bars. The behaviour of the beams was analysed in terms of their moment carrying capacity, load-deflection, cracking behavior and mode of failure. The experimental results show that beams reinforced with GFRP bars experienced lower ultimate load, lower stiffness, and larger deflection at the same load level compared with control beam. However, the performance of the SSRB (Stainless Steel Reinforced Beam) reinforced concrete beams improved slightly when compared to Glass Fibre Reinforced Polymer concrete beams.

Sumant U. Ladole (2012) studied about the **flexural behaviuor of concrete beams reinforced with glass fibre polymer.** Corrosion of steel reinforcement is one of the main problem facing the construction industries throughout the world. Many method’s have been used to minimize the problem but they lead’s to failure. Thus more durable reinforcement due to its non corrodible characteristic. This paper presents the flexural behavior of concrete beam each measuring (500 x 100 x 100) mm and Reinforced with direct roving glass fiber. The performance of their flexural strength and split tensile strength of beam and cylinder, have been observed However, the performance of Glass Fiber Reinforced Polymer (Directing roving glass fiber) reinforced concrete beam improved slightly.

bbb2.2 PROBLEM IDENTIFICATION

The flexural behavior and performance of FRP composites were different when applied in the concrete structures either as internal reinforcement or external strengthening. These phenomenal were occurred due to the different properties and orientations of the fibers used in the FRP composites. Therefore, further research and development needed to be carried out to study the performance of FRP when applied in the reinforced concrete structures

III. METHODOLOGY



IV. MATERIALS

4.1 Cement

Ordinary Portland cement is composed of calcium silicates and aluminate and aluminoferrite. It is obtained by blending predetermined proportions limestone clay and other minerals in small quantities which is pulverized and heated at high temperature around 1500 deg centigrade to produce clinker. The clinker is then ground with small quantities of gypsum to produce a fine powder called Ordinary Portland Cement (OPC). When mixed with water, sand and stone, it combines slowly with the water to form a hard mass called concrete. Cement is a hygroscopic material meaning that it absorbs moisture. In the presence of moisture it undergoes chemical reaction which is termed as hydration. Therefore cement remains in good condition as long as it does not come in contact with moisture. If cement is more than three months old then it should be tested for its strength before being taken into use.

The Bureau of Indian Standards (BIS) has classified OPC in three different grades. The classification is mainly based on the compressive strength of cement-sand mortar cubes of face area 50 cm^2 composed of 1 part of cement to 3 parts of standard sand by weight with a water-cement ratio arrived at by a specified procedure. The grades are

(i) 33 grade
(ii) 43 grade
(iii) 53 grade

The grade number indicates the minimum compressive strength of cement sand mortar in N/mm^2 at 28 days, as tested by above mentioned procedure.

In this investigation, Ordinary Portland Cement of grade 53 is used.

4.2 AGGREGATE

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste will mean less quantity of cement and less water, which will further mean increased economy, higher strength, lower shrinkage and greater durability.

Aggregate comprises about 55% of the volume of mortar and about 85% volume of mass concrete. Mortar contains aggregates of size of 4.75 mm and concrete contains aggregate upto a maximum size of 150 mm.

4.2.1 Coarse Aggregate

Coarse aggregate used for the construction works should be river gravel or crushed stone. It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped and should have granular or crystalline or smooth (but not glossy) non-powdery surfaces. Aggregates should be properly screened and if necessary washed clean before use.

Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications of IS-383. After 24-hrs immersion in water, a previously dried sample of the coarse aggregate should not gain in weight more than 5%. Aggregates should be stored in such a way as to prevent segregation of sizes and avoid contamination with fines.

4.2.2 Fine Aggregate

Aggregate which is passed through 4.75 IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Important thing to be considered is that fine aggregates should be free from coagulated lumps.

Grading of fine aggregates shall be such that not more than 5 percent shall exceed 5 mm in size, not more than 10% shall IS sieve No. 150 not less than 45% or more than 85% shall pass IS sieve No. 1.18 mm and not less than 25% or more than 60% shall pass IS sieve No. 600 micron.

4.3 STEEL

Rebar ,short for reinforcing bar, also known as reinforcing steel and reinforcement steel, is a common steel bar or mesh of steel wires commonly used as a tension device in reinforced_concrete and reinforced masonry structures, to strengthen and hold the concrete in compression. The surface of the rebar may be patterned to form a better bond with the concrete.

4.4 GLASS FIBER REINFORCED POLYMER (GFRP)

Two types of GFRP sections were used here. GFRP plate section and I-section were used as internal reinforcement instead of steel bar as shown in figure 4.1.

Fig 4.1 GFRP plate and I-section

4.5 WATER

Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

V. EXPERIMENTAL INVESTIGATION

5.1 CEMENT

5.1.1 Specific Gravity Test (IS 4031 Part 11:1988)

Weight of empty bottle (W1) = 26.8g

Weight of bottle +water (W2) = 75g

Weight of bottle + Kerosene (W3) = 65.5g

Weight of bottle + Cement + Kerosene (W4) = 74.8g

Weight of cement (W5) = 12.5g

$$\text{Specific gravity of cement (G)} = \frac{(W5 \times (W3 - W1)}{(W5 + W3 - W4) \times (W2 - W1)}$$

Specific gravity of cement (G) = 3.15

5.1.2 Standard Consistency Test (IS 4031 Part 4 : 1988)

Weight of sample taken, W1 = 300g

Table 5.1 Standard consistency test

Amount of water added	Weight of water added (W2)	Penetration of plunger from the bottom of the mould	% of water for standard consistency
90	90	11	30
96	96	9	32
99	99	8	33
105	105	6	35

Standard consistency = (W2/W1)x100 = 35 %

5.1.3 Initial setting time (IS 4031 Part 5 : 1988)

Table 5.2 Initial setting time

Sl No	Time in minutes	Pointer reading from the bottom
1	0	0
2	5	0
3	10	0
4	20	0
5	30	0
6	35	4
7	40	5.5

Initial setting time = 40 minutes

5.1.4 Final setting time (IS 4031 Part 5 : 1988)

Final setting time = 580 minutes

5.1.5 Fineness Modulus Test (IS 4031 Part 2 : 1988)

Weight of sample taken = 100g
Weight of material retained after sieving in 90µ = 3.6

% of Residue left on the sieve = weight retained /weight taken) x 100= 3.6

Fineness Modulus of Cement = 3.6

5.1.6 Compressive Strength Test on Cement Mortar Cube

Observation	I	II	III
Weight of cement in KN (W1)	200	200	200
Weight of standard	600	600	600

sand in KN (W2)			
Weight of water [P/4+3] x $w_1 + w_2$ /100	564	564	564
Area of specimen (A) in cm^2	49	49	49
Load fracture in KN Age 14 days 28 days	 110 140	 90 120	 110 125
Compressive strength (P/A) N/mm^2 14 days 28 days	 22.4 28.48	 18.36 24.48	 22.44 25.51

Average compressive strength	14 days	28days
	21.08N/mm^2	26.18 N/mm^2

5.1.7 Physical properties of cement

Specific gravity = 3.15

Consistency = 35%

Fineness Modules = 3.6

Initial setting time (min) = 40 minutes

Final setting time (min) = 580minutes

Average compressive strength = 26.18 N/mm^2 for 28days

5.2 COARSE AGGREGATE

5.2.1 Specific Gravity Test (IS 2386 Part I : 1963)

Weight of Container (W1) = 910g

Weight of Container + coarse aggregate (W2) = 6870g

Weight of Container + coarse aggregate + Water (W3) = 8230g

Weight of Container + Water (W4) = 4438g

$$\text{Specific gravity of Coarse aggregate (G)} = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)}$$

= 2.75

5.2.2. Fineness modulus Test (IS 383: 1970)

Table 5.3 Fineness modulus of coarse aggregate

Sl. No.	IS Sieve No mm	Weight retained	% of weight retained	Cumulative % weight retained	%weight Passing
1	20	0	0	0	100
2	10	2850	95	95	5
3	4.75	20	0.66	95.66	4.34

Confirming to table 2 of 1S 383-1970

$$\text{Fineness Modulus of Coarse aggregate} = \frac{\text{Cumulative \% weight retained}}{100}$$

Fineness Modulus of Coarse aggregate = 2.9

5.2.3 Physical Properties of coarse aggregate

Specific gravity = 2.75

Fineness modulus = 2.9

Water absorption = 0.5 %

5.3 FINE AGGREGATE

5.3.1 Specific Gravity (IS 2386 Part I : 1963)

Weight of pycnometer, W1 = 430g

Weight of pycnometer + sand W2 = 730g

Weight of pycnometer + Sand + Water, W3 = 1360g

Weight of pycnometer + Water, W4 = 1172 g

$$\text{Specific gravity of Sand (G)} = \frac{(W2 - W1)}{(W2 - W1) - (W3 - W4)}$$

= 2.68

5.3.2 Sieve Analysis of Fine Aggregate (IS 383 : 1970)

Weight of Material taken = 3000g

Table 5.4 Fineness Modulus of Fine Aggregate

Sl. no	IS Sieve No mm	Wt retained	% of weight retained	Cumulative % weight retained	% Passing
1.	4.75mm	0	0	0	100
2.	2.36mm	40	1.33	1.33	98.67
3.	1.18mm	350	11.67	13	87
4.	600 µ	1300	43.33	56.33	43.67
5.	300 µ	730	24.33	80.66	19.34
6.	150 µ	430	14.33	94.99	5.01

Fineness Modulus of Fine aggregate $= \frac{\text{Cumulative \% weight retained}}{100}$

Fineness Modulus of Fine aggregate = 2.5

Sand Confirming to Zone II

5.3.3 Aggregate crushing value test

Observation	I	II	III
Weight of surface dry sample (A)	2.66	2.66	2.66
Weight of fraction passing though IS 2.36mm sieve in kg (B)	0.775	0.725	0.760
Crushing value of aggregate	29.135	27.225	28.571

Aggregate crushing value $= \frac{B}{A}$ x 100

5.3.4 Physical Properties of Fine aggregates

Specific gravity =2.68

Fineness Modulus = 2.5

Water absorption = 1%

VI. MIX DESIGN

As per **IS 10262-2009**

6.1. STIPULATIONS FOR PROPORTIONING

(a) Grade designation = M30

(b) Type of cement = OPC 53 grade

(c) Maximum size of aggregate = 20mm

(d) Minimum cement content = 320kg/m^3 (IS 456 – Table 5)

(e) Maximum w/c ratio = 0.45

(f) Workability = 80mm (Slump)

(g) Exposure condition = severe for RCC

(h) Type of aggregate = Crushed angular aggregate

(i) Maximum cement content = 450kg/m^3

6.2. TEST DATA FOR MATERIALS

Cementm used = Ordinary Portland cement (53 grade)

Specific gravity of cement= 3.15

Specific gravity of coarse aggregate = 2.89

Specific gravity of fine aggregate= 2.68

Water absorption - coarse aggregate = 0.50 %

Water absorption - fine aggregate= 1.0%

Free (surface) moisture-coarse aggregate= Nil

Free (surface) moisture - fine aggregate= 2.0 %

Sieve analysis

(i)Fine aggregate conforming to zone II

(ii)Coarse aggregate confirming to table 2 of IS 383

6.3. TARGET MEAN STRENGTH OF CONCRETE

Target mean strength: In order that not more than the specified proportions of test results are likely to fall below the characteristic strength, the concrete mix has to be designed for a somewhat higher target average compressive strength (fck). The margin over the characteristic strength depends upon the quality control and the accepted proportion of result of strength tests below the characteristic strength, given by the relation.

$f_t = f_{ck} + 1.65\ s$

Where

f_t= target mean strength required in the laboratory at 28 day

f_{ck}= characteristic compressive strength required in the field at 28 days.

s= standard deviation (Table 39 of SP: 23 - 1982)

Target mean strength, ft = 30 + 1.65 X 5 = 38.25 N/mm^2

6.4. SELECTION OF W/C RATIO

From table 5 of IS 456, maximum w/c ratio = 0.45

Based on experience adopt w/c ratio as 0.43

0.43 < 0.45 Hence OK

6.5. SELECTION OF WATER CONTENT

Maximum water content for 20mm aggregates = 186L (Table 2 of IS 10262:2009)

Estimated water content for 100mm slum

$= 186 + [\frac{6}{100}x186] = 197L$

6.6. DETERMINATION OF CEMENT CONTENT

Water cement ratio = 0.43

Cement content $= \frac{197}{0.43} = 458.139kg/m^3$

6.7. PROPORTION OF VOLUME OF CA AND FA CONTENT

Volume of CA corresponding to 20mm size CA and FA for w/c ratio 0.5 = 0.62

In present case w/c ratio = 0.43

Therefore volume of CA is required to be increased. As w/c ratio is lower by 0.07 the proportion of volume of CA is increased by 0.014 (at the rate of -/+0.01 for every +/-0.05 change in w/c ratio)

Therefore corrected proportion of volume of CA for w/c ratio of 0.43 = 0.62+0.014= 0.634

Volume of FA content = 1-0.634

= 0.366

6.8. MIX CALCULATIONS

(a) Volume of concrete = $1m^3$

(b) Volume of cement $= =[\frac{\text{Mass of cement}}{\text{Specific gravity of cement}}]x[\frac{1}{1000}]$

$= [\frac{458.139}{135}]x[\frac{1}{1000}]$

$= 0.1454m^3$

(c) Volume of water $=[\frac{\text{Mass of water}}{\text{Specific gravity of water}}]x[\frac{1}{1000}]$

$= [\frac{197}{1}]x[\frac{1}{1000}]$

$= 0.197m^3$

(d) Volume of all in aggregate = [a-(b+c)]

= 1-[0.1454+0.197]

= $0.6576m^3$

(e) Mass of CA = d x Volume of CA x Specific gravity of CA x 1000

= 0.657x0.634x2.89x1000
= 1204.894kg

(f) Mass of FA = d x Volume of FA x Specific gravity of FA x 1000

= 0.6576 x 0.366 x 2.68 x 1000
= 645.026kg

CEMENT	: FINE AGGREGATE	: COARSE AGGREGATE
458.139	: 645.026	: 1204.894
1	: 1.41	: 2.63

6.9. DETERMINATION OF QUANTITY OF MATERIALS REQUIRED

Total volume of concrete required = Volume of cubes + Volume of beams

Volume of 9 cubes = 9x150x150x150 = $30375000mm^3$
= $0.030375m^3$

Volume of 8 beams = 8x750x150x150 = $135000000mm^3$
= $0.135m^3$

Therefore total volume of concrete required , V= $0.165375m^3$

Yield of 1g of cement ,Yc $= \frac{1}{3.15}+\frac{1.41}{2.68}+\frac{2.63}{2.89}+0.43$
$=2.1836cm^3/g$
$=0.0021836um^3/kg$

Weight of cement required, Wc $= \frac{V}{Y_c}$

$= \frac{0.165375m^3}{0.002183m^3/kg}$
= 75.8578kg

Weight of FA required = x x Wc
= 1.41x75.8578
= 106.9595kg

Weight of CA required = y x Wc
= 2.63x75.8578

= 199.506kg

Weight of water = k x Wc

= 0.43 x 75.8578

= 32.618L

VII. ANALYSIS OF CONCRETE PROPERTIES

7.1 GENERAL

Concrete was tested to find its workability and concrete specimens were tested to find its compressive strength for 7 days, 14 days and 28 days.

7.2 FRESH CONCRETE PROPERTIES

Slump cone test was used to find the workability of concrete. Slump value obtained was 80mm

7.2.1 Slump Cone Test

Unsupported concrete, when it is fresh, will flow to the sides and a sinking in height will take place. This vertical settlement is known as slump. In this test fresh concrete is filled into a mould of specified shape and dimension, and the settlement or slump is measured when supporting mould is removed. Slump increases as water-cement ratio is increased. For different works different slump values have been recommended.

Slump is a measure indicating the consistency or workability of cement concrete. It gives an idea of water content needed for concrete to be used for different works. A concrete is said to be workable if it can be easily mixed and easily placed, compacted and finished. A workable concrete should not show any segregation or bleeding. Segregation is said to occur when coarse aggregate tries to separate out from the finer material and we get concentration of coarse aggregate at one placer. This results in large voids, less durability and less strength. Bleeding of concrete is said to occur when excess water comes up at the surface of concrete. This causes small pores through the mass of concrete and is undesirable.

Slump cone test is the most commonly used method of measuring consistency. It doesn’t measure all factors contributing to workability. It is used as a control test and gives an indication of uniformity of batches. Slump apparatus is shown in Fig 7.1

Fig 7.1Slump Cone Test

7.1 Slump test value

SL.NO:	W/C RATIO	SLUMP VALUE(MM)
1	0.43	80

Slump value = 80mm

7.3 CASTING OF SPECIMEN

The concrete after workability was used for casting test specimens. Moulds were used to cast the specimen. Since the maximum size of the aggregate is 20 mm, cube moulds of size 150x150x150 mm were used. The cube moulds were used for compression test specimens. The inner surface of the mould was coated with a thin layer of waste oil in order to help the de moulding easy and to have sharp corners. Before applying oil, the inner surface was thoroughly cleaned and freed from moisture. The concrete was filled in three layers. Each layer was compacted with the standard tamping bar and the strokes of the bar were uniformly distributed across the cross section of the mould. The strokes were given such that it penetrated the underlying layer and the bottom layer was tamped throughout it its depth. The tamping bar of 16mm diameter and 60 cm long was, the lower end was butted pointed. After the top layer was compacted, the surface of the concrete was finished in level with top of the mould using a trowel.

7.4 TESTING OF HARDENED CONCRETE

Compressive strength test for cube specimens were conducted after 7th, 14th and 28th days. The test results are shown in table 7.1 and graphical representation is given in Fig 7.2.

Table 7.1 Compressive strength test results

AGE	SPECIMEN	COMPRESSIVE STRENGTH(N/mm^2)	AVERAGE COMPRESSIVE STRENGTH(N/mm^2)
7	1	28.7	28.4
	2	27.9	
	3	28.5	
14	1	31.3	31.83
	2	31.7	
	3	32.8	
28	1	36.72	37.04
	2	37.5	
	3	36.9	

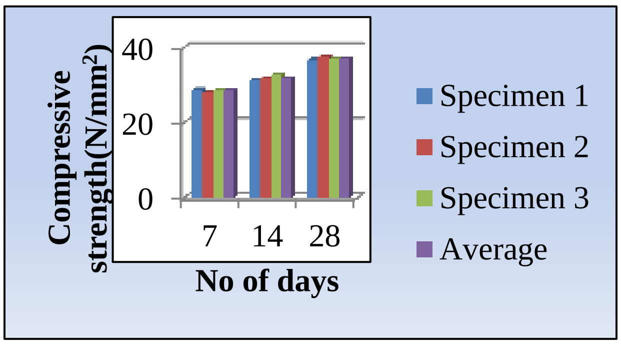


Fig.7.2. Compressive Strength of Concrete

7.5 SPLITING TENSILE STRENGTH OF CONCRETE

Cast the cylinder of size 150mmx300mm and cure for 7,14,28 days the specimen shall be tested immediately after removal from water note the diameter and length of specimen. place the specimen on a plywood strip, place the second plywood strip length wise on the top of the cylinder. Apply the load without shock and increase continuously at a nominal rate which in the range of 1.2 N/mm^2 per minute to 2.4 N/mm^2 per minute. Maintain the rate until failure and note the load applied

Splitting Tensile stress (T_{SP}) $= \frac{2P}{\pi DL}$

Where P = Applied Load

D = Diameter of specimen

L = Length of the specimen

AGE	SPECIMEN	TENSILE STRENGTH (N/mm^2)	AVERAGE COMPRESSIVE STRENGTH(N/mm^2)
	1	28.6	
7	2	27.7	28.6
	3	28.6	
	1	31.2	
14	2	31.8	31.7
	3	32.4	
	1	36.75	
28	2	37.7	37.2
	3	36.9	

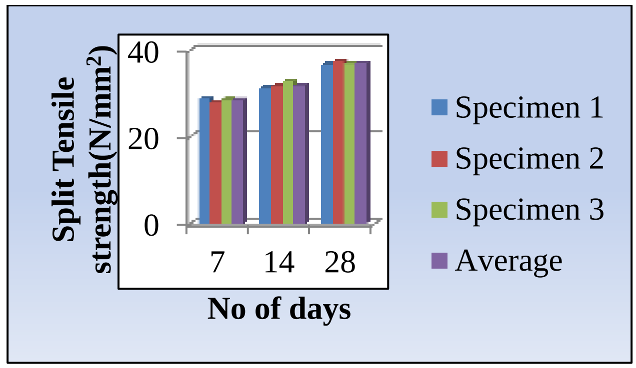


Fig.7.2. split tensile Strength of Concrete

VIII. DESIGN OF BEAMS

8.1 DESIGN OF REINFORCEMENT

Width, B = 150 mm Depth, D = 150mm

Length, L = 750mm Load, W = 30kN

Dead Load , w = 25 x 0.15 x 0.15 = 0.5625kN

Moment due to dead load and live load, M = 30 x 0.3 – 30 x 0.1 – (0.5626 x 0.6^2)/8= 5.97 kN

M_u = 1.5 x 5.97= 8.96 kN

Assume 10 mm ϕ bars and cover, d^1 = 25 mm

[Cl. G.1.1.C of IS 456 : 2000]

$M_{u,lim} = \frac{0.36\,x_u}{d}\left[1 - \frac{0.42 x_u}{d}\right] f_{ck} b d^2$

= 0.36 x 0.46[1− 0.42 x 0.46] x 150 x125^2 x 30 = 9.39kN

$M_u < M_{u,lim}$

Therefore, the section is singly reinforced.

[cl.G.1.1.b of IS 456 : 2000]

Amount of steel requied,

$M_u = 0.87\ f_y A_{st}\ d[1 - Ast\frac{fy}{bd\ fck}]$ 0.87 = 0.87 x 500 x A_{st} x 125 $[1 - \frac{500\ Ast}{150 \times 125 \times 30}]$

A_{st} = 200.46 mm^2

[cl.26.5.1.1 of IS 456 : 2000]

Minimum reinforcement required, $A_{st\ ,\ min} = \frac{0.85\ b\ d}{f_y}$ = 31.875 mm^2

Maximum reinforcement required, $A_{st\ ,\ max}$= 0.04 bD

= 900 mm^2

$A_{st\ ,\ max} > A_{st} > A_{st\ ,\ min}$

Hence safe.

Assume 10 mm diameter bars

Number of bars = $\frac{200.46}{\pi \times 5^2}$ = 2.55

≈ 3 bars

Assume 10 mm diameter bars for hanger bars

Number of bars = $\frac{31.875}{\pi \times 3^2}$ = 1.1

≈ 2 bars

Therefore, provide 3, 10mm diameter bars as main reinforcement and 2, 6mm diameter bars as hanger bars.

8.2 DESIGN FOR SHEAR

V = 30.16875kN

V_u = 45.25kN

$\tau_v = \frac{V_u}{bd} = \frac{45.25}{150} x \frac{1000}{125}$ = 2.41N/mm^2

Assume 2 legged, 6 mm diameter bars

$100\frac{A_s}{bd}$ = 0.302 N/mm^2

[Table 19 of IS 456 : 2000]

τ_c = 0.4064 N/mm^2

[Table 20 of IS 456 : 2000]

$\tau_{c,max}$ = 3.5 N/mm^2

[From Cl : 40.4.a of IS 456 : 2000]

Provide shear reinforcement as vertical stirrups

$V_{us} = V_u - \tau_c bd$

= 45.25 x 10^3 – 0.4064 x 150 x 125

= 37.63 Kn

$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$

$S_v = \frac{0.87 \times 500 \times 2 \times \pi \times 6^2}{37.63 \times 10^3}$

S_v = 81.71 mm

Maximum spacing = 0.75d

= 93.75mm

Provide 6mm diameter bars @ 75 c/c as shear reinforcement

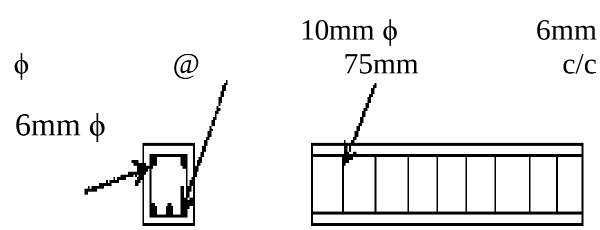


Fig.8.1 Cross section and longitudinal section of beam

IX. EXPERIMENTAL PROGRAMME

9.1 INTRODUCTION

This research program is designed to study the flexural behavior of the concrete beams reinforced with different geometries of GFRP reinforcing sections. Besides, one steel reinforced concrete beam is fabricated as the control beam for the comparison purposes. In this study, observation will be concentrated on the types of failures, cracking behaviors, deflection and ultimate load carrying capacity. Comparison made will lead to define the suitability of using GFRP to replace the conventional steel reinforcement in concrete structure. A total of four concrete beams with 150 mm width, 150 mm height and 750 mm length were tested under two-point loading until failure as shown in Figure 9.1

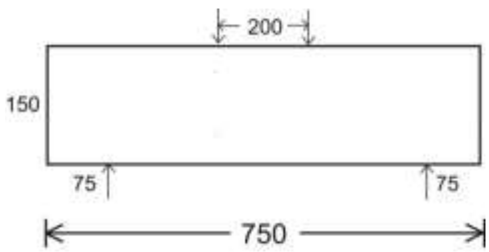


Fig 9.1 Schematic diagram for testing arrangement of beams

One steel reinforced concrete beam and three beams reinforced with GFRP sections were fabricated. Beam SC acted as control beam and reinforced with three high yield steel bars of diameter 10 mm. Beam GP reinforced with GFRP plate section and GI reinforced with GFRP I-section while beam GPI reinforced with combination of GFRP plate and I- section.

9.2. PREPARATION OF BEAMS

9.2.1 Reinforcement

Steel bar with 10 mm diameter and link with 6 mm diameter were cut according to the required length. Finally, all main reinforcements and links were tied together with the wire.

All information and detailing of the types, geometries and cross section area of reinforcements are shown in table 9.1

Table 9.1 Cross section area of reinforcements

Reinforcement	Geometry	Quantity	Reinforcement area(mm^2)
SC	Steel	3	235
GP	GFRP plate section	2	800
GI	GFRP I-section	2	800
GPI	GFRP plate and I-section	2	800

Fig 9.2 Reinforcement details for control bean

Fig 9.3 Reinforcement details for beam reinforced with GFRP plate section (GP)

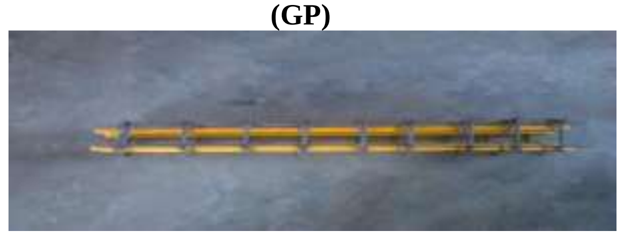


Fig 9.4 Reinforcement details for beam reinforced with GFRP I- section (GI)

Fig 9.5 Reinforcement details for beam reinforced with combination of GFRP plate and I-section (GPI)

9.2.2 Formwork

Steel mould is used as the formwork. Therefore, no special preparation was needed. However, the surface of the formwork needs to be laid with oil before casting the beams.

9.2.3 Concrete Mixture

Quantity of each constituent for the concrete mixture was prepared and weighed using the weighing scale. Concrete was mixed using the drum mixer. The following steps showed the procedures for proper mixing.

i. Wet the surface of the drum mixer to ensure uniform mixture.
ii. Pour part of the water into the mixer.
iii. Add the fine aggregate followed by the coarse aggregate.
iv. Add cement into the mixer and let them mix for a while.
v. Add the balance amount of water into the mixture.
vi. Let all constituents mixed for about 15 minutes in order to obtain a uniform mixture.

9.2.4 Placing Fresh Concrete

After conducting slump test, fresh concrete is placed into the formwork. The distance of placement must as low as possible to avoid segregation. After placing, concrete was compacted with vibrator. Finally, the top surface of the beam was leveled to produce a smoother surface as shown in figure 9.6.

Fig 9.6 Casting of beams

9.2.5 Curing

After 24 hours of casting, all specimens need to be cured. Concrete cubes and the beams were cured in the water tank.

9.3 FLEXURAL STRENGTH TEST

Flexural strength test was conducted after 28-day the concrete beams were fabricated. UTM was used for this test. Figure 9.7 shows the UTM that used for the flexural strength test.

Fig 9.7 Test set up for beams

X. RESULTS AND ANALYSIS

10.1 INTRODUCTION

The performance of GFRP reinforced concrete beams were analyzed based on the comparison with the conventional control beam. In order to indicate the results of analysis clearly, graphs, tables and figures were used. Finally, the results from four beams were compared in term of ultimate load, deflection, cracking pattern, bonding characteristic and mode of failure.

10.2 LOAD – DEFLECTION

The ultimate load carried by each beam and the deflection corresponding to the maximum load are presented in Table 10.1 whereas Figure 10.1 shows the load-deflection curves for all specimens.

Table 10.1 Comparison in term of ultimate load and deflection

BEAM	ULTIMATE LOAD(kN)	DEFLECTION(mm)
SC	69.5	11
GI	70	11.2
GP	84.2	10.5
GPI	76.8	10.9

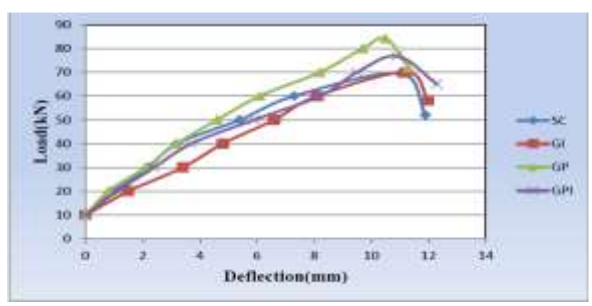


Fig 10.1 Graph of load versus deflection

10.3 CRACKING BEHAVIOR

The cracking profile of the control beam was the combination of minor and slightly major cracks along the beam. Different for the GFRP section beams, majority of the cracks were large and concentrated nearby the midspan. However, there were no cracks found nearby both supports for all cases. There were large number of cracks found along the control beam and the cracks' spacing was also close to each others. Both cracking patterns indicated that the steel reinforced concrete beam was more ductile compared to the GFRP reinforced concrete beam. Besides, the higher number of cracks and closer cracks' spacing also indicated that the steel rebar has good bonding behavior with the concrete. Steel rebar provided grip along its rough surface while the GFRP section has smoother surface which caused insufficient bonding with the concrete member. The following figure shows the cracking profile of all the beams tested.

Fig 10.2 Control beam SC

Fig 10.3 GFRP plate section reinforced beam GP

Fig 10.4 GFRP I-section reinforced concrete beam GI

Fig 10.5 Combination of GFRP plate and I-section reinforced concrete beam GPI

10.4 MODE OF FAILURE

The concrete failure in the compression zone was the major factor for the failure of beam. Reinforcement of the control beam yielded before the concrete failed in compression as can be expected for the under-reinforced concrete beam. While for both GFRP section reinforced concrete beams, concrete failed in the compression zone before the reinforcement rupture.

Table 10.2 Failure mode of each beam

BEAM	MODE OF FAILURE	DESCRIPTION
SC	Tension	Reinforcement yielded before concrete failed in compression zone
GI	Tension	Concrete failed in compression zone
GP	Tension	Concrete failed in compression zone
GPI	Tension	Concrete failed in compression zone

XI. CONCLUSION AND RECOMMENDATION

11.1 CONCLUSION

Throughout these series of the laboratory tests, GFRP section reinforced concrete beam exhibited the ductile failure modes and performed approximately the same flexural behavior and trend as would be expected in the steel reinforced concrete beam. GFRP section reinforced concrete beams were comparable in term of the ultimate loading carrying capacity and deflection behavior. However, the cracking behavior displayed an insufficient pattern as the cracks were extensive and larger compared to the conventional reinforced concrete beam.

Based on the overall results, analysis and comparison in term of the flexural behavior between the GFRP section and steel reinforced concrete beams, conclusions can be drawn as follows:

i. All GFRP sections reinforced concrete beams had higher ultimate load compared to the steel reinforced concrete beam.

ii. GFRP plate section which was arranged in the vertical alignment improved the crosshead displacement compared to the steel reinforced concrete beam. Meanwhile, the deflection behavior of the GFRP I-section reinforced concrete beam had higher deflection compared to both steel and GFRP plate section reinforced concrete beams.

iii. Steel reinforced concrete beam showed the highest stiffness value compared to the GFRP plate section and followed by the GFRP I and combination of GFRP plate and I-section reinforced concrete beams.

iv. GFRP reinforced concrete beam performs lower ductility and less bond behavior as the number of cracks is less and has larger cracks' spacing compared to the steel reinforced concrete beam.

v. All beams failed in the flexural / tension mode. Reinforcement of the control beam yielded before the concrete failed, whereas both GFRP reinforced concrete beams failed in the concrete at the compression zone.

vi. GFRP section is suitable to be used as an alternative to the conventional steel reinforcement in concrete beam if increment in the reinforcement area and roughen of the reinforcement surface are provided.

An overall conclusion can be stated that the GFRP section reinforced concrete beam performed well in the flexural especially the ultimate load capacity and deflection.However, both behaviors were greatly influenced by the shape and arrangement of the GFRP reinforcement in the concrete beam. Thus, the application of the GFRP section as an alternative to the conventional steel reinforcement in the concrete beam could be accepted. Improvement in the bonding behavior of the GFRP reinforcement by providing rougher surface with gripes will make the GFRP more competitive and practicable to replace the conventional steel reinforcement in the concrete structures.

11.2 RECOMMENDATION

There are several recommendations for the further experimental works regarding to the study of the FRP reinforced concrete structures in order to expand the knowledge and finding in this area:

i. Additional of the short fiber in the concrete mixture to inhibit and confine the cracking behavior of the GFRP section reinforced concrete beam.

ii. Combination of both internal and external strengthening methods using the FRP materials to reduce the crack width and spacing.

iii. Increment of the reinforcement area of the GFRP reinforcement in the concrete structures.

PUBLICATIONS

- ❖ First International conference on intelligent engineering Systems- 2IES -14 held at Easa College of Engineering and Technology, Coimbatore on 03-04-2014.
- ❖ Sixth National Level conference on Innovations in Civil Engineering – ICE'14 held at Kumaraguru College of Technology on 16-04-2014.

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