APPLICATION ALKALI RESISTANT GLASS FIBERS IN CONCRETE

A

THESIS

Submitted in partial fulfilment of the requirmrnt for the award of degree

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Under the supervision

Of

Kaushal Kumar

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By

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to

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HIMACHAL PRADESH, INDIA

MAY 2022

STUDENT'S DECLARATION

I hereby declare that the work presented in the thesis entitled "**Application of AR glass fiber in concrete**" submitted for partial fulfilment of the requirements for the degree of Master of Technology in Civil Engineering(structural engineering) at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Kaushal Kumar**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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23 May, 2022

CERTIFICATE

This is to certify that the work which is being presented in the thesis titled "**Application Of Alkali Resistant Glass Fiber In Concrete**" in partial fulfilment of the requirements for the award of the degree of Master of Technology in Civil Engineering(structural engineering) submitted to the Department of Civil Engineering**, Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Rohit Kumar (202651)** during a period from August, 2021 to May, 2022 under the supervision of **Kaushal Kumar**, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat. The above statement made is correct to the best of our knowledge.

Date: …………………

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Engineering	Department Civil Engineering	
JUIT,Waknaghat	JUIT,Waknaghat	

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ABSTRACT

Glass fiber reinforced concrete (GFRC) and (ARGFRC) are used in the field of civil engineering. This product has advantage of being light weight which not only reduces the overall cost of construction but also bringing economy in construction. The traditional use of "steel reinforcement undergoes corrosion and structural deterioration in reinforced concrete structures and prompted many researchers to seek alternative materials and rehabilitation techniques". Adopting new and sustainable scenario, alternative of steel reinforcement, it was found that "fibers like glass, carbon, aramid and poly-propylene provide very wide improvements in tensile strength, fatigue characteristics, durability, shrinkage characteristics, impact, cavitation's, erosion resistance and serviceability of concrete". The present work is only about finding application of GFRC and ARGFRC in new world of construction.

"The aim of the present study is to compare experimental results with the ABAQUS results". For this "Laboratory tests are planned to be carried out on a beam of 2400 x 200 x150 mm of M25 grade concrete for plain, steel fiber reinforced concrete, glass fiber reinforced sections". "Finite Element Analysis (FEA) have been performed using ABAQUS for the geometry considered in the experimental study. The numerical results from the FEA are presented in the results and discussion".And the second Aim is to "compare the results of compressive , flexure and split tensile strength of concrete having ARGF Of 0.5% and 1% by weight of cement". This comparison shows how "AR glass will change the mechanical properties of concrete".

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CHAPTER 1

Introduction

Concrete is the most widely used construction material. “Concrete is a composite material composed of fine and coarse aggregate bonded together with a fluid cement (cement paste) that hardens (cures) over time and has several desirable properties like high compressive strength, stiffness and durability under usual environmental factors”. Concrete has many advantages including “its low cost, availability of raw materials, resistance of fire and weather and high compressive strength”. At the same time “concrete is brittle and weak in tension”.

“Plain concrete has two deficiencies, low tensile strength and a low strain at fracture. These shortcomings are generally overcome by reinforcing concrete”. Normally reinforcement consists of “continuous deformed steel bars or pre-stressing tendons”. The advantage of “reinforcing and pre-stressing technology utilizing steel reinforcement as high tensile steel wires have helped in overcoming the incapacity of concrete in tension but the ductility magnitude of compressive strength”.

1.1 Fiber reinforced concrete

“FRC is a composite material consisting of a matrix containing a random distribution or dispersion of small fibres, either natural or artificial, having a high tensile strength”. Due to the presence of these “uniformly dispersed fibres”, the cracking strength of concrete is increased and it prevents cracking. “Some studies have shown that fibers can reduce crack widths within a concrete sample, which is an integral part in the deterioration of concrete because cracks allow corrosive materials to reach the rebar”. Figure 1.1 shows the commonly used Fiber shapes

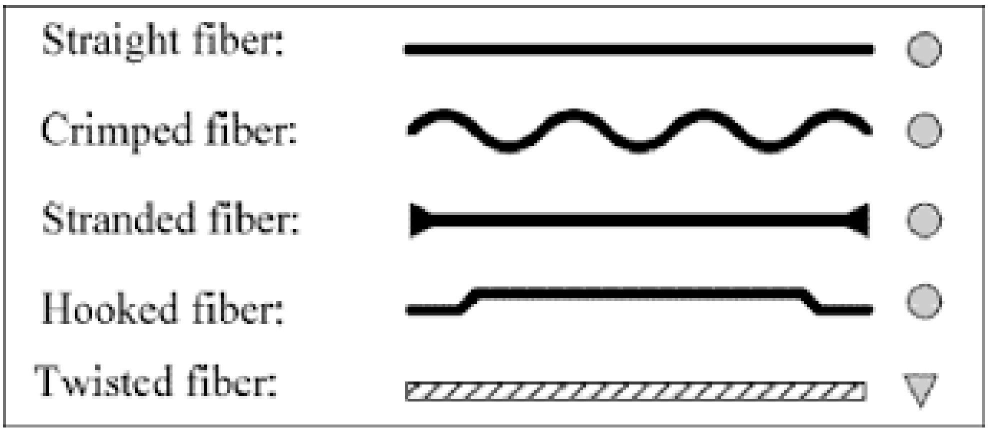


Fig.-1.1: Commonly used Fiber shapes

1.2 Surface texture of fiber

Surface defects because "the measured tensile strength of glass and other brittle materials to be significantly lower than their theoretical values". Coatings is an option to "heal surface flaws and modify surface properties". The raw fibers are having very smooth surface which makes it less adhesive and on the application of load the bond between fiber and matrix becomes weak and the fiber slips out. Due to slippage the "fiber surface" appears scarred and scratched. The smooth surface does not allow the fiber to resist the load to its greatest.

For improving his mechanical property of fiber, coating of fiber is done.

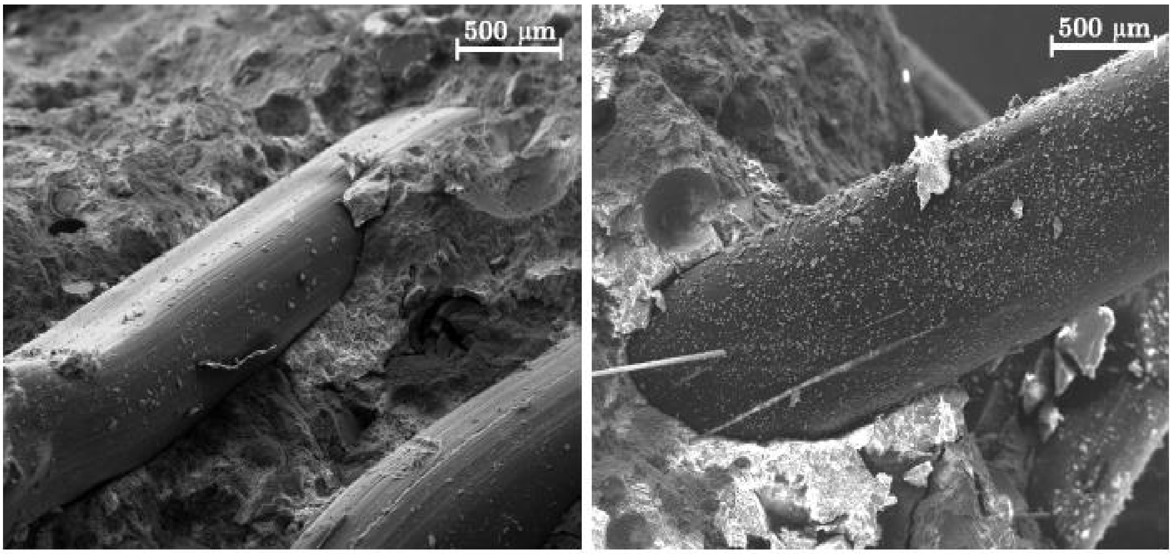
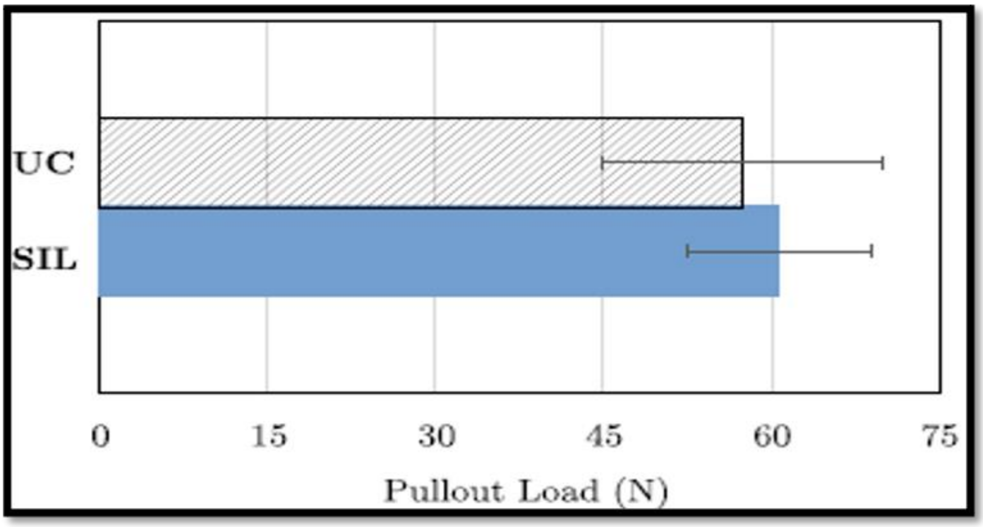


FIG.-1.2: SEM image of fiber surface after failure…

In the left we have uncoated fiber which seems to be clean from its outer surface with some scratches along its length.

The second one is a coated fiber. The micro particles attached on the surface of the fiber are silica particles which improves its bonding and resist detaching from matrix. Post cracking behavior shifts from plane concrete (brittle) to soften (uncoated) to coated fibers

Long softening post peak behavior that is typically of fiber reinforced concrete at mid or low fiber dosage turns into plastic softening response.



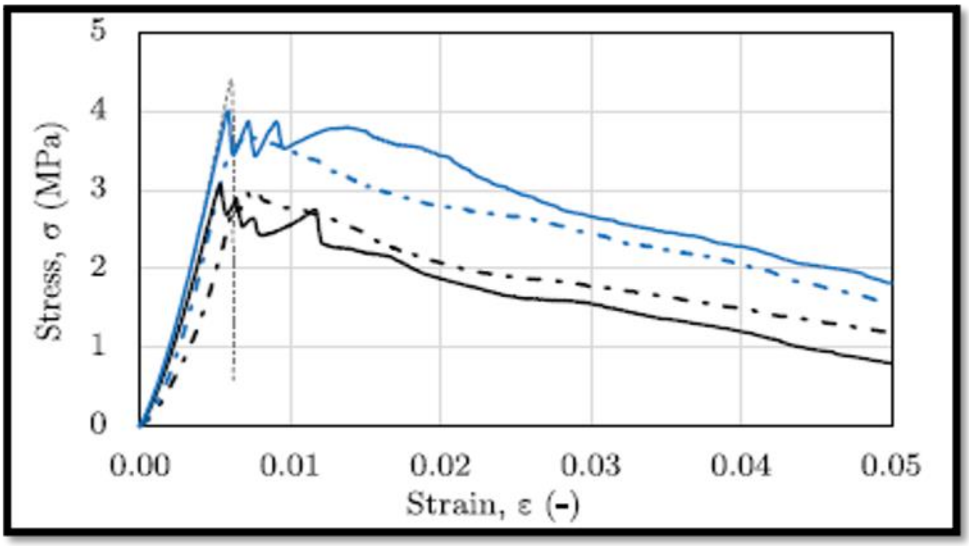


Fig.-1.3: Point bending test mean strength curve. “Plain mortar and FRC” group: “uncoated and silica coated for each curing time”. (8, 28 days)

1.3 Glass fiber

Glass fiber is made up of several “fine fibers” of glass. With diameters from 0.005mm to 0.015mm and usually round and straight. It has comparable mechanical properties to other fibers such as polymers and carbon fiber. Silica-based has been around for a long time. “Common glass fiber is readily available commercially in a variety of different chemical compositions” . They are commonly used for “reinforcement of thermosetting and thermoplastic polymers”. The term E stands for electrical as “E-glass is a good electrical insulator besides having good strength and a reasonable

Young's modulus". C stands for corrosion as "C-glass has a better resistance to chemical corrosion". S stands for "high silica content and S-glass is able to withstand higher temperatures than others".

Compound	**E- glass**	**C- glass**	**S- glass**	**Cemfil**
SiO_2	55.2	65	65.0	71.0
Al_2O_3	8.0	4.0	25.0	1.0
CaO	18.7	14.0		-
MgO	4.6	3.0	10.0	-
Na_2O	0.3	8.5	0.3	11.0
K_2O	0.2	-	-	
Li_2O	7.3	5.0	-	1.0

Table 1.1 show chemical composition of different glass fiber.

1.4 Alkali resistant glass fiber

When it comes to "construction industry and its weaknesses", a suitable and durable concrete can be obtained using "alkali-resistant glass fibers". The alkali resistance of AR glass fibers is a result of "adding zirconia (zirconium oxide) to the glass, the best fibers have zirconia contents of 19% or higher". The high "specific strength and stiffness" of these fibers implies a high potential for the reinforcement of cement concrete. Table 1.3 shows different properties of Alkali resistance glass fiber.

TABLE 1.2: Property of Alkali resistance glass fibers

	Density (kg/m^3)	**Tensile strength (MPa)**	**Tensile modulus (GPa)**	**Elongation (%)**
Alkali Resistant Glass fiber	1900	1100	73.1	4.4

1.5 ABAQUS and use

It is a software application used for both the “modeling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result”. “A subset of Abaqus /CAE including only the post-processing module can be launched independently in the Abaqus/Viewer product”.

Abaqus can easily model and analyses the results of FRP to improve the “bearing capacity of the concrete structures”. We can also analyse the “damage and failure of fiber reinforced composites” by using ABAQUS.

Modelling of plain concrete beam is easy and less time consuming.

- The modeling of plain concrete beam is done to compare result with Plain concrete, GRFC and ARGFC.

- Designing includes: dimension of the beam, type and magnitude of the load, type of support to be used, young's modulus and poisons ratio.

1.6 Objectives

- To Adopt Alkali resistant glass fibers in concrete and measure mechanical strength.
- To Model glass fiber as FRP rebar to improve the post cracking behavior (various permutations).
- To Measure the bond strength between FRP rebar and GFRC and compare with OPC concrete.

1.7Aim

The aim of using software is to compare the ABAQUS results of “plain concrete, reinforced concrete and fiber reinforced concrete” beam. Second aim is to adopt Alkali resistance glass fiber in concrete and find out the effect of AR glass fiber in concrete for compression , flexural and tensile strength at different w/c ratios.

1.8 Scope and limitation of study

This project focus on analytic and designing of glass fiber reinforced concrete. The project is limited to manual analysis of plain, steel reinforced and glass reinforced concrete in lab and software analysis using ABAQUS software and then comparing both the results.

Testing is done using various Water cement ratio i.e. 0.4, 0.45, 0.5, 0.55, 0.6 and using the FiBar of 12mm diameter and with fiber content of 0.5% and 1% by weight of cement.

CHAPTER 2

Literature review

This chapter presents the literature survey conduct on studies relevant to fiber reinforced concrete.

2.1 Fiber reinforced concrete

In a study conducted by Devid et al., for a group of specimens, "the effect of the GFRP introduced in the tensile zone, near the bottom external face of the prismatic beams, was investigated". He concluded that "0.7% fiber content did not produce significant mechanical strength gain in comparison with the reference specimens without fibers for all the analyzed conditions".After " Increasing the fiber content to 2.0% and, above all, to 5.0%, improved the flexural strength in a considerable manner, but it did not affect the compressive strength significantly".

The author comes to an end that "the use of GFRP with fiber contents of 5.0% is not advantageous, as the flexural strength that can be obtained with a less amount of short polymer fibers (say 2.0%) is practically the same, and there is no added value in introducing higher fiber contents".

2.2 Factors affecting the fiber-matrix bond in rcc

In a separate investigation by Banthia "the post-peak-load region where significant fiber pullout occured, the load-carrying capacity of the section, and consequently the energy absorption capacity, depends on how effectively the fibers have been bonded with the surrounding matrix"[10]. Further, since the "tensile load-carrying capacity of a RCC section is an integration of the load carried by the individual fibers, it is the performance of an individual fiber under an externally applied load that becomes a strong factor in deciding the toughness of the whole"[10].

It is concluded that the "pull-out behavior of a single fiber may be affected by numerous factors". On covering large number of basis, "the factors that may potentially affect the response of a fiber to a pull-out load are":

(1) First is "Fiber and matrix characteristics"

(2)Second is " Environmental characteristics"

(3)Third is " Loading characteristics"[10].

Deforming a fiber along its length is necessary in order to “maximize its resistance to pullout and to properly utilize the potential of steel”[10]. But “there is a limit to deforming a fiber, and excessively deformed fibers may cause a premature matrix splitting and fracture in the process of pullout, leading to considerable reductions in the pull-out energy consumption”[10].

Addition of “silica fume” improves “bond strengths”[10]. However this addition also renders the matrix more brittle, especially in the case of “excessively deformed fibers”[10]. Figure 2.1 depicts the effect of steel fibers on the flexural behavior of concrete beams[10].

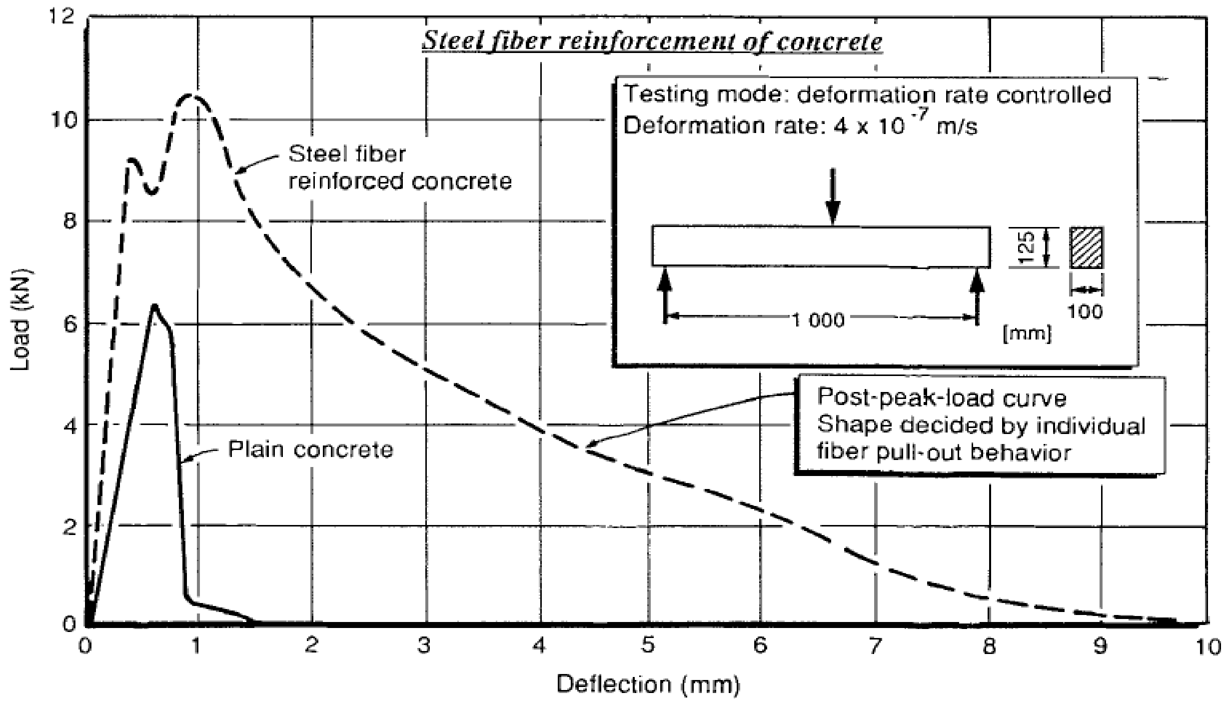


FIG. 2.1: Effect of “steel fibers” on the “flexural behavior” of concrete beams[10].

2.3 Nano-structured coating of glass fiber

In a study by Gao et al., [11] “Surface defects” caused the “measured tensile strength of glass and other brittle materials to be significantly lower than their theoretical values”[11]. Coatings of glass fiber can be used to “heal surface flaws and modify surface properties”[11]. In this the author performed some experiments of “coating for inproving alkali resistance and healing surface flaws of glass fiber” .The authors found that “with a low fraction of nanoreinforcements, the nanostructured and functionalized traditional glass fibers showed significant improvement in both environmental corrosion resistance and mechanical properties”[11].

2.4 Performance of ARGFRC

In a study conducted by Ghugal & Deshmukh "for an additional group of specimens the effects of Alkali-resistant glass fibers on workability, density, and on various strengths of M20 grade concrete were studied"[12]. Fiber content varied from 0.5 to 4.5% by weight of cement[12]. The experiments were "compressive strength, flexural strength, split tensile strength, and bond strength"[12]. The moulds used for compressive and bond strength were "Cubes of 150mm" and for split tensile strength he used cylinders of "150mm diameter and 300mm length". For flexure strength test "beams of 100*100*500mm were used" for test of 28 days.

"A significant improvement in the various strengths is observed due to inclusion of glass fibers in the concrete"[12].

Table 2.1: Compressive Strength of Normal Concrete and GFRC (MPa)

Fiber content (V_f) %	Compressive strength (MPa)		% Increase in compressive strength	
	7 days	28 days	7 days	28 days
0.0	24.22	31.48	–	–
0.5	24.44	31.99	0.90	1.62
1.0	25.21	34.03	4.08	8.10
1.5	26.16	35.31	8.00	12.16
2.0	27.05	36.50	11.68	15.94
2.5	27.20	36.50	12.30	15.94
3.0	27.25	37.40	12.51	18.80
3.5	27.39	38.19	13.08	21.31
4.0	28.27	39.50	16.72	25.47
4.5	28.46	40.44	17.50	28.46

Table 2.2: “Load-deflection, flexural and shear strength of normal concrete”. (MPa)

Fiber content (V_f) %	Maximum load (kN)	Maximum measured deflection (mm)	Flexural strength (experimental) (Equation (2)) (MPa)	Increase in flexural strength (%)	Flexural strength (MPa): Using IS456 [9]	Flexural strength (MPa): Using proposed formula Equation (3)	Flexural shear (MPa): Using Equation (4)	Flexural shear (MPa): Using Equation (5)
0.0	08.72	0.11	3.49	–	3.93	3.93	0.65	0.66
0.5	10.93	0.18	4.37	25.37	3.96	4.33	0.82	0.83
1.0	11.07	0.19	4.43	26.89	4.08	4.57	0.83	0.84
1.5	11.27	0.20	4.51	29.18	4.15	4.73	0.85	0.85
2.0	12.05	0.23	4.82	38.21	4.22	4.86	0.90	0.91
2.5	12.40	0.28	4.96	42.20	4.22	4.92	0.93	0.93
3.0	12.67	0.32	5.07	45.24	4.28	5.02	0.95	0.95
3.5	13.07	0.34	5.23	49.82	4.32	5.11	0.98	0.98
4.0	13.27	0.37	5.24	50.08	4.40	5.24	0.99	0.98
4.5	13.20	0.40	5.18	42.00	4.45	5.33	0.99	0.97

Table 2.3: “Split tensile and Bond strength of normal concrete and GFRC”. (MPa)

Fiber content (V_f) %	Cylinder split tensile strength (Equation (6)) (MPa)	% Increase in cylinder split tensile strength	Split tensile strength using Equations (7) and (8) (MPa)	Bond strength using Equation (9) (MPa)	% Increase in bond strength	Bond strength using Equations (10) and (11) (MPa)
0.0	2.51	–	2.52	6.25	–	6.29
0.5	2.52	0.40	2.54	6.54	4.64	6.56
1.0	2.60	3.79	2.59	7.30	16.80	7.39
1.5	2.62	4.47	2.62	8.10	29.60	7.80
2.0	2.62	17.22	2.65	8.29	32.64	8.35
2.5	3.22	28.31	3.53	8.36	33.76	8.35
3.0	3.62	44.38	3.63	8.45	35.20	8.62
3.5	3.64	45.21	3.65	7.90	26.40	7.90
4.0	3.72	48.40	3.69	7.20	15.20	7.20
4.5	3.73	48.68	3.75	6.85	9.60	6.85

Table 2.4: “Optimum fiber content and maximum percentage increase in various strength”.

Strength	Fiber content (V_f) %	Maximum value of strength (MPa)	Maximum % increase in strength
Compressive strength	4.5	40.44	28.46
Flexural strength	4.0	5.24	50.08
Split tensile strength	4.5	3.73	48.68
Bond strength	3.0	8.45	35.20

2.5 Role of the interface in glass fiber reinforced concrete

In the study conducted by A.J. Majumdar "when an alkali resistant glass fibre was used, the bending strength of the composite shows an initial increase over a period of months and then a slight reduction in strength is observed"[20]. The magnitude of the decrease in strength is "dependent on the conditions used in storing the material and there are indications that this trend is absent when PFA is included in the mix"[20]. The strength results are "interpretable in qualitative terms on the basis of the changes taking place in the interfacial zone between the fibre and the matrix"[20]. These changes are brought about by the "interaction of the glass fibre with the cement matrix as well as the continued hydration of the cement itself"[20].

2.6 Effect of ARGFC on crack and temperature resistance of light weight concrete

"Effects of alkali-resistant glass fiber reinforcement on the flexural strength and ductility, restrained shrinkage cracking and temperature resistance of lightweight concrete" were investigated by Mirza & Soroushian [13].

The effects of "alkali-resistance glass fiber at mass (volume) fractions up to 3% (0.75%) on the restrained shrinkage cracking attributes, flexural performance and temperature resistance of lightweight concrete were investigated"[13]. Alkali-resistant glass fibers were found to be "highly effective in controlling restrained shrinkage cracking of lightweight concrete"[13].

“Alkali-resistant glass fibers promote multiple cracking and reduce crack widths. Introduction of glass fibers also improves the flexural strength and ductility of lightweight concrete, and controls the negative impacts of exposure to elevated temperatures”[13].

The author concluded that the “Alkali-resistant glass fibers at about 1% mass fraction (0.25% volume fraction) are quite effective in enhancing the material properties of the lightweight concrete mixtures investigated in this project”[13].

CHAPTER 3

Material and methodology

This Chapter presents the details of Materials used in the study and the methodology adopted to test the specimens.

3.1 Methodology:

1. Study of Mix Design of M25 concrete and selection of ingredients of concrete mix as per the Mix Design (OPCC). Ingredients selected are cement, sand, coarse aggregate, glass fiber and glass rebar for OPCC.

2. Design of trial Mix.

3. Preparation of cube, beam and cylinder test samples for compressive, flexural, tensile strength with plain concrete and AR glass fiber reinforced concrete.

4. Casting of cubes of various water cement ratio and choose suitable w/c ratio for flexure and tensile strength test

5. Modeling a beams of plain, reinforced and GF on ABAQUS.

7. Comparing the results of OPCC, RCCC, GFRCC and ABAQUS model beams to draw conclusions.

Table 3.1 gives required specification for modelling in ABAQUS.

TABLE-3.1: Specification for ABAQUS MODELLING

Specifications	Plain concrete beams	Steel Reinforced concrete beams	Glass fiBar reinforced concrete
Grade of Concrete	M25	M25	M25
Grade of bar (mm)	-	Fe415	-
Dimension of beam (mm)	2400*200*150	2400*200*150	2400*200*150
Area of steel bar(mm)	-	107.46	107.46
Cover (mm)	-	25	25
Stirrups size (mm)	-	150*100	150*100
Spacing of stirrups (mm)	-	150	150

3.2 Material Used

3.2.1. Cement

Portland pozzolona cement of 43 Grade has been used for the study of ARGF concrete. The "specific gravity" was 3.15. Fig 3.1 shows weighting of cement

Fig 3.1

3.2.2. Aggregates

Aggregates used in concrete are manufactured by crushing quarried rock. For this study we used two types of aggregates i.e

1. Fine Aggregate: Fine aggregates which I used in mix were according to requirement i.e which passed through 4.75mm sieve.
2. Coarse Aggregates: Coarse aggregate which I used in mix were those which "retained on 4.75mm sieve". Generally the size of coarse should be 25mm or larger than this.

Fig. 3.2

3.2.3. Mould Used

For the compressive strength test on cube I used mould of size (15*15*15)cm which were properly oiled.

For flexure strength test I used mould of size (50*10*10)cm

For split tensile strength test, size of mould as 30cm in height and diameter was 15cm.

3.3. Mixing method

The mix design applied in the present study is presented in Table 3.2. The dry materials “cement sand and aggregates” were properly mixed with fiber alternatively (one batch with fiber and one without fiber for each water cement ratio) .Then the water was added into the dry materials or mix. After that mixing was done properly.

TABLE-3.2: Design mix proportion

Water cement ratio	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregates (kg)	Water (lts)	GFRC (kg)
0.4	450	581	1235	197	6.75
0.45	438	600	1218	197	6.57
0.5	394	631	1225	197	5.91
0.55	358	661	1227	197	5.37
0.6	328	689	1225	197	4.92

3.4. Casting of cube for compressive strength test

For compressive strength test , mould of (15*15*15)cm were used. After that the materials which were cement, sand , fine aggregates and coarse aggregates used for mixing with different w/c ratios. Fig. 3.3 shows the mixing process

Fig. 3.3

After mixing properly we put the mixture on mould in three layers and after each layer the process of vibration which is used for compaction was done on vibrating machine. After That we kept the samples for 24 hour at room temperature. Fig. 3.4 shows vibrating process and Fig. 3.5 shows prepared samples.

Fig.. 3.4

Fig. 3.5

After 24 hours we removed the samples from the mould and put these samples in curing tank for "period of 3, 7 and 28 days". For ARGF concrete we applied same process but we add AR glass fiber with percentage of 0.5% and 1% by weight of cement. Fig. shows the curing process.

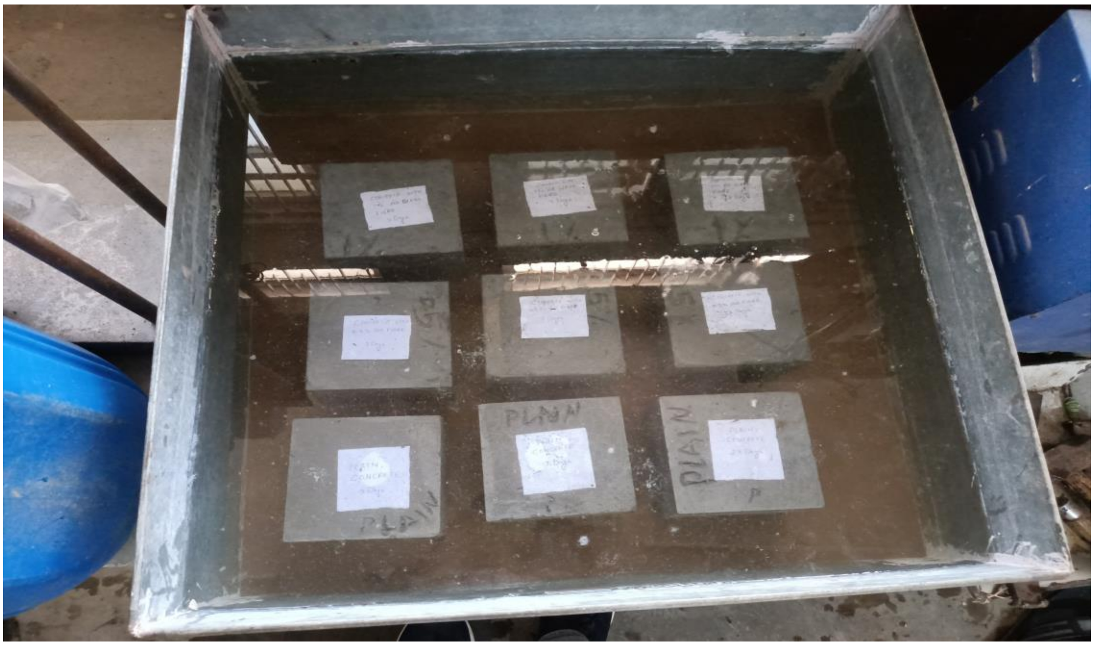


Fig.. 3.6

3.5 Casting of beam for flexture strength

For flexture strength test I used mould of (50*10*10)cm. For this test firstly mix of concrete according to required mix design i.e M30 was prepared with cement, sand, fine aggregates and coarse aggregates. In this two type of mixtures were prepared i.e one was of plain concrete and other with ARGF of percentage 0.5% and 1% by weight of cement. Then the mixture was put in mould and kept for 24 hours. After 24 hours beams were removed from moulds and were kept in curing tank for time period of 7 and 28 days for flexure strenghth test.

3.6 Casting of cube for pull out strength testing

As we performed an experiment on pull out apparatus and know about its working as it will required to check the strength of our GFRP cube with FRP rebar's.

We cast around 30 cubes of dimension (10x10x10) cm. We used OPC cement instead of PPC cement. We used M25 grade of concrete and used cement sand water and aggregate according to M25 mix design. We cast around 30 cubes which was further divided into pair of 6 cubes which means 6 cubes of w/c ratio of 0.40, 6 cubes of 0.45, 6 cubes of 0.50, 6 cubes of 0.55 and finally 6 cubes of 0.60 water cement ratio. Again in these pair of 6 cubes 3 were normal and other 3 had fiber mixed with it. We cast the cubes with FRP rebar at it centre. Glass fiber rebar of length 40cm was inserted 50mm above the surface of mould on concrete and then held with concrete of 50mm height.

FIG.-3.7. (a) (b)3.7

(IN FIG. 3.7.() HALF FILLED MOULD WITH CONCRETE AND GLASS FIBER REBAR HELD ON IT AS SHOWN IN FIG. 3.2)

3.7 Application

- ARGF is used in residential construction i.e

- use in foundations

- use in "repair & reinforcement of bearing capacity in brick and reinforcement concrete structures".

- Basements, structures up to G+3 floors, retaining walls, compound walls, etc.

- Industrial engineering:

-Floor pavements, chemical tanks, effluent retention tanks, etc.

- Effluent treatment and sewage treatment plants, reinforcements in underground concrete tanks, retaining walls

- Urban municipal structures, sewer collection structures, storm water drain channels, culverts, etc.

- Railway construction:

"Elements of railway sleepers for high-speed trains and underground railroads".

- Bridge building & reconstruction:

-Roads and bridges – Concrete pavements, bridge decks, side walk strips, subways, tunnels, etc.

3.8 ABAQUS modeling

Following steps are involved in modelling

1. The first step is "Elements type"
2. Second is "Material property"
3. Third is " Assigning sections"
4. Fourth is "Defining step"
5. Fifth is "Interaction between elements"
6. Sixth is "Specify boundary conditions and load"
7. Seventh is "Meshing"
8. Eight is "Assigning job"
9. And the last one is "Evaluating the results"

3.9 Modeling of fiber reinforced concrete beam

The modelling of FIBER REINFORCED CONCRETE BEAM is done by

1. Adding bars and stirrups to beam
2. Size of beam is 2400*200*150 mm
3. 12mm dia. Steel bar with, 10mm dia. stirrups

4. Interaction of concrete to reinforcement is EMBEDED TYPE
5. Support: simply supported beam, supports at 300mm and 2100mm
6. Load: [50, 40, 30, 20, 10] kN concentrated load at 1200mm was applied in y-axis for different results.
7. Comparison is made between plane concrete, steel fiber reinforced concrete, and glass fiber reinforced concrete.

3.10 Finite element modeling

"On the basis of central objective in research is finite element model of plain concrete beam were developed".

3.10.1. PLAIN CONCRETE BEAM

For modeling a plain beam of size 2400mm length, 150mm width and 200mm depth , requird material properties were assigned in ABAQUS software. After assigning properties an input file was created. This input file then "imported to create an orphan mesh". Orphan mesh was generated by "defining nodes and connecting them to define the elements". After these steps we went to job analysis and submitted our data for results.

3.10.2 Reinforced concrete beam and FRP concrete beam

For modeling of "reinforced concrete beam and FRP concrete beam" first we model a pain beam from same steps as mentioned above. After that model of FR and reinforced concrete was developed with required specifications as shown below in dimension of section. After assigning properties we fused plain concrete model and reinforced frame model together. Then mesh was created and job was established. After creating job analysis we submitted the model for results. Load applied of 50kN at the center (1200mm) of the beam for 3 point bend test with pinned supports at 300mm and 2100mm from either end. The application of load was in Y-axis (downward) and the results were compared to those of practical results.

DIMENSION OF THE SECTION

- Length – 2400mm
- Width – 150mm
- Depth – 200mm

- Mesh 2mm diameter
- Main Steel bars 12mm diameter& Stirrups 10mm diameter.
- Clear cover – 25mm

3.11 Simulations

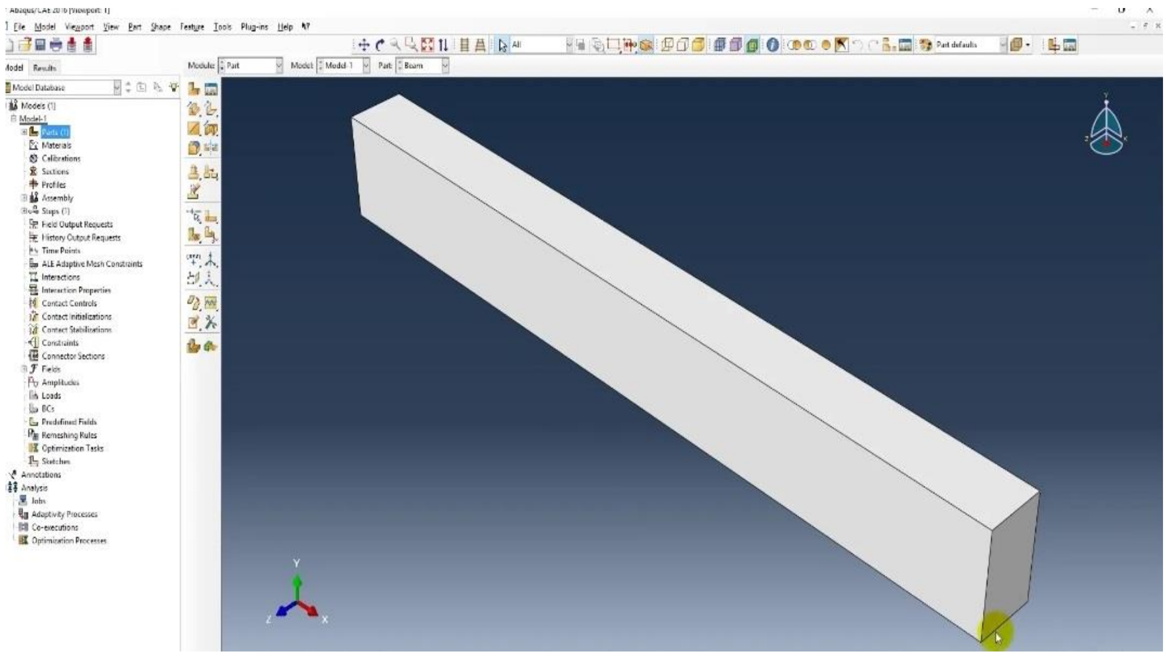


Fig.3.8: Beam Model in ABAQUS

Beam of dimension 200*150*2400mm was modelled in ABAQUS with well defined properties of material. Young's modulus and poisson's ratio for different materials are also provided, they are well defined in Table 3.4. The beam so formed of concrete is shown in Fig. 3.2.

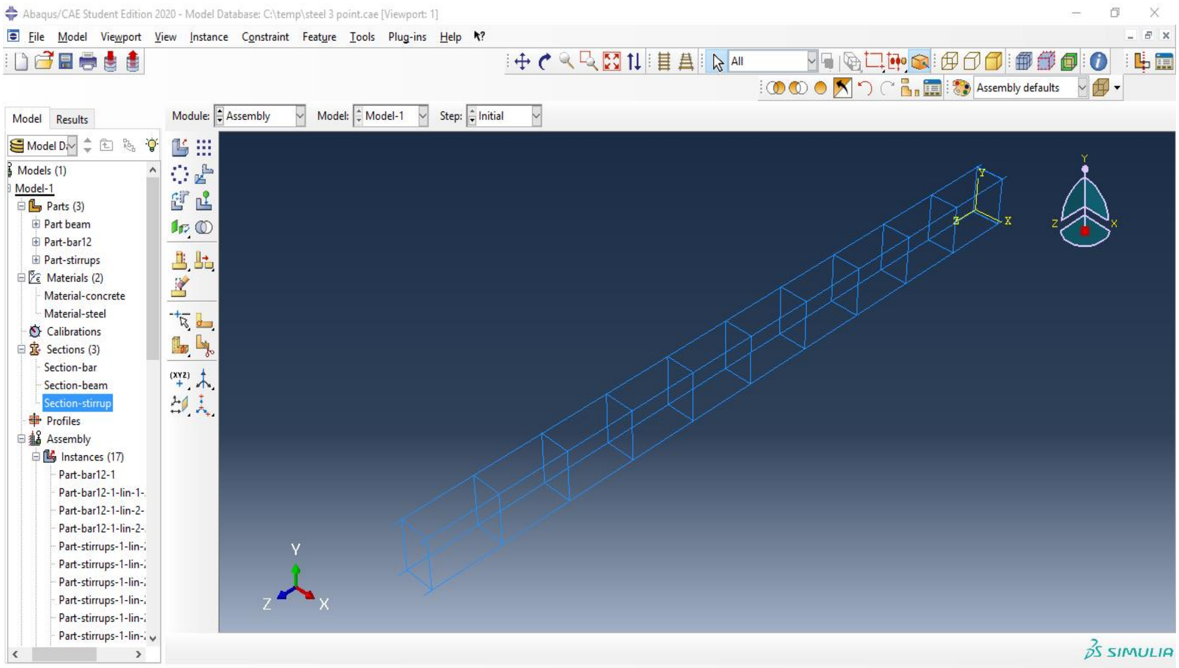


Fig.3.9: Reinforcement Model in ABAQUS

Concrete is reinforced either with steel bar or glass fiber rebar of 12mm diameter with stirrups of 10mm. embedded type interaction is provided in concrete and rebar. The whole will act as one body after interaction. The reinforcement provided can be seen in Fig. 3.3.

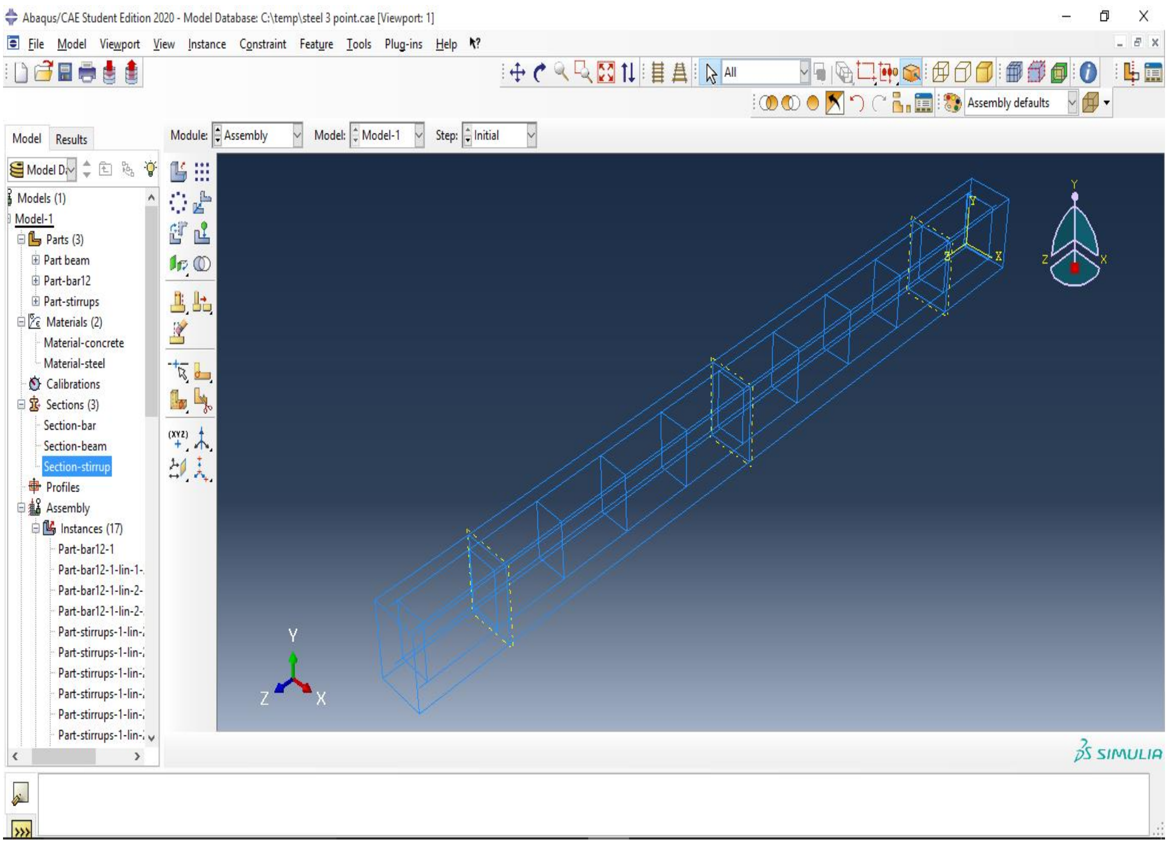


Fig. 3.10: Assembled Model for RCC Beam

At last the two materials are assembled and different planes are introduced for loading and supports. Plane sections are cut into desired section for identification of loading points. Assembly of reinforcement and concrete can be seen in Fig. 3.4.

3.12 Material properties

The material properties are taken from IS 456:2000

Elastic modulus of concrete = $5000\sqrt{fck}$

$= 5000\sqrt{25}$

= 25000 N/mm2

TABLE 3.3: Young's Modulus and Poisson's ratio for Glass, Steel And Concrete.

S.no	Material	Young's modulus E	Poisson's ratio υ
1	Cement concrete	25 GPa	0.22
2	Steel	210 GPa	0.3
3	Glass FiBar	55 GPa	0.21

The analysis for the RCC Beam is done in ABAQUS by FEM meshing tool. FEM meshing is done by quadrilateral mesh. "Boundary condition is assigned as fixed condition". Then we applied "Concentrated load" on the specimen. Job was input. Linear analysis was done. Meshed beam is shown in Figure 3.5.

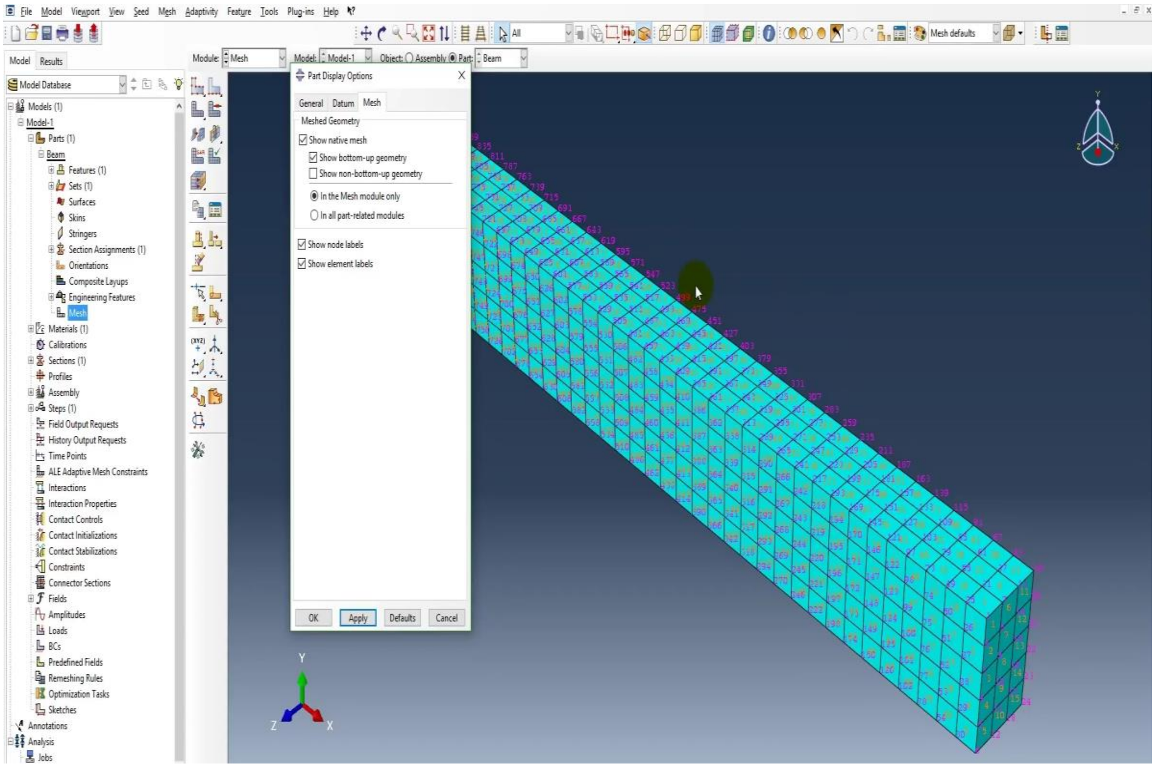


Fig.3.11: Meshed Concrete Beam

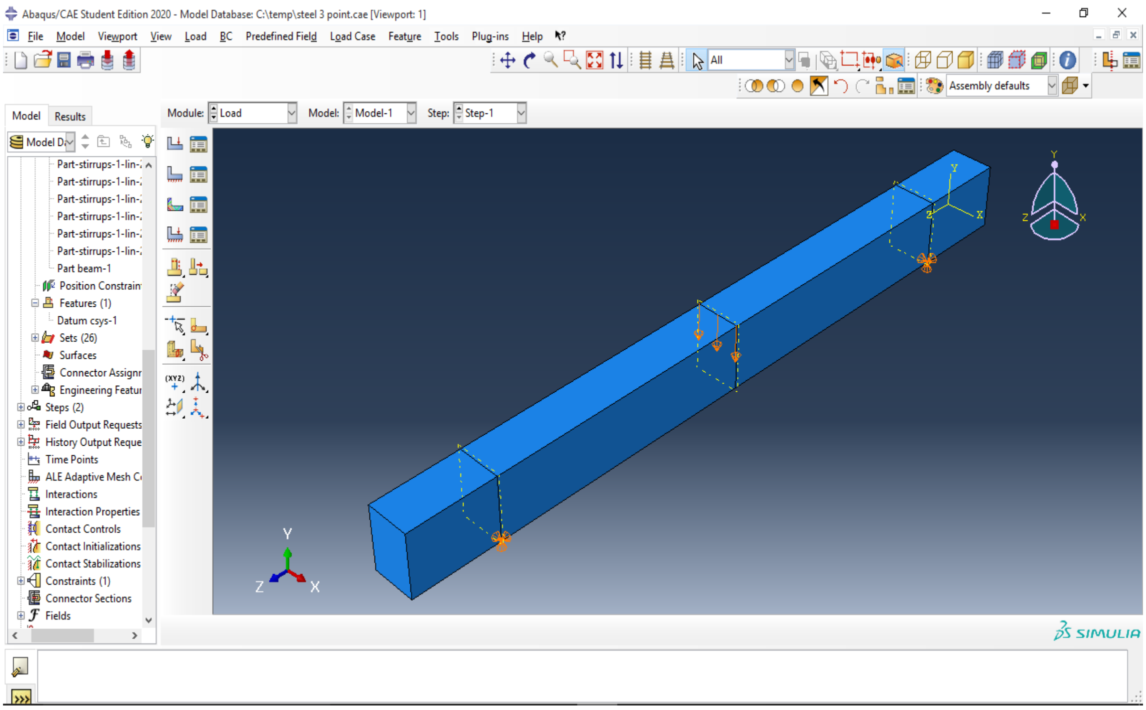


Fig. 3.12: Simply Supported Beam with Loading at Centre

Atlast created a sample reinforced concrete beam of dimension 200*150*2400mm with supports at 300mm and 2100mm and load of different magnitude is applied at the center of the beam i.e. at 1200mm as shown in Fig. 3.6.

CHAPTER - 4

Results and discussions

4.1 Compressive strength

The compressive strength was measured according to IS 516-1959 [18]. The cube samples were (15*15*15) cm in size and the result are shown in Table-4.1.The cubes were tested after a time period of 3,7 and 28 days. In this test I found that the compressive strength of concrete is increased with increased in alkali resistance glass fiber percentage i.e when we add 1 % of Cem-Fil anti crack HD (ARGF) it will increase the "compressive strength" . So the "compressive strength" attain by the concrete after time period of 28 days was 22.22 N/mm2.

TIME PERIOD	PLAIN CONCRETE	CONCRETE WITH 0.5% ARGF	CONCRETE WITH 1% ARGF
3 DAYS	240 KN	260 KN	300 KN
7 DAYS	330 KN	355 KN	410 KN
28 DAYS	470 KN	490 KN	500 KN

Table 4.1: Compressive Strength of ARGFRC and PCC

4.2 Flexture strength test

For the flexural strength of concrete I used beams of size (50*10*10) cm each for Plain concrete and Alkali resistance glass fiber of M30 mix design according to ASTM-D790. The beams were tested after time period of 7 and 28 days .

TIME PERIOD	PLANE CONCRETE BEAM	BEAM WITH 0.5% ARGF	BEAM WITH 1% ARGF
7 DAYS	1.85	2.88	4.35
28 DAYS	3.8	4.62	5.84

Table 4.2 Flexture strength

4.3 Split tensile strength test

TIME PERIOD	PLAIN CONCRETE CYLINDER	CONCRETE CYLINDER WITH 0.5% ARGF	CONCRETE CYLINDER WITH 1% ARGF
7 DAYS	1.52	1.62	1.88
28 DAYS	2.28	3.42	3.57

Table 4.3 Split tensile strength

The result of compressive and flexural strength can be narrowed down to:

1. With increase in Water-Cement ratio I obeserved that there is "decrease in Compression and Flexural strength".
2. Concrete mix with glass fiber embedded in it showed an increase of compressive strength by 22 KN/mm2 with water cement ratio of 0.45.
3. An average increase of 8 % compressive strength was observed in all the concrete mixes.
4. Whereas in Flexural strength ARGF reinforced Concrete with 0.50 water cement ratio showed an increase of 44% against the same control mix with a normal concrete without glass fiber embedded in it.
5. An average increase of 28% flexural strength was observed in all the concrete mixes.
6. Some amount of pull out force was required to break the bond strength of glass fibre itself and hence overall a larger flexural strength was observed.
7. Once a sufficient pull was generated by the testing machine crack started occurring from the weakest point of the bond.

4.4 ABAQUS stimulation and results

Deflection in X-Axis is too small for observation but still need to be considered. The deflection in X-Axis is either due to loose supports or loose interaction in material.

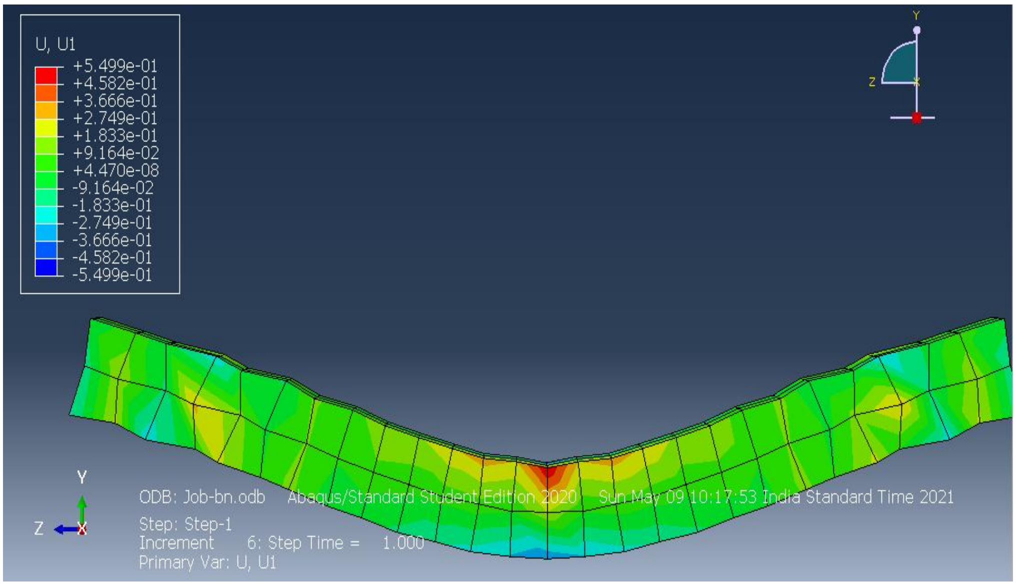


FIG. 4.1: DEFLECTION IN PRIMARY VARIATION IN X-AXIS IN PLAIN CONCRETE

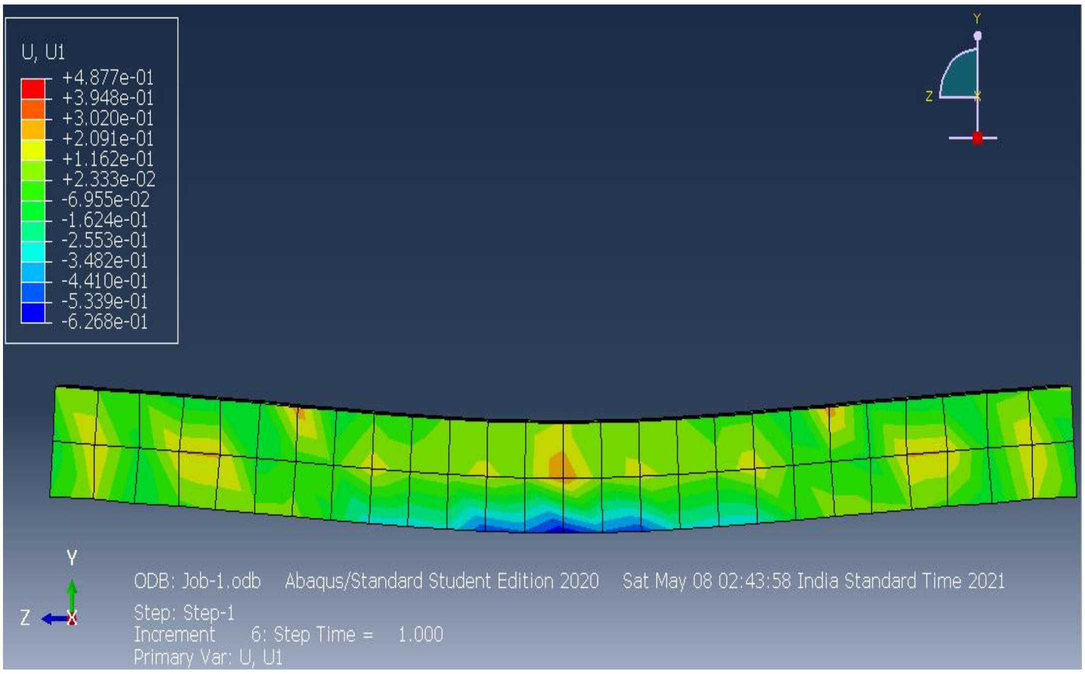


FIG. 4.2: DEFLECTION IN PRIMARY VARIATION IN X-AXIS IN RCC

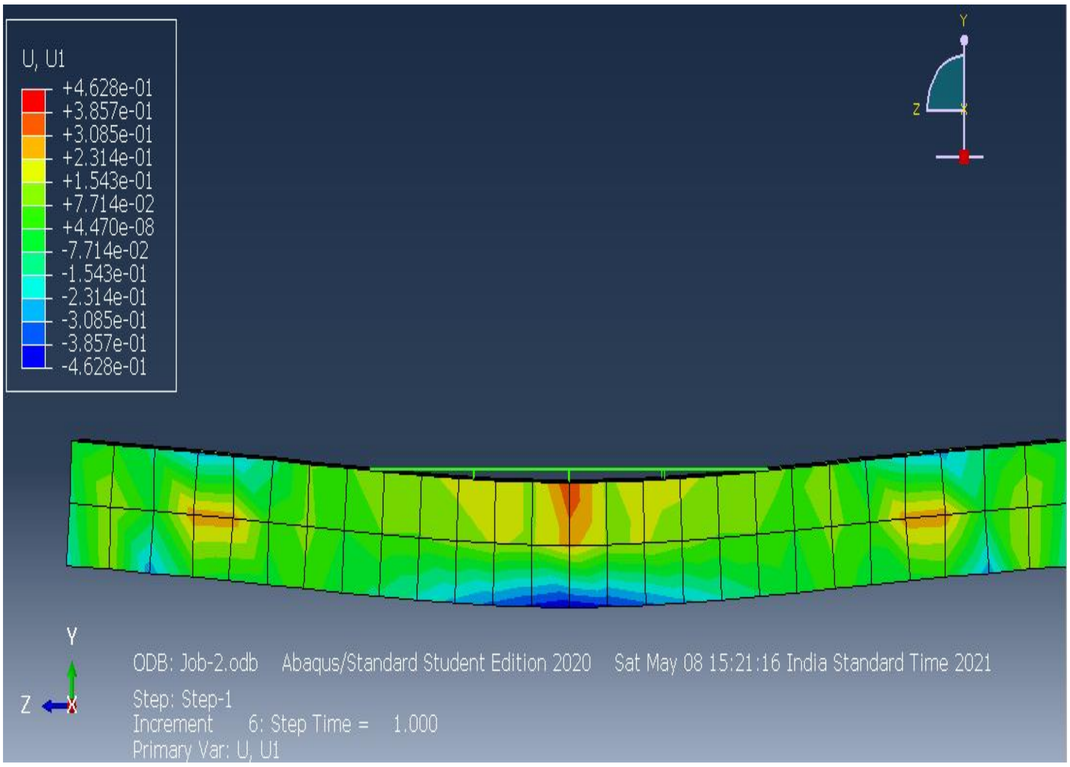


FIG. 4.3: DEFLECTION IN PRIMARY VARIATION IN X-AXIS IN GFRC

DEFLECTION IN Y-AXIS

Since -Y axis is the direction of application of load more deflection and stresses are seem in –Y direction. As shown in the following figures the deflection caused by load in PCC is much heigher than that in reinforced section. The reinforcement bears the load and provides more pull out reistance to the material. Once the reinforcement starts pulling out from concrete the deflection in concrete is observed clearly.

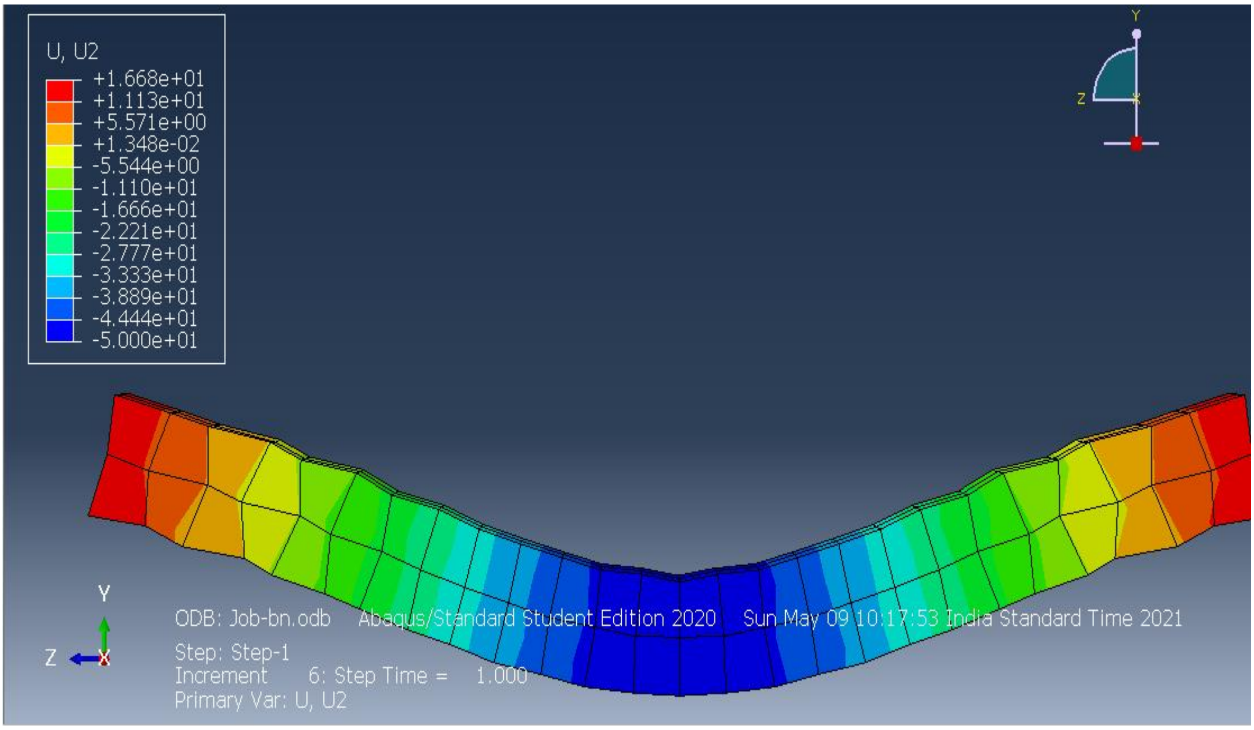


FIG. 4.4: DEFLECTION IN Y -AXIS IN PLAIN CONCRETE

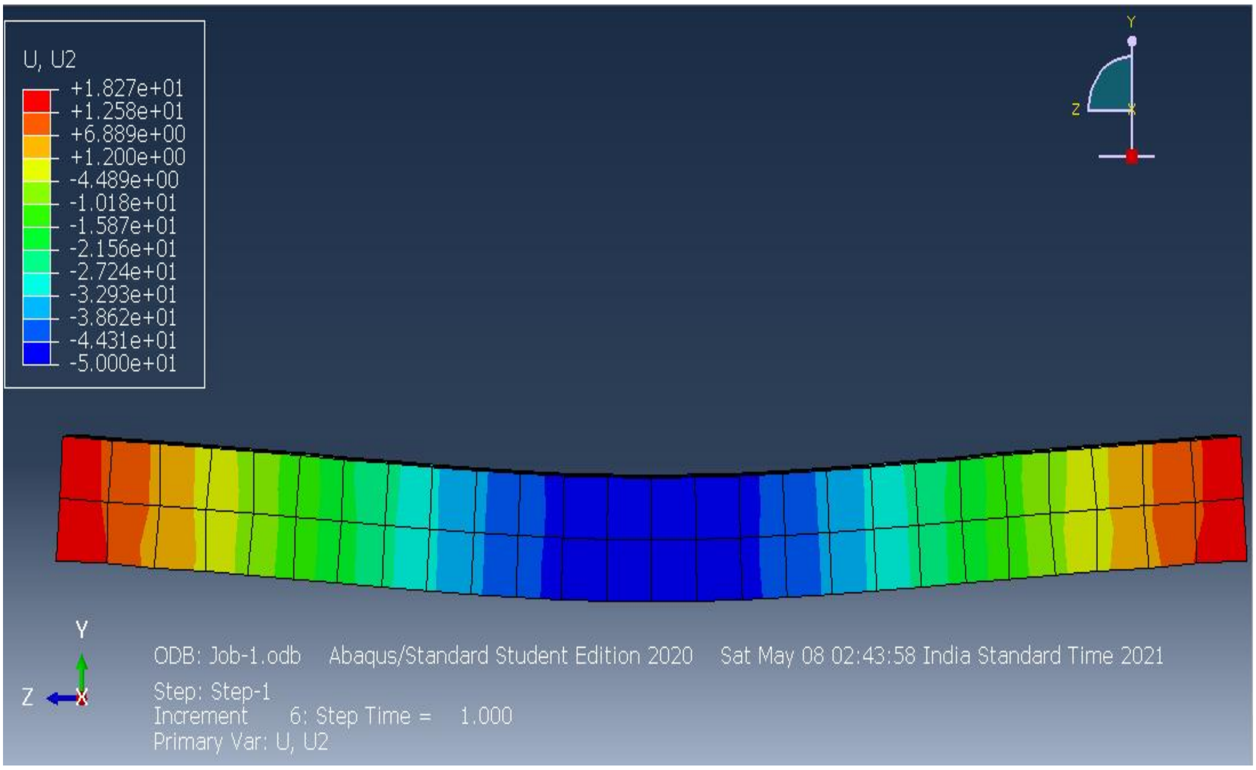


FIG. 4.5: DEFLECTION IN Y -AXIS RCC

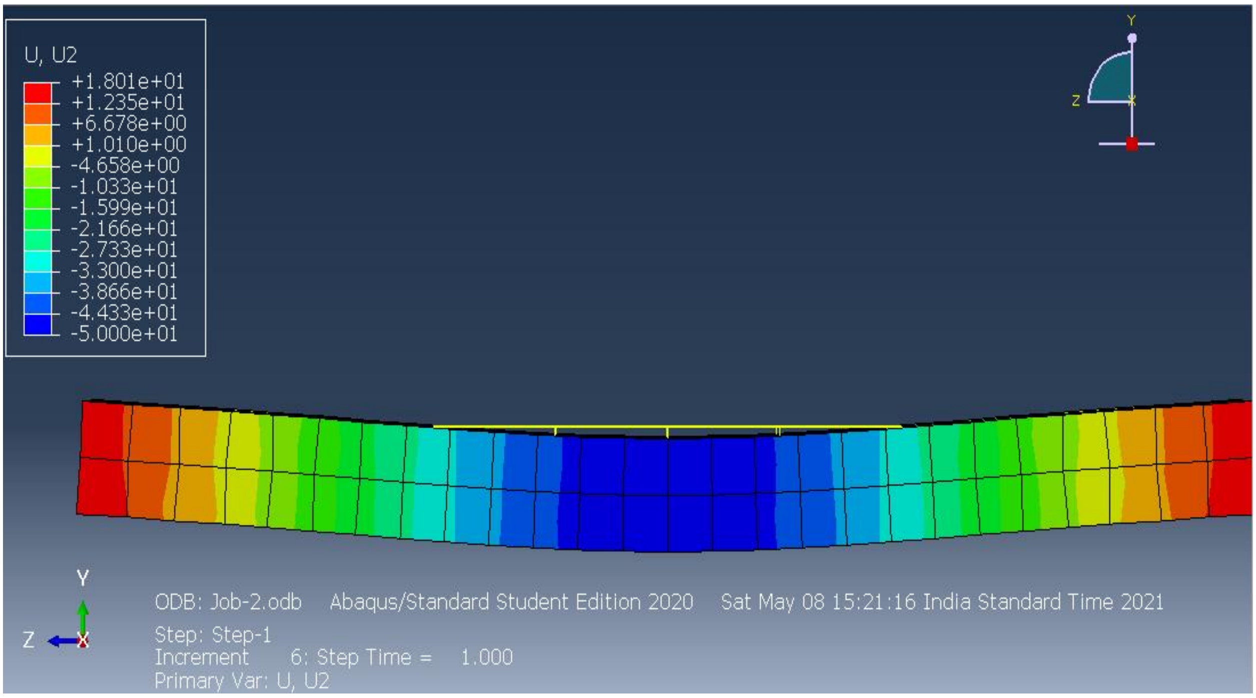


FIG. 4.6: DEFLECTION IN Y -AXIS GFRC

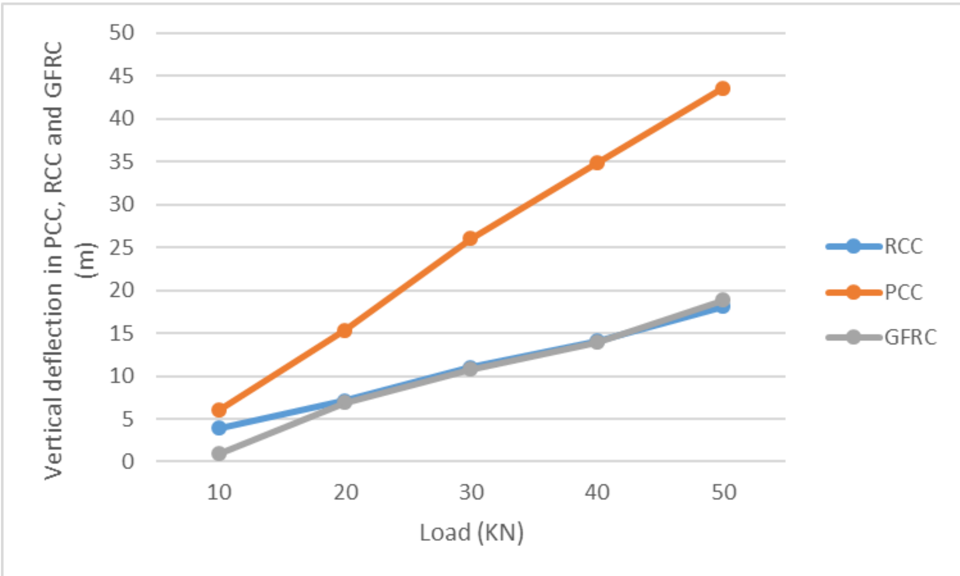


FIG. 4.7: Deflection in Y axis of PCC, RCC, GFRC at different load

Fig. 4.9. shows the deflection in Y-axis. Black line indicated deflection in RCC and GFRC and red line indicated deflection in PCC in mm. the deflection so produced at lower value of load is comparatively much different than that at higher load in case of RCC and GFRC.

RESULTANT STRESSES

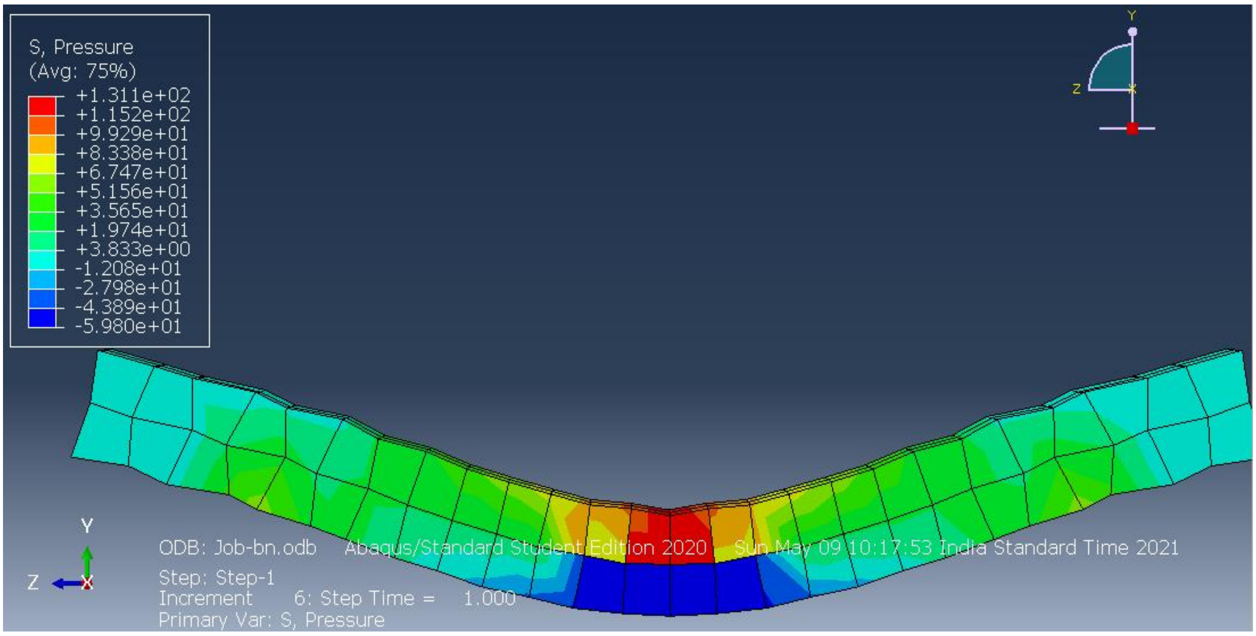


FIG. 4.8: RESULTANT STRESSES IN PCC

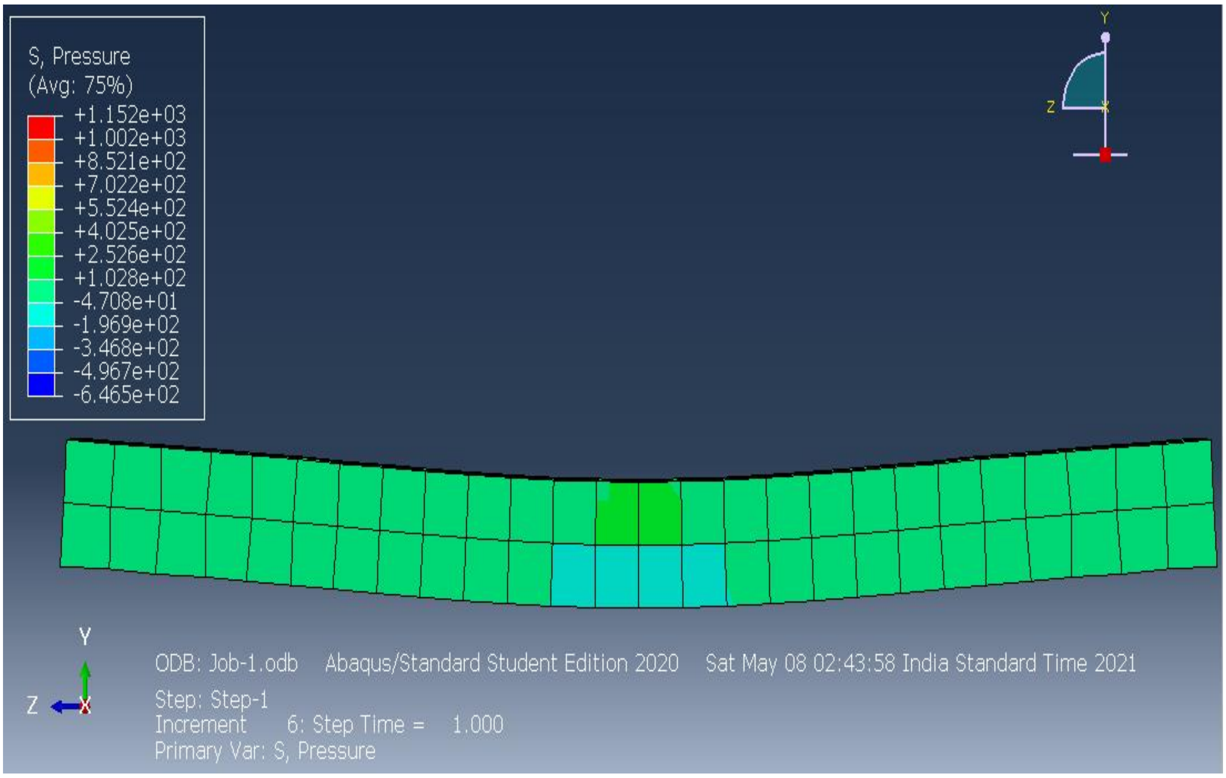


FIG. 4.9: Resultant Stresses in RCC

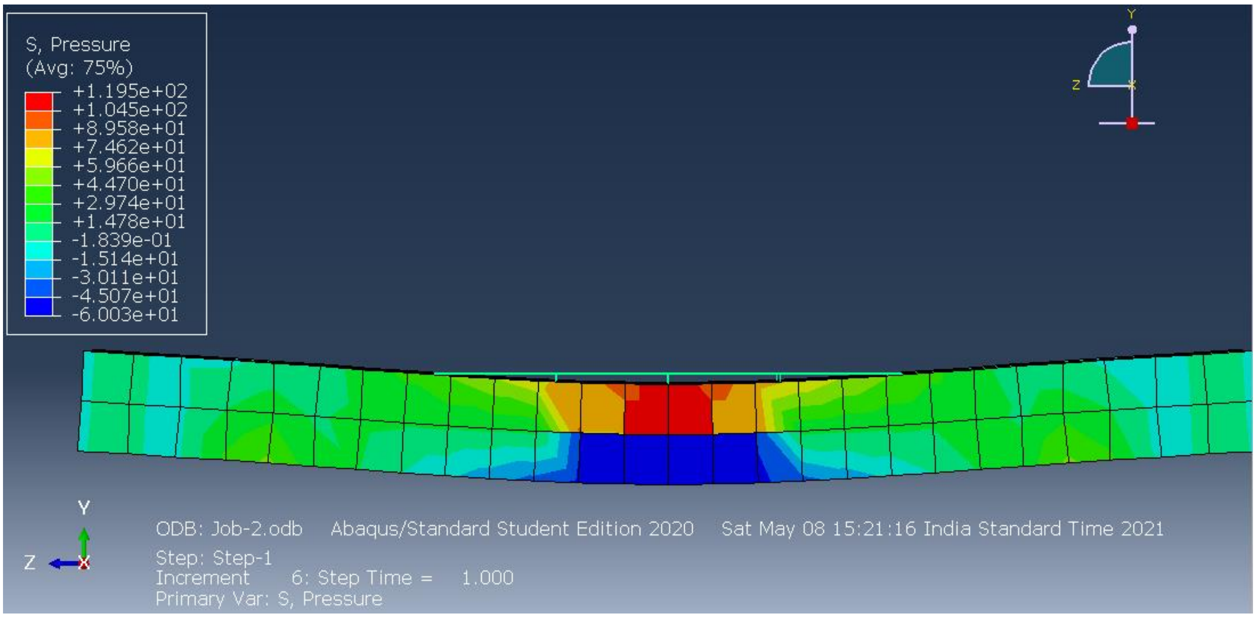


FIG. 4.10: Resultant Stresses in GFRC

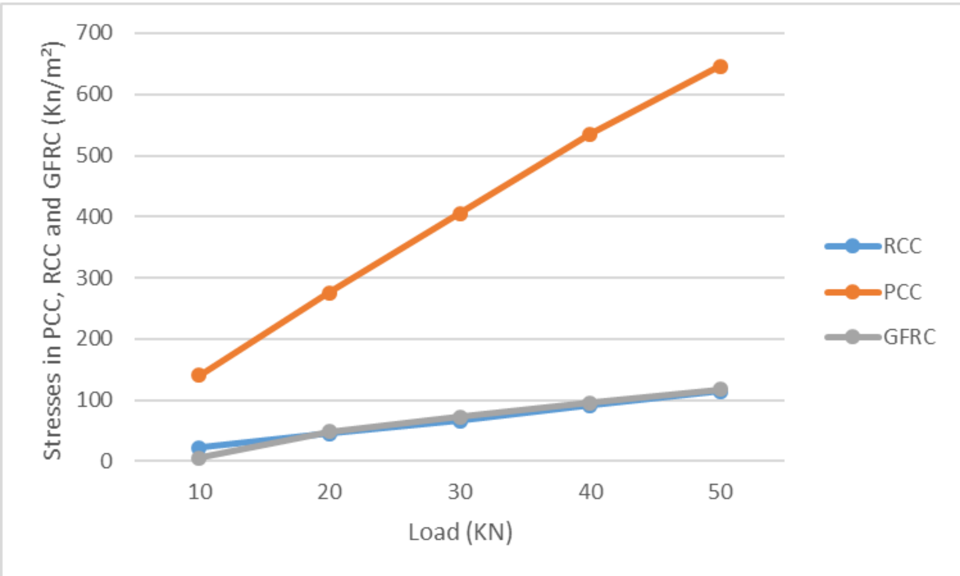


FIG.4.11. Stress vs Load

CHAPTER 5

Conclusions

This Chapter presents the summary of conclusions and inferences drawn in the present study

- In this study of ARGF concrete I found that the workability is inversely proportional to alkali resistance glass fiber content because when we increased ARGF content in concrete I found certain decrease in workability.
- A concrete mix with AR glass fiber embedded in it showed an increase of 13% in compressive strength in it with water cement ratio of 0.45 at 1% fiber content which was the highest deflection in it too. An average increase of 8 % "compressive strength" was observed in all the concrete mixes.
- Whereas in Flexural strength of ARGF Concrete with 0.50 water cement ratio showed a increase at 28 days with 1% ARvglass fiber embedded in it.
- A significant increase in "Flexural Strength" against the "Compressive Strength" was observed, whose credit can be given to the pull out strength of the Glass Fiber. Some amount of pull out force was required to break the bond strength of glass fibre itself and hence overall a larger flexural strength was observed.Once a sufficient pull was generated by the testing machine crack started occuring from the weakest point of the bond.
- At lower value of load applied the deflection in PCC as compared to that of RCC and GFRC is too high. Comparetable value of GFRC to RCC is also very less. At 10kN load, deflection at RCC is 5x and at PCC is 11x as comapered to GFRC but with increase in load the deflection difference start decresing and at load of 50kN the deflection is same for RCC and gfrc and that of PCC is double (2x) to them.Same is with the stresses at lower loading value the stresses introduced in beam is much lower. The difference between GFRC and RCC is 5 times and that of PCC is 25 times (25x), but with increase with the loading value, the difference decreses to equal in compsrision with RCC and 5times less as compared to PCC

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