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Determination of Elastic Behavior of RCC Section by Experimentation and Validation with FEA

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ABSTRACT
Experimental and Analytical study is conducted to check the elastic behavior of RCC and Fiber reinforced RCC section. Standard size and shapes of specimen s are casted with combination of RCC with and without steel fibers. Percentage of FRC is varied from 0.5% to 1.5% in RCC specimen. Elastic behavior of the specimen tested and studied for different loading conditions (Axial and Flexural). Observed results are plotted in different formats and validated using FEA.
***Keywords**:* Elastic behavior, FRC, RCC and FEA.

I. INTRODUCTION

In order to design an RC structural element, it is important to gain a general overview of reinforced concrete structures and an understanding of the basic material properties. It is also important to get acquainted with the basic concepts relating to performance criteria in reinforced concrete design. The aim of structural design is to design a structure so that it fulfils three criteria namely safety in terms of strength, stability and structural integrity; adequate serviceability in terms of stiffness, durability, deformation and economy. The behavior of section at various stages of loading can be studied in two parts i.e. initial un-cracked phase and the ultimate condition at collapse. For a simply supported beam subjected to gradually increasing load, the applied moment at any section is less than cracking moment M_{cr} and the maximum tensile stress in the concrete is less than its flexural tensile strength. This phase is called the un-cracked phase. In this case, the entire section is effective in resisting the moment. The un-cracked phase reaches its limit when the applied moment M becomes equal to the cracking moment M_{cr}. In the stress-strain curve, untracked phase falls within the initial linear portion. As the applied moment exceeds M_{cr}, the maximum tensile stress in concrete exceeds the flexural tensile strength of Concrete and the propagation of crack enhances. The cracks get developed in the bottom fibers of the beam. As the load increases, the cracks get widened and propagate towards the neutral axis. The cracked portion of the concrete becomes ineffective in resisting tensile stress. Hence, the effective concrete section is reduced. For further increment in the applied moment, strain in tension steel increases which results in an upward shift of the neutral axis and ultimately there is an increase in curvature and collapse occurs.

II. EXPERIMENTATION

In experimentation, 18 no of specimens are prepared and these are tested under different loading conditions. Specimens of RCC structure, FRC are subjected to axial type of loading and flexural type of loading. Combined loading i.e. axial and flexural is applied. Specimen is loaded in universal testing machine. It is fixed at both the ends. While loading the specimen axial alignment of machine axis and specimen axis is done carefully so as to avoid eccentric loading. Fig.4 shows experimental set up The load is gradually applied at 2mm/min ram velocity so as to get effect of static loading. Cross sections of specimens are as shown below.

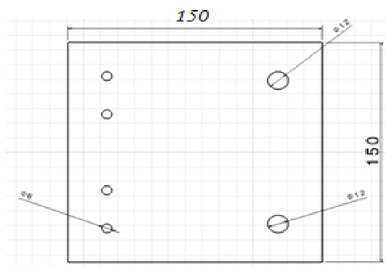


Fig.1 4 bars of ϕ 6mm and 2 bars of ϕ 12mm

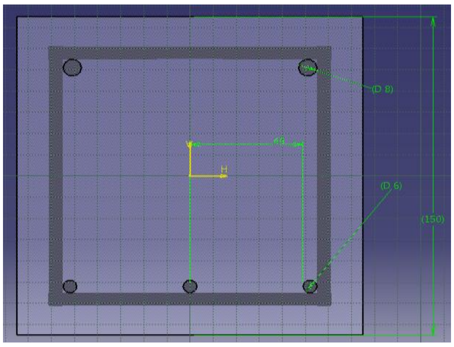


Fig.2 3 bars of ϕ 6mm and 2 bars of ϕ 8mm

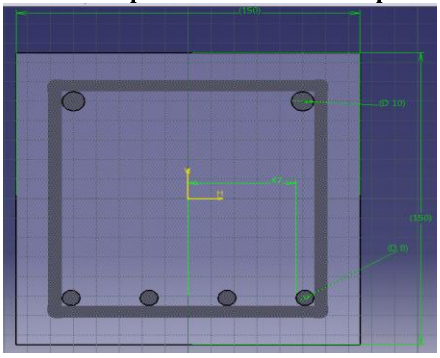


Fig.3 4 bars of ϕ 8 mm and 2 bars of ϕ 10mm

Fig.4 Casted Specimen

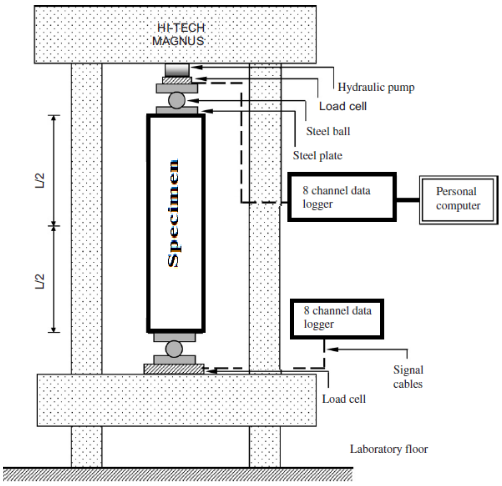


Fig.5 Experimental set up

Fig.6 Flexural loading Test

Table No.1 Details of specimen testing and Configurations

Test No.	Configuration	Loading condition	Percentage of fiber	Modulus of elasticity in (N/mm2)
RC1	2 bars of ϕ 8mm & 3 bars of ϕ 6 mm	Axial	Nil	26800
RC2	2 bars of ϕ 10 mm & 4 bars of ϕ 8 mm	Axial	Nil	27200
RC3	2 bars of ϕ 12mm & 4 bars of ϕ 6 mm	Axial	Nil	27800
RC4	2 bars of ϕ 8mm & 3 bars of ϕ 6 mm	Flexural	Nil	26900
RC5	2 bars of ϕ 10 mm & 4 bars of ϕ 8 mm	Flexural	Nil	27600
RC6	2 bars of ϕ 12mm & 4 bars of ϕ 6 mm	Flexural	Nil	28200
RCFb1	2 bars of ϕ 8 mm & 2 bars of ϕ 6 mm	Axial	0.5 %	27000
RCFb2	2 bars of ϕ 10 mm & 2 bars of ϕ 8 mm	Axial	1 %	27400
RCFb3	2 bars of ϕ 12 mm & 2 bars of ϕ 6 mm	Axial	1.5 %	28000
RCFb4	2 bars of ϕ 8 mm & 2 bars of ϕ 6 mm	Flexural	0.5 %	27100
RCFb5	2 bars of ϕ 10 mm & 2 bars of ϕ 8 mm	Flexural	1 %	28500
RCFb6	2 bars of ϕ 12 mm & 2 bars of ϕ 6 mm	Flexural	1.5 %	28900

Notification	Description	Loading
RC1	Reinforced concrete for specimen 1	Axial
RC2	Reinforced concrete for specimen 2	Axial
RC3	Reinforced concrete for specimen 3	Axial
RC4	Reinforced concrete for specimen 4	Flexural
RC5	Reinforced concrete for specimen 5	Flexural
RC6	Reinforced concrete for specimen 6	Flexural
RCFb1	RCC with FRC for specimen 1	Axial
RCFb2	RCC with FRC for specimen 2	Axial
RCFb3	RCC with FRC for specimen 3	Axial
RCFb4	RCC with FRC for specimen 4	Flexural
RcFb5	RCC with FRC for specimen 5	Flexural
RCFb6	RCC with FRC for specimen 6	Flexural

III. FINITE ELEMENT ANALYSIS

It consists of Finite element analysis of reinforced concrete and fibers. Elastic properties of RCCs are determined by using finite element analysis package ANSYS 14. Compressive strength as well as flexural strength is determined by using ANSYS software.

Table 2 Material Properties used in analysis

Sr. No.	Materials	Steel	Concrete
1	Modules of Elasticity in N/mm^2	200000	22361
2	Poisson's ratio	0.3	0.28
3	Density Kg/mm^3	7850 E-9	2400 E-9
4	Coefficient of Thermal Expansion (aplx) mm/mm ^{0}C	12 E-6	8 E -6

Models are freely meshed. Meshed model of each **Specimen is as shown in following figures.**

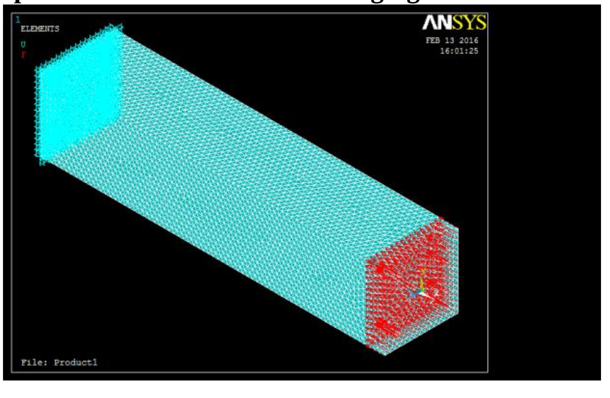


Fig.7 Boundary conditions model 1

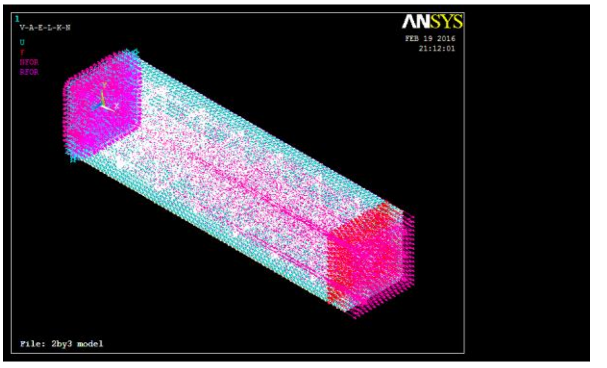


Fig.8 Boundary conditions model 2

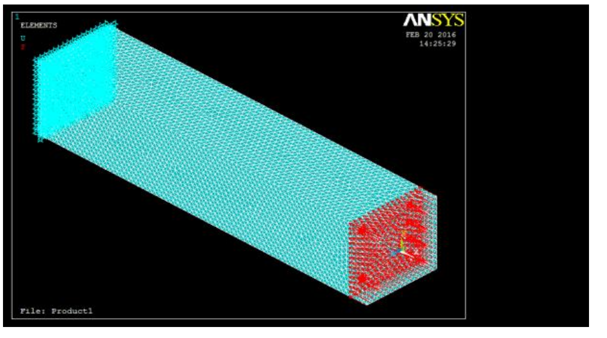


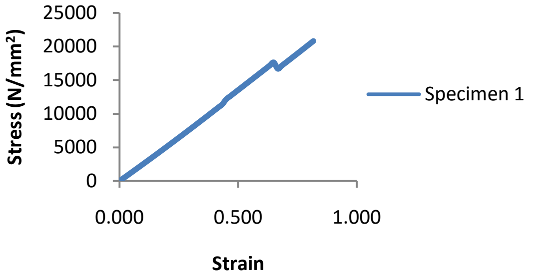
Fig.9 Boundary conditions model 3

All models are freely meshed. Element edge length was 10mm. Denser mesh is applied for meshing bars. Number of elements and nodes generated in each meshing are given in table 3

Table 3 Details of meshing of each model

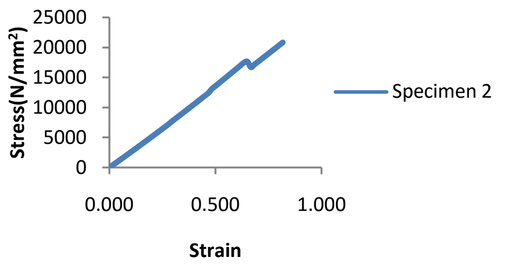
Model No.	Nodes	Elements
1	33558	150476
2	33560	150478
3	33555	150474
4	33559	150479

IV. RESULT AND DISCISSION



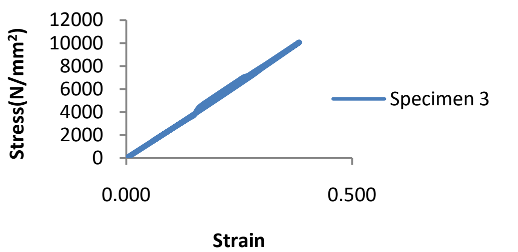
Graph 1 Stress Vs Strain curve for specimen 1 (RC)

Graph 1 shows Stress Vs strain curves it is obtained for specimen 1. It consists of 2 bars of ϕ 8mm & 3 bars of ϕ 6 mm. Maximum stress value is 22302 N/mm^2 and elastic modulus is 26800 N/mm^2.



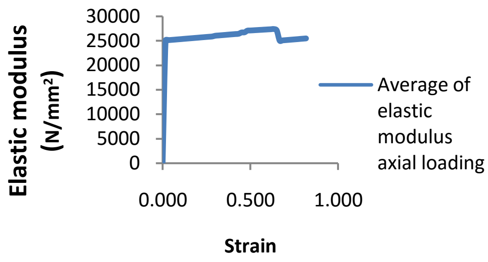
Graph 2 Stress Vs strain curve for specimen 2 (RC)

Graph 2 shows Stress Vs Strain curves it is obtained for specimen 1. It consists of 2 bars of ϕ 10 mm & 4 bars of ϕ 8 mm. Maximum stress value is 21203 N/mm^2 and elastic modulus is 27200 N/mm^2.



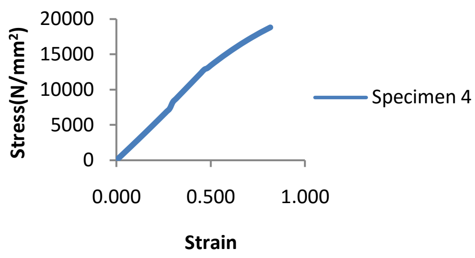
Graph 3 Stress Vs Strain curve for specimen 3 (RC)

Graph 3 shows Stress Vs Strain curves it is obtained for specimen 1. It consists of 2 bars of ϕ 12mm & 4 bars of ϕ 6 mm. Maximum stress value is 11503 N/mm^2 and elastic modulus is 27800 N/mm^2.



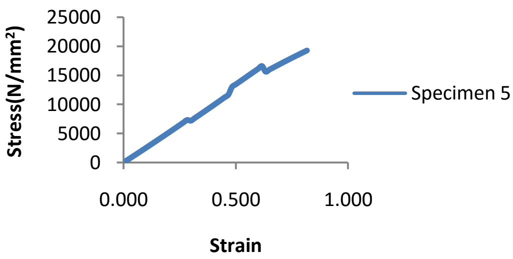
Graph 4 Average Elastic modulus Vs strain curve for axial load (RC)

Graph 4 shows Elastic modulus Vs Strain curves. It is obtained by average of specimen 1 to specimen 3. Average elastic modulus is 27036 N/mm2.elastic modulus varies in between range 25000 N/mm^2 - 27500 N/mm^2.



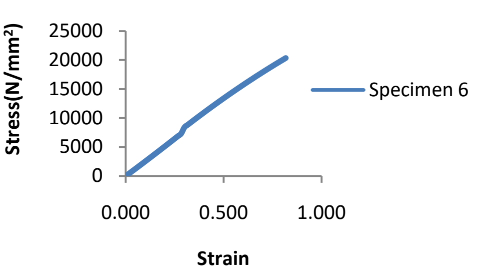
Graph 5 Stress Vs Strain curve for specimen 4 (RC)

Graph 5 shows Stress Vs Strain curves it is obtained for specimen 4. It consists of 2 bars of ϕ 8mm & 3 bars of ϕ 6 mm. Maximum stress value is 19302 N/mm2and elastic modulus is 26900 N/mm^2.



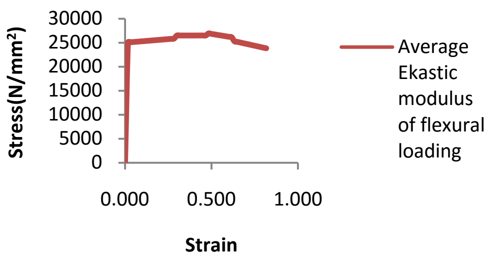
Graph 6 Stress Vs Strain curve for specimen 5 (RC)

Graph 6 Stress Vs Strain curves it is obtained for specimen 5. It consists of 2 bars of ϕ 10 mm & 4 bars of ϕ 8 mm. Maximum stress value is 19903 N/mm^2 and elastic modulus is 26800 N/mm^2.



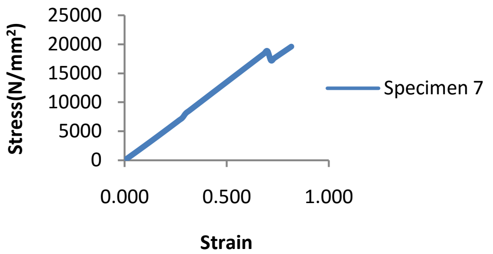
Graph 7 Stress Vs strain curve for specimen 6 (RC)

Graph 7 Stress Vs Strain curves it is obtained for specimen 6. It consists of 2 bars of ϕ 12mm & 4 bars of ϕ 6 mm. Maximum stress value is 21103 N/mm^2 and elastic modulus is 26200 N/mm^2.



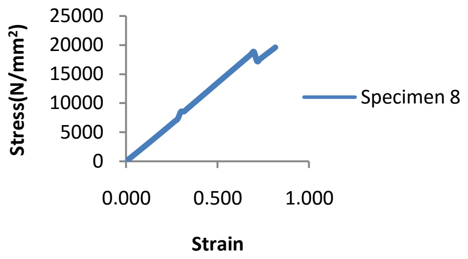
Graph 8 Average Elastic Modulus Vs Strain curve for flexural loading (RC)

Graph 8 shows Elastic modulus Vs Strain curves. It is obtained by average of specimen 4 to specimen 6. Average elastic modulus is 27107 N/mm2.elastic modulus varies in between range 24000 N/mm^2 - 27800 N/mm^2.



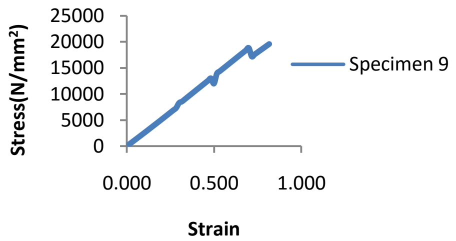
Graph 9 Stress Vs strain curve for specimen 7 (RC+FRC)

Graph 9 Stress Vs Strain curves it is obtained for specimen 7. It consists of 2 bars of ϕ 12mm & 4 bars of ϕ 6 mm. Maximum stress value is 19233 N/mm^2 and elastic modulus is 27003 N/mm^2.



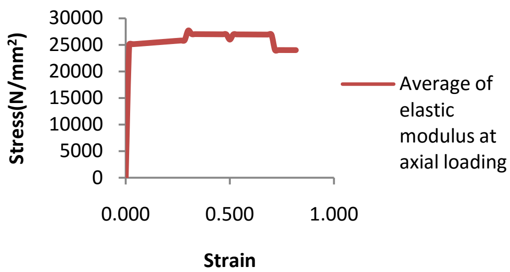
Graph 10 Stress Vs Strain curve for specimen 8 (RC+FRC)

Graph 10 Stress Vs Strain curves it is obtained for specimen 8. It consists of 2 bars of ϕ 10 mm & 2 bars of ϕ 8 mm. Maximum stress value is 19033 N/mm^2 and elastic modulus is 27401 N/mm^2.



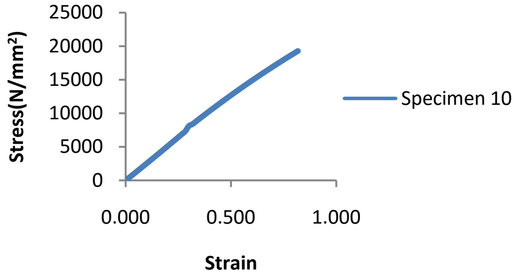
Graph 11 Stress Vs Strain curve for specimen 9 (RC+FRC)

Graph 11 Stress Vs Strain curves it is obtained for specimen 9. It consists of 2 bars of ϕ 12 mm & 2 bars of ϕ 6 mm. Maximum stress value is 19213 N/mm^2 and elastic modulus is 27597 N/mm^2



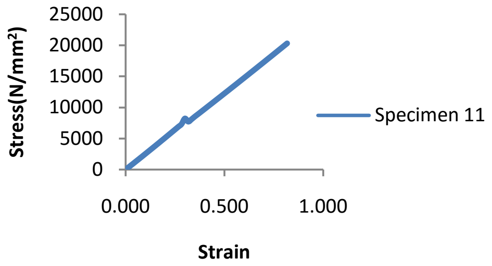
Graph 12 Average Stress Vs strain curve for axial loading (RC+FRC)

Graph 12 shows Elastic modulus Vs Strain curves. It is obtained by average of specimen 7 to specimen 9. Average elastic modulus is 28207 N/mm2.elastic modulus varies in between range 24000 N/mm^2 - 28800 N/mm^2.



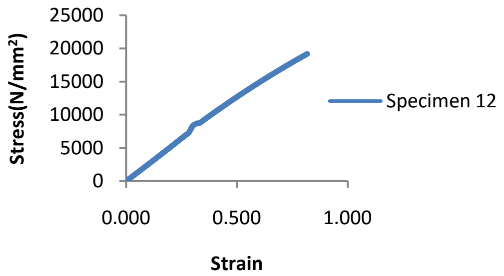
Graph 13 Stress Vs strain curve for specimen 10 (RC+FRC)

Graph 13 Stress Vs Strain curves it is obtained for specimen 10. It consists of 2 bars of ϕ 12 mm & 2 bars of ϕ 6 mm. Maximum stress value is 19413 N/mm^{2}and elastic modulus is 27005 N/mm^2.



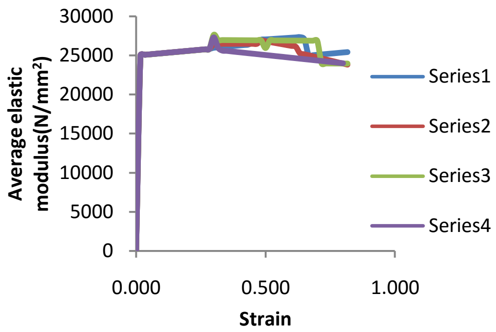
Graph 14 Stress Vs strain curve for specimen 11(RC+FRC)

Graph 14 Stress Vs Strain curves it is obtained for specimen 11. It consists of 2 bars of ϕ 10 mm & 2 bars of ϕ 8 mm. Maximum stress value is 22113 N/mm^2 and elastic modulus is 27399 N/mm^2.



Graph 15 Stress Vs strain curve for specimen 12 (RC+FRC)

Graph 15 Stress Vs Strain curves it is obtained for specimen 12. It consists of 2 bars of ϕ 12 mm & 2 bars of ϕ 6 mm. Maximum stress value is 18013 N/mm^2 and elastic modulus is 27503 N/mm^2 .



Graph 16 Comparative elastic modulus of different configuration of specimen

Graph 16 shows Comparative elastic modulus of different configuration of specimen series 1 shows curve of average elastic modulus from specimen 1 to specimen 3. It is obtained axially loaded specimen. Series 2 shows curve of average elastic modulus from specimen 4 to specimen 6. It is obtained flexural loaded specimen. Series 3 shows curve of average elastic modulus from specimen 7 to specimen 9. It is obtained axially loaded specimen. Series 4 shows curve of average elastic modulus from specimen 10 to specimen 12.

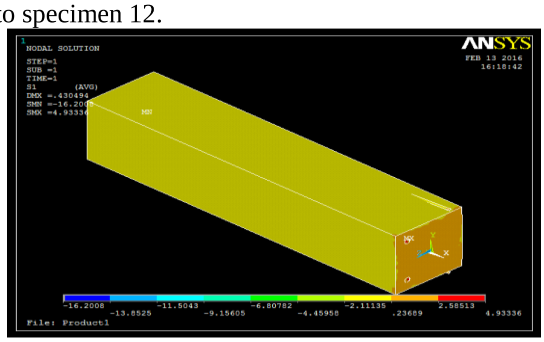


Fig.10 Contour plot of Stress for specimen 1

Figure 10 shows stress distribution for specimen 1. Maximum stress values 4.9 N/mm2 .It is indicated by red color.

Table 4 Result comparison

Specimen	Stress(KN/mm2)		Percentage Deviation
	Experimental	FEM	
RC1	22302	22197	0.47081
RC2	21103	21007	0.454912
RC3	11503	11273	1.999478
RC4	19302	19103	1.030981
RC5	19903	19307	2.994523
RC6	21103	21009	0.445434
RCFb1	19233	19175	0.301565
RCFB2	19033	19001	0.168129
RCFb3	19213	19117	0.499662
RCFb4	19413	19239	0.896307
RCFb5	22113	22101	0.054267
RCFb6	18013	17202	**4.502304**

V. CONCLUSION

i. It is observed that elastic modulus RCC increases by 14.81% for specimen 2 and 3.50% for specimen 3 as compared to specimen 1 during axial loading condition.

ii. It is observed that elastic modulus RCC increases by 1.075% for specimen 5 and 2.2% for specimen 6 as compared to specimen 5 during flexural loading condition.

iii. It is observed that elastic modulus increases 2.84% when specimen is combination RCC and FRC. It is also observed that elastic modulus decreases by 10.33% when specimen is made up of FRC only. There is 0.26% deviation in elastic modulus when specimens of same configuration with RCC and FRC are tested at axial and flexural loading condition.

iv. Finite element analysis of specimens has been carried out to validate the results of experimentation. There is maximum 4.5 % deviation in results of experimentation and FEM.

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