

Comparison of Elastic constants and Compressive strength of M40 Grade Concrete Cylinders Wrapped with and without GFRP Sheet

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Abstract: Cylindrical members are used in Civil application. Hence in the design, the performance of those members is needed. The present investigation presents comparison of M40 grade concrete cylinders wrapped with and without Glass Fiber Reinforced Plastic (GFRP) sheet. For this purpose, standard cylindrical specimens 150 mm x 300 mm were prepared and tested with and without wrapping of GFRP sheet to find compressive strength and elastic constants. The concrete cylinders with and without wrapping of GFRP sheet are tested under compression till failure. The load, lateral and longitudinal strains are measured. The secant modulus is increased by 40.25%, Poisson's ratio is decreased by 5.88% and large decrease in lateral & longitudinal strains observed for concrete cylinder wrapped with GFRP sheet compared to without GFRP sheet. The compressive strength is nearly same.

Index Terms: Compressive Strength, Elastic Constants, GFRP M40 Grade.

I. INTRODUCTION

In many civil applications, there is a need for increase of properties of material. Hence in the present investigation enhancement in the properties of M40 grade concrete cylinder with wrapping of Glass Fiber Reinforced Plastic (GFRC) sheet is studied [1]-[3]. The properties investigated are four elastic constants and compressive strength.

A. Elastic constants: The four elastic constants are defined as given below.

$$\text{Young's Modulus, } E = \frac{\text{Normal Stress}}{\text{Normal Strain}} = \frac{\sigma_n}{\epsilon_n}$$

$$\text{Rigidity Modulus, } G = \frac{\text{Shear Stress}}{\text{Shear Strain}} = \frac{\tau}{\gamma}$$

$$\text{Bulk Modulus, } K = \frac{\text{Hydrostatic stress}}{\text{Volumetric strain}} = \frac{\sigma_h}{\epsilon_v}$$

$$\text{Poisson's Ratio, } \mu = \frac{\text{Lateral or Transverse strain}}{\text{Axial or Longitudinal strain}}$$

Relationship between the elastic constants E, G, K, μ

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$$E = 2G(1 + \mu) = 3K(1 - 2\mu) = \frac{9KG}{3K + G}$$

II. EXPERIMENTAL INVESTIGATION

A. Objective

The objective of present investigation is to compare compressive strength and elastic constants for M40 grade concrete cylinders wrapped with and without GFRP sheet. Cylinders of standard size 150 mm (diameter) x 300 mm (height) were tested for 28 days.

B. Materials

The mix design of concrete requires the properties its ingredients. The properties of ingredients of concrete are determined and are presented below.

Cement: Locally available Panyem 53-Grade OPC is being used throughout the experiment. Table 1 shows the properties of cement used in concrete

Table.1 Physical properties of cement

S.NO	Property	Results
1	Normal consistency	31%
2	Specific gravity	3.06
3	Initial setting time Final setting time	90 Minutes 540 Minutes
4	Soundness (Expansion) Lechatlier method	1mm
5	Fineness of cement (Dry sieving method)	6%

Fine Aggregate (Sand):

Locally available sand is used for preparing the specimens. The properties of sand used are

Specific gravity = 2.67
Fineness modulus = 2.972
Zone = II

Coarse Aggregate (CA):

The CA is 20mm size, crushed and angular in shape. The aggregates are free from dust before used in the concrete. The Specific gravity of CA = 2.72



GFRP Sheet:

The sheet is bought from Hyderabad (OM SAI MARKET) which is of type E and having thickness 2.54 mm consisting of number of layers. One layer having thickness 0.25 mm is removed from the sheet. The cylinder is wrapped with GFRP sheet using adhesive (resin).

III. MIX DESIGN

Mix is designed as per IS: 10262-2009 for M40 grade of concrete. Table 2 shows mix proportion of concrete.

Table.2 Mix Proportions of Concrete

Water Cement Ratio	Cement, Kg/m ³	Fine Aggregate, Kg/m ³	Coarse Aggregate, Kg/m ³	Water, Kg/m ³
0.45	437.77	634.4	1148.93	197
	1	1.45	2.62	

IV. TEST RESULTS

The fresh concrete is prepared as per above mix proportion and properties are determined and are given below.

Slump Value = 82.5mm
Compaction Factor = 0.94

The six concrete cylinders (specimens) are casted using above mix proportion, and water cured for 28 days. In these, three specimens are wrapped with composite material. The cylinders are tested in compression testing machine measure load, axial displacement and lateral displacement. The loading rate applied is 0.5 kN/s. The lateral, longitudinal strains and Poisson's ratio of specimens with and without wrapping of GFRP sheet are shown in Table 3 & 4 respectively. Fig. 2 shows the variation of stress vs lateral & longitudinal strains for specimens with and without wrapping of GFRP sheet. The lateral and longitudinal strains are much less for specimens wrapped with GFRP sheet compared to without wrapping.

The compressive load, compressive strength, secant modulus and Poisson's ratio at secant modulus of the specimens are shown in Table 5. The secant modulus is calculated at 54.87% & 77.47% of ultimate load for cylinders without and with wrapping of GFRP sheet respectively. The rigidity modulus and bulk modulus are calculated using secant modulus and Poisson's ratio. The secant modulus is increased by 40.25% and Poisson's ratio is decreased by 5.88% for cylinder wrapped with GFRP sheet compared to without GFRP sheet. The compressive strength is nearly same and is less than target mean strength of M40 grade concrete for both cylinders.



Fig.1. Testing of wrapped cylinder

Table.3 Lateral, Longitudinal Strains and Poisson's ratio of Cylinders without Wrapping of GFRP sheet

Load (KN)	Specimen 1			Specimen 2			Specimen 3		
	Lateral Strain $\frac{\delta d}{d} \times 10^{-4}$	Longitudinal Strain $\frac{\delta l}{l} \times 10^{-4}$	Poisson's Ratio μ	Lateral Strain $\frac{\delta d}{d} \times 10^{-4}$	Longitudinal Strain $\frac{\delta l}{l} \times 10^{-4}$	Poisson's Ratio μ	Lateral Strain $\frac{\delta d}{d} \times 10^{-4}$	Longitudinal Strain $\frac{\delta l}{l} \times 10^{-4}$	Poisson's Ratio μ
0	0	0	0	0	0	0	0	0	0
50	0	4.67	0	0	5.30	0	0	4.67	0
100	-0.13	13.30	0.10	-0.13	13.0	0.10	-0.13	13.30	0.10
150	-0.40	20.30	0.19	-0.53	20.67	0.26	-0.40	20.30	0.20
200	-0.80	25.67	0.30	-0.93	26.33	0.35	-0.80	25.67	0.42
250	-1.33	32.67	0.40	-1.33	32.00	0.40	-1.33	32.67	0.46
300	-1.87	40.00	0.46	-2.00	39.67	0.500	-1.87	40.00	0.58
350	-3.07	46.70	0.640	-3.33	45.00	0.74	-3.07	46.70	0.80
400	-8.93	54.30	0.164	-8.67	55.00	0.156	-8.93	54.30	0.143
450	-18.67	67.00	0.280	-18.4	67.30	0.272	-18.67	67.00	0.277
500	-72.00	106.70	0.670	-71.33	108.30	0.655	-72.00	106.70	0.683

Table.4 Lateral, Longitudinal Strains and Poisson's ratio of Cylinders with Wrapping of GFRP sheet

L	Specimen 1	Specimen 2	Specimen 3
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a d (K N)	La te ra l St ra in $\frac{\delta d}{d} \times 10^{-4}$ mm/ mm	Lon gi tu di na l St ra in $\frac{\delta l}{l} \times 10^{-4}$ mm/ mm	Poi sso n's Ra tio μ	La te ra l St ra in $\frac{\delta d}{d} \times 10^{-4}$ mm/ mm	Lon gi tu di na l St ra in $\frac{\delta l}{l} \times 10^{-4}$ mm/ mm	Poi sso n's Ra tio μ	La te ra l St ra in $\frac{\delta d}{d} \times 10^{-4}$ mm/ mm	Lon gi tu di na l St ra in $\frac{\delta l}{l} \times 10^{-4}$ mm/ mm	Poi sso n's Ra tio μ
0	0	0	0	0	0	0	0	0	0
5	0	3.0	0	0	3.3	0	0	2.7	0
1	0	8.3	0	0	9.3	0	0	6.7	0
1	0	11.7	0	0	11.7	0	0	11.0	0
2	0	14.7	0	0	14.0	0	0	14.0	0
2	0	20.0	0	0	18.3	0	0	19.3	0
3	0	25.0	0	0	24.0	0	0	24.0	0
3	0	26.7	0	0	28.3	0	0	27.7	0
4	-0.13	30.3	0.004	-2.67	30.7	0.009	-2.00	30.0	0.007
4	-0.33	36.7	0.009	-6.00	39.3	0.015	-5.30	37.3	0.014
5	-3.67	42.7	0.086	-4.53	41.3	0.110	-4.13	41.0	0.100
5	-7.00	46.5	0.152	-6.50	46.0	0.141	-6.33	44.7	0.141
6	-11.30	50.0	0.226	-13.30	48.3	0.275	-12.67	49.3	0.257

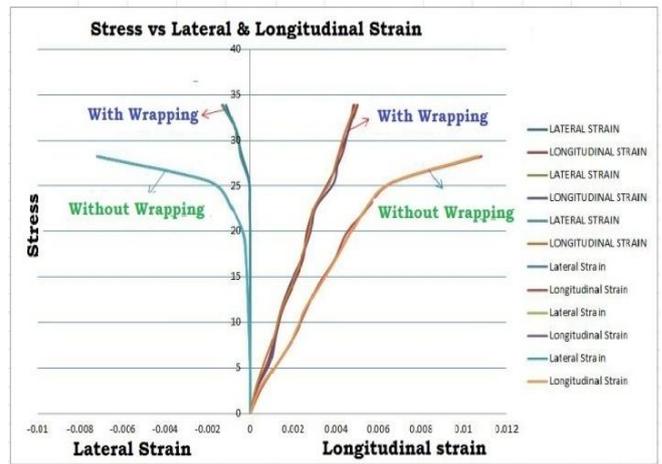


Fig.2. Stress vs Lateral & Longitudinal Strain Graph of Cylinders With and Without Wrapping of GFRP sheet

Table.5 Properties of Concrete Cylinder Wrapped with and without GFRP sheet

Type	Specimen No	1	2	3	Average
Without Wrapping	Compressive Load, kN	729.6	725.4	731.2	728.73
	Compressive Strength, f_{ck}	41.22	40.98	41.31	41.17
	Secant Modulus	4168	4114	4065	4116
	Poisson's Ratio	0.160	0.156	0.143	0.153
With Wrapping	Compressive Load, kN	710.0	715.0	711.5	712.2
	Compressive Strength, f_{ck}	40.11	40.39	40.20	40.23
	Secant Modulus	6956	6755	6956	6889
	Poisson's Ratio	0.152	0.141	0.141	0.144

Table.6 Compressive Strength & Elastic Properties of Concrete Cylinder With and Without Wrapping of GFRP sheet

Property	Without Wrapping	With Wrapping
Compressive Strength, N/mm^2	41.17	40.23
Secant Modulus, N/mm^2	4116.13	6889
Young's Modulus, (IS Code), N/mm^2	31622.77	31622.77
Rigidity Modulus, N/mm^2	1784.77	2979.7
Bulk Modulus, N/mm^2	1978.91	3202.23
Poisson's Ratio	0.153	0.144

The rigidity modulus and bulk modulus are calculated using secant modulus and Poisson's ratio and is shown in Table 6. The Young's modulus of M40 grade concrete is calculated using IS code formula give below.

$$E_c = 5000\sqrt{f_{ck}}$$

Large deviation observed between Young's modulus obtained from IS code and Secant modulus measured from experiment for both cylinders.

V. CONCLUSION

- The lateral and longitudinal strains are much less for concrete cylinder wrapped with GFRP sheet compared to without wrapping.
- The secant modulus is increased by 40.25% and Poisson's ratio is decreased by 5.88% for concrete cylinder wrapped with GFRP sheet compared to without GFRP sheet
- The compressive strength is nearly same and is less than target mean strength of M40 grade concrete for both concrete cylinders.
- Large deviation observed between Young's modulus obtained from IS code and Secant modulus measured from experiment for both cylinders.

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