Flexural Strengthening of Light Weight Reinforced Concrete Beams by Using Glass Fiber Reinforced Polymer

AKSHAY MAHADEV SHINDE[1], MUSKAN SHAKIL DESAI[2], ABHIJIT SARJERAO DAKAVE[3], PROF. A. C. THOKE[4]

[1, 2, 3] *Final Year B.Tech Student, Department of Civil Engineering, SETI, Panhala, Kolhapur, India*

[4] *Assistant Professor, Department of Civil Engineering, SETI, Panhala, Kolhapur, India*

Abstract- The use of Lightweight concretes has gained acceptance and popularity worldwide in the recent years in the construction and development of both the infrastructure and residential buildings. Light weight aggregate concrete has become more popular in recent advancements owing to the tremendous advantages it offers over the conventional concrete but at the same time light in weight and strong enough to be used for structural purposes. Replacement of natural aggregate with concrete such as light weight concrete by using sintered fly ash aggregate (natural aggregate), The main disadvantage of conventional concrete it is high self -weight. This heavy self-weight will make it to some extent an uneconomical structural material. Light weight concrete having low density facilitates reduction of dead load and to increase thermal insulation.

I. INTRODUCTION

- DATA ANALYSIS (MATERIAL USED)

A. Cement

Ordinary Portland Cement Birla Shakti (M43 Grade) confirming to IS 269-1976 was used throughout the investigation. Different test was performed on the cement to ensure that it confirms to the requirement of the IS specification. The physical properties of the cement were determined as per IS 4031-1968 and are presented in the following table 1.

TABLE 1
Physical analysis of Birla Shakti (M43 Grade) Cement

Sr. No	Properties	Value	Requirements of IS:8112 1989
1	Specific Gravity	3.15	-
2	Standard Consistency	31%	-
3	Initial Setting Time	104 min	Min 30 min
4	Final Setting Time	205 min	Max 600 min
5	Soundness	3.5	Less than 10%
6	Fineness	5.5	Less than 10%
7	Compressive strength (N/mm^2)		
	3 Days	28.35	Not less than 22 N/mm^2
	7 Days	35.48	Not less than 33 N/mm^2
	28 Days	52.68	Not less than 43 N/mm^2

B. Sand

TABLE 2
Properties of Fine Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	2.72
2	Fineness modulus	3.342
3	Silt content	4%
4	Water absorption (after 24hr)	2.6%

C. Sintered Fly Ash Aggregate

TABLE 3
Properties of sintered fly ash Aggregate

Sr. No.	Properties	Value
1	Specific Gravity	1.50
2	Fineness modulus	6.24
3	Water Absorption (after 24hr)	14.20%

D. Admixtures

Admixture Used for Project: - Algisuperplast N

E. Water:

Water is an important ingredient to make concrete. The purpose of adding water to concrete is, to distribute the cement evenly, react with cement chemically to produce calcium silicate hydrate gel and provide workable one. Small amount of water is needed to hydrate cement. Additional water is required to lubricate the mix. Excess water leads to bleeding stage ultimately creation of pores. Quantity of water is controlled by the w/c ratio. The water used must be free from oil, acid and alkali, salts and organic material. It should be potable.

II. M20 GRADE CONCRETE MIX DESIGN

M20 Grade Concrete mix design was done by using trial and error method with 100% Replacement of Natural Aggregate by Sintered Fly Ash Aggregate)

TABLE 4
FINAL MIX PROPORTION USING 100% REPLACEMENT OF NATURAL AGGREGATE BY SINTERED FLY ASH AGGREGATE

Cement	Sand	Sintered Fly Ash Aggregate	Water	Chemical
365	868.727	584.865	175.20	1% of Cement by Weight
1	2.377	1.602	0.48	

TABLE 5
QUANTITY OF INGREDIENT NEEDED FOR CASTING

Items	For 1 Cube	For 1 Beam	For 1 Cylinder
Cement (Kg)	1.232	1.825	0.573
Sand (Kg)	2.929	4.339	1.362
Coarse Aggregate (Kg)	0.000	0.000	0.000
Sintered Fly Ash Aggregate (kg)	1.974	2.924	0.918
Water (Kg)	0.591	0.876	0.275
Chemical (gm.)	12.32	18.250	5.730

III. STRENGTHENING OF BEAMS

Before bonding the composite fabric on to the concrete surface, the required region of concrete surface was made rough using a coarse sand paper texture and cleaned with an air blower to remove all dirt and debris. Once the surface was prepared to the required standard, the polyester resin was mixed in accordance with manufacturer’s instructions. Mixing was carried out in a plastic container (Accelerator Cobalt 3% (Intense blue liquid) and Hardener 1.5%) and continued until the mixture in uniform colour. When this was completed and the fabrics had been cut to size, the resin mixture was applied to the concrete surface. The composite fabric was then placed on top of polyester resin coating and the resin was squeezed through the roving of the fabric with the roller. Air bubbles entrapped at the epoxy/concrete or epoxy/fabric interface were to be eliminated. Then the second layer of the resin was applied and GFRP sheet was then placed on top of resin coating and the resin was squeezed through the roving of the fabric with the roller and the above process was repeated. During hardening of the resin, a constant uniform pressure was applied on the composite fabric surface in order to extrude the excess resin and to ensure good contact between the resin, the concrete and the fabric. This operation was carried out at room temperature. Concrete beams strengthened with glass fiber fabric were cured for 24 hours at room temperature before testing.

The experimental work consists of casting of four sets of reinforced concrete (RC) beams having grade M20, cross-sectional dimensions of 100mm x 200mm and 1100mm length. We provided 2-10mm Ø bottom reinforcement and 2-10mm Ø top with 6mm Ø vertical stirrups @ 300 mm c/c. The strengthening of the beams using GFRP sheet is done on bottom side wrap with three different length configurations namely Central 1/3 length of Testing (300 mm Length), Central 2/3 length of Testing (600 mm Length) & Full length of Testing (900 mm Length).

The experimental study consists of casting of four sets of reinforced concrete (RC) beams of grade M20, with 100% Replacement of Natural Aggregate with Sintered Fly Ash Aggregate. Total 12 no. of RC beam are cast and curing for 28 days.

1. First set of (3 no.) Light Weight RC beams designated as control beams (SET I).
2. Second set of (3 no.) Light Weight RC beams (SET II); all are strengthened using single GFRP mat wrap, (for Central 1/3 length of Testing [300 mm]).
3. Third set of (3 no.) Light Weight RC beams (SET III); all are strengthened using single GFRP mat wrap, (for Central 2/3 length of Testing [600 mm]).
4. Fourth set of (3 no.) Light Weight RC beams (SET III); all are strengthened using single GFRP mat wrap, (for Full length of Testing [900 mm]).

IV. TESTING SETUP

All the specimens are tested in Universal testing machine (UTM). The testing procedures for the all specimens are same. After the curing period of 28 days is over, control beams (SET I) are washed and its surface is cleaned for clear visibility of cracks. Where other set of Light Weight RC beams (SET II, SET III, SET IV) are strengthened by GFRP sheets. The load arrangements for testing of all sets of beam is consist of two-point loading as shown in Figure 1A and 1B.,

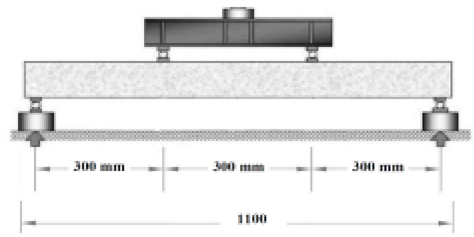


Figure 1 B: Experimental setup for testing of beams

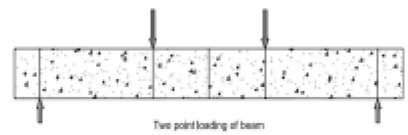


Figure 1 B: Experimental setup for testing of beams

A. Testing procedure

All the specimens were tested in the loading frame .The testing procedure for the entire specimen was same. After the curing period of 28 days was over, the beam as washed and its surface was cleaned for clear visibility of cracks. The most commonly used load arrangement for testing of beams will consist of two-point loading. This has the advantage of a substantial region of nearly uniform moment coupled with very small shears, enabling the bending capacity of the central portion to be assessed.

V. RESULTS ANALYSIS WITH RESPECT TO DEFLECTION

A. Introduction

This chapter describes the experimental results of all SETS beam (SET I, SET II, SET III, SET IV). Their behavior throughout the static test to failure is described using recorded data on deflection behavior, and the ultimate load carrying capacity. The mid-span deflection of each beam was compared with that of their respective control beams(as a practical deflection) and actual theoretical deflection . Also the load-deflection behavior was compared between three wrapping schemes having the same reinforcement (Central 1/3 length of Testing, Central 2/3 length of Testing and Full length of Testing). The mid-span deflections were much lower when bonded externally with GFRP sheets.

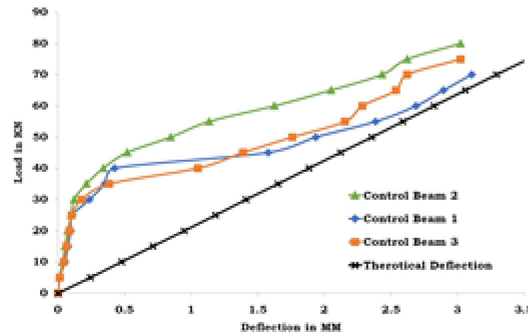
B. Load Deflection History

The two point static loading is applied on the beams and at the each increment of the load (1KN/sec). Deflections at the middle in beams are noted down and load Vs deflection curve of all the sets of beams is plotted. The Load- deflection of each strengthened beam is compared with that of their respective control beams (as a practical deflection) and actual theoretical deflection.

C. Load vs Deflection Results of Light Weight RC beams designated as control RC beams (SET I)

TABLE 6
LOAD VS DEFLECTION RESULTS OF CONTROL RC BEAMS (SET I)

Load In KN	Deflection in MM			
	Theoretical	Control Beam 1	Control Beam 2	Control Beam 3
0	0	0	0	0
5	0.243	0.014	0.0124	0.0132
10	0.478	0.053	0.035	0.044
15	0.712	0.076	0.053	0.0645
20	0.947	0.096	0.0721	0.08405
25	1.182	0.108	0.0984	0.1032
30	1.412	0.235	0.12	0.1775
35	1.651	0.351	0.212	0.383
40	1.885	0.425	0.341	1.049
45	2.12	1.578	0.52	1.39
50	2.355	1.935	0.845	1.76
55	2.589	2.385	1.135	2.1555
60	2.824	2.687	1.624	2.284
65	3.058	2.894	2.05	2.538
70	3.293	3.105	2.432	2.621
75	3.527		2.621	3.021
80	3.762		3.021	

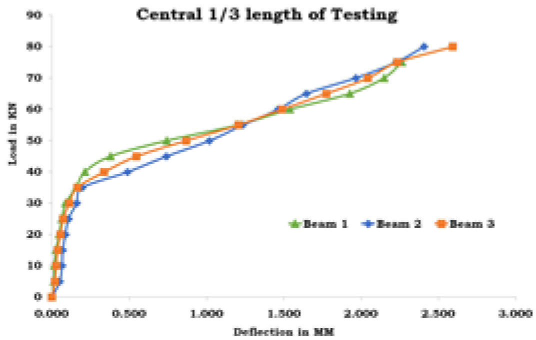


Graph 1 Load vs Deflection Results of control RC beams (SET I)

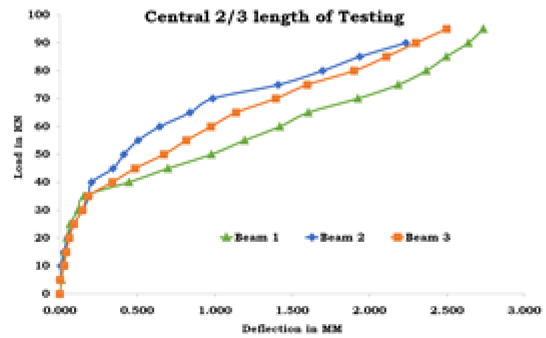
D. Load vs Deflection Results of Light Weight RC beams (SET II); all are strengthened using single GFRP wrap for Central 1/3 length of Testing (Length = 300mm).

TABLE 7
LOAD VS DEFLECTION RESULTS OF LIGHT WEIGHT RC BEAMS (SET II) (GFRP WRAP LENGTH = 300MM)

Load In KN	GFRP Wrap for Central 1/3 length of Testing		
	Beam 1	Beam 2	Beam 3
0	0.000	0.000	0.000
5	0.012	0.051	0.019
10	0.014	0.065	0.027
15	0.027	0.070	0.036
20	0.046	0.087	0.054
25	0.064	0.107	0.073
30	0.089	0.160	0.112
35	0.157	0.196	0.164
40	0.213	0.488	0.338
45	0.379	0.740	0.547
50	0.742	1.019	0.868
55	1.201	1.235	1.205
60	1.539	1.462	1.488
65	1.926	1.646	1.773
70	2.148	1.965	2.044
75	2.264	2.226	2.233
80		2.407	2.591



Graph 2 Load vs Deflection Results of Light Weight RC beams (SET II)(GFRP Wrap for Central 1/3 length of Testing, i.e.Wrap Length = 300mm)



Graph 3 Load vs Deflection Results of RC beams (SET II) (GFRP Wrap for Central 2/3 length of Testing, i.e.Wrap Length = 600mm)

E. Load vs Deflection Results of Light Weight RC beams (SET III); all are strengthened using single GFRP wrap for Central 2/3 length of Testing (Length = 600mm).

TABLE 8
Load vs Deflection Results of Light Weight RC beams (SET III)(GFRP Wrap Length = 600mm)

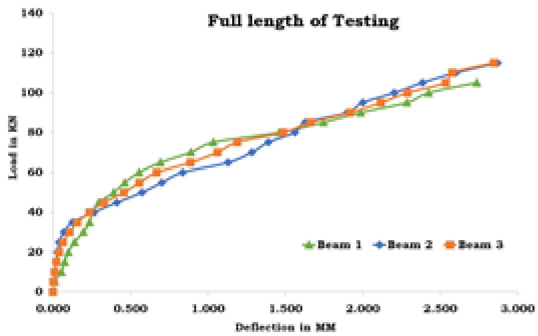
Load In KN	GFRP Wrap for Central 1/3 length of Testing		
	Beam 1	Beam 2	Beam 3
0	0.000	0.000	0.000
5	0.010	0.000	0.001
10	0.024	0.006	0.028
15	0.029	0.027	0.040
20	0.046	0.050	0.060
25	0.066	0.090	0.090
30	0.118	0.147	0.145
35	0.155	0.187	0.183
40	0.447	0.206	0.339
45	0.698	0.343	0.484
50	0.978	0.414	0.673
55	1.194	0.506	0.816
60	1.421	0.646	0.976
65	1.605	0.840	1.138
70	1.924	0.987	1.394
75	2.185	1.411	1.598
80	2.366	1.698	1.901
85	2.496	1.937	2.109
90	2.638	2.236	2.300
95	2.735		2.498

F. Load vs Deflection Results of Light Weight RC beams (SET IV); all are strengthened using single GFRP wrap for Full length of Testing (Length = 900mm).

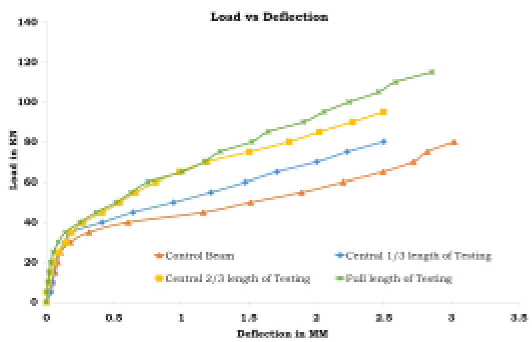
TABLE 9
LOAD VS DEFLECTION RESULTS OF LIGHT WEIGHT RC BEAMS (SET IV) (GFRP WRAP LENGTH = 900MM)

Load In KN	GFRP Wrap for Central 1/3 length of Testing		
	Beam 1	Beam 2	Beam 3
0	0.000	0.000	0.000
5	0.010	0.006	0.001
10	0.055	0.015	0.010
15	0.075	0.018	0.022
20	0.098	0.028	0.038
25	0.138	0.039	0.064
30	0.195	0.070	0.108
35	0.235	0.125	0.155
40	0.254	0.263	0.234
45	0.294	0.411	0.328
50	0.391	0.575	0.458
55	0.462	0.701	0.557
60	0.554	0.835	0.670
65	0.694	1.130	0.887
70	0.888	1.283	1.061
75	1.035	1.390	1.188
80	1.459	1.560	1.485
85	1.746	1.626	1.661
90	1.985	1.898	1.917
95	2.284	1.998	2.116

Load In KN	GFRP Wrap for Central 1/3 length of Testing		
	Beam 1	Beam 2	Beam 3
100	2.425	2.201	2.288
105	2.735	2.385	2.535
110		2.600	2.575
115		2.870	2.845



Graph 4 Load vs Deflection Results of Light Weight RC beams (SET II) (GFRP Wrap for full length of Testing, i.e.Wrap Length = 900mm)



Graph 5 Load vs Deflection Results of Light Weight RC beams (All SETS)

VI. DISCUSSION ON DEFLECTION

It is observed from Graph 8.15, Graph 8.19, Graph 8.23, that the deflection of beams (SET II, III and IV) when bonded with GFRP sheets with bottom side wrap is lesser than the control beams (SET I).

With reference to graph 5,

1. Maximum deflection of Control Beam (SET I) is 3.02 mm @ Load 80 KN
2. Maximum deflection of SET II is 2.499 mm @ Load 80 KN
3. Maximum deflection of SET III is 2.49 mm @ Load 95 KN
4. Maximum deflection of SET IV is 2.80 mm @ Load 115 KN

With reference to Tables and Graphs it is observed that for load of 80 KN the deflection of Light Weight Light Weight RC Beams designated as control Light Weight RC Beams (SET I) is 3.021 mm similarly for the same load the deflection of Light Weight RC Beams strengthened using single GFRP mat wrap for Central 1/3 length of Testing [300 mm] (SET II) is 2.4993 mm, Light Weight RC Beams strengthened using single GFRP mat wrap for Central 2/3 length of Testing [600 mm] (SET III) is 1.7991 mm and Light Weight RC Beams strengthened using single GFRP mat wrap for Full length of Testing [900 mm] (SET IV) is 1.5226 mm.

CONCLUSION

Successfully achieved reduction in deflection for Strengthening of Light Weight RC Beams with GFRP warp for Full length of Testing (i.e. 900mm length) by 40.44 %.

REFERENCES

[1] AbdulKadir Ismail Al-hadithi, Self Compacting Light Wt concrete containing ponzo. Aggregate, University of Anbar, Iraq (Jan-2019).

[2] AFAF Mo.wedatalla, Abubaker A.M Ahmed, Effect of curing and Period of Curing on Concrete,(Sep, 2018).

[3] Ahsan Ali, Shahid Iqabab, Thomas Bier, Yuri Ribakov, Study on structure of concrete, Germany,(March,2016).

[4] Amalu R.G, Azeef Ashraf, Muhammat Hussain, Use of waste plastic as fine aggregate substitute in concrete, UKF COE,India, (April,2016).

[5] Amir Hossein Niknamfar, Generating structural Light wt. Concrete, AIISE, USA (Nov,2017).

[6] A.R. Pourkhorshidi,M. Najimi, T. Parhizkar (July 2012), "Application of Pumice Aggregate in Structural Lightweight Concrete"Asian Journal of Civil Engineering (Building and Housing) Vol. 13, No. 1, Issue 1.

[7] Anil Godara, Anurag Maheswari, Ashish Kumar Meena, Rakesh Kumar Saini (May 2018), "Experimental study on light weight concrete with pumice stone as a partial replacement of coarse aggregate", ISSN: 2277-2723, Volume 7, Issue 5.

[8] B. Devi Pravallika, K. Venkateswara Rao (2015), "The study on strength properties of light weight concrete using light weight aggregate" International Journal of Science andResearch(IJSR) ISSN: 2319-7064, Volume 5, Issue 6.

[9] B. Jose Ravindra Raj, V. Ravikumar (April 2017), "Experimental behaviour of light weight aggregate and mineral admixtures based light weight concrete", International Journal of Emerging Technologies in Engineering Research (IJETER) ISSN: 2454-6410, Volume 5, Issue 4.

[10] Chrdsaqusiri Pattanponga, Properties of cellular light wt. concrete using calcium bottom ash, Portland cement,geopolymer mortar (January,2020).

[11] Davoud Tavakoli, Use of Waste material in Concrete, Iran (April,2018).

[12] Dr. K Rajeskhar, M Praveen Kumar, (Sept 2016)Light weight concrete by partial replacement of coarse aggregate by pumice stone and cement by GGBS using M30 grade of concrete.

[13] Dr.Sunila George, Rajeshwari S, (2015), "Experimental study of light weight concrete by partial replacement of coarse aggregate using pumice aggregate", International Journal of Scientific Engineering and Research (IJSER) ISSN: 2347-3878, Volume 4, Issue 5.

[14] Dr. U. Rangaraju, Lakshmi Kumar Minapu, M K M V Ratnam, (Dec 2014), "Experimental study on light weight aggregate concrete with pumice stone, silica fume and fly ash as a partial replacement of coarse aggregate" International Journal of Innovative Research in Science, Engineering and Technology ISSN: 2319-8753, Volume 3, Issue 12.

[15] G. Gunasekaran, Light wt. Concrete by using Cocunut shell as Aggregates, SRM University,India (Feb,2008).

[16] HirzoMihashi TomoyaNishiwaki, Development of Engineered self healing & self Repairing concrete, Hirzostate of Art-Report (April,2012).

[17] Issac Ibukan Akinwumi, Curing effect on Properties of high strength Concrete, Convenant University (June, 2014).

[18] Jose Barrose De Aguiar, Habib Trouzine, Malika Medine, Structural light wt. concrete properties, USA (August,2017).

[19] K. Mahendra ,K. Venkataramana, L. Hari Krishna ,M.Rajasekhar, S. Prashanth "Experimental Investigation On Structural Lightweight Concrete By Partial Replacement Of Coarse Aggregate Using Pumice Aggregate"International Journal of Engineering Applied Sciences and Technology, 2020 Vol. 4, Issue 11, ISSN No. 2455-2143, Pages 429-433.

[20] Khashayar Jafari Mostafa, Vahab, Study of Behaviour of Concrete under Axial & Triaxial load, USA (August,2017).

[21] Kothari Akash and Chaudhari Balasaheb(April 2017) Study of lightweight precast concrete using polystyrene.

[22] Kourosh Kabiri, Super Absorbant Polymer, Iran (June,2008).

[23] Lakshmi Kumar, Minapu, et al (Dec 2014) Study on Light Weight Aggregate Concrete with Pumice Stone, Silica Fume and Fly Ash as a Partial Replacement of Coarse Aggregate.

[24] M. Indumathi,P. Selvaprasanth, S. Mathan Kumar, and (Feb 2019) "Development of Light Weight Concrete Using Pumice Stone"International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056, Volume: 6, Issue: 2.

[25] M. Maghfouri, Quality control of light wt. aggregate concrete based on initial and final water absorption Test, Iraq (June,2017).

[26] Sukmin Kwon, Tomoya Nishiwaki, Takatsune Kikuta, Material Design Method for light wt. Cement base & its Applications (June,2017).