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Dimensional Effect on Flexural Strength of Prestressed Concrete Beam by Incorporating Glass Fibers and Fly Ash

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ABSTRACT:

In this research, an attempt was made to study the effects of depth & length on flexural strength of prestressed concrete beam with high strength glass fibers. In brief, an attempt was made to produce high performing prestressed concrete by adding glass fibers.The experimental program was designed to verify and calibrate the size effect theory. In this program 27 cube samples of size 150mmx150mmx150mm for different percentages of glass fibre with cement concrete were casted and tested. The concrete mixes had 0%, 0.25%, 0.50%, 0.75% of glass fibres by weight of concrete were added.It revealed that 0.25% glass fibers were found to be most favorable combination of concrete mix having optimum compressive strength and with this concrete mix casting of prestressed concrete flexural members.

The beam specimens had varying length & depth keeping the aspect ratio same and all the beam specimens had a constant width of 100 mm.The beam specimens were tested on universal testing machine (UTM) for flexural strength at the age of 28 days, 9 beam specimens for single point loading and 9 beam for two points loading. Deflections were measured with dial gauges. Experimental and analytical results of flexural strength and deflection were compared.

Key words: Prestressed concrete, flexural strength, dimensional effect, glass fibres, dial gauges.

I. INTRODUCTION

It is important to consider effect of member length and cross sectional depth, for a given width, on the ultimate strength of a concrete flexural member. For all types of loading conditions, the trend of variation of the strength of a member needs to be established, when the member length and sectional depth vary. Most concrete structural members experience combined loading conditions composed of compression, tension, moment and shear. In case of a prestressed concrete member, the fundamental idea was that concrete resists compressive stress and steel resists tensile stress. As per Jin- Keun Kim, Seong Tae Yi and Jang Ho Jay Kim, the fracture mechanics based on formulation of size effect theory. The focus of this study was to develop and clarify size effect in prestressed concrete members. It was a well-known fact that there was an effect of size difference in nominal strength of prestressed concrete members.

The size effect phenomenon (nominal strength varies with the size of structure) was an inherent property of the behavior of many engineering materials, i.e. the strength and brittleness increase with increasing element size. Thus, concrete becomes perfectly brittle on a sufficiently large scale. The results from laboratory tests which were scaled versions of the actual structure cannot be directly transferred to them. The major importance of size effect can be obtained from deterministic and statistical. An increase of the specimen size causes an increase of weak spots that induces a decrease of the material strength. The aim of our research was to investigate experimentally and numerically a deterministic and stochastic size effect in prestressed concrete beams under bending. The experiments were carried out with three different geometrically similar prestressed concrete beams. The specimens had a constant thickness of 0.1 m, varying lengths of 0.8 m, 1.0 m and 1.2 m, and varying depth 0.08 m, 0.1 m and 0.12 m, respectively. For each size, three samples were made. The beams were subjected to single and double point loading and controlled by vertical displacement. The failure mode was of a flexure type in concrete.

In a larger structure, the fracture process zone occupies a smaller portion of the cross section; i.e., it was more localized. Therefore, the response was closer to that predicted by linear elastic fracture mechanism (LEFM), for which the fracture process zone was assumed shrunken to a point. In a small structure, for example,

such as in a laboratory specimen, the fracture process zone occupies a large portion of the cross section and the failure behavior was closer to plastic limit analysis, which means that the strength limit was reached simultaneously in most of the failure surface. Thus, the size effect, defined as the dependence of the nominal strength on the structure size for geometrically similar structures, represents a transition from plastic limit analysis at very small sizes to LEFM at very large sizes.

II. RESEARCH SIGNIFICANCE

1. The presented research was aimed at studying the mechanical properties like optimum percentage of glass fibres with cement concrete. To determine the optimum compressive strength from trial mixes. The optimum concrete mix was used to determine the flexural strength.

2. The present study was also aimed at determining and verifying the hypothesis that the beam specimens with varying length & depth keeping same aspect ratio and all the specimens had a constant width of 100 mm.

3. The study also aims to determine the shear and flexural strength of the prestressed concrete beams based on the cross sectional dimensions, span and amount of steel used and compared with actual strength obtained based on experimental and analytical results. The research findings will be help the engineers to understand the overall performance of prestressed concrete with glass fibres for shear and flexural strength in prestressed concrete.

III. EXPERIMENTAL PROGRAM

The experimental programme was divided in four phases a) Concrete mix design as per IS 10262-1982 for trial mix different grade of concrete. To determine the optimum percentages of glass fibres by weight of concrete and the maximum compressive strength. b) Two prestressed strands of 4 mm diameter each and with a prestressing force 13578.37N (1081 MPa) in each strand. c) Casting of beam specimens with varying length and depth having same aspect ratio and constant width. d) Testing of all prestressed beam specimens with single and double point loading for shear, flexural strength and measurement of deflections at different loadings. Also, comparison of experimental and analytical results.

IV.SPECIMEN DESIGN:

There were three groups of beam specimens-
Group one was having six beam specimens with span of 1200mm and cross sectional width 100mm and depth 120mm.
Group two was having six beam specimens with span of 1000mm and cross sectional width 100mm and depth 100mm.
Group three was having six beam specimens with span of 800mm and cross sectional width 100mm and depth 80mm. shown in figure 1.

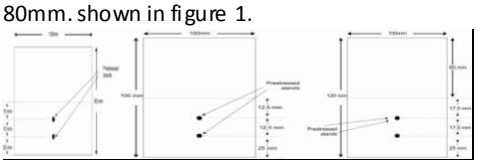

Fig. 1a Fig. 1b Fig. 1c

Figure-1

All specimens were designed to have same prestressing force Pu=27156.74N and same amount of prestressed steel (25.11 mm^2).Two strands are used having 4mm diameter.

V. MATERIALS

Prestressed strand (IS:1786-1979) having ultimate tensile strength 175 kg/mm^2,proof stress at 0.2 percent extension 169.1Kg/mm^2,modulus of elasticity 21485 Kg/mm^2. Cement of 53 grade .Fineness of cement = **5% < 10%** (IS:269-1976),Standard Consistency Test=29.25% <30% (IS:4031-1968),Initial Setting Time = 115 minutes > 30 minutes (minimum)(IS:269-1976),Final Setting Time = 258 minutes < 600minutes(maximum)(IS:269-1976).Batch type concrete mixing (IS:4634:1968) was carried out. Coarse aggregate consisted of a 20mm maximum size with crushing value=(Weight of fraction passing through 2.67mm I.S. sieve/Weight of aggregate)=(541/2888)x100=18.73%(IS:2386-Part-4) and Aggregate impact value=(Weight of fraction passing through 2.67mm I.S. sieve / weight of sample)=(46/400)x100=11.50%<45%(IS 283-1970).Fine aggregate (IS 2386-Part-I-1963) specific gravity=2.6 and fineness modulus=2.9.Potable water was used for mixing and curing of concrete (IS:456-2000).Water/cement(W/c) ratio was 0.42<0.6 (IS 456-2000).Water reducing admixture(IS 9103:1999) 0.25% by weight of cement. For glass fibers and FA (IS 3812 – Part I– 2003) physical and chemical properties refer Appendix-A.

For mix design proportions as per IS code method the mix proportions were 1:1.046:2.12 and W/c ratio 0.42.The concrete batch weights were 420.75 Kg/Cum cement, glass fibers 105.187 Kg/cum(0.25% by weight of concrete), 74.25 Kg/Cum Fly ash (17% by replacing to cement), 518 Kg/cum river sand, 1053 Kg/cum course aggregates (10-20mm nominal size), 208 Kg/cum water, water reducing admixture (FLOWCON-PC 163 JK) 1.23 Kg/Cum.

V. SPECIMEN CASTING:

27 cube samples of size 150mmx150mmx150mm by adding different percentages of glass fibres by weight of concrete. All cubes were casted in one lift and consolidated using machine vibrator. After final setting of cubes, the cube moulds were removed and cubes were kept in water tank for curing.
All beam specimens size 100mmx120mm x1200mm, 100mm x 100mm x1000 mm and 100 mmx80 mm x 800 mm were casted with optimum compressive strength in

three lifts and consolidated using tamping rods. After setting the specimens were covered with wet gunny bags. The burlap was kept for 3days and prestressing force were transferred to concrete. At the end of the third day, the forms were stripped and specimens were kept for curing up to 28days.

VI. PRESSTRESSING PROCEDURE

The prestressing strands were tensioned by using single strand hydraulic jack a day prior to casting. The strand force was calculated by elongated length of tensioned strand as well as by pressure transducer installed on the hydraulic jack. Tensioned strands were locked on steel abatements by using barrels (male and female cone). Pretension beam specimens were casted by using optimum compressive strength mix. After three days of casting of beam specimens, a gradual tension transfer procedure to concrete was used to cut the strands by mechanical cutter simultaneously. Beam specimens were tested for shear and flexural strength at the age of 28 days.

The step-by-step procedure used for prestressing the strand are as follows-

1) The strand was passed through rear end of steel abetment of prestressed yard and anchor grip assembled.

2) Another end of strand was passed through the front steel abetment and hydraulic jack with anchor grip. Jack and temporary anchor grip assembled at the front end of strand.

2) The pump was operated after closing and opening the necessary knobs according to manufacturer's instructions.

3) When slack of the strand was removed, the zero indicating collars were set to the nearest convenient graduation on the ram. The required extension was measured from graduation.

4) After tensioning the strand up to required extension, immediately locking of wedge was done by hammering the wedges dolly through a slot provided in the nose.

5) The jack was then retracted by closing and opening the necessary knobs. The temporary anchor grip was released from the tendon.

VII. TEST SETUP AND PROCEDURE

The beam specimen was simply supported with a concentrated load applied at mid span, as shown in figure-2.The load was applied by using UTM (100 tons capacity) in 100kg increments up to failure load. At each load increment, cracks were inspected and marked, and the beam specimens were photographed. Continuous monitoring was carried out all through the testing.

VIII. RESULT ANALYSIS

After reviewing and comparing the results, the following points were predominantly revealed which are mentioned below:-

In two points loading as indicated that the beam specimens initially deflects gradually and exceeds its analytical limit. The beam 100 x 120 x 1200mm deflected more than other beams of sizes100 x 100 x 1000mm and 100 x 80 x 800mm, also, it had high yield strength. The deflection of the beam increases with increasing depth and length with constant aspect ratio and also increases yield strength of the beam. Where as in single point loading, average deflection of 100 x 120 x 1200 mm beam was found to be less as compared to the other sizes beam specimens & it had low yield strength. It means ultimate strength of the beam specimens were increased with increasing the depth and length with constant aspect ratio.

Experimental values of flexural strength of prestressed concrete beam specimens were more than the analytical values as shown in result table 1.Experimental deflection of prestressed concrete beam were more than the analytical deflection. It means that the beam specimens had high ductile property.

From overall study and comparison of graphs it revealed that the deflection in all the specimens had considerable fluctuation in their deflection values and effect of dimensions of beam specimens on flexural strength were tabulated.

IX. CONCLUSIONS

1. For two points loading, Series-1 were having more shear strength than Series-3 and Series-5 of beam specimens.But, flexural strength were exactly reverse ,i.e. flexural strength were reducing with increasing span and depth and due to increasing moment of inertia.

2. For single point loading,Series-2 were having more shear strength than Series-4 and Series-6 of beam specimens. But, flexural strength were exactly reverse, i.e. flexural strength were reducing with increasing span and depth and due to increasing moment of inertia.

3. From study of graphs it was clearly revealed that the flexural strength of long span beam is less than the shorter span in prestressed concrete beam.

4. Experimental shear and flexural strength were increased by two to three times than analytical strength, it was an effect of glass fibres interlocking in concrete particles, which improved the strength.

5. Ductility of prestressed concrete beam specimens were increased by incorporating glass fibres and load verses deflection pattern were observed almost same for single and two points loading.

6. The use of glass fiber in prestressed concrete enhances the mechanical properties like early compressive, shear and flexural strength.

7. The yield strength of long span beam is less than the shorter span in prestressed concrete beam.

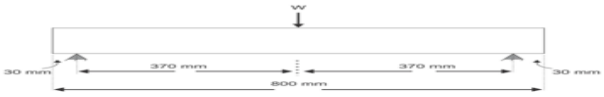

Fig.2a

Fig.2b

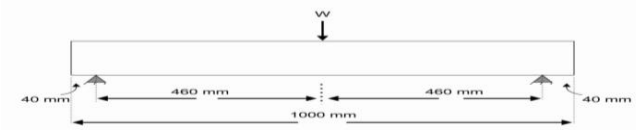

Fig.2c

Fig.2d

Series	Beam Specimen	Size (WidthxDepthxLength) in mm	Point loads	Moment of Inertia in mm^4	F_{ck} in MPa	E_c of Concrete in Mpa	Experimental					Analytical		
							Strength in (N)	Avg. strength in (N)	Flexural strength in MPa	Deflection in mm	Avg. deflection in mm	Strength in (N)	Flexural strength in MPa	Deflection in mm
Series-1	PC-GF-2-B-1	100x120x1200	Two	14400000	75	43223.25	14000	12666.67	10.555	8.307	8.307	5100	4.25	0.614
	PC--GF-2-B-2	100x120x1200	Two	14400000	75	43223.25	11000			4.42				
	PC-GF-2-B-3	100x120x1200	Two	14400000	75	43223.25	13000			12.4633				
Series-2	PC-GF-1-B-4	100x120x1200	Single	14400000	75	43223.25	9000	9666.67	12.08	6.333	8.070	3400	4.25	0.409
	PC-GF-1-B-5	100x120x1200	Single	14400000	75	43223.25	8000			8.366				
	PC-GF-1-B-6	100x120x1200	Single	14400000	75	43223.25	12000			9.533				
Series-3	PC-GF-2-B-7	100x100x1000	Two	8333333	75	43223.25	10000	11666.66	11.66	3.75	3.72	4860	4.86	0.58
	PC-GF-2-B-8	100x100x1000	Two	8333333	75	43223.25	7000			3.24				
	PC-GF-2-B-9	100x100x1000	Two	8333333	75	43223.25	18000			4.18				
Series-4	PC-GF-1-B-10	100x100x1000	Single	8333333	75	43223.25	5000	8333.34	12.50	6.03	8.378	3240	4.86	0.229
	PC-GF-1-B-11	100x100x1000	Single	8333333	75	43223.25	8000			9.573				
	PC-GF-1-B-12	100x100x1000	Single	8333333	75	43223.25	12000			9.533				
Series-5	PC-GF-2-B-13	100x80x800	Two	4266667	75	43223.25	7000	8666.67	10.83	5.59	5.91	4522	5.652	0.544
	PC-GF-2-B-14	100x80x800	Two	4266667	75	43223.25	8000			8.42				
	PC-GF-2-B-15	100x80x800	Two	4266667	75	43223.25	11000			3.73				
Series-6	PC-GF-1-B-16	100x80x800	Single	4266667	75	43223.25	7000	5333.34	10.00	7.946	6.34	3015	5.653	0.213
	PC-GF-1-B-17	100x80x800	Single	4266667	75	43223.25	5000			6.256				
	PC-GF-1-B-18	100x80x800	Single	4266667	75	43223.25	4000			4.84				

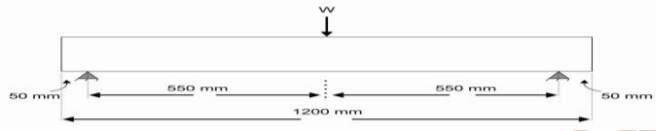

Fig.2e

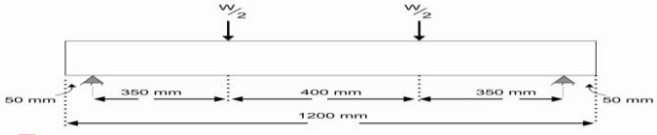

Fig.2f

Figure 2: Test set up

Table 1. Result Table

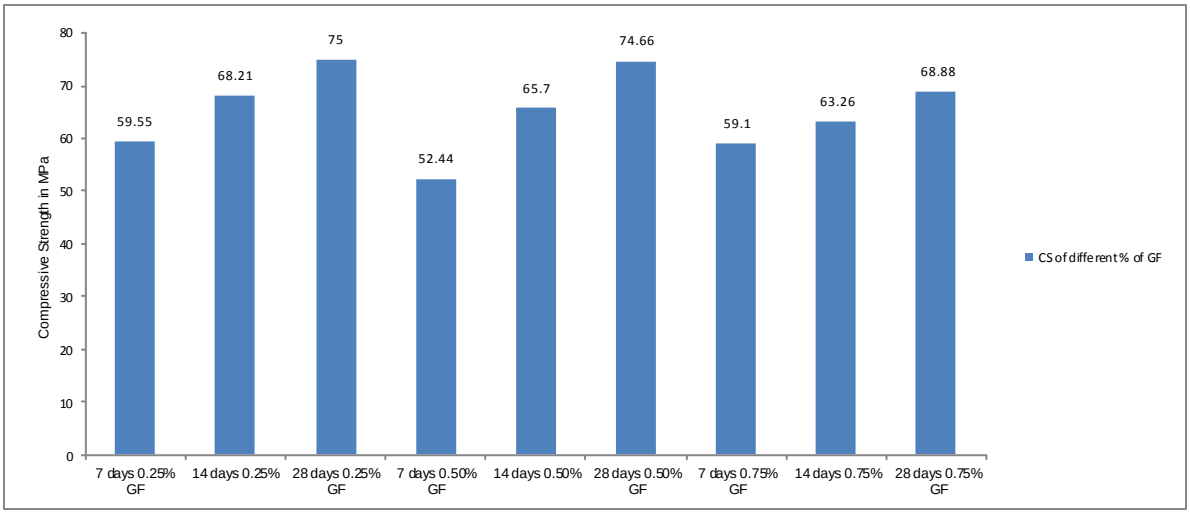

Figure 3: Compressive Strength of different percentage of glass fibres

From above test results it revealed that 0.25% glass fibres (by weight of concrete) were most favorable combination for concreting of flexural member.

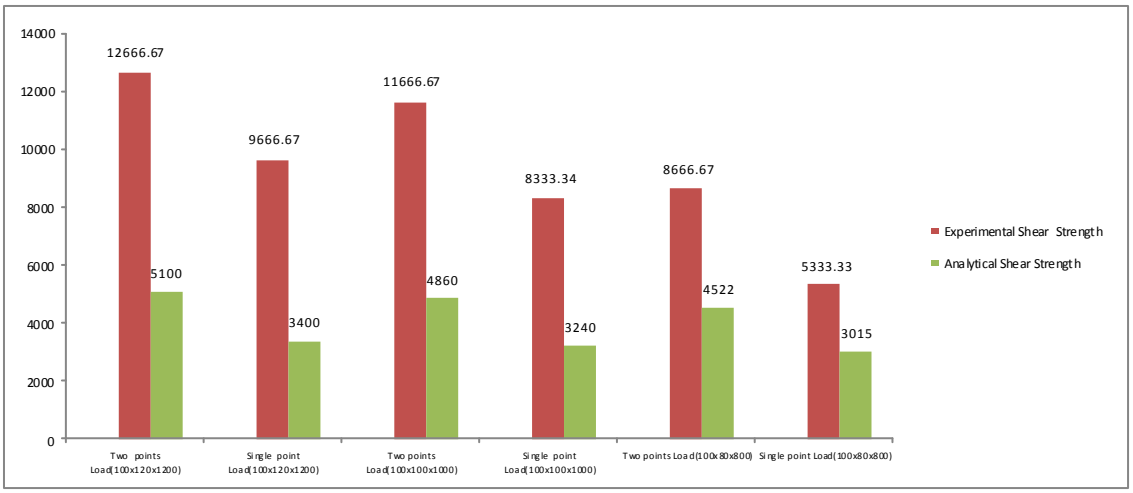

Figure 4: Shear Strength of different span and cross section

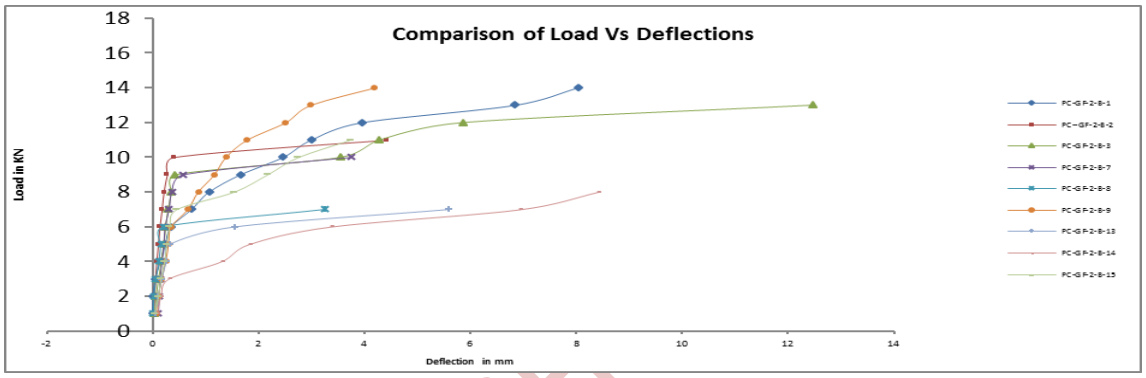

Figure 5: Deflections of two points loading

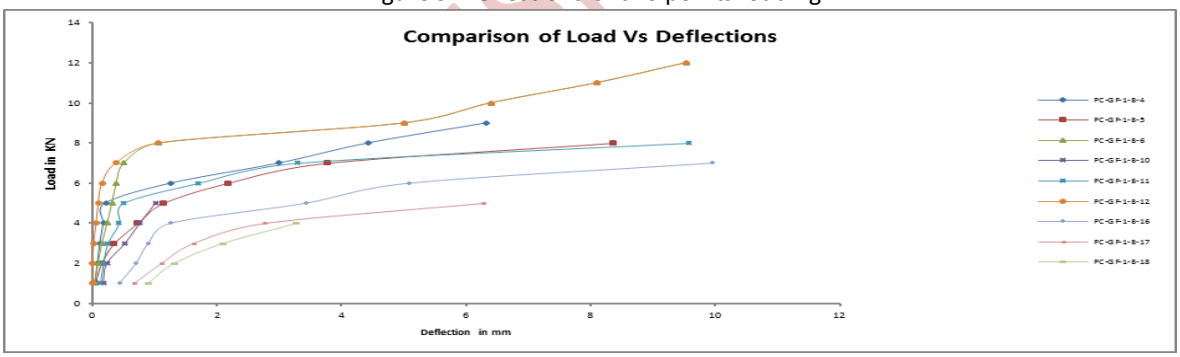

Figure 6: Deflections of single point loading

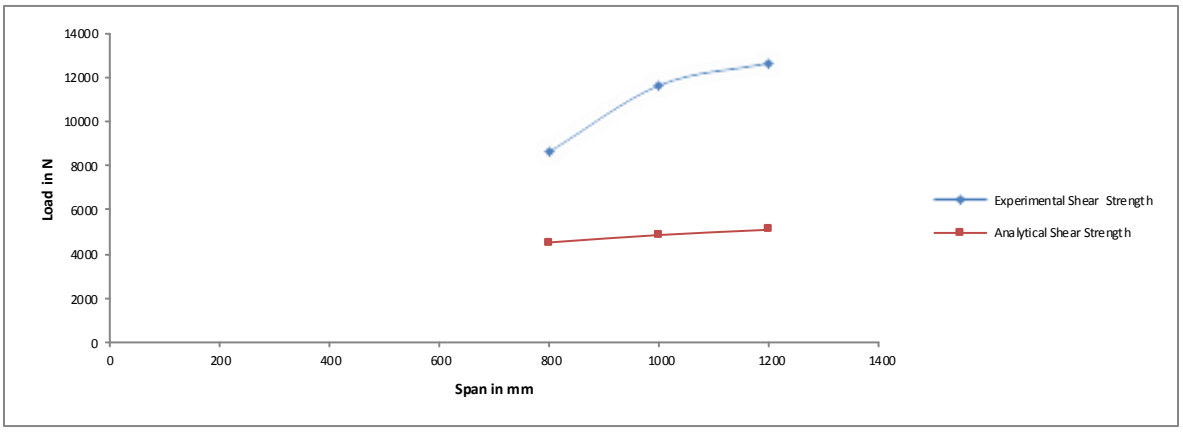

Figure 7- Comparison of Shear Strength of two points loading

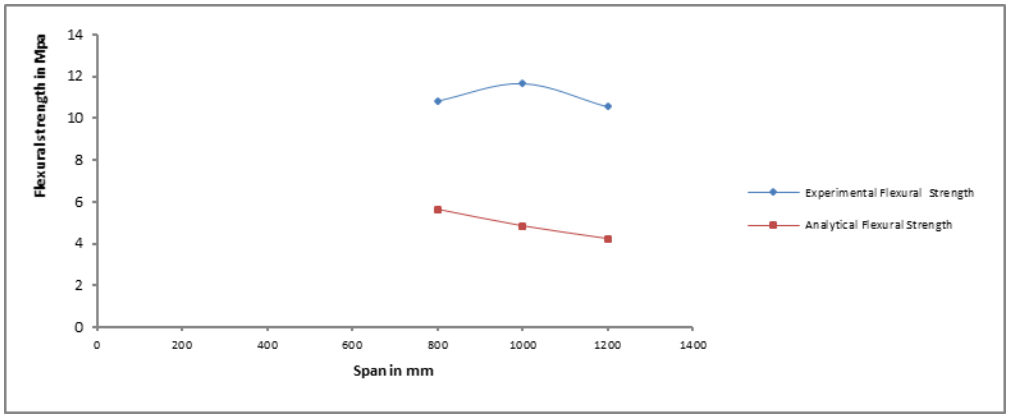

Figure 8- Comparison of Flexural Strength of two points loading

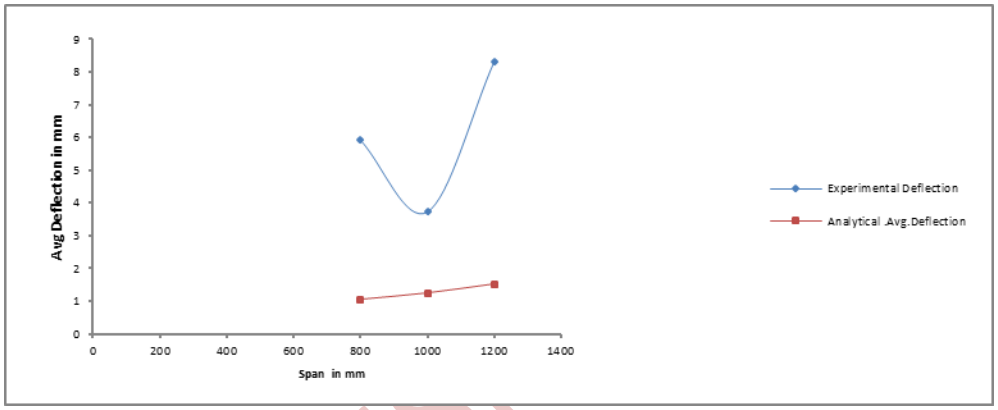

Figure 9- Comparison of Deflection of two points loading

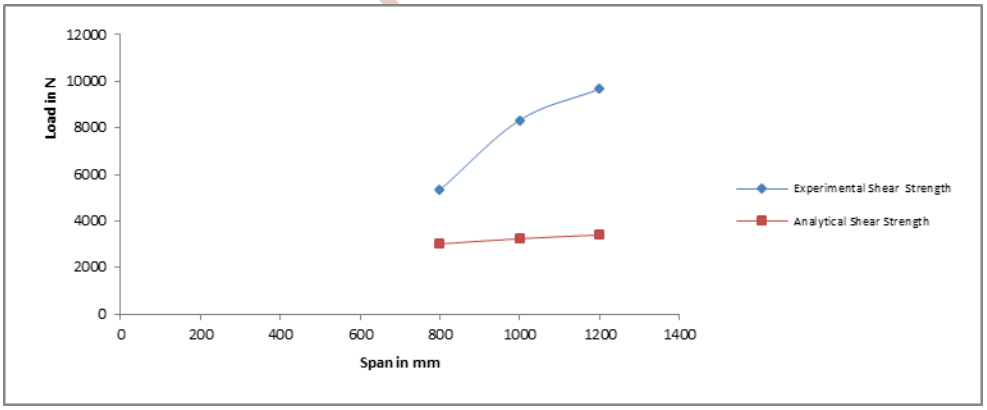

Figure 10- Comparison of Shear Strength of single point loading

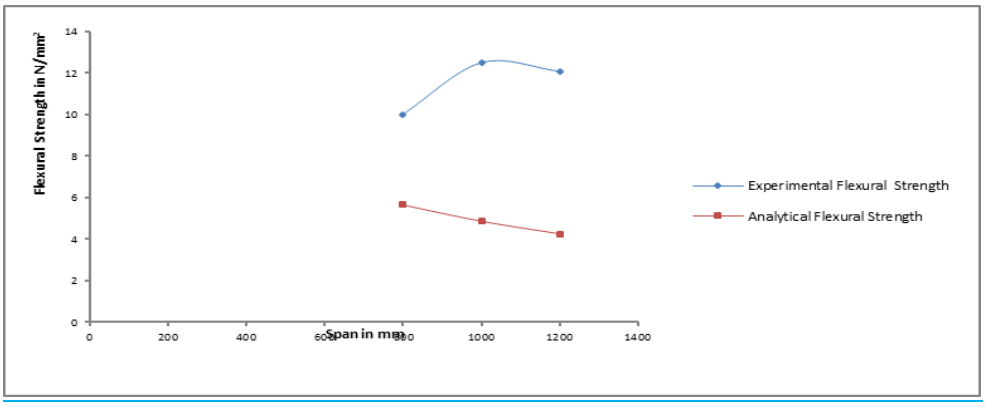

Figure 11- Comparison of Flexural Strength of single point loading

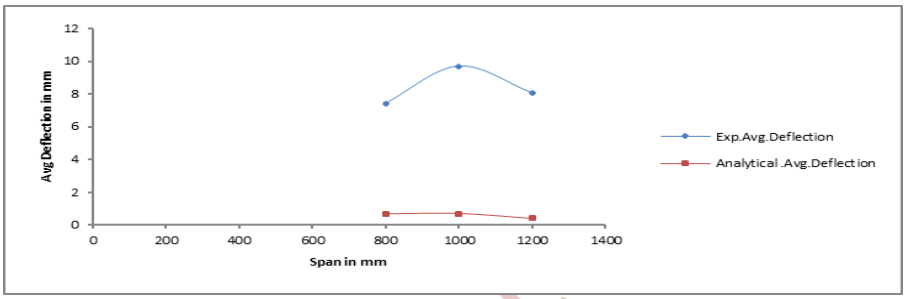

Figure 12- Comparison of Deflection of single point loading

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Sr.No.	Component	Cem-FIL AR-Glass
1	Silica Dioxide(SiO_2)	62.0
2	Sodium Oxide(Na_2O)	14.8
3	Calcium Oxide(CaO)	5.6
4	Aluminum Oxide(Al_2O_3)	0.8
5	Zirconium dioxide (ZrO_2)	16.7

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APPENDIX A

LIST OF SYMBOLS and Word Meaning

Symbol	Description
PC-GF-2-B-1,2,3	*Prestressed concrete with 0.25% glass fibres for two points loadings beam specimens 1,2,3 respectively*
PC-GF-2-B-4,5,6	*Prestressed concrete with 0.25% glass fibres for single point loading beam specimens 4,5,6 respectively*
Es	*Modulus of elasticity of steel inMPa=200x10^{3}MPa*
E_c	*Modulus of Elasticity of Concrete in MPa=5000$\sqrt{F_{ck}}$ as per IS 456-2000*
F_{ck}	*Characteristic compressive strength of concrete in MPa*
Fpu	*Ultimate tensile strength of steel in MPa= 1800Mpa*
Fcr	*Flexural and splitting tensile strengths of concrete=0.7$\sqrt{F_{ck}}$*
OPC	*Ordinary Portland Cement*
FA	*Fly Ash*
GF	*Glass Fibres*
Y and d	*Total Deflection*

APPENDIX B - Physical and Chemical properties of Glass Fibres & Fly Ash

Table 2 Chemical composition of Selected Glass Fibers

Table 3 Physical Properties of *AR*–Glass Fibers:

Sr. No.	Property	Requirements
1	*Density,T/m^3.*	*2.6*
2	*Elastic modulus,GPa .*	*73*
3	*Tensile strength,MPa .*	*1700*
4	*Specific Gravity*	*2.7*
5	*Strain at break(%)*	*3.6*
6	*No of fibers,Million/kg.*	*220*

Table 4: Chemical requirements of Fly Ash as per IS: 3812 – Part-1 : 2003

Sr. No.	Characteristics	Requirements
1	Silicon dioxide (SiO2) plus iron oxide (Fe2O3) percent by mass, Min	70.0

2	Silicon dioxide (SiO2), percent by mass, Min	35.0
3	Reactive silica in percent by mass, Min	20.0
4	Magnesium oxide (MgO), percent by mass, Max	5.0
5	Total sulphur as sulphur trioxide (SO_3), percent by mass, Max	3.0
6	Available alkalis, as sodium oxide (Na2O), percent by mass, Max	1.5
7	Total chloride in present by mass, Max	0.05
8	Loss on ignition, percent by mass, Max	5.0

Table 5 : Physical requirements of Fly Ash as per IS: 3812 – Part-1 : 2003

Sr. No.	Characteristics	Requirements Grade I	Requirements Grade II
1	Fineness – Specific surface in m2/kg by Blain's permeability method, Min	320	250
2	Lime reactivity – Average comp. strength in N/mm2, Min	4.5	3.0
3	Comp. strength at 28 days in N/mm2, Min	Not less than 80 percent of the strength of corresponding plain cement mortar cubes	Not less than 80 percent of the strength of corresponding plain cement mortar cubes.
4	Soundness by Autoclave test expansion of specimens, percent, Max	0.8	0.8

APPENDIX C

Sample calculation for analysis of beam specimen:

Data:

- Cross section of beam = 100 mm x 120 mm
- Length of beam = 1200 mm
- Stress in each strand = 1081 N/mm^2
- Diameter of each strand = 4 mm
- Area of each strand = 12.56 mm^2
- Total area of two strands=25.12 mm^2
- $I = \frac{bd^3}{12}$ = 14.4x10^6 mm^2
- Y = d/2 = 75 mm
- Z = I / Y = 192 x 10^3 mm^3
- Pu = Total Prestressing Force = 27156.74 N
- Eccentricity = e = 50 mm
- Self-weight of beam(W_D)=0.10x0.12x1x24=0.288 KN/m
- Assume 20% prestressed losses

To find out safe superimposed load for zero bottom stress:

$$F_b = \frac{Pf}{A} + Pf.\frac{e}{Z} - \frac{M_T}{Z}$$

$$0 = 0.8X\frac{27156.74}{12000} + \frac{0.8X27156.74X50}{192000} - \frac{M_T}{192000}$$

M_T = 1520.79x10^3 N.mm

Where,

$M_T = M_L + M_D$

1520.79x10^3 = W_L x L/4 + W_D xL^2/8 = W_L x 1200/4 + (0.288x1200^2)/8= W_Lx600/4 +51.84x10^3

W_L = 4893.87 N

Total load carring capacity= W=W_{D+} W_L=288 +4893.87 N =5181N

Deflection at center of Simply Supported Beam (δ) = $\frac{\frac{5}{385}W_L\, xL^4}{EI}$ +W_D xL^3/48EI **= 0.60mm**

----------End----------