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Appraisal of strength properties of fibre reinforced concrete

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Abstract:-The main purpose of this research is based on the investigation of the use of Steel fibres and Glass fibres in structural concrete to enhance the mechanical properties of concrete. The objective of the study was to determine and compare the differences in properties of concrete containing steel fibres and Glass fibres in concrete. This investigation was carried out using several tests, compressive test, split tensile test and flexural test. mix batches of concrete containing 0.2% to 1% with an interval of 0.2% by wt. of cement. 'Hooked' steel fibres and glass fibres were added to determine the enhancement of mechanical properties of concrete. The workability of concrete significantly reduced as the fibre dosage rate increases. The super plasticiser used in experimental study is Masterpolyheed 8340 and 0.8 % dosage by weight of cement is taken.

Keywords:- Fibre Reinforced Concrete; Steel Fibre(SF); Glass Fibre(GF); Natural Fibre; Compressive strength; Flexural strength.

Introduction:-Plain concrete possesses a very low tensile strength, limited ductility little résistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks evidently leading to brittle fracture of the concrete. in the past attempt have been made to impart improvement in tensile properties of concrete member by way of using conventional reinforced steel bar and also by applying restraining technique, but these technique however do not increase the inherent tensile strength of concrete itself. In plane concrete and similar brittle materials, structural cracks (micro-crack) develop even before loading. Particularly due to drying shrinkage or other cause of volume change. The width of these initial cracks seldom exceeds a few microns, but their other two dimensions may be of higher magnitude. When loaded, the micro cracks propagate and open up, and owing to the effect of stress concentration, additional cracks form in places of minor defects. The structural crack proceeds slowly or by tiny jumps because they are retarded by various obstacles, changes of direction in bypassing the more resistant grains in matrix. The development of such micro-crack is the main cause of inelastic deformation in concrete.

Fibre-reinforced concrete is generally made with a high cement content and low water/cement ratio. When well compacted and cured, concretes containing steel fibres seem to possess excellent durability as long as fibres remain protected by cement paste. Ordinary glass fibre cannot be used in Portland cement mortars and concretes because of chemical attack by the alkaline cement paste. In this experimental investigation main focus on increasing the 97 Int. J. Struct. & Civil Engg. Res. 2013 Shelorkar Ajay P et al., 2013 tensile strength of concrete by using hook ended steel fibres, as well as addition of metakaoline with steel fibres. . The main goal of the investigator or concrete researchers is to improve the tensile strength and flexural strength of concrete. To optimize this serious defect partial incorporation of fibres is practiced.

1.Type of fiber used in reinforced concrete

1.1 Steel fibre reinforced concrete

Steel fiber reinforce concrete is a composite material which is made up from Cement concrete mix and steel fiber as a reinforcing.

1.2 Glass fiber reinforced concrete

Glass fibre–reinforced concrete is (GFRC) basically a concrete composition which is composed of material like cement, sand, water, and admixtures, in which short length discrete glass fibers are dispersed. Inclusion of these fibres in these composite resultsin improved tensile strength andimpact strength of the material.GFRC has been used for a period of 30 years in several construction elements but at that time it was not so popular, mainly in non-structural ones, like facingpanels (about 80% of the GRC production), used in piping for sanitation network systems, decorative non-recoverable formwork, and other products At the beginning age of the GFRC development, one of the most considerable problems was the durability of the glass fiber, which becomes more brittle with time, due to the alkalinity of the cement mortar. After some research, significant improvement have been made, andpresently, the problem is practically solved with the new types of alkali-resistant (AR resistance) glass fibers and with mortar additives that prevent the processes that lead to the embrittlement of GFRC.

2. Materials

2.1 . Cement

Ordinary Portland cement available in local market of standard brand was used in the investigation. The Cement used has been tested for various proportions as per IS 4031-1988 and found to be confirming to various specifications of IS 12269-1987.The specific gravity was 3.1 and fineness was 330 kg/m^2. The cement also confirms to 53 Grade.

2.2. Coarse Aggregate

Machine Crushed angular granite metal of 20 mm size from a local source was used as coarse aggregate. It is free from impurities such as dust, clay particles and organic matter etc, The coarse aggregate is also tested for its various properties., the specific gravity, and fineness modulus are found.

2.3. Fine Aggregate

The locally available river sand was used as fine aggregate in the present investigation. The sand should be devoid of impurities like clay matter, salt and organic matter and is tested for different properties as per IS2386-1963, such as specific gravity, fineness modulus, moisture content etc. The fine aggregate is confirming to standard specification.

2.4 Glass Fibers

The glass fibers of Cem-FIL Anti-Crack HD with Modulus of Elasticity of 72 GPA, Filament diameter 14 microns, Specific Gravity of 2.68, length of 12mm and having the aspect ratio of 857.1. For 1 Kg, the number of fibers is 212 million.

2.5. Steel Fibres

The steel fibers used in the experimental study were HELIX 5-25 with the following properties:

Length: 25 mm (1.00 in)

Diameter: 0.50 mm (0.02 in)

Fiber density : 25,307 fibers/kg (11,500 fibers/lb)

Tensile Strength: 1700 Mpa (minimum)

Material: High Carbon Steel Wire

Coating: Electroplated Zinc

2.6 Water

Water is used 23% of cement by weight in order to mixed the ingredient .

2.7 Superplasticiser

The super plasticizer used in experimental study is Master polyhead 8340 manufactured by BASF. The manufacturer describes it as an economical admixture based on modified polycarboxylic ether. The product has been primarily developed for applications in ready mix and site-batched concrete. Master Polished 8340 is specially designed to allow considerable reduction of mixing water while maintaining control on extend of set retardation. Master Polished 8340 is free of chloride & low alkali. It is compatible with all types of cements .it passes the following properties:

Aspect	Reddish brown liquid
Relative Density	1.10 ± 0.01 at 25°C
Ph	> 6 at 25°C
Chloride ion content	< 0.2%

Table1: Test results of concrete ingredients

Material	Property	Test Results	IS Code
Cement	Fineness	1.26	IS 4031 (Part 1) 1996
	Normal consistency	32%	IS 4031 (Part 4) 1988
	Specific Gravity	3.1	IS 4031 (Part 11) 1988
	Initial and Final Setting time	45 & 600 min	IS 4031 (Part 5) 1988
Fine Aggregate	Fineness modulus	2.42	IS 383 – 1970

	Zone confirm to	2	
	Specific Gravity	2.65	IS 2386 (Part 3) 1963
	Moisture Content	2.51	
Coarse Aggregate	Fineness modulus	7.46	IS 383 – 1970
	Specific Gravity	2.6	IS 2386 (Part 3) 1963
	Water absorption	1.11	

3 Design of reference concrete mix

Based on preliminary test results as presented in Table 1 reference concrete mix was designed as per Indian standard method by IS: 10262-1982

3.1 Design Stipulations

Grade of concrete = M40

The quantities of materials per cubic metre of concrete are summarised as below.

Table 2: Calculation of reference concrete mix

Cement (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Water (in litre)
438	666.18	1066.4	197.16
1.00	1.52	2.43	0.45

3.2 Optimum Dosage of Superplasticiser

Cement and water content of the reference mix (RMX) was reduced at a time simultaneously by 5%, 10%, & 15% at each stage, super plasticiser was added at 0.4%, 0.8%, and 1.2% by weight of cement. At each level of reduction of cement & water with addition of super plasticiser, workability & strength values were determined and compared.

There were one water reducers, three levels of cement reduction & three dosages of water reducers. Thus (1 x 3 x3 =) 9 mixes were made. The following tests were conducted on the reference mix. . Table 3 and Table 4 show mix details and quantities of materials used.

Table 3: Mix details

Mix	**Mix details**
SRA1	RMX – 5 % W & C+0.4 % SP
SRA2	RMX – 5 % W & C+0.8 % SP
SRA3	RMX – 5 % W & C+1.2 % SP
SRB1	RMX – 10 % W & C+0.4 % SP
SRB2	RMX – 10 % W & C+0.8 % SP
SRB3	RMX – 10 % W & C+1.2 % SP
SRC1	RMX – 15 % W & C+0.4 % SP
SRC2	RMX – 15 % W & C+0.8 % SP
SRC3	RMX – 15 % W & C+1.2 % SP

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Table 4: Quantity of Materials used per cubic metre of Concrete without fibres

Mix	C.AGG (kg)	F.AGG (kg)	Wt of cement (KG)	Wt of Water kg	W/C ratio	% Dosage of SP
RMX	1066.4	666.18	438	197.16	0.45	0
SRA1	1066.4	666.18	416.1	187.3	0.45	0.4
SRA2	1066.4	666.18	416.1	187.3	0.45	0.8
SRA3	1066.4	666.18	416.1	187.3	0.45	1.2
SRB1	1066.4	666.18	394.2	177.4	0.45	0.4
SRB2	1066.4	666.18	394.2	177.4	0.45	0.8
SRB3	1066.4	666.18	394.2	177.4	0.45	1.2
SRC1	1066.4	666.18	372.3	167.5	0.45	0.4
SRC2	1066.4	666.18	372.3	167.5	0.45	0.8
SRC3	1066.4	666.18	372.3	167.5	0.45	1.2

4. Test Results and Discussion

Tests were conducted on each mix to evaluate both workability and strength values.

4.1 Workability Tests

As seen from the table for workability the first reduction of cement and the water content was 5 % with increasing super plasticizer content at an interval 0.4 as we can see from the table that after the first reduction in cement water content there has been no slump in the mix on further increasing it to 0.8, a slump of 5 mm is observed on increasing further the slump was found to be shear. On further reduction of cement water content it is observed that there was a significant increase in slump at 0.4% of superplasticiser and it was increasing further with increase in super plasticizer content until it collapsed at 1.2% of dosage. On further reduction of cement water content and addition of superplasticiser at various dosages it was found that at 15% reduction of cement and water content and at 0.8% of dosage of superplasticiser there was a consistent mix with a slump of 100 mm which was suitable for the program.

Table 5: Workability test result

Cement	Fine aggregate	Coarse aggregate	Water
372.3	666.18	1066.4	167.5
1.00	1.79	2.87	0.45

4.2.Compressive Strength Test

It can be seen from the table that the compressive test results for RMX indicate the 7 days and 28 days strength of the reference mix. The objective was to select the mix with less amount of superplasticiser and less amount of cement content to produce an economic mix. So the mix which gives more strength than the reference mix and also has minimum superplasticiser and cement content was found to be at 15% reduction of cement content and 0.8% dosage of superplasticiser which satisfied both the conditions of minimum cement and minimum superplasticiser with compressive strength more than the reference mix. This dosage of superplasticiser is called as optimum dosage of superplasticiser and this mix was used throughout the experiment for fiber reinforced concrete. As a consequence of selecting this mix we would save about 66 kgs of cement per meter cube of concrete along with 29 liters of water.

Table 6.Compressive strength after 7 and 28 days curing

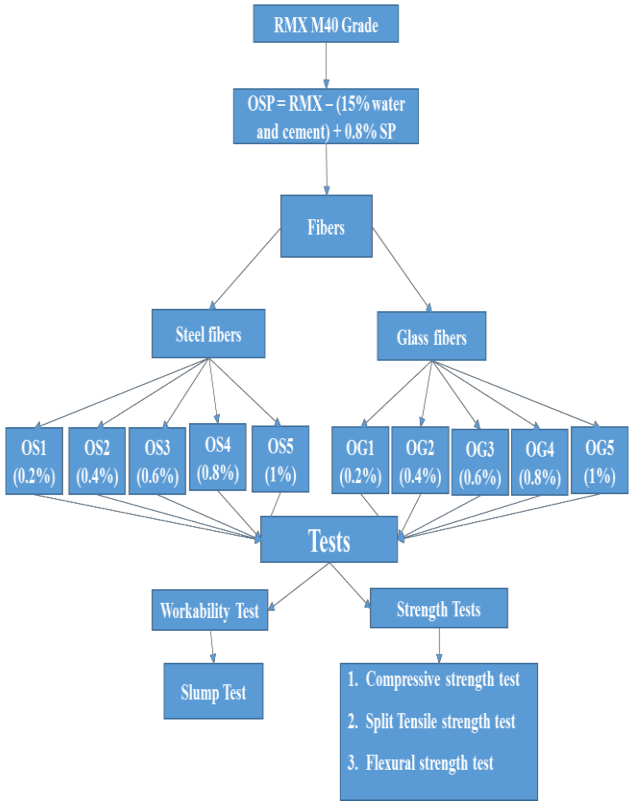
Mix	Compressive Strength (MPa)	
	7 days	28 days
RMX	29.5	43.3
SRA1	34.8	38.3
SRA2	35.0	39.9
SRA3	28.9	40.7
SRB1	34.7	43.0
SRB2	34.4	40.0
SRB3	35.0	39.3
SRC1	29.6	44.3
SRC2	35.4	46.2
SRC3	37.2	47.1

Table 7: Revised Mix ratio at 15 % simultaneous reduction of cement and water.

Mix	Wt of cement per m^3 of concrete	Wt of Water per m^3 of concrete	W/C ratio	% Dosage of SP	Slump(mm)
RMX	438	197.16	0.45	0	50
SRA1	416.1	187.3	0.45	0.4	--
SRA2	416.1	187.3	0.45	0.8	5
SRA3	416.1	187.3	0.45	1.2	Shear
SRB1	394.2	177.4	0.45	0.4	180
SRB2	394.2	177.4	0.45	0.8	200
SRB3	394.2	177.4	0.45	1.2	Collapse
SRC1	372.3	167.5	0.45	0.4	37
SRC2	372.3	167.5	0.45	0.8	110
SRC3	372.3	167.5	0.45	1.2	180

4.3. Experimental programme

The experimental programme has been divided into two phases, steel fibre and glass fibre. The flow chart depicts the series of activities to be followed in the program.



4.4. Mix and Specimen Preparation

All the ingredients were first mixed in dry condition in the concrete mixer machine for one minute. Then, 75 percent of

calculated amount of water was added to the dry mix and mixed thoroughly for one minute. At this stage, remaining 25 percentage of water mixed with super plasticizer was poured into the mixer and mixed for one minute. Later, required quantities of fibres were sprinkled over the concrete mix and mixer machine was allowed to rotate to get a uniform mix.

To prepare specimen for various mixes, the quantity of materials required and specimen details are presented in Tables 3.8 and 3.9 for various experimental works. The prepared concrete mix was poured in moulds (after applying oil inside the mould) in three layers and was vibrated using table vibrator for 1 minute. The same procedure was adopted for specimen preparation throughout this research work.

Table 8: Details of mix proportioning

Type	Mix	Proportions
Reference Mix	RMX	1:1.52:2.43:0.45
optimised SP + RMX	OSP	RMX + 0.8% OF SP
STEEL FIBRES	OS1	OSP +0.2% SF
	OS2	OSP +0.4% SF
	OS3	OSP +0.6% SF
	OS4	OSP +0.8% SF
	OS5	OSP +1% SF
GLASS FIBRES	OG1	OSP +0.2% GF
	OG2	OSP +0.4% GF
	OG3	OSP +0.6% GF
	OG4	OSP +0.8% GF
	OG5	OSP +1% GF

Table 9: Quantity of Materials used per cubic metre of Concrete

Type	Mix	Wt of Cement (Kg)	Fa /c	Ca /c	W /c	% SP	% Fiber	Density of fiber (T/cum)
Reference Mix	RMX	438	1.52	2.43	0.45	0	0	NA
optimised SP + RMX	OSP	372.3	1.79	2.86	0.45	0.8	0	NA
STEEL	OS	372.	1.7	2.8	0.4	0.	0.2	7.76

FIBRES	1	3	9	6	5	8		
	OS2	372.3	1.79	2.86	0.45	0.8	0.4	7.76
	OS3	372.3	1.79	2.86	0.45	0.8	0.6	7.76
	OS4	372.3	1.79	2.86	0.45	0.8	0.8	7.76
	OS5	372.3	1.79	2.86	0.45	0.8	1	7.76
GLASS FIBRES	OG1	372.3	1.79	2.86	0.45	0.8	0.2	2.6
	OG2	372.3	1.79	2.86	0.45	0.8	0.4	2.6
	OG3	372.3	1.79	2.86	0.45	0.8	0.6	2.6
	OG4	372.3	1.79	2.86	0.45	0.8	0.8	2.6
	OG5	372.3	1.79	2.86	0.45	0.8	1	2.6

Table 10: Specimen details

Test	Type of Specimen	Dimensions (mm)	No. of specimens
Compressive strength test after 7 and 28 days of curing	Cube	150 X 150	20 X 6 = 120
Split Tensile strength after 7 & 28 days of curing	Cylinder	150 X 300	11 X 6 = 66
Flexural strength test after 7 & 28 days of curing	Prism	500 X 100X100	11 X 6 = 66
		Total	232

4.5.Strength Tests

Tests were conducted on hardened concrete to find out workability, Compressive strength, Split tensile strength, Flexural strength as per the procedure given below.

Table 11: Slump values for fibres

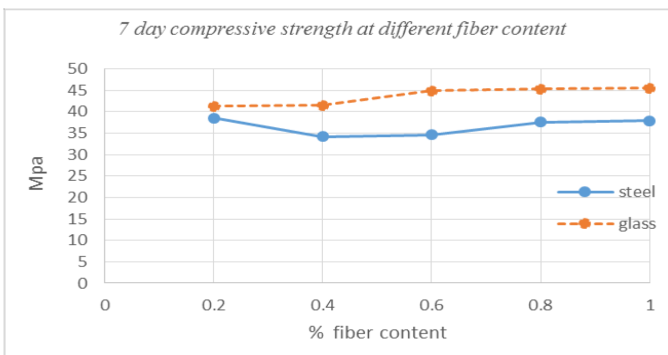
Mix	% SP	% of fibres	Slump mm	
			Glass fiber	steel fiber
RMX	0	0	110	110
1	0.8	0.2	70	100
2	0.8	0.4	40	50
3	0.8	0.6	10	30
4	0.8	0.8	0	10
5	0.8	1	0	5

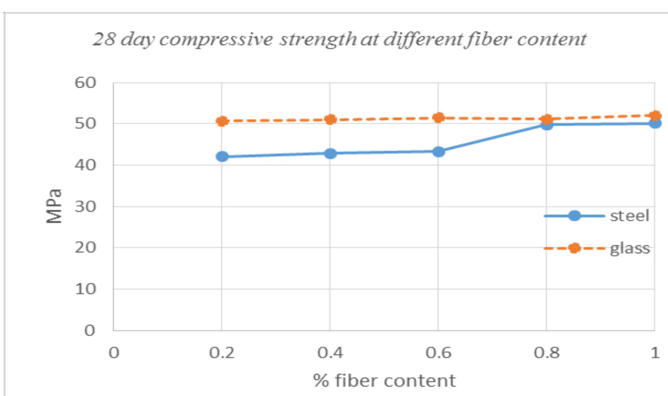
4.6.Compression Test

Compression test results are shown in the Tables below From compression test results, it is observed that on increasing volume of fibres, compressive strength was also increased.

Table 12.compressive strength in Mpa

%SP	%Fiber	Steel fiber		Glass fiber	
		7days	28 days	7days	28 days
0	0	29.4	43.31	29.48	43.3
0.8	0.2	38.52	42.12	41.3	50.7
0.8	0.4	34.21	42.86	41.5	51.0
0.8	0.6	34.72	43.35	44.9	51.4
0.8	0.8	37.63	49.83	45.3	51.1
0.8	1	37.91	50.12	45.5	52.0



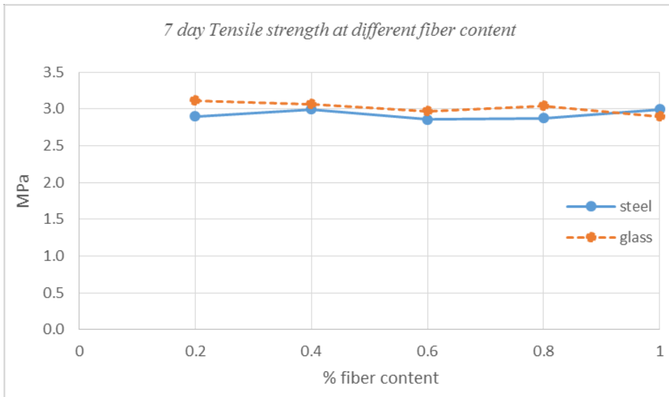


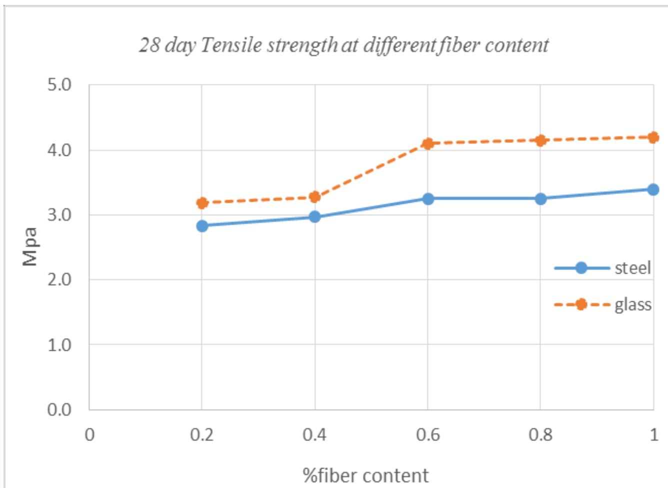
4.7.Split tensile test

Split tensile strength test on cylinders were conducted at the end of 7 and 28 days curing. Based on split tensile test results shown in Tables below and Figures.

Table 13.split tensile strength in Mpa

%SP	% Fiber	Steel fiber		Glass fiber	
		7days	28days	7days	28days
0	0	2.60	2.81	2.6	2.8
0.8	0.2	2.78	2.82	3.12	3.19
0.8	0.4	2.92	2.97	3.13	3.28
0.8	0.6	2.86	3.24	3.0	4.15
0.8	0.8	2.83	3.26	3.0	4.15
0.8	1	2.98	3.40	2.9	4.20

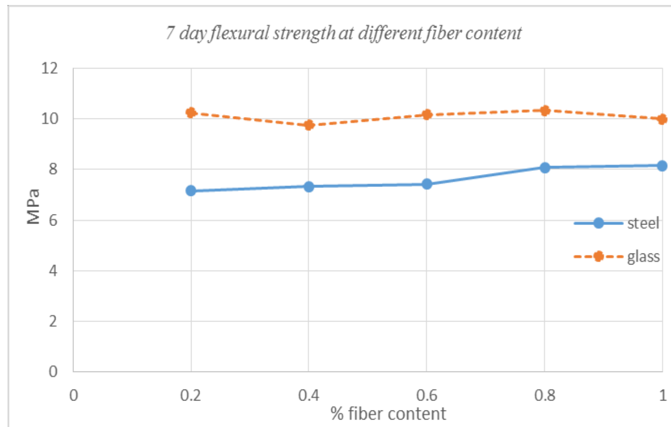


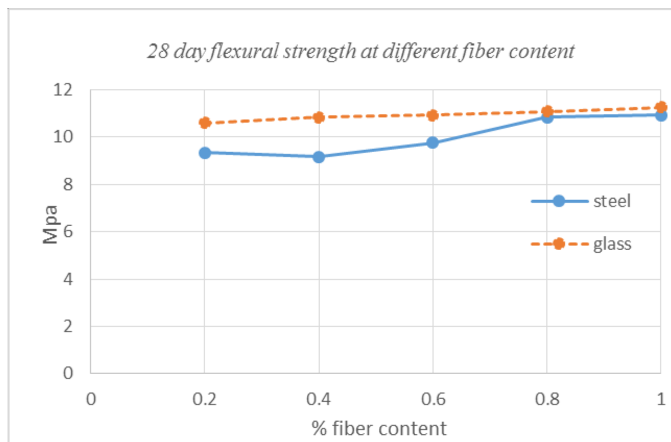


4.8.Flexural test

Flexural strength test under two-point loading was conducted at the end of 7 and28 days curing. Based on modulus of rupture or flexural strength test results shown in Table below.

Table 14.Flexural Strength in Mpa					
%SP	%Fiber	Steel fiber		Glass fiber	
		7days	28 days	7days	28 days
0	0	7.53	9	7.5	9
0.8	0.2	7.17	9.3	10.3	10.6
0.8	0.4	7.35	9.4	9.5	10.8
0.8	0.6	7.42	9.8	10.2	10.9
0.8	0.8	8.08	10.8	10.3	11.1
0.8	1	8.19	10.9	10.4	11.3





5. Conclusions

1. Because of the re-proportioned mix ratio obtained by simultaneous reduction of cement and water content, about 66 kg of cement could be saved per cubic metre of concrete. It has been understood that is possible to achieve same strength and workability characteristics with reduction in cement and water content by 15% with the help of super plasticizers and fibres.

2. Super plasticizer increases workability of concrete. The slump value of mixes containing super plasticizer is more than that of normal concrete. While adding fibres with concrete mixes, workability of concrete decreases with increase in the volume of fibres from 0.2% to 1%.

3. The early age compressive and flexure strength (7 day strength) for glass fibres reinforced concrete is observed to be higher than that of steel fibres but it was found to be almost equal after 28 days of curing which indicates that in long term both the concrete mixes perform equally good in compression and flexure

4. The tensile strength of both the mixes at 7 days strength were found to be almost equal but as the days of curing increases the tensile strength of glass fibre reinforced concrete is found to be much higher than that of steel fibre especially at higher fibre contents that is from 0.6% onwards

5. It is seen that there is an optimum fibre content beyond which the increase in strength properties with increase in fibre content is not possible.

6. The workability of steel fibre reinforced concrete is seen to be more than glass fibre reinforced concrete for same fibre content. The increase in super plasticizer content at high water content resulted in higher setting time of the mix and also collapse slump.

7. The effect of balling of fibres at higher fibre contents have also been discussed. Proper dispersion of fibres at the time of mixing can ensure to avoid balling effect and proper mixing time before the introduction of fibres ensures the required workability of the mix.

5.1 Precaution to be taken while using Steel Fibres

During mixing, placing and finishing of steel fibres with other constituents of concrete, there are many chances for the workers to get wounding in the palm of the hand. Hence operations are to be carried out with utmost care. Generally steel fibres are found in many applications. While using steel fibres for laying air field pavements, some steel fibres may be projected upwards if finishing of pavements is poor and this may cause problems in the tyres of the airplane. Hence it requires skilled work for proper laying. It will not be suitable for the construction hydraulic structures due to rust of steel fibres and concrete construction in chemical industries where chloride exists.

5.2 Scope for Future Research

1. The cement and water content of the reference mix can be further reduced with proportionate increase in super plasticizer content and the behaviour can be studied.

2. Other types of fibres also can be used in the mix and their performance can be compared with each other to create a suitable mix for the required condition.

3. The experimental procedure can be repeated on different grades of concrete and the behaviour of high strength concretes can be studied.

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