An Experimental Study on Polypropylene Fibre as Partial Replacement of Cement in Self Compacting Concrete

A.Venkateshu,
Post Graduate Student,
Department of Civil Engineering, BITS,
VIZAG, Andhra Pradesh, India.

Dr. N. Victor Babu
Professor,
Department of Civil Engineering BITS,
VIZAG, Andhra Pradesh, India.

***Abstract*— Self compacting concrete (SCC) is the concrete that is able to flow under that is able to flow in the interior of the form work, filling it in a natural manner and passing through the reinforcing bars and other obstacles ,flowing and consolidating under the action of its own weight .These properties enable the SCC to be an excellent material for constructions with complicated shapes and congested reinforcement .One of the main advantages in using SCC is the minimization of skilled labour needed for placing and finishing the concrete. All these benefits decrease the costs and reduce the time of the building process over constructions made from traditionally vibrated concrete. However, hardened self compacting concrete is still as brittle as normal concrete and has a poor resistance to crack growth. To improve the post –peak parameters of SCC ,polypropylene (Recron fibers) are added.**

As self compacting concrete offers several economic and technical and benefits the use of polypropylene, polyester and glass fibers extends its possibilities .Polypropylene fibers bridge cracks ,retard their propagation and improve several characteristics and properties of the SCC .The purpose of thesis is to investigate the effects of weight fraction of polypropylene on the compressive strength, split tensile strength and modulus of elasticity of polypropylene fibers reinforced self compacting concrete .For this purpose, Recronfibers where used .Four different fiber volumes were added to concrete mixes at 0.1,0.2,0.3 and 0.4 percent by weight of cement .Four different mixes were prepared .After 28 days of curing ,compressive strength ,split tensile strength and modulus of elasticity were determined. It was found that, inclusion of polypropylene fibers significantly affects the compressive strength, split tensile strength and modulus of elasticity of self-compacting concrete.

Keywords*— Recronfibers; formatting; self compacting; hardened.

I. INTRODUCTION

Concrete is an artificial stone and its excellence resistance to compression resembles the properties of natural stone. It is a pseudo fluid for a part of its early age. It's Strength and other properties can be regulated to some extent during its manufacture. The key to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. The quality of the paste determines the character of the concrete. The strength of the paste, in turn, depends on the ratio of water to cement. The water-cement ratio is the weight of the mixing water divided by the weight of the cement.

A mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is not cost effective and can more easily crack. A properly designed mixture possesses the desired workability for the fresh concrete and the required durability and strength for the hardened concrete.

The durability of concrete is ability to withstand the environmental conditions to which it is exposed. Main requirements of durability are:

- An upper limit to the w/c ratio without lowering flow
- Good compaction with a lower limit of cement content

When large quantities of heavy reinforcement is to be placed in a member it is difficult to ensure that the formwork gets completely filled by concrete without voids or honeycombs. Compaction by mechanical vibrator is very difficult in this situation. Such problems can be avoided using self-compacting concrete.
Self-compacting concrete describes a concrete with ability to compact itself by means of it weight without requirement of vibration. It is placed in the same way as ordinary concrete without vibration. It is very fluid and can pass through passed around obstructions and fill all round and corners of the structure which saves labour time and energy. It gives placement efficiency of 300% and labour can be reduced by 70%. The guiding principle involved in this self-compacting concrete is that sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists.

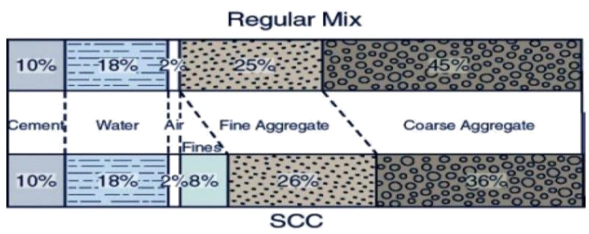

Fig. 1. Regular Mix Vs SSC

ISSN No: - 2456 - 2165

SSC allows easier pumping, flows into complex shapes, minimizes voids to produce a high degree of homogeneity and uniformity. Hence SCC allows for denser reinforcement, optimized sections. Two important properties specific to SCC in its plastic state are its flow ability and stability. The high flow ability of SCC is generally attained by using high range water reducing (HRWR) admixtures and not by adding extra mixing water. The stability or resistance to segregation of the plastic concrete mixture is attained by increasing the total quantity of fines in the concrete and/or by using admixtures that modify the viscosity of the mixture. Increased fines contents can be achieved by increasing the content of cementitious materials or by incorporating mineral fines. Control of aggregate moisture content is also critical to producing a good mixture. SCC mixtures typically have a higher paste volume, less coarse aggregate, and higher sand to coarse aggregate ratio than typical concrete mixtures.

POLYPROPYLEN FIBER

Polypropylene (PP) is a versatile thermoplastic material, which is produced byPolymerizing monomer units of polypropylene molecules into very long polymermolecules or chains in the presence of a catalyst under carefully, controlled heat and pressure. Propylene is an unsaturated hydrocarbon, containing only carbon and hydrogen atoms

CH2=CH
|
CH3
(Propylene)

There are many ways of polymerization of the monomer units, but PP as aCommercially used material in its most widely used form is produced with catalysts that produce crystallizable polymer chains. Propylene molecules add to the polymer chain only in a particular orientation, depending on the chemical and crystal structure of the catalyst, and a regular, repeating three-dimensional structure is produced in the polymer chain. Propylene molecules are added to the main polymer chain, increasing the chain length.Polypropylene is one of the fastest growing classes of commodity thermoplastics,with a market share growth of 6-7% per year and the volume of polypropylene produced is exceeded only by polyethylene and polyvinyl chloride. The moderate cost and favorable properties of polypropylene contribute to its strong growth rate. Polypropylene is one of the lightest of all thermoplastics (0.9 g/cc).

Polypropylene Fibers in Concrete:

Plain concrete possess a very low tensile strength, limited ductility and little resistance 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, eventually leading to brittle fracture of the concrete. Although every type of fibre has been tried out in concrete not all of them can be effectively and economically used. Steel fibre is the one of the most commonly used fibre which improves flexural impact and fatigue strength of concrete. Polypropylene is good and increasing impact strength unlike that of flexural strength. Carbon fibres makes the concrete high modulus of elasticity and flexural strength.

Manufacture of Polypropylene Fibers:

The commercial production of polypropylene started in 1960s, where low price polymer was converted into useful textile fiber. Polypropylene fibers then became available in two forms monofilaments (or spinneret) fibers and film fiber .Extrusion of synthetic polymers into fibers by spinneret was used to produce polypropylene fibers which are normally circular in cross-section and are used in many textile and carpet end uses.

There is another process of film extrusion, which is more economical and particularly suited for the processing of isotactic polypropylene. In this process, the extruder is fitted with a die to produce a tubular or flat film which is then slit into tapes, and monoaxially stretched. The ‘draw ratio's a measure of the extension which is applied to the fiber during fabrication and draw ratios of about 8 are common for polypropylene film. Having achieved the production of films with adequate properties, their use in concrete is made possible by fibrillation which is the creation of longitudinal splits and can be controlled by the use of carefully designed pin systems on rollers over which the stretched films are led.

When these fibers are added to the concrete during mixing cycle, the mixing action opens the bundles and separates the individual fibers. This type is available in fiber lengths from 12 mm to 50 mm.

Bond between Polypropylene Fibers and Concrete Matrix:

The efficiency of fiber reinforcement depends not only on the mechanical properties of the fibers but also on the bond at the interface between the fibers and the concrete matrix. In terms of physiochemical adhesion, there is no bond between polypropylene fibers and the cement gel, because this type of fiber is chemically inert. Several methods have been tried to improve the bond between the polypropylene fibers and the concrete; one of the ways is to treat the fiber surface. By this approach, quite remarkable improvement has been obtained in the fiber-matrix bond. Another way is by improving the mechanical bond, namely, adding end buttons to the fibers or twisting them. By this method, the bond of polypropylene fibers with concrete has improved from a value of about 0.55 MN/rn2 (80 psi) to a value of about 3.45 MN/m2 (500 psi).

In general, the bond between the fiber and the concrete depends on the length, geometry, surface and the modulus of elasticity of the fiber.

II. PROPERTIES OF POLYPROPYLENE FIBER

Physical properties:

a. Density : 0.91 gm/c.c
b. Elasticity : very good
c. Moisture regain: 0%
d. Resiliency: good
e. Melting point : 170ºC
f. Ability to protest friction: good
g. Color : white
h. Luster : bright to light

Mechanical properties**:**

a. Tensile strength : 25-30 Mpa
b. Flexural Modulus : 1.2-1.5 Gpa
c. Elongation at break : 150-300%
d. Strain at yield : 10-12%

Chemical properties:

a. **Acids** : Acid does not affect on polypropylene fiber. It has excellent protesting ability against acids

b. **Base** : Base also does not affest on polypropylene fiber.
c. Effect of bleaching : It has enough ability to prevent the harmful action of bleaching agent under 65ºC.
d. **Organic solvent** : Organic solvent does not cause harm to polypropylene fiber during action.
e. **Protection ability against light** : It losses energy by sunlight.
f. **Protection ability against insects** : It does not affected by insects.
g. **Dyes** : Difficult to dye polypropylene fiber because its moisture regain is 0%

Recron3S fibres:

Concrete is widely recognized as a cost-effective, versatile construction material. Yet it is also best with a number of drawbacks that are inherent to its composition. By generally accepted engineering standards, concrete is relatively brittle and lacks flexural strength. Intertwined with these problems is concrete's propensity to crack in both its plastic (early-age) and hardened (long-term) state. Early-age cracks are microscopic fissures caused by the intrinsic stresses created when the concrete settles and shrinks over the first 24 hours after being placed. Long-term cracking is in part caused by the shrinkage that transpires over the months, perhaps years, of drying that follow. In either case, these cracks can jeopardize the overall integrity of the concrete and not allow it to maintain – or possibly ever attain – its maximum performance capability.

Recron3S Fibre Reinforcement Systems can provide a solution to Recron fibres are engineered micro fibres with a unique "triangular" cross-section, used in secondary reinforcement of concrete. It complements structural steel in enhancing concrete's resistance to shrinkage cracking and improves mechanical properties such as flexural/split tensile and transverse strengths of concrete along with the desired improvement in abrasion and impact strengths.

III. NECESSITY OF THE WORK

For several years the problem of durability was a major topic of interest. One solution to overcome this problem is to switch over ordinary concreting methods to self-compaction concrete which can be compacted to every corner of formwork without the means of vibrator.

IV. OBJECTIVE OF PRESENT WORK

The main objective of present work is to systematically study the workability, strength of concrete by replacing the cement with different percent's of Recron fibres by weight and Combined effects on strength of concrete.

V. METHODOLOGY

Self-compacting concrete is the current research area today. The present study is utilization of Portland Slag cement with chemical admixtures. Therefore an attempt was made to investigate the mechanical properties of self-compacting using the Portland Slag Cement and adding various percentages of Recron Polypropylene fibre. Each category of mix contains 4 mixes like PP01, PP02, PP03, and PP04.

The essential components of SCC is super plasticizer. It is to be ensuring that dosage is sufficient to make the concrete flow under its own weight. Several trial mixes were conducted to determine the optimum dosage of SP in order to achieve the required properties. Fresh concrete properties were investigated and hardened concrete tests such as compressive strength for cube on 150×150×150 in mm, and split tensile strength for cylinders of size 150×300 mm were casted and tested for 7, 14 and 28 days.

The following specimens were casted for hardened concrete tests:

Number of cubes casted for compressive strength tests = 30 samples

Number of cylinders casted for split tensile strength and Young's modulus tests = 30 samples

Total number of samples = 60 samples

VI. LITERATURE REVIEW

Javed and Shahzad (2006) studied the shear capacity of concrete increases when fibres are added. There is a remarkable increase in load carrying capacity up to first crack appears The addition of Polypropylene fibres at low values actually increases the 28 days compressive strength but when the volumes get higher than the compressive strength decreases from original by 3 to 5%. The tensile strength increases about 65%~70% % up to 0.40% after which it decreases. There is about 80% increase in flexure strength by adding 0.20% fibres in concrete after which strength starts reducing with further increment in fibre ratios. The shrinkage cracking is reduced by 83 to 85% by addition of fibres up to 0.35% and 0.50 %.

Shah and Modhere,(2009) studied the Influence of Steel and Polyester Fibres in the Self-Compacting Concrete.It was observed that there were no problems in mixing of SCC with 0.5% hooked end steel fibres and 0.1% polyester fibres. The fibres distribution was uniform. However, SCSFRC mix exceeded the upper limits suggested by EFNARC. All mixtures had a good flow ability and possessed self-compact ability characteristics. In conclusion, the fibre length, geometry and dosage play an important role in SCC. In hardened state, polyester fibres did not increased strengths much but reduce micro cracks, and crack propagations. SCC with hooked end steel fibres increased compressive strength 25 %, tensile strength 40% and flexural strength 65 % at 28 days. To use the advantages of SCFRC efficiently, all parameters affecting the properties of concrete in respect of the production and the durability of concrete structures should exactly be known. In this way SCFRC can be designed optimally. Finally, it was found that a considerable amount of fibres allowed in self-compacting concrete.

Indrajit and Modhera(2011) studied the effect of polyester fibres on engineering properties of high volume fly ash concrete as The compressive strength gaining is comparatively slower at 3 and 7 days for all mix particularly for high 60% of fly ash and higher mix M35 and M40. Targeted values at 7 days for plain HVFA concrete is of the 72% to 78% which is as better as normal concrete without fly ash. Beyond 7 days the increase in strength is of order 65 to 76% and all mix shows satisfactory values at age of 28 days. Inclusion of fibre at the rate of 0.25% by mass of the cementitious material does not have much effect on the w/c ratio and 60 min. slump values as well. For higher proportion of cementing material in higher concrete grade the dosage of plasticizer was increased to 1.00% to achieve desired slump and workability. Increase in compressive strength at 7 days age for all mix with fibre varies between 7.00 to 9.50% Increase in 28 days compressive strength as compared to plain HVFA concrete is of the order 9.75 to 15 %. All sample shows required flexural strength at 14, 28 and 56 days age. Increase in strength between 14 to 28 days is of order 22 to 30% and 28 to 56 days is 7.50 to 13.5%. 55% cement replacement shows optimum gain of compressive and flexural strength for all grade of plain and fibre reinforced HVFA concrete.

Jyoti Narwal et. al. (2013) proved this theory by similar values from the ultrasonic pulse velocity test. It is seen from the results the cubes and beams having 1% fibre mix is showing surface temperature lower than the specimens with 0.5% and 0% fibre. It can be concluded that, as the percentage of fibre increases the specimen can handle high temperature and stays cool compared to the 0% fibre specimens. The present study was undertaken to investigate the behaviour of steel fibrous reinforced concrete beams with conventional longitudinal reinforcement and shear reinforcement. The optimum fibre volume percentage for all the series was obtained as 1.5%. The further increase in fibre content reduced the load carrying capacity of the specimens. With addition of steel fibres in concrete mix of the specimens the appearance of first crack was delayed. The presence of steel fibres also improved the post cracking behaviour of the specimens of all the series due to crack arresting phenomenon.

Murahari and Rama mohan (2013) studied the effects of Polypropylene fibers on the strength properties of fly ash based concrete, Compressive strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in compressive strength as compared with normal plain concrete (without fibers) Splitting tensile strength of concrete increases gradually by addition of Polypropylene fiber from 0.15% to 0.30%. There is increase in splitting tensile strength as compared with normal plain concrete (without fibers). Flexural test of concrete gradually increases with the addition of Polypropylene fiber. There is increase in Flexural test as compared with normal plain concrete (without fibers).

VII. CONCRETE MIX DESIGN

In this experiment the mix was designed using Nan-Su method. In this method first the amount of aggregates required is determined and the paste of binders is then filled into the voids of aggregates to ensure that the concrete thus obtained has flow ability. The principle consideration of the proposed method is to fill the paste of binders into voids of the aggregate frame work piled loosely.

The following are the various steps involved in the design process of mix.

Step 1: Calculation of Coarse and Fine aggregate contents;

The content of coarse aggregate is obtained as $W_g = PF \times W_{gl} \times \left(1 - \frac{s}{a}\right)$

The content of fine aggregate is obtained as $W_s = PF \times W_{gl} \times \left(\frac{s}{a}\right)$

Where
Wg = content of coarse aggregate in kg/m^3

Wgl = unit weight of loose packed coarse aggregates in kg/m^3
Wsl = unit weight of loose packed fine aggregate in kg/m^3
S/a = volume of ratio of fine aggregates to total aggregates PF = Packing factor

Step 2: Determine the cement content;
Assuming each kg of cement provide a strength of 20 psi for SCC Cement needed per unit volume of concrete =C= target strength/20 kgs

Step 3: Determine the mixing water content required by cement;
Assuming water- cement ratio, Wwc = weight of cement * water-cement ratio

Step 4: Determine the dosage of SP;
Assuming the dosage of SP as percent by weight of cement, the weight of dosage is WSP = weight of cement * percent of dosage of SP

Assume PF= 1.2 and S/a = 0.54,
Loose bulk density of soil is 1508 kg/m^3 and coarse aggregate is 1435 kg/m^3

On substitution, $W_g = PF \times W_{gl} \times \left(1 - \frac{s}{a}\right)$

= 1.2* 1435*(1-0.54) = 792.98 kg

$W_s = PF \times W_{gl} \times \left(\frac{s}{a}\right)$

=1.2*1508*0.54 = 975.15 kg

TABLE I. 1m^3 concrete mix proportions are:

Cement	:	495 kg
Coarse aggregate	:	792.98 kg
Fine aggregate	:	975.15 kg
Water	:	158.4 kg
SP	:	3.96 kg

Hence the ratio is given as

Cement: CA: FA: Water: SP = 1:1.602:1.97:0.32:0.008

VIII. RESULTS & DISCUSSIONS

Compressive Strength of concrete: The cubes are casted with different percentages of Polypropylene and the same are tested in compression testing machine. The strength values of cubes with various percentages are shown in table below.

TABLE II. Compressive Strength of concrete

S.No	Sample Designation	% of Polypropylene	7 days strength Mpa	14 days strength Mpa	28 days strength Mpa
1	PP00	0	41.63	45.21	55.56
2	PP01	0.1	34.444	44.44	48.41
3	PP02	0.2	28.222	34.44	38
4	PP03	0.3	26	26.889	30.222
5	PP04	0.4	32	37.556	38.92

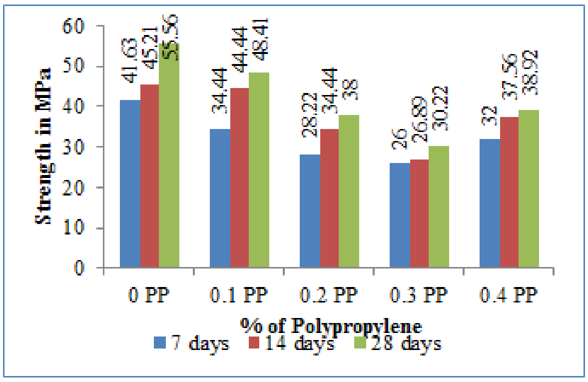

Fig.2. Compressive Strength Variation with % of Polypropylene

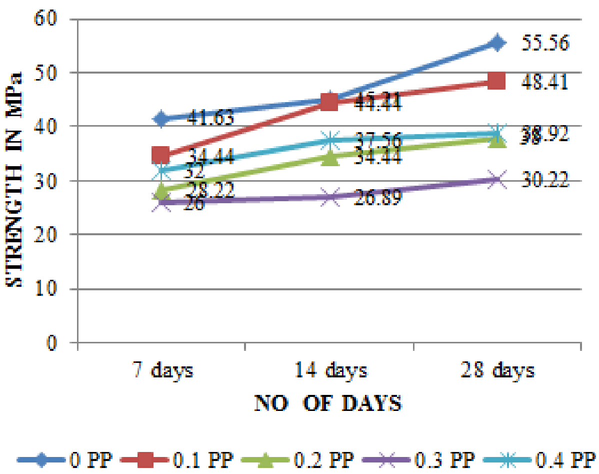

Fig.3. Compressive Strength Variation with No of Days

Split tensile strength of concrete: The split tensile strength values with various percentages are shown in tables below

TABLE III. Split tensile strength values

S.No	Sample Designation	% of Polypropylene	7 days strength Mpa	14 days strength Mpa	28 days strength Mpa
1	PP00	0	2.203	2.312	2.825
2	PP01	0.1	2.934	3.005	3.25
3	PP02	0.2	1.98	2.051	3.04
4	PP03	0.3	1.909	2.687	3.32
5	PP04	0.4	2.121	2.581	3.53

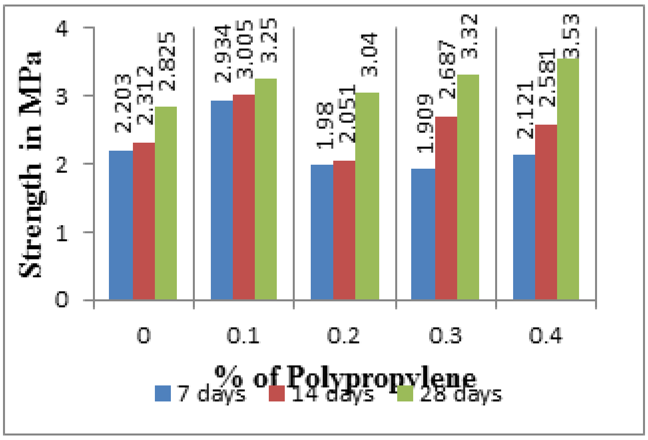

Fig.4. Split tensile Strength Variation with % of Polypropylene

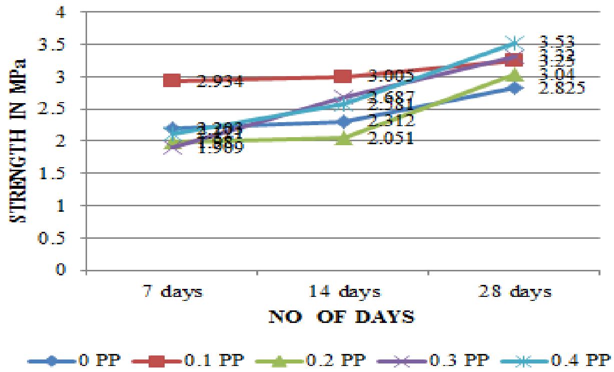

Fig.5. Compressive Strength Variation with No of Days

IX. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions can be drawn according to the results of the study

Compressive strength:

- As the percentage increases from 0 to 0.4% the strength was reduced from 55.56Mpa to 30.22 Mpa (i.e. by 45.6%) up to 0.3% of polypropylene.
- But there was sudden increase in strength value of 39Mpa was observed at 0.4% Polypropylene

- Also the percentage of increase of the strength from 7 days to 28 days at all percentage was gradually reduced up to 0.3% Polypropylene but sudden increase in 0.4%

Split tensile strength:

- The strength of concrete was increased by 15%, 7%,17.5% and 24.9% at dosage of 0.1%, 0.2%, 0.3% and 0.40% of fibre respectively.
- The rate of increase in percentages of strength was reducing up to 0.2% of Polypropylene, but thereafter rate was increased.
- Of the above percentages of Polypropylene, maximum value of strength is obtained at 0.4% Polypropylene

Elastic modulus of concrete:

- The elastic modulus of concrete was marginally reduced by increasing percentage of Polypropylene and also the variation was non uniform.
- But the elastic modulus has its maximum value at 0.0% of Polypropylene having value of 25727.7 Mpa
- Among the different percentages of Polypropylene 0.2% has maximum value of 25371.5Mpa

Recommendations:

- Studies on creep and shrinkage properties may be carried out
- Studies on type and quantity of super plasticizer used, in order to achieve workability properties.

REFERENCES

1. C. Selin Ravikumar and T.S. Thandavamoorthy "*Glass Fibre Concrete: Investigation on Strength and Fire Resistant Properties*" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 9, Issue 3 (Sep. - Oct. 2013), PP 21-25

2. Shrikant M. Harle *"Review on the Performance of Glass Fiber Reinforced Concrete"*

3. Civil Engineering Department, Prof. Ram Meghe College of Engineering and Management, Amravati, Maharashtra. ISSN 2278-3652 Volume 5, Number 3 (2014), pp. 281-284

4. Mohammed Karem Abd Technical Institute-Babylon, Lecturer Evaluation Of Using Glass Fiber On Properties Of Self-Compacting Concrete, Journal of Kerbala University , Vol. 11 No.1 Scientific . 2013

5. Kolli.Ramujee "*Strength* properties *of polypropylene fibre reinforced concrete"*

6. International Journal of Innovative Research in Science, Engineering and Technology. Vol.2, Issue 8, August 2013.

7. Hajime Okamura and Masahiro Ouchi "*Self-compacting concrete*" Journal of

8. Advanced Concrete Technology Vol. 1,No. 1,5-15, April 2003

9. Nan Su, Kung-Chung Hsu, His-Wen Chai "*A simple mix design method for self-compacting concrete"* National Yunlin University of Science and Technology, Department of Civil Engineering, Nanya Institute of Technology. Cement and Concrete Research 31 (2001) 1799-1807.

10. Indrajit Patel, C D Modhera "*Study effect of polyester fibres on engineering properties of high volume fly ash concrete"* Applied Mechanics Department, B & B Institute of Technology, Vallabh Vidya Nagar, Gujarat. Journal of Engineering Research and Studies E-ISSN 0976-7916

11. Dr. Vagheesha S. Mathda, Ms. Hemali K. Khaire, "*Study of Effects of Polyester Fibers on Compressive Strength of Concrete*" International Journal for Research in Applied

12. Science and Engineering Technology, Volume 4 Issue I, January 2016, ISSN: 2321-9653.

IS CODES:

1. IS 455:1969- Specification for Portland cement (fourth version)

2. IS 2386(Part I):1963- Specification for method of test for aggregates for concrete. Part I particle size and shape. Reaffirmed 1997

3. IS 383:1970- Specifications for coarse and fine aggregate from natural sources for concrete Reaffirmed 1997

4. IS 516:1959- Specifications for methods of test for strength of concrete

5. IS 269:2013- Specification for ordinary Portland cement 33 grade

6. IS 460(part 1)-1985- Specification for test sieves

7. IS 456-2000-Plain and reinforced concrete code of practice

8. IS 10262:2009-Specification for concrete mix proportioning (guide lines)