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EFFECT OF FLY ASH IN SELF-COMPACTING CONCRETE USING GLASS FIBERS

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Abstract— **In this article, attempt has been made to improve the performance of self compacting concrete using fly ash and glass fiber. Self compacting concrete was first developed in 1988 to achieve durable concrete structures. Since then, various investigations have been carried out and this type of concrete has been used in practical structures in Japan, mainly by large construction companies. SCC can also be used in situation where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or wall with congested reinforcement. Self compacting concrete has significant environmental advantages in compaction to the vibrated concrete. The self compacting concrete must meet the filling ability and passing ability with uniform composition throughout the process of transport and placing. Hence, Self compacting concrete demands large amount of powder (cementitious and pozzolanic materials) content and fines for its cohesiveness and ability to flow without bleeding and segregation. In this present investigation, part of the cementitious material is replaced with pozzolanic material fly ash, and the properties of self compacting concrete in fresh and hardened states were studied. The increase of the percentage of the fly ash influences the bleeding and segregation in SCC. Hence, the addition of glass fibres can improve ductility, post crack resistance, energy absorption capacity and bleeding resistance. Taking these advantages into account a study was done. The various properties of the materials to be used in the experimental programme were determined. The specification of glass fibers and the advantages of using them along with concrete were studied. A detailed review of literature on glass fiber reinforced concrete was also done. The fresh and hardened properties of Self Compacting Concrete (SCC) using fly ash with glass fibers were evaluated. The aggregates were kept constant for all concrete mixtures. The SCC mixtures were prepared with 0% up to 100% of fly ash and maximum 0.05% of glass fibers. The strength test namely, Compressive Strength Test, Split Tensile Strength Test and Flexural Strength Test are carried out in this investigation. To test the characteristics of self compacting concrete, Slump cone test, J – ring test, L – box test were conducted to test the characteristic of self compacting concrete.**

Keywords: Self Compacting Concrete, Fly Ash, Glass Fiber, Fresh Properties, Mechanical Strength

I. INTRODUCTION

Usage of self compacting concrete has become very widely present and varied in recent years. Self compacting concrete is such that after casting into the formwork does not require vibrating. The filling ability and stability of self compacting concrete in the fresh state can be defined by four characteristics: flow ability, viscosity, passing ability and segregation resistance. The concrete mixture will be classified as a self compacting one, if all the mentioned characteristics are present [1-2].

Supplementary cementitious materials are used to improve a particular concrete property, such as resistance to alkali-aggregate reactivity. The optimum amount to use should be established by testing to determine (1) whether the material is indeed improving the property, and (2) the correct dosage rate, as an overdose or under dose can be harmful or not to achieve the desired effect. Supplementary cementitious materials also react differently with different cement.

Self compacting concrete requires a high slump that can easily be achieved by superplasticizer addition to a concrete mixture. To avoid segregation on superplasticizer addition, a simple approach consists of increasing the sand content at the cost of the coarse aggregate content by 4% to 5% [5, 6]. But the reduction in aggregate content results in using a high volume of cement which, in turn, leads to a higher temperature rise and an increased cost. An alternative approach consists of incorporating a viscosity modifying admixture to enhance stability [7].

Use of fly ash and blast furnace slag in SCC reduces the dosage of superplasticizer needed to obtain similar slump flow compared to concrete made with Portland cement only [8]. Also, the use of fly ash improves rheological properties and reduces cracking of concrete due to heat of hydration of the cement [9]. Properties of super flowing concrete containing fly ash and reported that the replacement of cement by 30% of fly ash resulted in excellent workability and flow ability.

In the 1980s CANMET designed the so-called high volume fly ash (HVFA) concrete. In this concrete 55-60% of the Portland cement is replaced by Class F fly ash and this concrete demonstrated excellent mechanical and durability properties [10-12]. In order to extend the general concept of HVFA concrete and its applications to a wider range of infrastructure construction, In this article outlines the preliminary results of a research project aimed at producing and evaluating SCC incorporating high volumes of fly ash.

Fibres are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Fibre reinforced concrete is relatively a new construction materials developed through extensive research and development work during the last two decades. Incorporation of fiber in concrete has found to improve several properties like tensile strength, cracking resistance, ductility, impact and wear resistance and fatigue resistance [13].

Many fibers like steel, polypropylene, glass, asbestos, nylon, coir, etc have been used in the past. Out of these asbestos fibers concrete is successful although its exposure is detrimental to the health of human beings. Steel fibers improve ductility, flexural strength and toughness. Corrosion damage and increased density are the drawbacks of the steel fibers. The initial studies showed deterioration of glass fibers due to corrosive alkali environment of the cement paste. The alkali resistant glass fiber, which is developed, recently has overcome this defect and can be effectively used in concrete.

The aim of this work was to check the possibility of preparing self compacting concrete by using fly ash instead of cement and also studies the properties of SCC by adding Glass Fibers. From the above literature thoroughly studied and it is found that split tensile strength and strength of concrete value is equal to normal concrete when the recycled coarse aggregate is replaced up to 50% and eco sand is replaced up to 30% of natural river sand. In this study the split tensile strength and concrete strength improving methods by using fly ash and glass fibers in self compacting concrete is introduced.

II. RESEARCH SIGNIFICANCE

The main objective of the present investigation was study the strength of self compacting concrete over a wide range of concrete strengths with varying dosages of fly ash. In this research investigates the making of SCC more affordable for the construction market by replacing high volumes of Portland cement by fly ash. High volume of mineral powder is a necessity for a proper SCC design. In this study, mechanical properties of SCC, incorporating 0% to 100% of Class F fly ash, as a cement replacement have been investigated. For a newly development material like glass fiber self compacting concrete studies on slabs under flexure. The literature indicate that while some studies on flexure behavior of steel fiber reinforced concrete slabs are available on normal concrete, a comprehension study which involve flexure behavior of glass fiber reinforced self compacting concrete are not available. Hence, considering the gap in the existing literature, an attempt has been made to study flexural behavior of glass fiber reinforced self compacting concrete.

III EXPERIMENTAL STUDY

a.Materials

Portland Cement

Ordinary Portland Cement (OPC) of 53 grades conforms to the Bureau of India standard specifications with specific gravity 3.14. The compressive strength of cement obtained at 28 days is 53MPa. The chemical composition of cement is reported in Table 1.

Table 1 Chemical Composition of Ordinary Portland Cement

Characteristics	Percentage
$SiO_2+Al_2O_3+Fe_2O_3$	30.90
CaO	62.75
MgO	0.4
SO_3	2.5
Na_2O	1.3
Loss of ignition	2.12

b.Natural Coarse Aggregate

The natural coarse aggregate, obtained from the locally available quarries with size in between 10mm to 12mm satisfy the grading requirements of BIS. The specific gravity of 2.67 and fineness modulus 5.51 was used.

c.Natural Fine Aggregate

The natural fine an aggregate, obtained from the local river is passed through 4.75 IS sieve. Fine aggregates shall be such that not more than 5 percent shall exceed 5mm in size, not more than 10% shall pass IS sieve No.150, not less than 45% or more than 85% shall pass IS sieve No.1.18mm and not less than 25% or more than 60% shall pass IS sieve No.600 micron. Properties of natural fine and coarse aggregates were arrived and listed in Table 2.

Table 2 Properties of fine and coarse aggregates

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.62	2.67
Fineness modulus	2.80	5.51
Bulk Density (Kg/m^3)	2620	2670

d.Fly Ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electric precipitator. Fly ash is the most widely used pozzolanic material all over world. ASTM broadly classifies fly ash into two classes, that are, Class F and Class C. In this study Class F fly ash is used.

The fly ash meets the general requirements of ASTM Class F fly ash that has relatively high CaO content of 8.70% and alkali content (Na_2O equivalent) of 0.60% and the specific gravity is 2.1. The chemical composition and physical composition of fly ash used in this study is given in Table 3 and 4.

Table 3 CHEMICAL COMPOSITION

Chemical compound	Class F fly ash
SiO_2	54.90%
Al_2O_3	25.80%
Fe_2O_3	6.90%
CaO	8.70%
MgO	1.80%
SO_2	0.60%
Na_2O & K_2O	0.60%

Table 4 PHYSICAL PROPERTIES

Physical Compound	Properties
Colour	Whitish grey
Specific gravity	2.1
Specific surface	2000 to 2200 cm^2/g
Moisture	Nil

e.Chemical Admixtures

Chemical admixture is a substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture is also referred as superplasticizer. Each type of superplasticizer has defined ranges for required quantities of concrete mix ingredients, along with corresponding effects. Dosages needed vary by the particular concrete mix and type of super plasticizer used.

A water-reducing admixture, constitute of a Poly Carboxylic Ether (PCE). It is free of chloride and low alkali. In this study Glenium B233 is used as super plasticizer for producing SCC. The property of Glenium B233 used in this study is given in Table 5.

Table 5 PROPERTIES OF GLENIUM B233

Physical and Chemical Compound	Properties
Aspect	Light brown liquid
Relative density	1.09±0.01 at 25 □ C
PH	≥6
Chloride ion content	<0.2 %
Solid content	Not less than 30 % by weight
Optimum dosage	0.5 – 1.5% by weight of cementitious materials

f.Viscosity Modifying Agent

The sequence of addition of superplastizer and VMA into concrete mix is very important. If VMA is added before the super plastizer, it swells in water and becomes difficult to flow concrete. To avoid this problem VMA should be added after the super plastizer has come into contact with the cement particles.

In this study Glenium Stream 2 admixture was used and it enhanced viscosity, exhibits superior stability and controlled bleeding characteristics, thus increasing resistance to segregation and facilitating placement. The property of Glenium Stream 2 used in this study is given in Table 6.

Table 6 PROPERTIES OF GLENIUM STREAM 2

Physical and Chemical Compound	Properties
Aspect	colourless free flowing liquid
Chloride content	<0 .2 %
Optimum dosage	0.1%

g.Glass Fibres

The glass fibers used are of Cem-FIL Anti-Crack HD with modulus of elasticity 72 GPA, Filament diameter 14 microns, specific gravity 2.68and length 12 mm (Properties as obtained through the manufacturer are shown on table 7).

Table 7 PROPERTIES OF GLASS FIBRE CEM-FIL ANTI-CRACK HIGH DISPRESION

Property	Recycled coarse aggregate
Specific gravity	2.68
Elastic Modulus (Gpa)	72
Tensile Strength (Mpa)	1700
Diameter (Micron)	14
Length (mm)	12
Number of fiber (million/kg)	235

h.Mix Design And Mix Proportion

In this present investigation different self compacting fly ash concrete were designed at varying fly ash dosages. The proportions of the concrete mixtures are summarized. For all the mixtures, the coarse and fine aggregates were kept constant and weighed in a room dry condition. To develop a self compacting concrete with fly ash, replacement ranges from 0 to 100%. The advantages of this methodology are that at higher replacement percentages the self compacting concrete is more economical.

The trial mix details used for M_{30} grade self compacting concrete with replacement of cement by fly ash is shown in Table 8. Mix proportion used for the specimen preparation is shown in Table 9.

i.PREPARATION AND CURING OF SPECIMENS

All the concrete mixtures were mixed for 5mins in a laboratory mixer. Thorough mixing and adequate curing are most essential for achieving a good self compacting concrete. Before casting, a variety of tests were conducted on the concrete mixtures to determine their properties at it fresh state including the slump flow, flow time, segregation resistance and wet density. For each concrete mixture, 9 numbers of

150mm cubes were cast for the determination of compressive strength, 9 numbers of 150 ϕ x300mm cylinder were cast for the determination of split tensile strength. Furthermore, 3 numbers of 150mm x 150mm x 700mm prisms were cast for measuring the flexural strength. After casting, all the specimens were covered with plastic sheets in the laboratory at 27 °C until the time of testing.

Generally, the demoulding was done between 12 to 24 hours of casting. There were no problems in demoulding for concretes up to 40% replacement of cement by fly ash. For fly ash replacements 50% and above, problems like materials sticking to the mould and loss in edges and corners were noticed, if the demoulding was done after 24 hours period. However, for concretes above 50% replacement of fly ash the immersion curing was adopted after few days of moist curing.

Table 8 Trial Mix for M_{30} Grade concrete

S.NO	Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (kg/m^3)	S.P (%)	VMA (%)
1	TR1	380	137	906	796	233	1.4	0.1%
2	TR2	382	136	903	798	234	1.4	0.1%
3	TR3	382	136	905	796	234	1.4	0.1%
4	TR4	384	134	903	798	235	1.4	0.1%
5	TR5	386	132	901	800	236	1.4	0.1%
6	**SCC**	**386**	**132**	**901**	**800**	**236**	**1.4**	0.1%

Table 9 MIX PROPORTION FOR M_{30} GRADE OF CONCRETE

<table>
<tr><th>Mix</th><th>Cement (kg/m^3)</th><th>Fly ash (kg/m^3)</th><th>F.A (kg/m^3)</th><th>C.A (kg/m^3)</th><th>Water (Lit/m^3)</th><th>S.P (Lit/m^3)</th><th>VMA (Lit/m^3)</th><th>Glass Fiber</th></tr>
<tr><td rowspan="5">Conventional SCC</td><td rowspan="5">386</td><td rowspan="5">132</td><td rowspan="5">901</td><td rowspan="5">800</td><td rowspan="5">236</td><td rowspan="5">7.252</td><td rowspan="5">0.518</td><td>0.01%</td></tr>
<tr><td>0.02%</td></tr>
<tr><td>0.03%</td></tr>
<tr><td>0.04%</td></tr>
<tr><td>0.05%</td></tr>
<tr><td>FASCC10%</td><td>347.4</td><td>170.6</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td><td rowspan="10">Nil</td></tr>
<tr><td>FASCC20%</td><td>308.8</td><td>209.2</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC30%</td><td>270.2</td><td>247.8</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC40%</td><td>231.6</td><td>286.4</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC50%</td><td>193</td><td>325</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC60%</td><td>154.4</td><td>363.6</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC70%</td><td>115.8</td><td>402.2</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC80%</td><td>77.2</td><td>440.8</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC90%</td><td>38.6</td><td>479.4</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td>FASCC100%</td><td>0</td><td>518</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td></tr>
<tr><td colspan="9">Combined Mix Proportion for M_{30} Grade of Concrete</td></tr>
<tr><td>FAAFSCC</td><td>231.6</td><td>286.4</td><td>901</td><td>800</td><td>236</td><td>7.252</td><td>0.518</td><td>0.03%</td></tr>
</table>

j.Preparation And Curing Of Specimens

All the concrete mixtures were mixed for 5mins in a laboratory mixer. Thorough mixing and adequate curing are most essential for achieving a good self compacting concrete. Before casting, a variety of tests were conducted on the concrete mixtures to determine their properties at it fresh state including the slump flow, flow time, segregation resistance and wet density. For each concrete mixture, 9 numbers of 150mm cubes were cast for the determination of compressive strength, 9 numbers of 150 ϕ x300mm cylinder were cast for the determination of split tensile strength. Furthermore, 3 numbers of 150mm x 150mm x 700mm prisms were cast for measuring the flexural strength. After casting, all the specimens were covered with plastic sheets in the laboratory at 27 □ C until the time of testing.

Generally, the demoulding was done between 12 to 24 hours of casting. There were no problems in demoulding for concretes up to 40% replacement of cement by fly ash. For fly ash replacements 50% and above, problems like materials sticking to the mould and loss in edges and corners were noticed, if the demoulding was done after 24 hours period. However, for concretes above 50% replacement of fly ash the immersion curing was adopted after few days of moist curing.

k.Testing Methods

In this experiment, the following test methods are used to characterize the workability properties of self compacting concrete for the final acceptance of the self compacted concrete mix proportions: slump-flow test for flow ability, L-box test and J-ring test for testing passing ability.

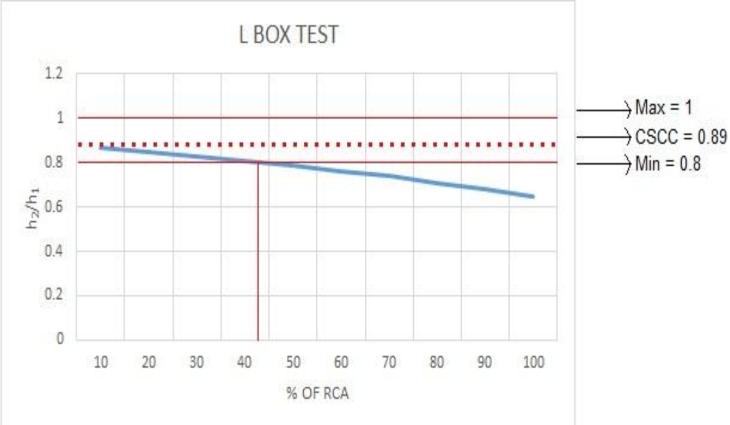
The slump flow test was used to evaluate the free deformability and flow ability of the SCC in the absence of any obstruction. A standard slump cone was used for the test and the concrete was poured in the cone without compaction. The slump flow value is represented by the mean diameter (measured in two perpendicular directions) of concrete testing by using the standard slump cone.

The L-box test was performed; this test has been used to access the flow ability of concrete. During the test, SCC was allowed to flow upon the release of a trap door from the vertical section to the horizontal section via few reinforcement bars of an L shape box. The height of the concrete at the end of the horizontal section was compared to the height of concrete remaining in the vertical section.

The properties of concrete for each mix on various sizes of specimen are conducted at different ages of curing according to the procedures given in Indian Standard Code of practices and ASTM. The details of property, age at test, size of specimens along with test methods are presented in table 10.

IV RESULTS AND DISCUSSION

Figure 2, 3 & 4 provides a summary of the properties of the fly ash self compacting concrete mixes in the fresh state. As it is evident, the basic requirements of high flowability and segregation resistance, as specified by guidelines on self compacting concrete by EFNARC, are satisfied. The workability values are maintained by adding suitable quantities of superplasticizers.



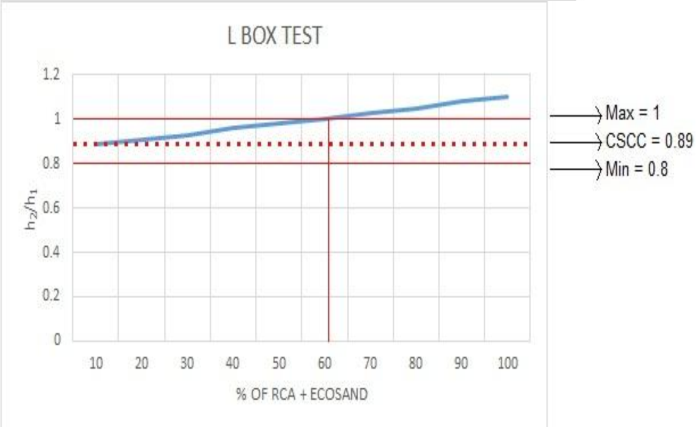
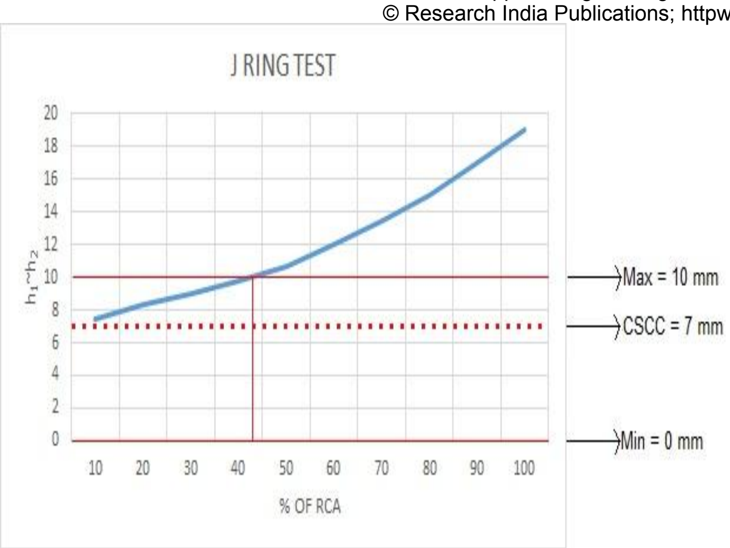


Figure No. 1 Slump Test



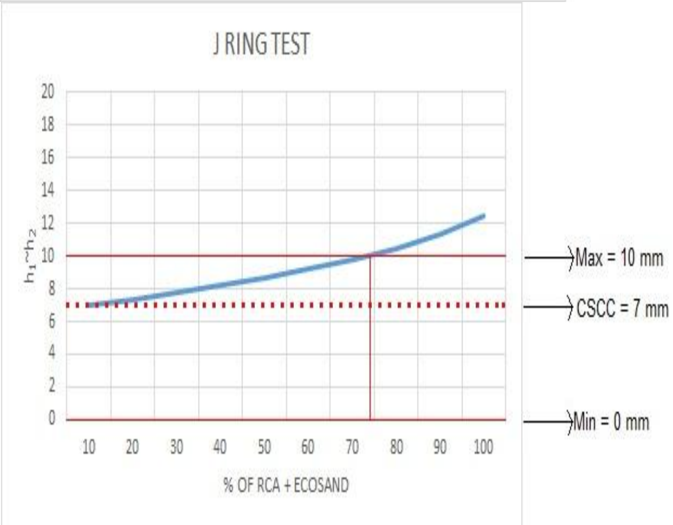
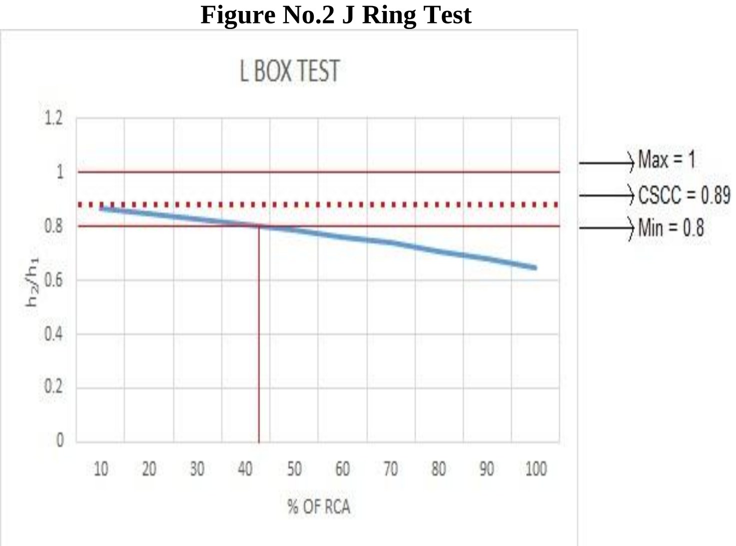


Figure No.2 J Ring Test



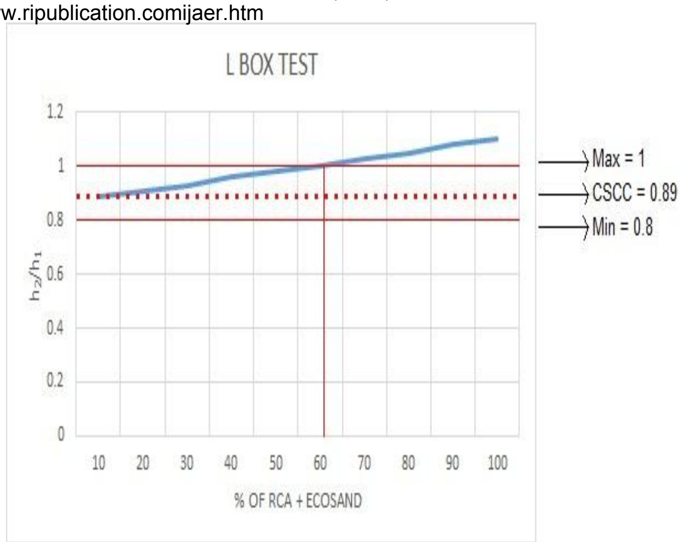
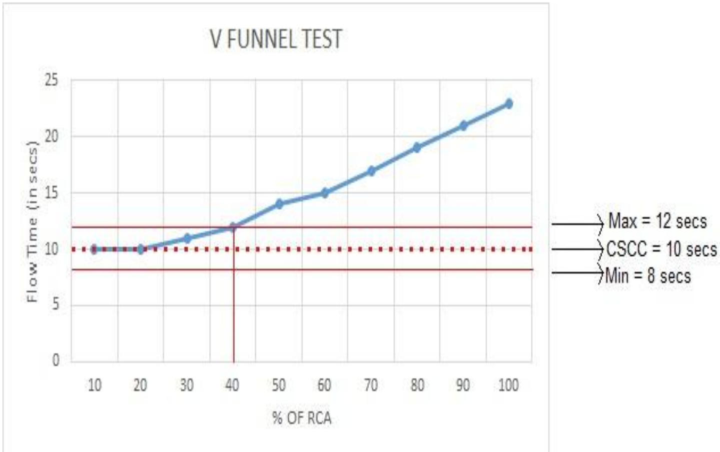


Figure No. 3 L Box Test



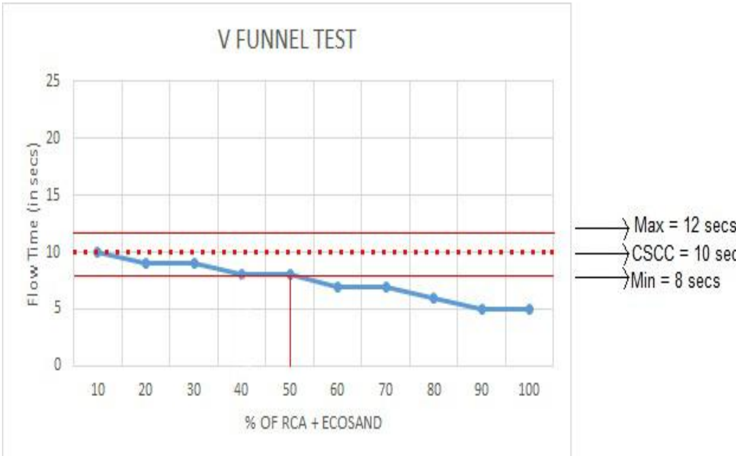
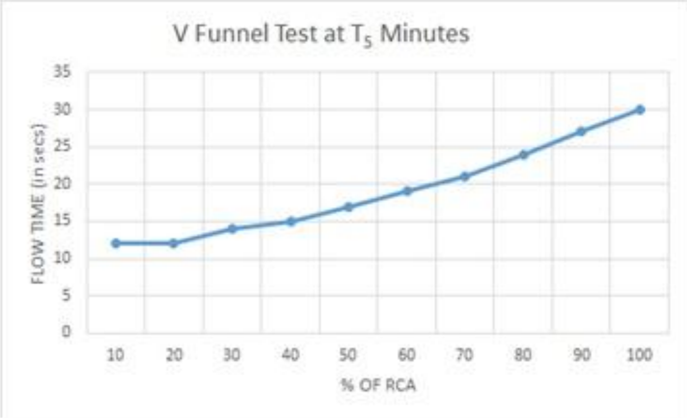


Figure No. 4 V FUNNEL TEST



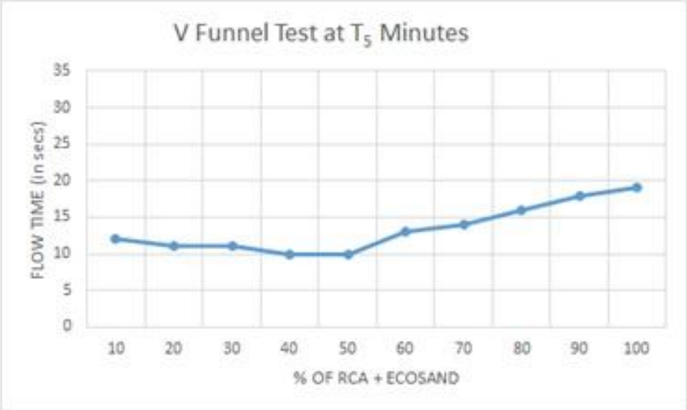
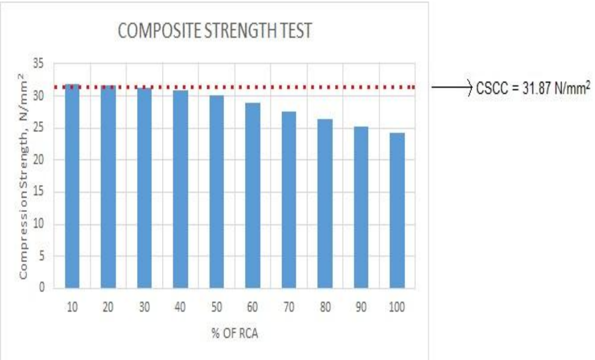


Figure No. 5 V FUNNEL TEST @ T_5 MINUTES



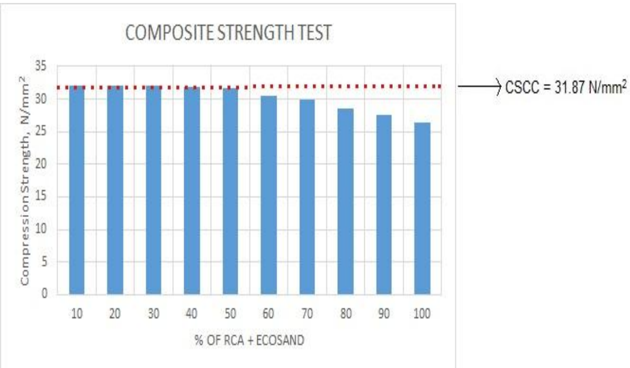


Figure No.6 Compressive Strength Test

Several test methods have been developed in attempts to characterize the properties of SCC. The above graph gives the characteristic of SCC. However the figure (2, 3, 4, 5 & 6) gives the list of test methods for workability properties of SCC based on EFNARC specification and guidelines. In this study, SCC properties are thoroughly tested for utilization of fly ash, glass fiber and fly ash along with glass fiber. SCC properties were satisfied up to 50% replacement of fly ash, 0.03% of glass fiber and 40% of fly ash with 0.03% of glass fiber. The improved results of combining the effects of addition of glass fiber and replacement of fly ash are tabulated in table. 10.

Table 10 Fresh Concrete Properties for Combined Mix

Test	Result
Slump Test	745mm
Ring Test	9.5mm
Box Test	0.9
V Funnel Test	10 Sec
V Funnel Test @ T_5 Mins	13 Sec

For Hardened Concrete

COMPRESSIVE STRENGTH TESTING:

A comparative study on properties of a fly ash and glass fibers in self compacting concrete for M_{30} grade of concrete are studied. Tests of compressive strength 28 days yielded the results are shown in fig (7). All the mixtures quickly gain strength, and after 7 days they achieve more than 90% of the strength they have at the age of 28 days. Compressive strength of self compacting concrete value is equal to conventional self compacting concrete when the replacement ratio is 50% of fly ash and it remains the same for 0.05% of addition of glass fibers

Split tensile strength:

In this investigation, the Split tensile strength test of self compacting concrete is carried out with 0% to 100% replacement of fly ash with cement for M_{30} grade of concrete. In addition, glass fibers are added with SCC having a volume of 0.01% to 0.05%. The tests are carried out after 28 days of curing. The results are shown in figure (8). All three mixtures quickly gain strength, and after 7 days they achieve more than 90% of the strength at the age of 28 days. The split tensile strength is decreased after 40% of fly ash used instead of cement. In case of glass fibers, the split tensile strength is increased throughout all mix proportions.

Flexural strength

In this investigation, the flexural strength test of self compacting concrete is carried out with 0% to 100% replacement of fly ash with cement and addition of glass fibers. The tests are carried after 28 days of curing. The results are shown in figure (9). Flexural strength of fly ash self compacting concrete is equal to the conventional self compacting concrete when the replacement ratio is 50%. The addition of glass fibers has shown increase in the flexural strength for all the mix proportions.

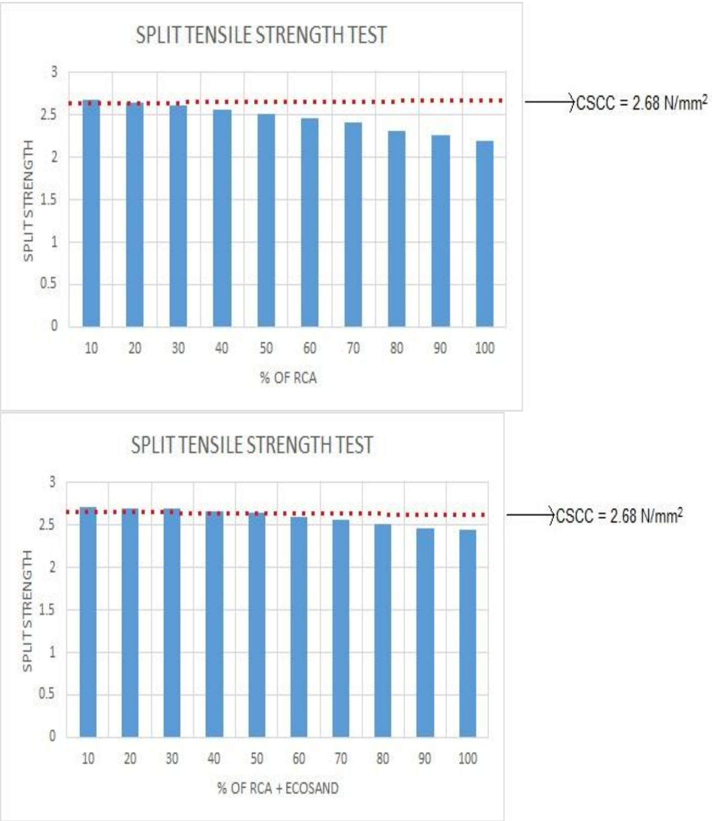


Figure No.7 Split Tensile Strength Test

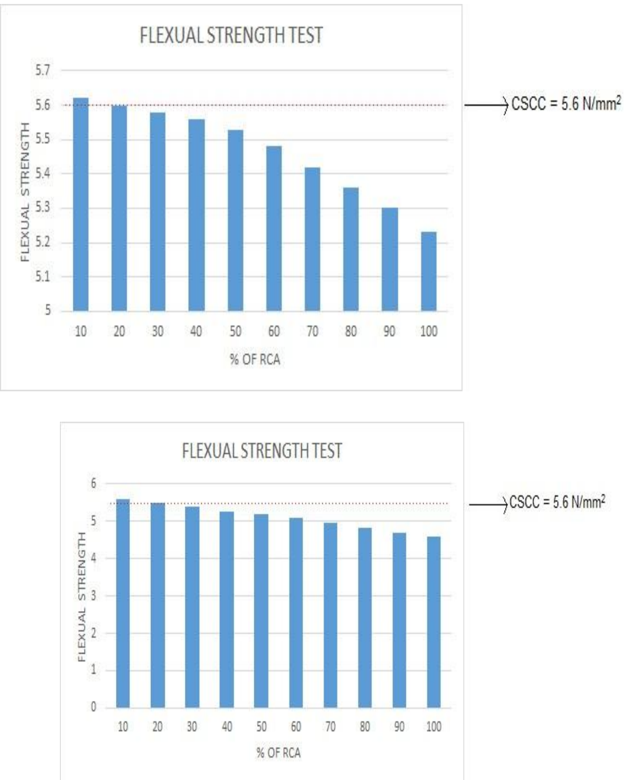


Figure No.8 Flexural Strength Test

Table 11 Hardened Properties for Combined Mix

Test	Result (N/mm^2)
Compressive Strength Test	39.15
Split Tensile Strength Test	3.02
Flexural Strength Test	5.85

a.Analysis Of Test Result And Discussion

The use of fly ash and glass fibers along with the self compacting concrete are studied for various mix proportions. The tests are carried at 7, 14 & 28 days. Fresh and hardened properties of self compacting concrete with fly ash have resulted in a maximum value at 40% replacement of cement and while that of with glass fibers have resulted in a maximum value of 0.03% addition to the self compacting concrete.

The fresh concrete properties lead to the bleeding and segregation of the self compacting concrete when the ratio of cement replaced by fly ash exceeds 50%. So in the presence of excess water the settling process is delayed and demoulding process also requires more than 24 hours. When glass fibers are used as an addition and as it exceeds 0.03%, the fresh concrete properties like flow ability and passing ability are directly affected.

When combining the results of 40% of fly ash and 0.03% of glass fibers in self compacting concrete gives a better result in both the fresh and hardened properties of concrete.

V CONCLUSION

Studies on different properties of fly ash with glass fibers are carried out in this paper. Based on the results obtained and interpretation the following conclusions are drawn from the study:

- The present investigation has shown that it is possible to design a Self compacting concrete incorporating high volume of Class F fly ash. All the high volume fly ash concretes have satisfied the fresh concrete properties.
- From the above investigation higher strength of self compacting concrete produced with 40% of fly ash replaced.
- In this study, it can be concluded that self compacting concretes of lower strength can be produced at a fly ash replacement is more than 40%.
- From above discussion of test results, it can be observed that addition of glass fibers tested improves the load carrying capacity of conventional self compacting concrete. Maximum strength obtained at 0.03% of glass fibers added into the concrete.

- Replacement of fly ash with cement at a ratio of 40% has resulted in the increase in the hardened properties such that the compressive strength, split tensile strength and flexural strength has been increased by 10.6%, 3.73% and 1.785% respectively
- Addition of glass fibers at a rate of 0.03% has also increased the compressive strength by 11.6%, split tensile strength by 8.95% and flexural strength by 2.14% thereby improving the hardened properties.
- The combination of results of both the fly ash and glass fibers have resulted in an improved result with the effects such that the compressive strength is increased by 22.84%, the split tensile strength is increased by 12.68% and the flexural strength is increased by 4.46%.
- Based on the experimental investigation it was observed the addition of glass fibers in self compacting concrete gives a homogeneous and cohesive mix with marginal decrease in workability.

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