International Journal of ChemTech Research
CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555
Vol.10 No.8, pp 13-20, 2017

Behaviour of Hybrid Fibre Reinforced Self Compacting Concrete using Foundry Sand

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Abstract : The construction activities in the last few decades have increased many folds in almost all the developing countries of the world. Sand is becoming a scarce commodity globally because of its growing demand day by day. It is the need of time to search such alternative materials that would partially or fully replace sand used in concretes without affecting its quality, strength and other characteristics. In order to reduce time and to improve the filling capacity of highly congested structural members by its own weight without any vibration self-compacting concrete (SCC) is adopted.

The primary aim of this study is to explore the feasibility of SCC using foundry sand and hybrid fibres[2,5].As the mix design was designed based on finding the optimum percentage of replacement of foundry sand and hybrid fibres based on literature review and development of a suitable mix for SCC using code requirements, that would satisfy the requirements of the plastic state. This offers a unique area of application of self-compacting concrete which can flow through every corner of extensively reinforced area without any vibration and more effective for seismic lo.

This research consists of: (i) finding out the percentage of replacement of optimum percentage of foundry sand and hybrid fibres based on literature review; (ii) development of a suitable mix for SCC that would satisfy the requirements of the plastic state.

1.0 Introduction

Cement-based materials are the most abundant of all man-made materials and are among the most important construction materials, and it is most likely that they will continue to have the same importance in the future. However, these construction and engineering materials must meet new and higher demands. When facing issues of productivity, economy, quality and environment, they have to compete with other construction materials such as plastic, steel and wood. One direction in this evolution is towards self-compacting concrete (SCC), a modified product that, without additional compaction energy, flows and consolidates under the influence of its own weight. The use of SCC offers a more industrialised production. Not only will it reduce the unhealthy tasks for workers, it can also reduce the technical costs of in situ cast concrete constructions, due to improved casting cycle, quality, durability, surface finish and reliability of concrete structures and eliminating some of the potential for human error[3,7]. However, SCC is a sensitive mix, strongly dependent on the composition and the characteristics of its constituents. It has to possess the incompatible properties of high flow ability together with high segregation resistance.

1.1 Objective of the Work

- To determine the properties and strength of conventional self-compacting concrete without hybrid fibres.
- To determine the properties and strength of hybrid fibre reinforced self-compacting concrete.
- To compare the normal self-compacting concrete with hybrid fibre reinforced self-compacting concrete.

Foundry dust is a discarded material from metal industry. It is a mixture of high quality silica sand and some amount of ferrous and non-ferrous material. The physical and chemical properties of foundry dust depends mainly on the type of casting process and the industry sector from its originates.

Foundry sand is basically a fine material. It can be used in many of the same ways as natural or manufactured sand. This includes many civil engineering applications such as formation of embankments, filling low lying areas, hot mix asphalt (HMA) and for making Concrete. Foundry sand is also being used extensively agriculturally as topsoil in agricultural fields.

Glass fibre also called fibreglass. It is material made from extremely fine fibres of glass Fiberglass is a lightweight, extremely strong, and robust material[8,9]. Although strength properties are somewhat lower than carbon fibre and it is less stiff, the material is typically far less brittle, and the raw materials are much less expensive. Its bulk strength and weight properties are also very favourable when compared to metals, and it can be easily formed using moulding processes.

Steel fibre is the most common fibre type in the building industry. Steel fibres acts as a bridge to retard their cracks propagation, and improve several characteristics and properties of the concrete. The addition of steel fibres does not change considerably the compressive strength and the modulus of elasticity of concrete but has noteworthy effects on the residual tensile strength and flexural strength

2.0 Materials

2.1 Cement

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. The cement should be of uniform colour i.e. grey with a light greenish shade and free from any hard lumps. Generally Portland cement is used for SCC.

2.2 Fine Aggregates

The sand used for the experimental programme was locally procured and conformed to Indian Standard Specifications IS: 383-1970. The sand will be first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and then should be washed to remove the dust. The fine aggregates belonged to grading zone- II.

2.3 Coarse Aggregate

The maximum size of aggregate is generally limited to 20mm. Aggregate of size 10 mm is desirable for structures having congested reinforcement. The crushed stone is generally used as a coarse aggregate. The nature of work decides the maximum size of the coarse aggregate. Locally available coarse aggregate having the maximum size of 10 mm will be used in our work. The aggregates should be tested as per IS: 383- 1970

2.4 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. Water from lakes and streams that contain marine life also usually is suitable. Ordinary potable water of normally pH 7 is used for mixing and curing the concrete specimen.

2.5 Foundry Sand

Foundry sand consists of clean, uniformly sized, high quality silica sand that is bonded to form moulds of both ferrous and non-ferrous metal castings. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and industry sector from which it originates. It can be reused several times in foundries but after a certain period it becomes a waste material referred as used pr spent foundry sand. It is basically a fine aggregate that can be used in many ways as natural and manufactured sands.

Fig 2.1 Foundry sand

2.6 Viscocrete 20 HE

ViscoCrete 20 HEis a third generation super plasticizer for concrete and mortar. The product is suitable for tropical and hot climatic conditions.ViscoCrete-20 HEis especially suitable for the production of concrete mixes which require high early strength development, powerful water reduction and excellent flowability.

Fig 2.2 Super plasticizer

2.7 S-Glass Fibre

S-Glass or high strength grade glass was originally developed for high strength in scc. The tensile strength of glass fibers is determined by the structure connectivity of the silicate network, notably,by the absence of alkali oxides, which are not readily integrated into the structure. The structure of boron oxide, though being a part of the network, is weaker than that of silicon oxide, and therefore, boron oxide serves as a flux. Several high-strength glass fibers are known S-glass is preferred.

Fig 2.3 S-Glass Fibre

2.8 CRIMPED STEEL FIBRES

Crimped steel fiber are low carbon, cold drawn steel wire fibers designed to provide concrete with temperature and shrinkage crack control, enhanced flexural reinforcement, improved shear strength and increase the crack resistance of concrete. psi crimped steel fiber complies with astm c1116, standard specification for fiber reinforced concrete and shotcrete and astm a820, type i, standard specification for steel fibers for fiber reinforced concrete. these steel macro-fibers will also improve impact, shatter, fatigue and abrasion resistance while increasing toughness of concrete. Dosage rates will vary depending upon the reinforcing requirements and can range from 25 to 100 lbs/yd³ (15 to 60 kg/m³).

Fig 2.4 Crimped Steel Fibre

3.0 Properties of Materials used

3.1 Cement

Table: 3.1Properties of cement

S.No	Properties	Values
1.	Specific Gravity	3.13
2.	Bulk Density	1440 kg/m^3
3.	Surface area	225 m^2/kg
4.	Initial setting time	28 min
5.	Final setting time	600 min

3.4foundry Sand

Table: 3.4 Properties of Foundry sand

S.No	Properties	Values
1.	Specific Gravity	2.4
2.	Bulk Density	2590 kg/m^3
3.	Moisture Content	4 %

3.3 Coarse Aggregate

Table:3.3 Properties of coarse aggregate

S.No	Properties	Values
1.	Specific Gravity	2.7
2.	Bulk Density	1660 kg/m^3
3.	Size	10 mm

3.4Fine Aggregate

Table:3.2 Properties of fine aggregate

S.No	Properties	Values
1.	Specific Gravity	2.60
2.	Bulk Density	1660 kg/m^3

3.5 S-Glass Fibre

Table: 3.5Properties of glass fibre

Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young modulus (GPa)
S-Glass	2.48	4590	91

4.0 Results and Discussions

4.1 Fresh Properties

SCC containing different proportion of waste foundry sand and flyash was tested for Slump flow, V-funnel, U-Box, L-box. The results of fresh properties of all Self-compacting concretes with waste foundry sand and hybrid fibres are included in table below. As per EFNARC, slump flow of t_{30cm} time ranging from 3 to 6seconds is considered adequate for a SCC,which is an indication of a good deformability. In terms of slump flow, all SCCs does not exhibited satisfactory slump flows in the range of 5 to 10 seconds except MIX 1.

Table 4.1Fresh concrete test calculation for M_{30}

Combination	Slump Flow (Sec)	V-Funnel (Sec)	L-Box	U-Box (Cm)
MIX 1	5	14	0.80	30
MIX 2	7	15	0.77	32
MIX 3	9	13	0.73	33
MIX 4	10	11	0.70	35

As per EFNARC, V- funnel time ranging from 6 to 12 seconds is considered adequate for a SCC. The V-funnel flow times were in the range of 11-15 seconds. Test results of this investigation indicated that all SCC mixes does meet the requirements of allowable flow time except MIX-1. The L-box ratio H2/H1 for the mixes was above 0.8 which is as per EFNARC standards. The L-box ratio H2/H1 for the all mixes were 0.8 to 0.70. Test results of this investigation indicated that all SCC mixes does meet the requirements of allowable ratio H2/H1 except MIX-1. U-box difference in height of concrete in two compartments was in Properties of Self-Compacting Concrete Incorporating Waste Foundry Sand and hybrid fibres the range <30cm. U-box difference in height of concrete in two compartments of all mixes were 30cm to 35cm. All the fresh properties of concrete values were nearly equal to that of the values given by European guidelines.

4.2 Hardened Properties

4.2.1 Compressive Strength

Effect on compressive strength of M30 Grade concrete mixes MIX-1 (10%FS&1% HF), MIX-2 (10%FS &1.5% HF), MIX-3 (10%FS &2% HF), and MIX-4(10%FS &2.5% HF), at the age of 7, 28days are shown below

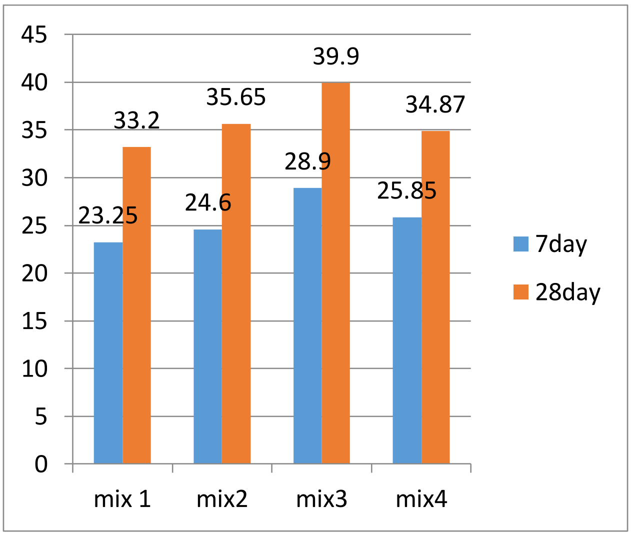

Fig 4.1 comparison of compressive strength test results

When the replacement of fine aggregate with 10% foundry sand , 1% hybrid fibre it gives good results in compressive strength with increase in 11% thancontrolscc. Whenthe replacement of fine aggregate with 10% foundry sand , 1.5% hybrid fibre it gives good results in compressive strength, of increase in 19.5%.When the replacement of fine aggregate with 10% foundry sand , 2% hybrid fibre it gives good results in compressive strength, with increase in 30% than normal scc.Whenthe replacement fine aggregate with 10% foundry sand, 2.5% hybrid fibre it gives good results in compressive strength, with increase in 11.6% than normal scc.

4.2.2 Split Tensile Strength

Effect on split tensile strength of M30 Grade concrete MIX-1 (10%FS &1% HF), MIX-2 (10%FS &1.5% HF), MIX-3 (10%FS &2% HF), and MIX-4(10%FS &2.5% HF), at the age of 7, 28days are shown below

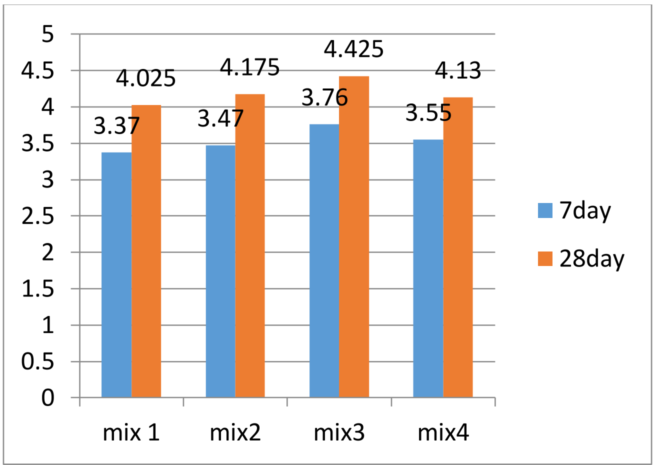

Fig 4.2 comparison of split tensile strength test results

When the replacement of fine aggregate with 10% foundry sand , 1% hybrid fibre it gives good results in split tensile strength with increase in 10.7% than control scc. When the replacement of fine aggregate with 10% foundry sand , 1.5% hybrid fibre it gives good results in split tensile strength, of increase in 11.1% than control scc. When the replacement of fine aggregate with 10% foundry sand, 2% hybrid fibre it gives good results in split tensile strength, with increase in 17.7% than normal scc. When the replacement fine aggregate with 10% foundry sand, 2.5% hybrid fibre it gives good results in split tensile strength, with increase in 11% than normal scc.

4.2.3 Flexural Strength

Effect on Flexural strength of M30 Grade concrete mixes concrete MIX-1 (10%FS &1% HF), MIX-2 (10%FS &1.5% HF), MIX-3 (10%FS &2% HF), and MIX-4(10%FS &2.5% HF), at the age of 7, 28days are shown below

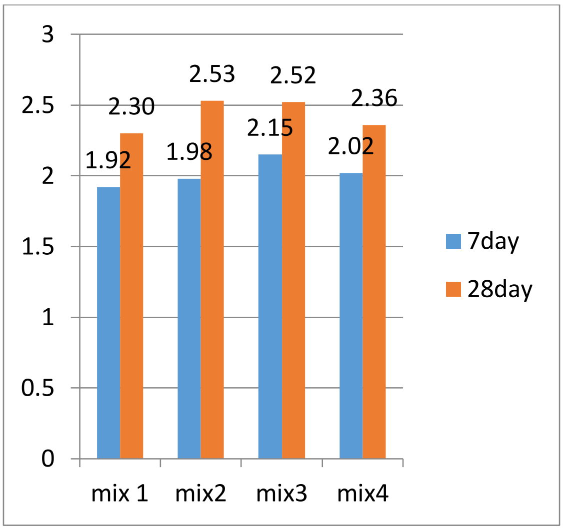

Fig.4.3 comparison of flexural strength test results

When the replacement of fine aggregate with 10% foundry sand , 1% hybrid fibre it gives good results in Flexural strength with increase in 10.7% than control scc. When the replacement of fine aggregate with 10% foundry sand, 1.5% hybrid fibre it gives good results in Flexural strength, of increase in 11.85% than control scc. When the replacement of fine aggregate with 10% foundry sand , 2% hybrid fibre it gives good results in Flexural strength, with increase in 11.8% than normal scc. When the replacement fine aggregate with 10% foundry sand, 2.5% hybrid fibre it gives good results in Flexural strength, with increase in 11% than normal scc.

5.0 Conclusions

5.1 Compressive Strength

1. Compressive strength of concrete mixes increased due to replacement of fine aggregate with foundry sand and hybrid fibre. However, compressive strength observed was appropriate for structural uses.
2. M30 (29.4MPa) grade concrete mix obtained increase in 28-day compressive strength from 29.4MPa to 39.9MPa on 10% replacement of fine aggregate with foundry sand and 1% hybrid fibres. Maximum strength was achieved with 10% replacement of fine aggregate with foundry sand and 2% hybrid fibres.

5.2 Split Tensile Strength

1. Concrete mixes obtained linear increase in 28-day splitting tensile strength from 3.75MPato 4.425MPa for concrete mix on replacement of fine aggregate with foundry sand along with hybrid fibre.
2. Splitting tensile strength of all concrete mixes was found to increase in with varying percentage of foundry sand and hybrid fibres.
3. Maximum increase in splitting tensile strength was observed at 10% replacement of fine aggregate with foundry sand and2% hybrid fibre

5.3 Flexural strength

1. Concrete mixes obtained increase in 28-day Flexural strength from 2.14MPato 2.53MPa for concrete mix on replacement of fine aggregate with foundry sand and hybrid fibre.

2. Flexural strength of all concrete mixes was found to increase in with varying percentage of foundry sand and hybrid fibre.
3. Maximum increase in Flexural strength was observed at 10% replacement of fine aggregate with foundry sand and 1.5% hybrid fibre.

6.0 References

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