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Microstructural Studies on Self Compacting Concrete Using Binder, Fine Aggregate and Hybrid Fibres

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ABSTRACT –

Concrete is made up of components such as coarse aggregate embedded in cement-sandmortar. Strength parameters and microstructure characteristics of SCC were investigated. Incorporation of foundry sand in concrete minimizes the usage of natural river sand and M-sand. Utilization of metakaolin give good concrete properties, reduces the usage of OPC cement, minimal usage of OPC cement gives lesser amount of Co2 emission which leads to stable ecosystem. In this project four different mixes(Mix- 1:MK-20%,TFS-40%, Mix-1:MK-25%,TFS-40%, Mix-1:MK-

20%,TFS-80%, Mix-1:MK-25%,TFS-80%) were arrived by replacing fine aggregate with treated foundry sand and OPC by metakaolin. Conventional fine aggregate was replaced by treated foundry sand (40% and 80%); OPC was replaced by metakaolin (20% and 25%). Fresh concrete properties of SCC such as flow ability, filling ability, passing ability and segregation resistance for those mixes were conducted and results are obtained. Similarly hardened concrete properties such as compressive strength and split tensile strength tests were conducted and results are obtained. Further microstructure analysis is to be carried out.

Key Words: Self Compacting Concrete (SCC), Metakaolin (MK), Treated Foundry Sand (TFS), Glass Fibre (GF), Polypropylene Fibre (PF), Sika_Viscocrete_20HE, E-DAX, SEM Analysis

1. INTRODUCTION

All the construction materials such as cement, sand and coarse aggregate are obtained directly from natural sources. Due to infrastructure development there is a huge requirement to meet the demand. Concrete being a most preferred material for construction is used in many industries. This increases the depletion of the available natural resources. The increased production of cement causes environmental effects.

The invention of self compacting concrete (SCC) is considered as a major evolution in construction industry. As the name says the concrete flows under its own weight without any vibration. This concrete type finds major application where congested reinforcement is used and in places which requires higher mechanical compaction. SCC also provides better surface finish, segregation resistance, uniform consolidation etc. when large quantity of heavy reinforcement is to be cast in a reinforced concrete member, it is difficult to ensure that the formwork gets completely filled with concrete. Thus, fully consolidation without voids or honeycombs through compaction by manual or mechanical vibrators is very impractical in this situation, it generates delays and additional cost in the projects and hence, the development of SCC.

The improvement construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and other civil engineering constructions.

1.1 Objective

- To obtain the fresh and hardened properties of SCC using foundry sand.
- To determine properties and strength of SCC incorporated with hybrid fibres.
- To find the optimum percentage replacement of the foundry sand in SCC.
- To investigate the structural performance of SCC.
- To determine chemical composition of Treated foundry sand by E-DAX.
- To study the inter molecular arrangement of SCCby Scanning Electron Microscope (SEM).

1.2 Scope

- To minimize the usage of OPC in order to making sustainable environment
- To minimize the usage of M-sand to avoid the over mining in quarries.
- To find out the chemical composition of foundry sand to avoid the adverse effect on concrete.
- To study the inter molecular arrangement of SCCby Scanning Electron Microscope (SEM), it helps to identifying the bond between the aggregate and cement sand mortar.

2. LITERATURE REVIEW

i) Gurpreet Singh, Ankush Thakur, "Incorporation of waste foundry sand in concrete", 2018

A huge amount of sand is being used by the metal foundries within the metal casting process, the sand is successfully recycled and reused by the foundries. There were five percentages of replacement to which foundrysand was replaced by weight of fine aggregates i.e. 0, 10, 20, 30 and 40% by weight of the fine aggregate. Tests were conducted for mechanical and durability properties of all replacement levels at different curing periods. In this study, the effect of used foundry sand as a substitution of fine aggregate on the compressive strength, Flexural strength, split tensile strength and Modulus of elasticity of cement concrete of M30 grade was investigated.

ii) Radhika R.S, Vennila A, venkatasubramani R, Sreevidya V, "Behaviour of Hybrid Fibre Reinforced Self Compacting Concrete using Foundry sand",2017

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 scarcecommodity 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 fibres2,5.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 uniqueareaof application of self-compacting concrete which can flow through every corner of extensively reinforced area without any vibration and more effective for seismic location. 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.

iii) Arjun N , Vennila A, Sreevidya V, "Experimental Study on Self-Compacting Concrete with Foundry Sand and Glass Powder",2017

This paper explores an experimental study on self compacting concrete with Foundry sand and glass powder. Environmental pollution a major problem facedbymankind, mainly in the construction industry the production of Portland cement causes the emission of pollutants that causes serious threat to the environment. The pollution effects on environment due to cement production can be reduced by increasing the usage of waste products in our construction industry. Usage of Foundry sand and glass powder is such a remedial measure and in the present study, sand and cement is being replaced with Foundry sand and Glass powder. Viscocrete 20 HE preferred foradmixture. The percentage replacement of glass powder with cement includes 10 percent, 20 percent, 30 percent, 40 percent, 50 percent. The fine aggregate is 90 percent of sand and 10 percent of foundry sand. The Mix design for SCC was arrived as per the guidelines of EFNARC. The mix design and the tests to be conducted like material testing, strength tests are being discussed in this paper.

iv) Ali Reza Taheri Fard, "Combined Effect of glass fibre and polypropylene fibre on mechanical property of self- compacting concrete",2016

Self-compacting concrete is state-of-the-art technology in all over the world in construction field. This concrete which has high performance can be usedforcasting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible tocast, giving a far superior surface than conventional concrete. Inanother aspect, using types of fibres can redeem mechanical and dynamical characteristic of concrete as well as reducing cracking in concrete. In this study, we are going to scrutinize both combined and entity effect of polypropylene and glass on mechanical properties of concrete and Rheological

Characterization of Self-Compacting Concrete. For this case, we prepared 10 specimen including (A) polypropylene fibre with Volume fraction of 0.1, 0.2, 0.3 and Glass with volume friction of 0.1, 0.2, 0.3 and (B) combined polypropylene fibre and glass. Inspection of these experiments has shown that combined polypropylene fibre and glass can enhance tensile and bending strength, plus it dramatically increase toughness of concrete.

v) Yasser Sharifi, Iman Afshoon, Zeinab Firoozjaei and Amin Momeni, "Utilization of Waste Glass Micro- particles in Producing Self-Consolidating Concrete Mixtures", 2016

In this paper They present research would be achieved using ground waste glass (GWG) micro particles in self-consolidating concrete (SCC). Here, the influences of GWG micro particles as cementing material on mechanical and durability response properties of SCC are investigated. The aim of this study is to investigate the hardened mechanical properties, percentage of water absorption, free drying shrinkage, unit weight and Alkali Silica Reaction (ASR) of binary blended concrete with partialreplacement of cement by 5, 10, 15, 20, 25 and 30 wt% of GWG micro particles. Besides, slump flow, V-funnel, L-box, J-ring, GTM screen stability, visual stability index (VSI), setting time and air content tests were also performed as workability offresh concrete indicators. The results show that the workabilityof fresh concrete was increased by increasing the content of GWG micro particles. The results showed that using GWG micro particles up to maximum replacement of 15 % produces concrete with improved hardened strengths. From the results, when the amount of GWG increased there was a gradual decrease in ASR expansion. Results showed that itis possible to successfully produce SCC with GWGascementing material in terms of workability, durability and hardened properties.

vi) D.Anjali, S.S.Vivek and G.Dhinakaran, "Compressive Strength Of Metakaolin Based Self-Compacting Concrete", 2015

Self-compacting concrete (SCC) refers to high strength concrete which will compact under its own weight and does not require external vibration. SCC composition consists of maximum volume of fine aggregate and powder content, whereas coarse aggregate occupies lesser quantity. The concrete prepared for SCC was highly fluid and it was achieved by Super plasticizers and Stabilizers of optimum dosages. In present work, an experimental study was made to study the strength of SCC using metakaolin (MK). Here cement was replaced by MK with 15%. For an experimental investigation, conventional vibrated concrete CVC and SCC cube and cylinder specimens were cast and tested at the age of 28 days after curing. The concrete mix design was developed using ACI code provisions for conventional and SCC type concrete. With the obtained results, it was found that compressive and split tensile strength of SCC specimens found to be higher compared to CVC. Finally, the increase of powder content by mineral admixtures improves the flow property and strength parameters of SCC

3. PRELIMINARY TESTS AND MIX DESIGN

The materials used to perform the above study are initially tested for their basic properties. Cement, metakaolin, m-sand, foundry sand Coarse aggregate, are performed with Specific gravity test, water absorption test, Sieve analysis, Bulk density test, Impact test, Crushing test are performed and test values are used to obtain the required mix design.

3.1 E-DAX REPORT FOR FOUNDRY SAND

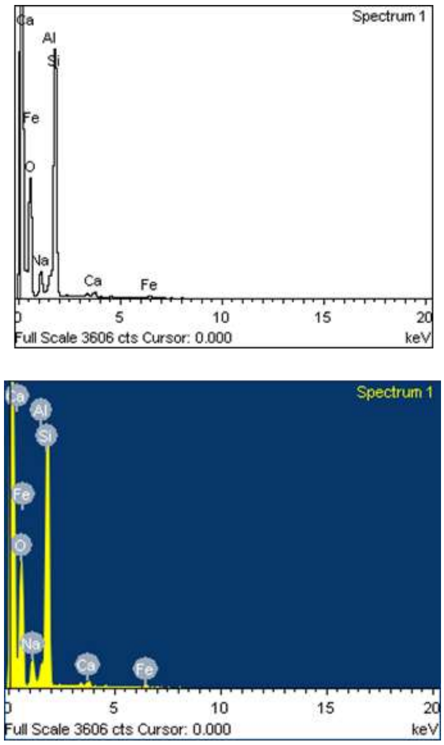

Fig 1: Spectrum Obtained By E-DAX

- Chemical composition of treated foundry sand obtained by E-DAX laboratory test
- The following graphs are showing chemical composition of treated foundry sand

The following table shows the various percentile of minerals presents in the treated foundry sand.

Table1: Chemical Composition Of Foundry Sand

COMPONENT	PERCENT
SiO_2	91.2%
Na (Albite)	5.02%
Al_2O_3	1.78%
Fe_2O_3	1.09%
CaO	0.91%
LOI	5.15%

- Based On The Report, The Treated Foundry Sand Contains High Silica (91.2%) Content, Because Of The Source Of Foundry Sand Is Sea Sand.
- Next To The Silica The Combination Of Sodium (5.02%) And Calcium (0.91%) Covers The Major Part In The Treated Foundry Sand. This Will Leads To The Efflorescence Deposit In The Concrete Surfaces Due The Salinity Caused By These Minerals.
- The remaining percentiles are covered by alumina (1.78%) and iron (1.09%).

Table -2: Mix Proportion of SCC

CEMENT	FA	CA	WATER	VMA
465	995.13	720.61	180.98	5.022
1	2.14	1.55	0.39	0.018

Table -3: Total Amount of Materials For 1m3 of Concrete

% OF REPLACEMENT	CEMENT (kg)	METAKAOLIN (kg)	M- SAND (kg)	T- SAND (kg)	FIBRE (kg)
MIX-1	372	93	597.03	398.1	GF-0.6 PF-0.6
MIX-2	348.75	116.25	597.03	398.1	GF-0.6 PF-0.6
MIX-3	372	93	226.03	796.1	GF-0.6 PF-0.6
MIX-4	348.75	116.25	226.03	796.1	GF-0.6 PF-0.6

Coarse aggregate content is found to be 720.61 kg for all percentages of replacement.

4. EXPERIMENTAL INVESTIGATION

Fresh concrete or plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state.

Slump cone test, L-Box test, V-channel testand U- Boxtestare the four basic fresh concrete test to be conducted in order to determine the workability of the self compacting concrete.

Fig 2: Slump Cone test

Fig-3: L- Box Test

Fig 4:V-Channel Test

Fig 5: U- Box Test

One of the purposes of testing hardened concrete is to confirm that the concrete used at site has developed the required strength. The test methods should be simple, direct and convenient to apply. The controlled concrete is cast and cured for 28 days and the tests for hardened concretesuchas compressive strength, split tensile strength tests are done.

Fig 6: Compression Test On Cube

Fig-7: Split Tensile Strength On Cylinder

The number of specimens casted and their test values are listed in the table below;

TABLE 4: Description of Specimen

Percentage of replacement	**No. of specimens**
NOMINAL SCC	2 CUBES 2 CYLINDERS
MIX-1	
MIX-2	
MIX-3	
MIX-4	

5. RESULTS AND DISCUSSION

SCC containing different proportion of Treated Sand, Metakaolin And Same proportion of Glass Fibre, Polypropylene Fibre was tested for Slump flow, V-funnel, U- Box, and L-box. The results of fresh properties of all Self- compacting concretes with treated foundry sand and Metakaolin are included in table below. In terms of slump flow, all SCCs exhibited satisfactory slump flows in therange of 3-6sec, which is an indication of a good deformability.

As per EFNARC, time ranging from 6 to 12 seconds is considered adequate for a SCC. The V-funnel flow times were in the range of 6–10 seconds. Test results of this investigation indicated that all SCC mixes meet the requirements of allowable flow time. The L-box ratio H2/H1 for the mixes was above 0.8 which is as per EFNARC standards. U-box difference in height of concrete in two compartments was in Properties of Self-Compacting Concrete Incorporating Treated sand , Metakaolin, glass fibre and polypropylene fibre the range <30cm. All the fresh properties of concrete values were in good agreement to that of the values given by European guidelines.

TABLE 5: Fresh Concrete Properties

COMBINATIONS	**SLUMP FLOW**	**L-BOX**	**V- CHANNEL**	**U- BOX**
NOMINAL	4	0.8	5	30
MIX-1	6	0.8	6	31.5
MIX-2	9	0.77	7	32.3
MIX-3	11	0.73	9	33.6
MIX-4	13	0.70	11	35

Compressive strength tests are carried out on cubes of size 150 mm x 150 mm x 150mm. The results obtained are compared with the results of a control mix specimens. Effect on compressive strength of M30 Grade concrete mixes MIX-1 (TFS-40%, MK-20%, GF-0.125%, PF-0.125%), MIX-2(TFS-40%,MK-25%,GF-0.125%,PF-0.125%), MIX3(TFS80%,MK- 20%, GF-0.125%, PF-0.125%), MIX-4(TFS-80%,MK-25%,GF-1.125%,PF-0.125%) at the age of 7, 28days are tabulated below.

TABLE 6: Compressive Strength Test Results

S. No	Conc. Mix	7 days load (kN)	Comp. strength (N/mm2)	28 Days load (kN)	Comp. strength (N/mm2)
1	Nominal	470	20.8	680	30.2
2	MIX-1	420	18.6	625	27.7
3	MIX-2	440	19.5	640	28.4
4	MIX-3	480	21.3	700	31.1
5	MIX-4	520	23.1	750	33.3

Chart -1: Compressive strength test results

The maximum values for compressive strength test are obtained for MIX-4 (TFS-80%,MK-25%,GF-0.125%,PF- 0.125%) with an increase of 11% strength value at 28 days when compared to normal mix.

For the determine of split tensile strength of concrete cylinder specimens of diameter 150 mm and height 300 mm were casted. The cylinders were casted for the optimum values obtained from compression test. The tests were conducted on cylinders at an age of 7 and 28 days. Effect on split tensile strength of M30 Grade concrete mixes MIX-1 (TFS-40%, MK-20%, GF-0.125%, PF-0.125%), MIX-2(TFS- 40%,MK-25%,GF-0.125%,PF-0.125%), MIX3(TFS80% ,MK-

20%, GF-0.125%, PF-0.125%), MIX-4(TFS-80%,MK-25%,GF-0.125%,PF-0.125%) at the age of 7, 28days are tabulated below.

TABLE 7: Split Tensile Strength Test Results

S.No	Conc. Mix	7 days load (kN)	Split tensile. Strength (N/mm2)	28 Days load (kN)	Split tensile. Strength (N/mm2)
1	Nominal	130	1.83	230	2.68
2	MIX-1	110	1.5	160	2.26
3	MIX-2	120	1.69	180	2.5
4	MIX-3	135	1.91	250	3.57
5	MIX-4	150	2.12	280	3.96

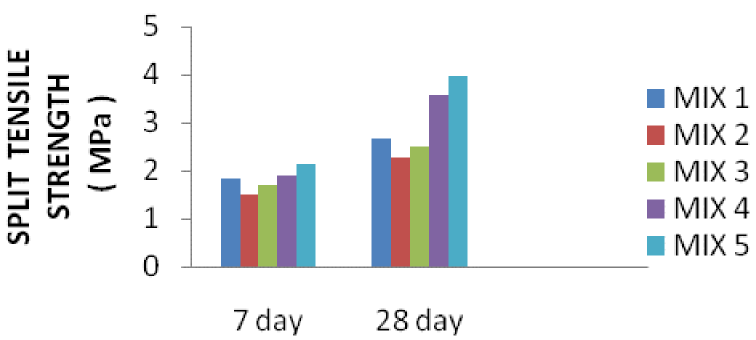

Chart -2: Split tensile strength test results

6.SEM- ANALYSIS REPORT

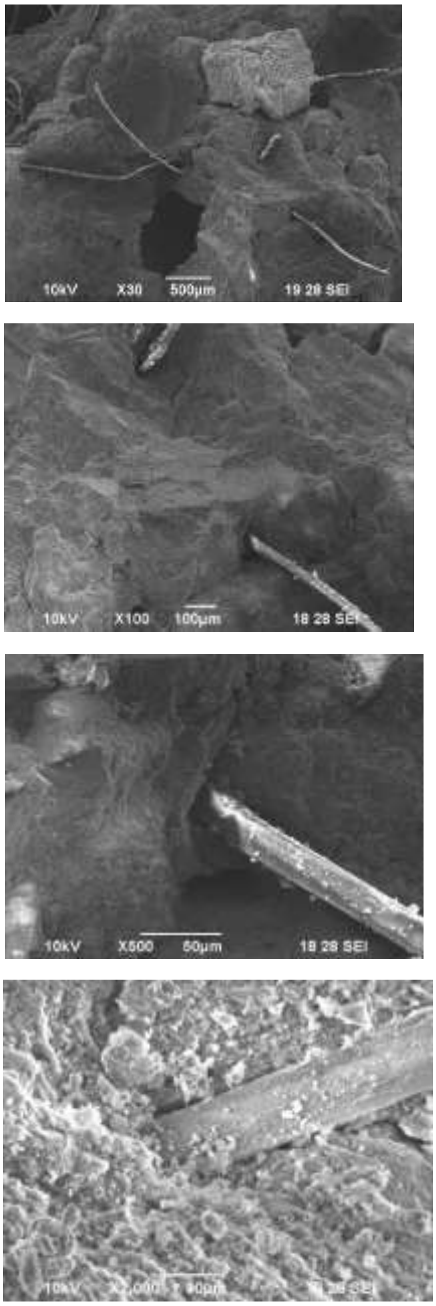

Fig-8: Images Captured At Various Scale By SEM

• Micro structural arrangements of concrete specimen can be obtained by Scanning Electron Microscope (SEM).

• A Scanning Electron Microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with afocusedbeam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the surface topography and composition of the sample.

• This shows the binding between the cement paste and aggregates.

• The major reason for failure occurs in concrete is caused by cracking occurs in the Interfacial Transition Zone (ITZ).

• The black hole represents the voids (or) pores present in the concrete; if the diameter of theholeis bigger, it means the diameter of voids also bigger.

• Due to this phenomenon the load carrying capacity of the concrete will also reduced.

• In this report the diameter of the hole is small, so the strength will also higher for this concrete mix.

• The major reason for increasing the compressive strength(11%) is strong bond between cement paste and aggregates.

• The wire like ingredients in concrete represents the fibre present in the concrete, fibres are helps to increasing the split tensile strength (9%) and avoids the shrinkage cracks in the concrete surface.

7. CONCLUSION

• The self-compacting concrete with the use of treated sand, metakaolin, glass fibre and polypropylene fibre is found to be economical and environment friendly.

• Four different mixes were derived by varying the treated sand and metakaolin percentage.

• Replacement of M-sand by 80% of treated-sand gives higher strength when compared to control mix.

• Replacement of OPC by 25% of metakaolin gives better result when compared to control mix.

• MIX-4 shows 11% increase in compressive strength value and 9% increase in split tensile strength value when compared to control mix.

• strength of concrete may increase when metakaolin percentage is increased.

• Further treatment of foundry sand with electro static precipitator may give good concrete properties.

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