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A STUDY ON FRESH CHARACTERISTICS OF SELF COMPACTING CONCRETE BY USING MINERALS (SILICA FUME & METAKOLIN AND CHEMICAL ADMIXTURES (POLY CARBOXYLATE ETHER)

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Abstract: This study presents an experimental investigation on self-compacting concrete (SCC) with cement (Portland pozzolanic cement) replacement of a Silica Fume (5%, 10%, 15% and 20%) Metakaolin (5%, 10%, 15% and 20%) and addition of chemical admixtures like Poly carboxylate ether super plasticizer (SP). Self-Compacting concrete is a concrete that exhibit the high flow ability and avoid the segregation and bleeding. There are several methods for testing its properties in the fresh state: the most frequently used are Slump−flow test, V−funnel L−box and U-box. The slump, V-funnel and L-Box test are carried out on the fresh SCC and in harden concrete compressive strength and split tensile strength values are determined. Attempts have been made to study the properties of such SCCs and to investigate the suitability of Silica Fume(SF) and Metakaolin(MK) to be used as partial replacement materials for cement in SCC.

***Keywords* –Self Compacting Concrete, Silica Fume, Metakaolin, Poly carboxylate ether, workability tests.**

I. INTRODUCTION

Concrete production contributes heavily to greenhouse gas emissions, thus a need exists for the development of durable and sustainable concrete with a lower carbon footprint. (Neeraja & Sharma, 2019). Self Compacting Concrete is a special kind of innovative concrete, which does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete(Ardalan et al., 2020). Concrete that requires little vibration or compaction has been used in Europe since the early 1970s but self-compacting concrete was not developed until the late 1980’s in Japan. In Europe it was probably first used in civil works for transportation networks in Sweden in the mid1990’s. The EC funded a multi-national, industry lead project “SCC” 1997-2000 and since then SCC has found increasing use in all European countries(Hemalatha et al., 2017).

Self-compacting concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The fluidity and segregation resistance of SCC ensures a high level of homogeneity, minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finish and durability to the structure(Ponikiewski & Katzer, 2017). SCC is often produced with low water-cement ratio providing the potential for high early strength, earlier remolding and faster use of elements and structures. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction(Engineering, 2015). Self-compacting concrete (SCC) has been described as the most revolutionary development in concrete construction for several decades(Wara & Neeraja, 2019).

II MATERIALS REQUIRED

CEMENT:

(PPC – Ultratech Cement) was used for the investigation. It was tested for its physical properties in accordance with Indian Standard specifications. The properties of cement shown in Table1

Table 1: Properties of Cement

S.No	Property	Values
1	Specific Gravity	3.05
2	Normal Consistency	34 %
3	Initial Setting time	45mins
4	Final setting time	480mins

FINE AGGREGATE:

Standard sand is silica sand used in making concrete and cement tests. The fine aggregate obtained from river bed, clear from all sorts of organic impurities was used in this experimental program. The fine aggregate was passing through 4.75 mm sieve and the grading zone of fine aggregate was zone II as per Indian Standard specifications. The properties of Fine aggregate are shown in Table 2.

Table 2 Properties of Fine Aggregate

S.No	Property	Values
1	Specific Gravity	2.6
2	Fineness Modulus	3.237
3	Grading of Sand	Zone – II

COARSE AGGREGATE:

Coarse aggregate are the crushed stone is used for making concrete. The commercial stone is quarried, crushed and graded. Much of the crushed stone used is granite, limestone and trap rock. Graded crushed stone usually consists of only one kind of rock and is broken with sharp edges. Machine crushed granite broken stone angular in shape was used as coarse aggregate. The maximum size of coarse aggregate was 12 mm and the properties of coarse aggregate are shown inTable3

Table 3: Properties of Coarse Aggregate

S.No	Property	Values
1	Specific Gravity	2.60
2	Water Absorption	0.3%
3	Fineness Modulus	7.69

WATER:

Water is an important ingredient of concrete, which not only actively participates in the hydration of cement but also contributes to the workability of fresh concrete. Cement is a mixture of complex compounds, the reaction of cement with water leads to its set hardening. All compounds present in the cement are anhydrous but when brought into contact with the water they get hydrolysed, forming hydrated compounds. The two principal functions of water in a concrete mix are to effect hydration and improve workability.

SILICAFUME:

Silica Fume is highly pozzolanic mineral admixture, which is mainly utilized to improve concrete strength and durability of concrete. Silica Fume reacts with calcium hydroxide formed during hydration of cement results in the increase in strength and also the Silica Fume fills the voids between cement particles leads to increase in the durability. Silica Fume is procured from ASTRRA CHEMICALS.

Fig. 1: Silica fume

Table4: Physical properties of Silica Fume

S.No.	Physical Properties	Results
1	Physical State	Micronized Powder
2	Odour	Odourless
3	Appearance	White Colour Powder
4	Colour	White
5	Pack Density	0.76 gm/cc
6	P^H of 5% SOLUTION	6.90
7	Specific Gravity	2.63
8	Moisture	0.058%
9	Oil Absorption	55 ml / 100 gms

Table 5: Chemical properties of Silica Fume

S.No.	Chemical Properties	Results
1	Silica (SiO2)	99.886%
2	Alumina (Al2O3)	0.043%
3	Ferric Oxide (Fe2O3	0.040%
4	Loss On Ignition	0.015%
5	Sodium Oxide (Na2O)	0.003%
6	Titanium Oxide (TiO2)	0.001%
7	Calcium Oxide (CaO)	0.001%
8	Potassium Oxide (K2O)	0.001%
9	Magnesium Oxide (MgO)	0.000%

METAKAOLINE:

It is fired (calcined) under carefully controlled conditions to create an amorphous aluminosilicate that is reactive in concrete. Like other pozzolans (fly ash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide (lime) by-products' produced during cement hydration.

Fig. 2: Metakaoline

Calcium hydroxide accounts for up to 25% of the hydrated Portland cement, and calcium hydroxide does not contribute to the concrete's strength or durability. Metakaolin combines with the calcium hydroxide to produce additional cementing compounds, the material responsible for holding concrete together.

Less calcium hydroxide and more cementing compounds means stronger concrete. It is very fine and highly reactive, gives fresh concrete a creamy, non sticky texture that makes finishing easier.

Our experience has shown that optimal performance is achieved by replacing 10% to 15% of the cement with Metakaolin. While it is possible to use less, the benefits are not fully realized until at least 10% Metakaolin is used. The advantage of replacing some of the cement with Metakaolin, rather than simply adding Metakaolin to the mix, is that any existing color formulas or mix designs won't change, or will only very slightly change.

SUPER PLASTICIZER (SP):

The admixture poly carboxylate ether was used as a super plasticizer. It was used to provide necessary workability. The physical and chemical characteristics were tabulated in Table 6

Table 6: Physical and chemical characteristics of the poly carboxylate admixture

S.No.	Physical and chemical properties	Results
1	Appearance	Yellow-brown liquid
2	% solid residue	Approx. 38%
3	p^H	5.3–5.4
4	Specific gravity : kg/l	Approx. 1. 09

III CONCRETE MIX DESIGN:

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required workability, strength, durability as economically as possible, is termed as the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states (Kumari, 2013) . If the plastic concrete is not workable, it cannot be properly placed and compacted. The property of workability, therefore, becomes of vital importance.

- Mix design for Self Compacting concrete (for natural sand):

Several methods exist for the mix design of SCC. The general purpose mix design method was first developed by Okamura and Ozawa (1995).(Shi et al., 2015)

Table 7: Properties of Materials used for Mix design (for Natural sand)

Type of cement	PPC 43 Grade
Maximum nominal size of aggregate	12 mm (8 mm-12 mm)
Minimum content of cement	320 kg/m3
Maximum water cement ratio	0.45
Specific gravity of cement	3.05
Specific gravity of coarse aggregate	2.6
Specific gravity of fine aggregate	2.6

Table 8: Mixture Proportions for Trial and SCC (Kg/m^3)

S.No	Trail 1	Trail 2	Trail 3	SCC
Binder (kg/m3)	483	461	491	537
Water (lit)	170	162	177	193
Fine Aggregate (kg/m3)	339	951	912	828
Coarse Aggregate(kg/m3)	309	771	756	760
Super plasticizer (lit)	4.348	4.152	5.891	4.826

IV EXPERIMENTAL INVESTIGATION:

The experimental investigation is carried out to obtain the fresh properties of concrete by replacement of cement with silica fume and Metakaolin and combinations of both silica fume and Metakaolin by using chemical admixture. In the present investigation concrete specimens were prepared with various combinations of silica fume 5%, 10%, 15% ,20% and Metakaolin 5%, 10%, 15% ,20% and equal proportions of both silica fume and Metakaolin with 5% ,10%,15% and 20% of cement replacement by weight. A concrete mix can only be classified as Self-compacting Concrete if the requirements for all three characteristics are fulfilled: Based on the EFNARC guidelines(EFNARC, 2005) some of the available fresh property tests such as slump flow, V-funnel, L-box and U-box tests were conducted to evaluate the fresh properties. EFNARC specifications for SCC workability tests requirements in fresh state are given below in table 9.

Table 9: Requirements of SCC given by EFNARC Guidelines

S.No	Method	Property
1	Slump-flow by Abrams cone	Filling ability
2	T50cmslumpflow	Filling ability
3	V-funnel	Filling ability
4	V-funnel at T5minutes	Segregation resistance
5	L-box	Passing ability
6	U-box	Passing ability

Fig. 3: Slump flow Process

V RESULTS & DISCUSSIONS:

Tests were conducted on fresh concrete, Standard procedures were adopted for testing. The results of the experimental investigations are presented and discussed herein. The experimental program was designed to compare the properties of filling ability, passing ability, segregation resistance with different replacement levels of Portland Pozzolana Cement (Ultratech cement 43 grade) with Silica Fume and Metakaolin. The various tests namely slump flow, V-funnel, L-box and U-box were conducted to the test the workability and passing ability of standard and high strength self- compacting concrete as per EFNARC guidelines(Ahmad et al., 2019).

Table 10: Fresh properties of Self Compacting Concrete

Concrete Mixes	CONCRETE MIXES	Slump flow (600-800mm)	V-funnel (6-12sec)	L Box (h2/h1)	U Box (h2-h1) mm
CC	Control concrete	670	10	0.8	27
M1	PPC+5%SF	660	10	0.9	31
M2	PPC+10%SF	640	11	0.9	30
M3	PPC+15%SF	620	11	0.9	32
M4	PPC+20%SF	610	12	1.0	30
M5	PPC+5%MK	640	09	0.8	29
M6	PPC+10%MK	620	10	0.9	29
M7	PPC+15%MK	610	11	0.9	30
M8	PPC+20%MK	600	11	1.0	30
M9	PPC+5%SF+5%MK	650	10	1.0	31
M10	PPC+10%SF+10%MK	640	11	1.0	32
M11	PPC+15%SF+15%MK	610	12	1.0	32
M12	PPC+20%SF+20%MK	600	12	1.0	30

1. Trial and error procedure have to be adopted for maintaining flow ability, self- compatibility and obstruction clearance as per EFNARC guidelines till to arrive consistent SCC mix.
2. As increasing the SF and MK and combined mixing of SF&MK contents from 5 to 20 percentages the V-funnel flow values increased from 10 to 12 sec.
3. As increasing the SF and MK contents from 5 to 20 percentages the L-Box test results are increased from 0.8 to 1 and combined mixing of SF&MK have no change in results they are remain same.
4. As increasing the SF contents are from 5 to 20 percentages the U-Box test results are increased from 5% to 10% and then decreased from 10-20% and MK contents from 5 to 20 percentages constant at 5-10 percentages and 15-20 percentages and combined mixing of SF&MK contents are increased up to 15% and then decreased.

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