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Experimental investigation on fly ash based self-compacting concrete with metakaolin.

Investigación experimental en hormigón autocompactante a base de cenizas volantes con metacaolín.

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ABSTRACT

Self-Compacting Concrete (SCC) is a fresh concrete which is highly flowable, and it can flow readily into place, fill the formwork without any compaction and without undergoing any significant segregation. It is used in the construction where it is hard to use vibrators for consolidation of concrete. High amount of cement and chemical admixtures used in SCC reduces its wide scale usage. Metakaolin can be used as a better substitute to cement due to its cementitious properties. Metakaolin combines with $Ca(OH)_2$ produces additional cementation compounds and makes concrete strengthen. This study aims to experimentally investigate the fresh and strength properties of flyash based self-compacting concrete with different percentage replacement levels of metakaolin with cement. To obtain the optimum percentage of metakaolin in flyash based SCC in which metakaolin is partially replacing cement at 10%, 15% and 20% by weight of cement. M40 grade equivalent flyashbased SCC was established based on fresh properties such as flow ability and passing ability and strength parameters like compressive strength, spilt tensile strength and flexural strength. The results showed that fresh properties decreased as the metakaolin content increased. The strength parameters increased about 15.2%, 12.82% and 14.1% for 15% metakaolin.

Keywords—Self-Compacting Concrete, Metakaolin, Fly Ash.

RESUMEN

El hormigón autocompactante (SCC) es un hormigón fresco que es muy fluido y puede fluir fácilmente a su lugar, llenar el encofrado sin ninguna compactación y sin sufrir una segregación significativa. Se utiliza en la construcción donde es difícil utilizar vibradores para la consolidación de hormigón. La gran cantidad de cemento y aditivos químicos utilizados en SCC reduce su uso a gran escala. El metacaolín se puede utilizar como un mejor sustituto del cemento debido a sus propiedades cementosas. El metacaolín combinado con Ca (OH) 2 produce compuestos de cementación adicionales y fortalece el concreto. Este estudio tiene como objetivo investigar experimentalmente las propiedades frescas y de resistencia del hormigón autocompactante a base de cenizas volantes con diferentes niveles porcentuales de sustitución de metacaolín con cemento.Obtener el porcentaje óptimo de metacaolín en SCC a base de cenizas volantes en el que el metacaolín está reemplazando parcialmente al cemento al 10%, 15% y 20% en peso de cemento. El SCC basado en cenizas volantes equivalente al grado M40 se estableció en base a propiedades frescas como la capacidad de flujo y la capacidad de paso y parámetros de resistencia como la resistencia a la compresión, la resistencia a la tracción derramada y la resistencia a la flexión. Los resultados mostraron que las propiedades frescas disminuían a medida que aumentaba el contenido de metacaolín. Los parámetros de resistencia aumentaron aproximadamente un 15,2%, 12,82% y 14,1% para el 15% de metacaolín.

Palabras clave: hormigón autocompactante, metacaolín, cenizas volantes.

INTRODUCTION

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[2]. 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. The process is quite complex and can be simplify by understanding the relative significance of various mixture parameters on key properties of SCC. This includes deformability, passing ability filling capacity and segregation resistance. As with any new technology, there was clearly a learning curve to overcome, and refinement of the materials and mix proportions used to take care and patience to finally achieve optimum performance[1], [2] SCC mixes usually contain superplasticizer, high content of fines and/or viscosity modifying additive (VMA). The use of superplasticizer maintains the fluidity, the fine content provides stability of the mix resulting in resistance against bleeding and segregation. The cement industry was one of the main producers of carbon dioxide, a potent greenhouse gas. This cement production can be reduced by using supplementary cementitious material. Various types of pozzolanic materials that improves the cement properties. One of the most commonly used pozzolanic material was metakaolin[2][1][4]. Because it possesses a high reactivity with calcium hydroxide having the ability to accelerate cement hydration. Metakaolin reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel, it is very effective pozzolanic materials and effectively enhances the strength parameters of concrete [4], [5], [7].

MATERIAL AND METHODS

The method adopted for this study is as follows

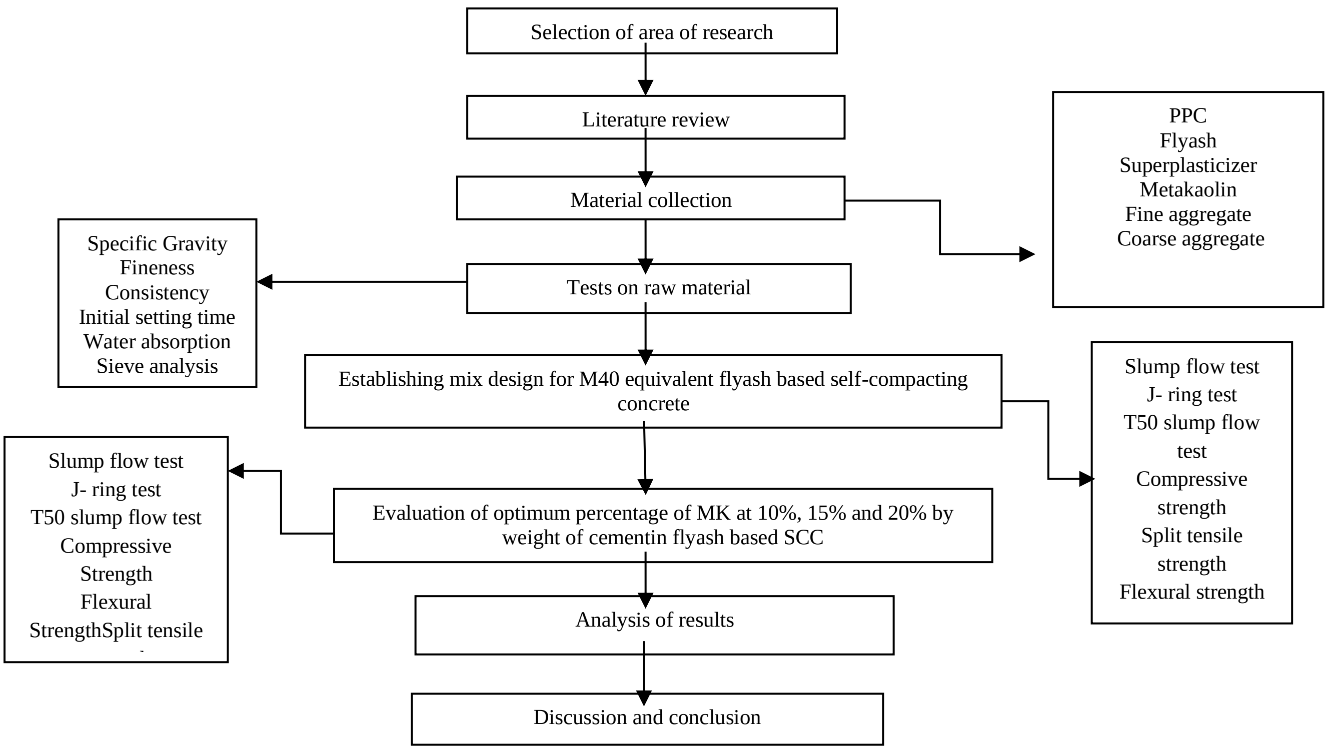

Fig 1: Flowchart of Methodology

The materials used in the experimental study are, cement (PPC), flyash, coarse aggregate, fine aggregates upper plasticizer and metakaolin as replacement material for cement. In the present experimental work, Portland pozzolana cement was used confirming to IS 1489:1991 (Part 1). Cement is generally used as the main binder material. Metakaolin is an anhydrous calcined form of the clay mineral kaolinite. Metakaolin of specific gravity 2.6 is used for this study and collected from Chennai.Fly ash is an industrial waste product which is accepted as an environmental pollutant, generated during the combustion of coal for energy production. The fly ash of specific gravity 2.57 and Class-F was collected from Marymatha Construction Company, Ambalamugal, Ernakulam.

Fine aggregate usually consist of river sand. Due to the scarcity of river sand and the environmental impact of river excavations. M-sand is used as fine aggregate for this study. M-sand properties wereconfirming to Zone I of IS 383:1970 (Reaffirmed 2016). Coarse aggregates are commonly considered as inert fillers. The coarse aggregate of size ranging from 12.5 mm to 4.75 mm was used for casting. The properties of coarse aggregates were confirming to IS 383:1970 (Reaffirmed 2016).

Water is an important ingredient of self- compacting concrete, as it actively participates in the chemical reaction with cement. The strength of cement concrete comes from the bonding action of the hydrated cement gel. Superplasticizer are additives used in making high strength concrete. Master Glenium 51 is a chloride free, high range water reducing and waterproofing admixture.Table 1 gives the various tests and properties of the materials.

Table 1: Materials and Properties

Material	Experiment	Result
Cement	Specific gravity	3.2
	Initial setting time	40 minutes
	Consistency	33%
Fine aggregate	Specific gravity	2.63
	Water absorption	1.23%
	Fineness modulus	2.9
Coarse aggregate	Specific gravity	2.65
	Water absorption	0.72%
	Fineness modulus	2.49
Flyash	Specific gravity	2.57
Metakaolin	Specific gravity	2.6

MIX DESIGN

Mix design was done as per EFNARC and IS 10262:2009. Mix design of M40 equivalent Flyash based self - compacting concrete with varying percentages of metakaolin mix are given in table 2.

Table 2: Mix proportions

Mix	Nomenclature	Proportion
SCC equivalent to M40 grade containing 30% Flyash	F3O	1:0.42:1.98:1.77:0.34
SCCequivalent to M40 grade containing 30% Flyashcontaining 10% Metakaoilin	F3OMK10	0.85:0.42:0.142:1.98:1.77:0.34
SCCequivalent to M40 grade containing 30% Flyash containing 15% Metakaoilin	F30MK15	0.78:0.42:0.214:1.98:1.77:0.34
SCCequivalent to M40 grade containing 30% Flyash containing 20% Metakaoilin	F30MK20	0.71:0.42:0.28:1.98:1.77:0.34

CASTING AND TESTING

To determine the fresh properties of SCC, various tests performed like slump flow, T50 slump flow test time and J-ring test. All these tests were to check passing ability, viscosity/ flowability and filling ability of self- compacting concrete.The tests conducted on SCC mixes in hardened state were compressive strength test, split tensile strength test, flexural strength test.Cubes, cylinders and beams are casted for different mix proportion of self- compacting concrete and are tested for 7 and 28 days are shown in figure 2.

Figure 2. Slump flow test and casted specimens

RESULTS AND DISCUSSIONS

Compressive Strength: The compressive strength of fly ash based self-compacting concrete cubes made with varying percentage of metakaolin are tested after 7 and 28days are shown in fig 3. After 28 days of curing the SCC with 15% metakaolin gives the maximum compressive strength and the value is 56.4 N/mm^2. This mix gives 15.2% increase in strength at 28 days when correlated to control mix. After this the metakaolin percentage is increased then the compressive strength is decreased. The metakaolin addition can be adopted as a method to improve the compressive strength of SCC. All the SCC mix with metakaolin exhibited higher compressive strength than the control mix.

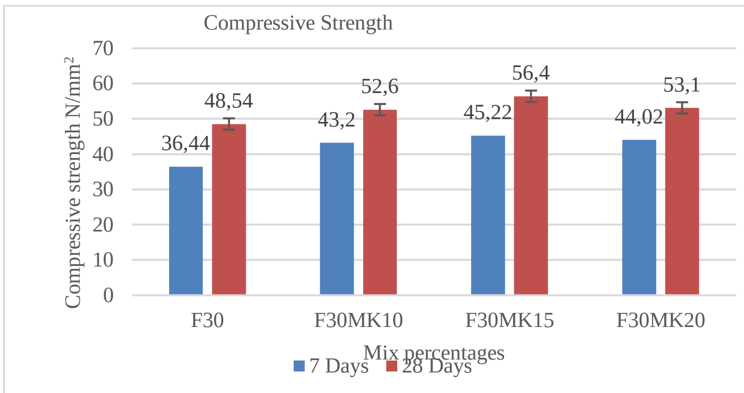

Fig 3: of Variation of compressive strength of Fly Ash Based SCC with Varying % of MK

Split Tensile Strength: The effect of metakaolin in flyash based self- compacting concrete on the split tensile strength are shown in fig 4. The split tensile strength value of SCC increases with increase in percentage of cement replacement with metakaolin upto a 15%. The split tensile strength increases a maximum of 4.4N/mm^2 for 15% of MK and the metakaolin content exceeds the value of 20%, the split tensile strength decreases to 4.1 N/mm^2 .The split tensile strength gain maximum at 15% replacement of cement with metakaolin and this mix gives 12.82% increase in split tensile strength compared to control mix

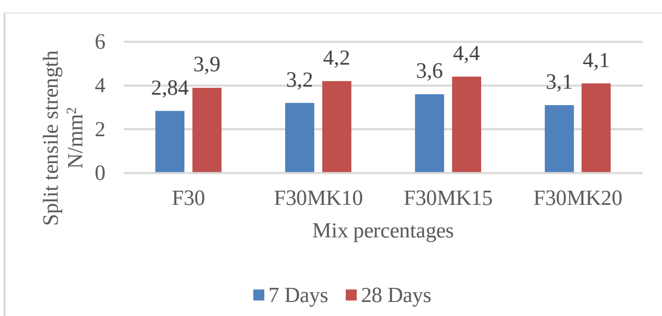

Fig 4: of Variation of split tensile strength of Fly Ash Based SCC with Varying % of MK

Flexural Strength: The effect of metakaolin in flyash based self- compacting concrete on the flexural Strength are shown in figure 5. the maximum flexural strength is 6.1 N/mm^2 for 15% replacement of metakaolin. The mix gives 14.1% increase in flexural Strength compared to control mix. The metakaolin percentage increases to 20% then the flexural strength is decreased. Therefore, the optimum percentage of metakaolin in flexural strength is obtained as 15%.

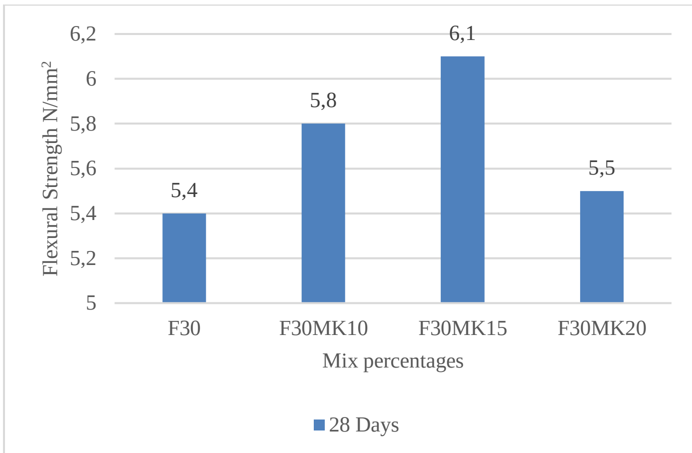

Fig 5: of Variation of flexural strength of Fly Ash Based SCC with Varying % of MK

Workability: The slump flow of Mk15 was measured to be 690 mm while this could be decreased to 675 mm, when MK introduced to 20%. The 15% addition of metakaolin in SCC mixes slightly increased the self compactability characteristics such as filling ability, passing ability and resistance to segregation. The obtained values are given in table 6.

Table 6: Mix proportions

Mixes	Slump flow (mm)	T50 slump flow(sec)	J-ring (mm)	Passing ability (mm)	Remarks(as per ASTM 1621/C 1621M)
F30	680	2.5	671	8	No visible blocking since
F30MK10	685	2.7	677	8	passing ability values are
F30MK15	690	2.5	681	9	between 0-25mm
F30MK20	675	2.9	667	8	

As conclusion, this work was intended to analyze the fresh properties and strength parameters of SCC prepared with partial replacement of cement with metakaolin. Based on the results obtained from the current research, the following main conclusion can be summarized. The control mix can be adopted as Fly Ash30 (from literature) based on fresh and strength parameters. Self- compacted concrete can be achieved using metakaolin as a cementitious material. There is a great positive effect of increasing metakaolin content on the compressive, tensile and flexural strength at 7&28 days age for self- compacted concrete. Using metakaolin content from 10 to 20% by weight of cement as replacement gives higher strength than samples without metakaolin content. The maximum strength could be obtained by using 15% of metakaolin as replacing percentage by weight of cement. However, the inclusion of metakaolin in concrete reduces the workability of concrete. In order to counter the problem, superplasticizer is used in concrete to produce SCC. The 15% addition of metakaolin in SCC mixes slightly maintained the self compactability characteristic like filling ability, passing ability and resistance to segregation.The fly ash based self-compacting concrete with 15% of metakaolin in cement can be used where compaction is very difficult due to the presence of heavy reinforcement like beams, column etc.

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