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Effect of metakaolin and alccofine in high strength concrete.

Efecto del metacaolín y la alcofina en hormigones de alta resistencia.

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ABSTRACT

High strength concrete is defined as concrete with characteristic cube strength above 40 MPa. The applications of high strength concrete are bridges, aqueducts, dams, high rise buildings etc. This work involves the comparative study of various mineral admixtures such as alccofine and metakaolin on high strength concrete. Alccofine is a new generation micro fine concrete material which is beneficial with respect to workability as well as strength. The desirable properties of Metakaolin make it mostly preferred additives in high strength concrete. In this study, cement is partially replaced with alccofine, metakaolin at 5, 10 and15%. The mechanical properties like compressive strength, flexural strength and split tensile strength are evaluated and compared. The strength properties are maximum for the concrete mix with alccofine.

Keywords—high strength concrete, metakaolin, alccofine.

RESUMEN

El hormigón de alta resistencia se define como hormigón con una resistencia al cubo característica superior a 40 MPa. Las aplicaciones del hormigón de alta resistencia son puentes, acueductos, presas, edificios de gran altura, etc. Este trabajo implica el estudio comparativo de diversos aditivos minerales como la alccofina y el metacaolín sobre hormigón de alta resistencia. Alccofine es un material de hormigón micro fino de nueva generación que es beneficioso con respecto a la trabajabilidad y la resistencia. Las propiedades deseables del metacaolín lo convierten en los aditivos más preferidos en el hormigón de alta resistencia. En este estudio, el cemento se reemplaza parcialmente con alccofina, metacaolín al 5, 10 y 15%. Se evalúan y comparan las propiedades mecánicas como la resistencia a la compresión, la resistencia a la flexión y la resistencia a la tracción dividida. Las propiedades de resistencia son máximas para la mezcla de hormigón con alccofina.

Palabras clave: hormigón de alta resistencia, metacaolín, alcofina.

INRODUCTION

High strength concrete (HSC) may be defined as concrete with specified characteristic cube strength above 40N/mm^2. The main applications for HSC in-situ concrete construction are in offshore structures, columns for tall buildings, long-span bridges and other highway structures. Admixtures are added in concrete to improve the quality of concrete. Mineral admixtures include alccofine, metakaolin (MK) which possess certain characteristics through which they influence the properties of concrete. Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance 'performance of concrete' in fresh and hardened stages due to its optimized particle size distribution. The carbon footprint can be reduced by replacing the cement with supplementary cementitious materials. Metakaolin is an anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin. It is the most effective pozzolanic material. 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

MATERIAL AND METHODS

The method adopted for this study is as follows (Fig. 1).

The materials used in the experimental study are, cement (PPC), metakaolin and alccofine as replacement material for cement, coarse aggregate and fine aggregate 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. It is the most effective pozzolanic material. The coarse aggregates are generally crushed stones with size ranging from 20 mm to 4.75 mm. They occupy around 70% of the total volume of concrete. The coarse aggregates used were with a nominal size of 20mm. The properties of coarse aggregates were confirming to IS 383:1970 (Reaffirmed 2016). Water is an important ingredient of 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.

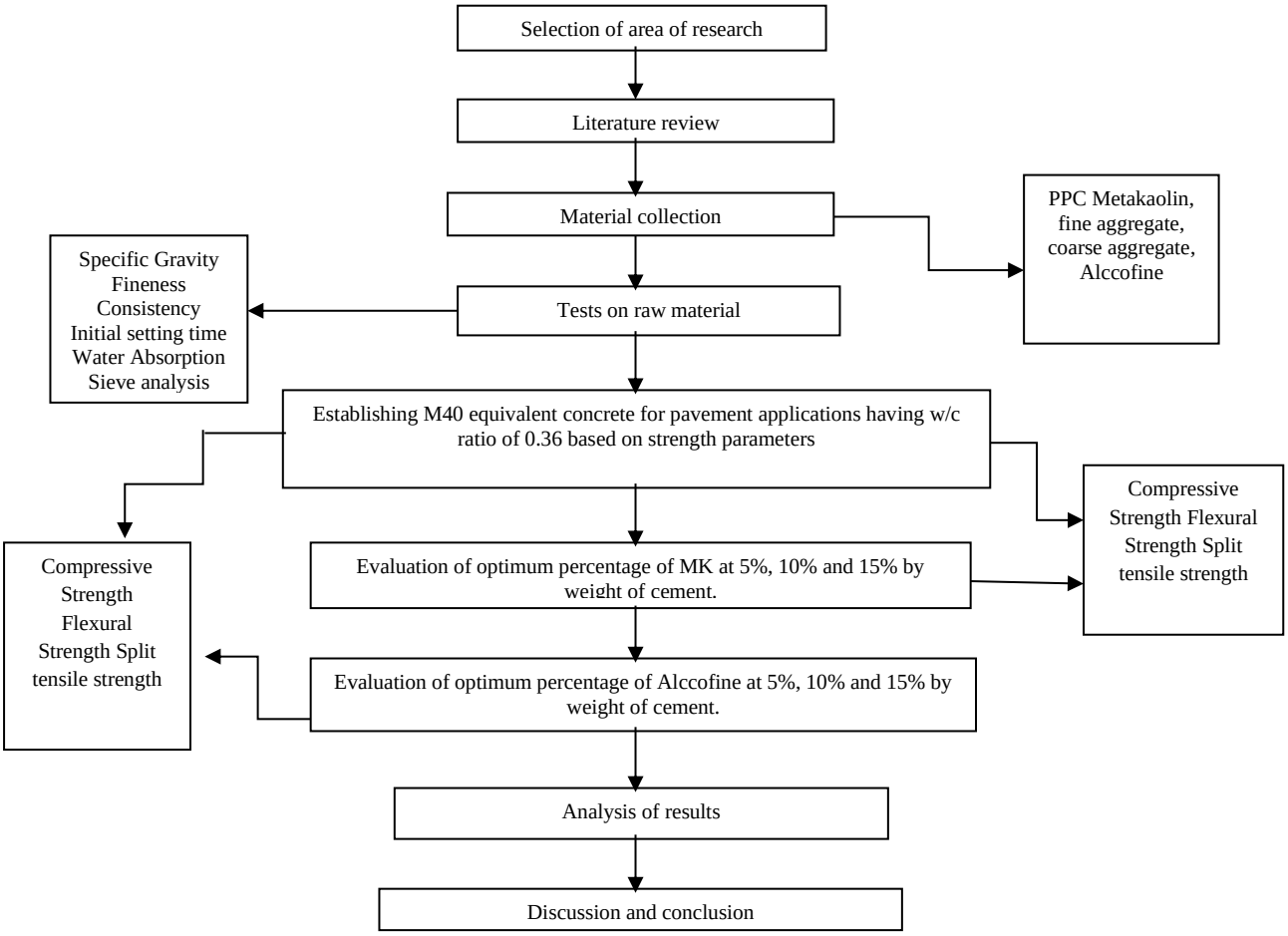

Fig 1: Flowchart of Methodology

Table 1 gives the various tests and properties of the materials.

Table 1: Materials and Properties

Material	Experiment	Result
Cement	Specific gravity	3.19
	Initial setting time	40 minutes
	Consistency	33%
Coarse aggregate	Specific gravity	2.66
	Water absorption	0.72%
Fine aggregate	Specific gravity	2.63
	Water absorption	1.23%
Metakaolin	Specific gravity	2.6
Alccofine	Specific gravity	2.8

The mix was designed as per IS 10262-2019. The cement was replaced by metakaolin and alccofine by weight. The proportions of components in the high strength concrete in each mix are given in table 2.

Table 2: Mix proportions

Mix	Nomenclature	Proportion
High strength concrete	HSC	1:1.6:3:0.36
High strength concrete containing 5% Metakaoilin	HSCMK5	0.95:0.05:3:0.36
High strength concrete containing 10% Metakaoilin	HSCMK10	0.9:0.1:3:0.36
High strength concrete containing 15% Metakaoilin	HSCMK15	0.85:0.15:3:0.36
High strength concrete containing 5% Alccofine	HSCMK5	0.95:0.05:3:0.36
High strength concrete containing 10% Alccofine	HSCMK10	0.9:0.1:3:0.36
High strength concrete containing 15% Alccofine	HSCMK15	0.85:0.15:3:0.36

Cubes, cylinders and beams are casted for different mix proportions of high strength concrete and are tested for 28 days.

Fig 2: Casted specimens

RESULTS AND DISCUSSIONS

Compressive strength: The influence of metakaolin and alccofine replacement levels on high strength concrete for compressive strength is shown in figure 3. The test is carried out on cubic specimens of size 150x150x150mm. Each specimen is tested for 28 days. It is clear that the use of metakaolin has a significant effect on compressive strength due to the pozzolanic effect where increase in metakaolin content to a certain extend increases the compressive strength of different mixes of high strength concrete. 10% metakaolin content gives the maximum compressive strength of 53.74 N/mm² at 28 days which is 7.8% more when correlated to control mix.10% metakaolin content gives the maximum compressive strength of 53.74 N/mm² at 28 days which is 7.8% more when correlated to control mix. 10% alccofine content gives the maximum compressive strength of 53.74 N/mm² at 28 days which is 7.8% more when correlated to control mix.10% metakaolin content gives the maximum compressive strength of 54.04 N/mm² at 28 days which is 8.32% more when correlated to control mix.

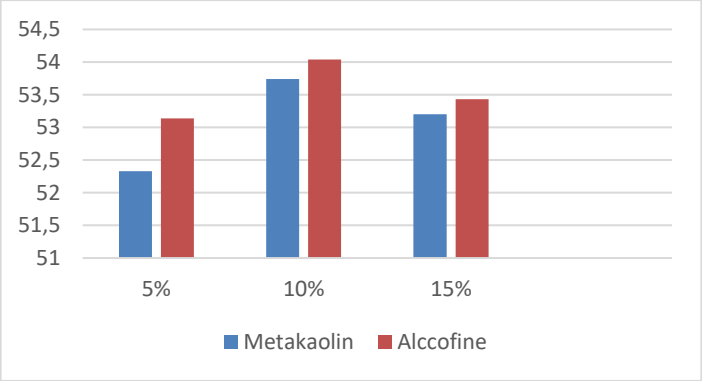

Fig 3: Variation of compressive strength of high strength concrete with varying % of metakaolin and alccofine

Split tensile strength: Figure 4 shows the influence of metakaolin and alccofine replacement levels on concrete forsplit tensile strength. The test is carried out on cylindrical specimens of size 150x300mm. Each specimen is tested for 28 days.Maximum strength of 5.25 is gained at 10% metakaolin replacement at 28 days and this mix gives 23.4% increase in split tensile strength when compared to control mix.Maximum strength of 5.50 is gained at 10% alccofine replacement at 28 days and this mix gives 26.9% increase in split tensile strength when compared to control mix.

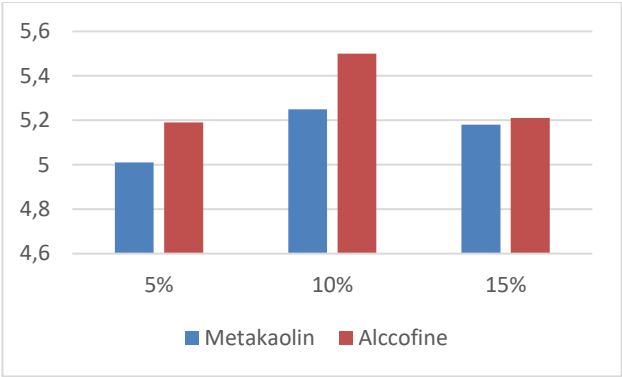

Fig 4: Variation of split tensile strength of high strength concrete with varying % of metakaolin and alccofine

Flexural strength -The influence of metakaolin and alccofine replacement levels on high strength concrete for flexural strength is shown in figure 5. The test was conducted as per IS 516:1959 (Reaffirmed 2013) in Universal testing machine. Each specimen is tested for 28 days. 10% metakaolin content gives maximum flexural strength of 5.41 N/mm² at 28 days which is 13.30% more when correlated to control mix. 10% alccofinecontent gives maximum flexural strength of 5.89 N/mm² at 28 days which is 20.3% more when correlated to control mix.

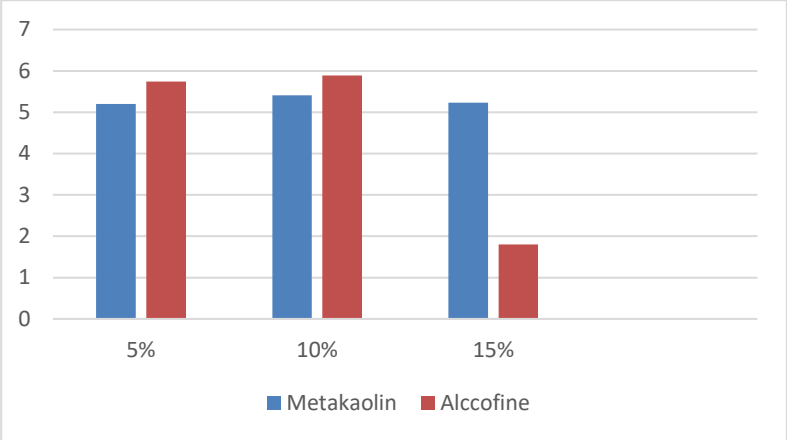

Fig 5: Variation of flexural strength of high strength concrete with varying % of metakaolin and alccofine

As conclusion, this work intended to analyze the mechanical properties of High strength concrete prepared with partial replacement of mineral admixtures namely Alccofine and Metakaolin. The utilization of mineral admixtures as a partial replacement of cement increases the strength properties of concrete and also reduces the construction cost with efficient utilization of industrial waste. The compressive strength split tensile strength and flexural strength increases with the replacement of cement with metakaolin. The maximum compressive strength of high strength concrete with 10% metakaolin mix is 53.74 N/mm^2,

split tensile strength is 5.25 N/mm^2 and the flexural strength is 5.41 N/mm^2, which are greater than the control mix. The optimum amount of metakaolin was obtained as 10% in terms of compressive strength, split tensile strength and flexural strength. It was due to the filler effect, dilution effect(physical) and the pozzolanic reaction of metakaolin with $Ca(OH)_2$ (chemical effect) forming additional C-S-H gel. The replacement of cement with 10% of MK showed an increase of 7.8% in compressive strength, 23.4% in split tensile strength and 13.30% in flexural strength when compared with control mix. The mechanical properties increase with the increase in addition of alccofine and then decreases. The maximum compressive strength of high strength concrete with 10% alccofine mix is 54.04 N/mm^2, split tensile strength is 5.50 N/mm^2 and the flexural strength is 5.89 N/mm^2, which are greater than the control mix. The optimum amount of alccofine was obtained as 10% in terms of compressive strength, split tensile strength and flexural strength. It was due to optimized size, ultra-fine nature (finer than other hydraulic materials), unique chemical composition and high glass content in alccofine. So it can be concluded that the concrete mix with alccofine shows greater increase in strength properties when compared with concrete mix with metakaolin.

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