Strength and durability properties of quaternary blended high strength concrete

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Abstract. Concrete is in great demand due to global infrastructure expansion. Cement is a critical component in the production of concrete because it binds the ingredients together. But the primary issue arises in the environment due to the release of toxic gases such as CO_3 and sulphur into the atmosphere. To overcome this, some other cementitious materials, namely admixtures, were utilized as partial replacements for the cement. In this study, concrete was made for M70 grade with a quaternary blend in composition with cement, silica fume, metakaolin, and alccofine. Silica fume is largely used as a mineral admixture in high-strength and high-performance concrete. Metakaolin is a cementitious material developed from the heat treatment of natural kaolin deposits. Alccofine is a new type of admixture in concrete. These materials not only lower the consumption of cement but also help concrete maintain its qualities, so it is proposed to study the mechanical, and durability properties of hardened concrete. This paper mainly highlights on the utilization of metakaolin, Alccofine and silica fume as they replaced the cement in varying proportions to get the required strength of M70 grade concrete for 7 days of compressive, and split tensile strength.

1 Introduction

Concrete is an amalgamated material prepared up by admixing cement, aggregates, and water that hardens over time. The main stream of the concretes used are lime as base, such as Portland cement concrete or concretes produced by means of various hydraulic cements. Certain road surfaces are made of concrete as well, such as Asphalt concreting, where the binding material is bitumen. Polymer concrete in which the reinforcing material is a polymer. Cement chemically responds with the water and further components to generate a complex composites that binds all of the constituents together to make a robust stone-like substance. Majority of the studies have been conducted, and it has also been discovered that exposure circumstances have a substantial impact on durability. This notion has been modified in light of what has been discovered in other countries.

Blended cement is ordinary Portland cement (OPC) mixed with additives such as metakaolin, Alccofine and silica fume to improve its characteristics for numerous uses. Concrete's durability, workability and chemical resistance enhanced using blended cement. Blended cement is an excellent choice for a wide range of applications, including high-rise buildings and long bridges. Replacing 10% metakoline, 5% alccofine, 10% silica fume with cement gives much better compressive strength after 7 days.

2 Review of Literature

Chandak, 2018 stated that the use of 25% MK in place of cement results in increased strengths of all fundamental parameters, including as flexure, compressive, split, and tensile strengths, as well as improved durability.

Mahim Mathur, 2018 stated that the as the raise in the content of the alccofine as the partial substitute to cement exhibited the raise in the slump by 10% on the account of fresh property of concrete.

Narender Reddy, 2018 concluded from his experimental investigation, concrete attained greater density as it shown enhancement in strength characteristics of hardened concrete by the utilised constituents of Nano silica and alccofine. The dense packing of concrete with nano and micro particles helps in restricting the entry of unwanted substances such as water, air and other chemicals into the concrete thereby increasing the durability and strength.

R. Rathan Raj & P.R. Kalyana Chakravarthy, 2017 observed the greater resistance of concrete specimens under compressive loading as the mixes were exhibited 16% more strength than the nominal mix at the end of 7, 28 days of curing.

CH Jyothi Nikhila, 2015 Stated from a conducted study on compressive strength property of metakaolin based concrete. Strength was observed 15% more as contrasted to nominal mix.

Harish stated 10% replacement level of silica fume shown superiority in results beyond that level strength diminished, from his experimental study to evaluate strength characteristics of concrete made using silica fume as the partial replacement to cement.

3 Material properties and Methodology

To develop the mechanical properties of optimum dose age of Alccofine Metakaolin and Silica fume were incorporated as part replacement to cement. The cement used was 53-grade OPC, was to have a chosen gravity of 3.12, a fineness of 7.5, and initial and final setting durations 28 and 570 min respectively. Fine aggregate utilized was river sand. Sand has a bulk density of 1.8 g/cm^3 and a specific gravity of 2.68, respectively. The coarse aggregate used is crushed rock fines retained on a 4.75mm screen and passing through a 10mm sieve. Coarse aggregate used complies with IS 383 and has undergone physical property testing referenced by IS 2386-1963. It has a specific gravity of 2.75, a bulk density of 1450 kg/m3 in the free condition and 1560 kg/m^3 when condensed. Tap water was used for mixing and hardening of the specimens.

Fig. 1 : Alccofine

Fig. 2 : Metakolin

Fig. 3 : Silica fume

Table 1: Parameters of Alccofine , Metakoline & silica fume

Properties	**Formula**	**% Composition**	**Properties**	**% Composition**
Lime	CaO	30-34	Silica	83.85
Silicon dioxide	SiO_2	30-36	Iron oxide	1.88
Aluminum oxide	Al_2O_3	18-25	Alumina	1.88
Ferric oxide	Fe_2O_3	0.8-3.0	calcium	2.05
Magnesium oxide	MgO	6-10	Potassium oxide	4.30
Sulfur trioxide	SO_3	0.1-0.4	Magnesium oxide	1.28
Physical properties of Alccofine			**Physical parameters of silica fume**	
Specific gravity	2.97		Specific gravity	2.2

Properties	**% Composition**
SiO_2	55.50%
Al_2O_3	36.50%
Fe_2O_3	2%
TiO_2	1%
k_2O	1.70%
Na_2O	0.1%
Physical parameters of Metakaolin	
Specific gravity	2.6

The mix proportioning was carried out in accordance with the EFNARC mix design criteria for amalgamation of concrete M70 with the substitution levels of of Alccofine, metakaolin and silica fume with 0.3 water-cement ratio and 2 % of chemical admixture in various dosages, as shown in Table 2.

Table 2 : Mix proportion of M70 grade

Mix	AF %	MA %	SILICA FUME %	Cement	AF	MA	SILIKA FUME	FA	CA	Water
					Weight in Kg/m^3					
M0	0	0	0	428	0	0	0	321	963	129
M1	5%	10%	10%	321	21.4	42.8	42.8			
M2	5%	15%	5%	321	21.4	64.2	21.4			
M3	5%	5%	15%	321	21.4	21.4	64.2			
M4	0	10%	10%	342.4	-	42.8	42.8			
M5	5%	5%	5%	363.8	21.4	21.4	21.4			
M6	0	5%	10%	363.8	-	21.4	42.8			

Concrete's compressive strength can range from 17 MPa to 28 MPa for residential buildings and higher for commercial construction. Some applications use greater stresses of more than 70 MPa and cure times of 7, 14, and 28 days. Cylinders were casted and tested after the required period of curing done.

Fig.4 Compressive Testing machine with sample

Fig. 5 Specimen under Tensile load

4 Results

After the 7days of curing, the compressive strength test was assessed. The outcomes are shown in Table 3. After 7days of standard curing, the split tensile strength was calculated. The outcomes are detailed in Table 3.

Table 3 Compressive and Split tensile strength

Mix	Compressive strength (N/mm^2)	Split Tensile strength (N/mm^2)
	7 Days	7 Days
M0	50	10
M1	62.75	12
M2	36.5	11
M3	47.5	10.5
M4	30.5	10.5
M5	45.1	11
M6	56.75	11.5

5 Conclusions

- Table 3 outcomes specified that utilization of Alccofine, Metakaolin, and Silica Fume Mix M1 exhibited better results when compared to other mixes under compression.
- From Table 3 results shown that the split tensile strength of using Alccofine, Metakaolin, and Silica Fume Mix M1 shows better results when compared to other mixes.
- The end result expressed that the compressive strength increased in about 25% when cement was replaced with 5% alccofine, 10% silica fume, and 10% metakaolin.
- The results shown that the split tensile strength increased by about 25% when cement was replaced with 5% alccofine,10% silica fume, and 10% metakaolin.

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