Experimental Study on the Behavior of Self Compacting Self Cured Concrete Using Chemical Admixtures and Metakaolin

Balaji .M, Dhilip Sharma.S
Vigneshwaran.A, Fayaz ahamed.K

Abstract:
Concrete is the second most consumed material in the world after water and it is used most widely in the construction industry due to its high compressive strength and other properties. Self-compacted concrete has the ability to compact itself only by means of its own weight without the requirement of vibration. Self-curing is the process of retaining the water in the concrete to increase the degree of hydration. This paper deals with an experimental investigation on the characteristics of self-compacting concrete (SCC) and self- compacting self-cured concrete (SCSCC) prepared by replacement of the cement by metakaloin, adding super plasticizer using M30. The compressive strength and split tensile test for various SCSCC mixes were tested and the results are compared with the SCC

1. INTRODUCTION

Curing of concrete is maintaining satisfactory moisture content in concrete during its early ages in order to develop the desired properties. Curing of concrete plays a major role in developing the concrete microstructure and pore structure, and hence improves its durability and performance. Good curing is not always practical in many cases due to the non-availability of good quality water. Water resources are becoming valuable every day. Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight.

The demand for Portland cement is increasing dramatically in developing countries. Portland cement production is one of the major reasons for CO2 emissions into atmosphere. It is due to the use of fossil fuels, including the fuels required to generate electricity during cement manufacturing process. The use of pozzolanas for making concrete is considered efficient, as it allows the reduction of the cement consumption while improving the strength and durability properties of the concrete. Metakaolin when used as a partial replacement substance for cement in concrete, it reacts with Ca(OH)2 one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is obtained by thermal activation of kaolin clay. This activation will cause a substantial loss of water in its constitution causing a rearrangement of its structure. To obtain an adequate thermal activation, the temperature range should be established between 600 to 750ºC.

Metakaolin is used in oil well cementing to improve the compressive and flexural strength of the hardened cement. Metakaolin also reduces the hardened cement permeability to liquids and gases. Hence by partially replacing Portland cement with Metakaolin not only reduces carbon dioxide emissions but also increases the service life of buildings The production of Portland cement is not only costly and energy intensive, but it also produces large amount of carbon emission. The production of one to of Portland cement produces approximately one ton of CO2 in the atmosphere. Limestone is a raw material available in nature; it is primary need for production of cement material. Earlier it was used directly to form silica flume mortar as a binding material in construction. Supplementary cementitious materials are often used to reduce cement contents and improve the workability of fresh concrete, increase strength and enhance durability of hardened concrete. SCMs used in the manufactured concrete products industry as well as a review of blended cements. There are various types of supplementary cementitious material as fly ash, silica fume, slag cement, metakaolin, rice husk ash, coconut shell etc. Out of above Supplementary

Cementitious Materials (SCMs) we use Metakaolin as partial replacement of cement and experimental investigation is carried out. The advantages like high strength, durability and reduction in cement production are obtained due to the incorporation of metakaolin in concrete and the optimum percentage replacement of metakaolin ranging from 8 to 12% to obtain maximum 28-days compressive strength of concrete. Durability and the other mechanical properties of concrete are improved when pozzolanic materials are incorporated in concrete because of the reaction between metakaolin and the free calcium hydroxide during the hydration of cement and consequently forms extra calcium silicate hydrate (C-S- H). Consequently, the use of metakaolin concrete in civil structures is wide spreading. Incorporation of metakaolin in concrete has an adverse effect on workability. Therefore, super plasticizer is needed for higher percentage of cement replacement by metakaolin. In this paper our attempt has been made to study the effect of metakaolin on strength properties of concrete considering a constant watercementitious material ratio of 0.38 for M-30 grade concrete mix.

Mechanism for Achieving Self Compactability

The method for achieving self-compactability involves not only high deformability of paste or mortar, but also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bars. Okamura and Ozawa have employed the following methods to achieve selfcompactability:

(1) Limited aggregate content (2) Low water-powder ratio (3) Use of super Plasticizer

The frequency of collision and contact between aggregate particles can increase as the relative distance between the particles decreases and then internal stress can increase when concrete is deformed, particularly near obstacles. It has been revealed that the energy required for flowing is consumed by the increased internal stress, resulting in blockage of aggregate particles. Limiting the coarse aggregate content, whose energy consumption is particularly intense, to a level lower than normal proportions is effective in avoiding this kind of blockage.

Highly viscous paste is also required to avoid the blockage of coarse aggregate when concrete flows through obstacles. When concrete is deformed, paste with a high viscosity also prevents localized increases in the internal stress due to the approach of coarse aggregate particles. High deformability can be achieved only by the employment of a super plasticizer, keeping the water-powder ratio to be very low value.

The aggregate content is smaller than conventional concrete which requires vibrating compaction. The degree of packing of coarse aggregate in SCC is around 50% so that the interaction between coarse aggregate particles when the concrete deforms may become small. In addition, the ratios the fine aggregate volume to its solid volume in the mortar is to be considered. The degree of packing of fine aggregate in SCC's mortar is around 60% so that the shear deformability when the concrete deforms may be limited. On the other hand, the viscosity of the paste in SCC is the highest of the other types of concrete due to the lowest water-powder ratio. That is effective in inhibiting segregation.

Application of SCC

The application of concrete without vibration in highway bridge construction is not new. For examples, placement of seal concrete underwater is done by use of a termite without vibration, mass concrete has been placed without vibration, and shaft concrete can be successfully place without vibration. These seal, mass and shaft concretes are generally of lower strength, less than 34.5 MPa and difficult to attain consistent quality. Modern application of self-compacting concrete is focused on high performance better and more relights quality, dens and uniform surface texture, improved durability, high strength and faster construction.

Self-Curing Concrete

"Self or internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing water". Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'. In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated light weight fine aggregates, super absorbent polymers, or saturated wood fibres) created.

Need for Self Curing

When the mineral admixtures react completely in a blended cement system, their demand for curing water can be much greater than that in a conventional ordinary Portland cement concrete. When this water is not readily available, due to depercolation of the capillary porosity, for example, significant autogenous deformation and cracking may result. Due to the chemical shrinkage occurring during cement hydration, empty pores are created within the cement paste, leading to a reduction in its internal relative humidity and also to shrinkage which may cause early-age cracking. This situation is intensified in HPC due to its generally higher cement content, reduced water/cement ratio and the pozzolanic mineral admixtures (fly ash, silica fume).The empty pores created during self-desiccation induce shrinkage stresses and also influence kinetics of cement hydration process, possible under saturated curing conditions.

Potential Materials for Self Curing

The following materials can provide internal water reservoirs: Lightweight aggregate, LWS Sand (Water absorption -17%), LWA 19mm coarse (Water absorption 20%), Super absorbent polymers (SAP), Shrinkage Reducing Admixture (SRA) (propylene glycol type), and Wood powder. In this paper, the self-curing is achieved in self compacting concrete, by using Super plasticizer (SP).

Improvements in Concrete Due To Self-Curing

Reduces autogenously cracking, largely eliminates autogenously shrinkage, Reduces permeability, Protects reinforcing steel, Increases mortar strength, Provides greater durability, Greater utilization of cement, Lower maintenance, Higher modulus of elasticity, Reduces the effect of insufficient external curing.

Objective

- To find the hardened concrete properties of self- compacting self-cured concrete with metakaolin.
- To have an idea about self-compacting self-curing concrete.
- To find the hardened concrete properties using SP and mineral.
- To have an idea about making procedure of self- compacted self-cured concrete.
- To find fresh properties of SCC – filling ability and passing ability - for mix design purposes in the lab.

SCOPE

- This concrete having self-compact ability with which it can be placed in the every corner of formwork without vibration causing no segregation.
- The performance evaluation method of fresh Self- Compacting Concrete widely differs depending on whether vibration is given to the concrete during placing.
- Self-Compacting Concrete that can be placed without any external forces other than gravity.
- Due to less vibration is needed, SCC can be used in precast product plants.
- It helps to reduce the number of workers required at the construction site.
- In precast product plants as well, SCC is highly effective in reducing the noise as it requires no vibration.

2. METHODOLOGY

This section briefly explains the methodology adopted in this. The following methodology has been adopted to achieve above objective.

In the first phase, properties of all ingredient of concrete were found out. In the second phase, initially compressive strength of cubes .The experimental investigation is conducted as detailed below. All the materials tests were conducted in the laboratory as per relevant Indian Standard codes. Basic tests were conducted on fine aggregate, coarse aggregate, and cement to check their suitability for concrete making. The properties of fine and coarse aggregates, sieve analysis of fine and coarse aggregates, tests on cement are to be found.

The study aims to investigate the strength related properties of concrete of M_{30} grade with self-compacting concrete. The cubes will be casted as per the M $_{30}$ grade of concrete. Cube specimens having 150x150x150mm would be casted and cured.

3. MATERIAL USED:

CEMENT:

The following materials were used for experiment confirming to various standards. Ordinary Portland cement of 53 grade (Coromandal King) available in the local market is used in the investigation. The cement used has been tested for various properties as per IS 4031-1988 and found to be conforming to various specifications of IS 122691987. The specific gravity is 3.09 and fineness is 2600 cm^2/gram.

Fine aggregate:

Locally available crushed sand was used as fine aggregate which confirms to zone II of IS 383-1983. Coarser sand were preferred, as finer sand increases the water demand of concrete and very fine sand may not be essential in metakaolin concrete as it usually has larger content of fine particles in the form of cement and mineral admixtures such as metakaolin etc. The specific gravity of fine aggregate is 2.69 and fineness modulus is

Coarse aggregate:

Crushed angular granite metal from a local source was used as coarse aggregate having size ranging from 10mm to 20mm. The specific gravity of coarse aggregate is 2.68, fineness modulus is 7.2 and water absorption is 0.7%.

Metakaolin:

Commercially available Metakaolin from.Chennai, having the properties as shown in Table is used.

Water:

The water used for the study was free of acids, organic matter, suspended solids, alkalis and impurities which when present may have adverse effect on the strength of concrete.

Super plasticizer:

Super plasticizers used in the experimental work conforming to IS 9103-1999, was supplied by a private agency and it is a Sodium Naphthalene Sulphonate based retarder type Super plasticizers EB-821/R with a dosage of 0.8 to 1.2% by volume to weight of total binder content of concrete. Necessary properties, given by supplier are given.

COMPOSTION

CEMENT

Standard consistency	32%
Specific gravity	3.15
Fineness modulus	2.67%
Initial setting time	15 minutes
Final setting time	495 minutes

FINE AGGREGATE

Fineness modulus	4.79
Specific gravity	2.66
Water absorption	0.92
Bulk density	1.84 g/cc

COARSE AGGREGATE

Fineness modulus	4.71
Specific gravity	2.67
Water absorption	0.45
Bulk density	1.66g/cc

METAKAOLIN

Specific area (cm2/g)	150000-180000
Specific gravity	2.5

Colour	Ivory to cream
Mean grain size (μm)	2.54

METAKAOLIN: PRODUCTION AND SOURCES

The main sources of metakaolin are kaolin clay and paper sludge after suitable treatment. Metakaolin can also be obtained by the calcination of indigenous lateritic soils. . The development of pozzolanic properties in fired clays mainly depends on the nature and abundance of clay minerals in the raw material, the calcination conditions and the fineness of the final product. The calcination temperature producing the reactive state is usually in the range of 600–800°C. On heating, re crystallization and formation of MK ($2SiO_2Al_2O_3$) or mullite ($3Al_2O_3\_2SiO_2$) take place resulting in a decline of material reactivity. The following section details the process of production of metakaolin.

PRODUCTION OF METAKAOLIN FROM KAOLINE

Kaolin is a phyllosilicate, consisting of alternate layers of silica and alumina in tetrahedral and octahedral coordination, respectively. This electrically neutral crystalline layer structure, which is a common characteristic of clay minerals, leads to a fine particle size and plate like morphology and allows the particles to move readily over one another, giving rise to physical properties such as softness, soapyfeel and easy cleavage. Kaolinite is the mineralogical term for hydrated aluminium disilicate, $Al_2SiO_5(OH)_4$... Under normal environmental conditions, kaolin is quite stable. However, when kaolin heated to temperature of 650–900 ^{O}C it loses 14% of its mass in bound hydroxyl ions. This heat treatment, or calcination, breaks down the structure of kaolin such that the alumina and silica layers become puckered and lose their long-range order. Result of this de hydroxylation and disorder is metakaolin, a highly reactive transition phase, amorphous material with pozzolanic and latent hydraulic reactivity, suitable for use in cementing applications.

Advantages

- There is better control of shrinkage and cracks due to reduction of heat of hydration
- It can be safely used for water retaining structures as well as structures near shore as its usage leads to water tightness
- It can be safely used in concrete as there is lesser rebound
- Metakaolin helps in production of abrasion resistant concrete as it lies second to diamond on hardness scale
- It imparts better spray ability to the cement products
- It enhances compressive as well as tensile strength of concrete
- It is environment acceptable or eco-friendly or does not causes pollution
- In mixer it disperses very easily
- It leads to removal of formation at an earlier stage because of high initial set.

4. DESIGN AND MIX

CEMENT	1081.05KG
FINE AGGREGATE	595.33KG
COARSE AGGREGATE	5166KG
WATER	186 LITRE
SP	1% OF WEIGHT OF CEMENT
METAKAOLIN POWDER	REPLACING 10% BY WEIGHT OF CEMENT

M_{30}=1:1.15:2

The strength parameters of self-cured concrete were found out for 7days and 28 days.

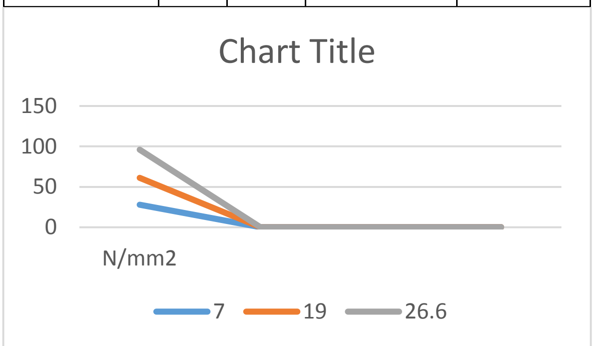
Concrete specimens cast using SP for 0.5%, 1%, 1.5%.The optimum dosage of SP for self-cured concrete was found out to be 1% by weight of cement.

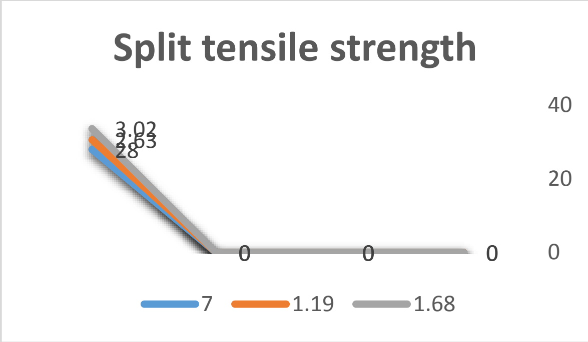
M30 grade of concrete is adopted for the investigation. The conclusions of the test are
The optimum dosage is 1%.Addition of SP leads to a significant increase of mechanical strength (Compressive and Splitting tensile).
Compressive strength of self-cured concrete for dosage of 1% was higher than SCC. Split tensile strength of self-cured concrete for dosage of 1% was higher than SCC.

CASTING AND TEST RESULTS FOR MINERAL AND WITH CHEMICAL ADMIXTURES ONLY

TEST RESULT FOR MIXES

Test	Days	Chemical and mineral admixtures		
		S1	S2	10%METAKALOIN REPLACED& 0.5 AND1.0 ADMIXTURE USED
Compressive stress in N/mm²	7	19.0	26.6	
	28	33.2	34.8	
Split tensile strength in N/mm²	7	1.19	1.68	
	28	2.63	3.02	





5. RESULTAND DISCUSSION

Results of compressive strength of concrete: The test was carried out conforming to IS 516:1959 to obtain compressive strength of M-30 grade of concrete. The compressive strength of high strength concrete with OPC, metakaolin and super plasticizer concrete at the age of 7 and 28 days are presented. There is a significant improvement in the strength of concrete because of the high pozzolanic nature, fineness of the metakaolin and its void filling ability. It was found that cement can be replaced effectively with Supplementary Cementitious Materials (SCM's) like Metakaolin. In the case of strength and durability, the SCM's shows better results than normal mixes. With regard to workability and setting time, Metakaolin generally required more super plasticizer and it reduces the setting time of pastes as compared to control mixtures. When compared with cement, the use of Metakaolin may be uneconomical due to its high cost whereas it is economical in the aspects of durability and strength.

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