ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Experimental Studies on High Performance Concrete Using Metakaolin

Annadanam Sudhakar
M Tech (Structural Engineering),
Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions-Integrated Campus-9L,
C.Gollapalli, Tirupati Rural, Chittoor Dist,
AP-517505

Prof. K.Rajasekhar
Principal & HoD,
Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions-Integrated Campus-9L,
C.Gollapalli, Tirupati Rural, Chittoor Dist,
AP-517505

ABSTRACT

High performance concrete (HPC) has been defined as concrete that possesses high workability, high strength and high durability. The primary application for HPC have been structures requiring long service lives such as oil drilling platform, long span bridges and parking structures. HPC still requires good construction practice and good curing to deliver high performance Metakaolin is refined kaolin clay that is fired (calcined) under carefully controlled conditions to create an amorphous alumino silicate that is reactive in concrete. Like other pozzolans (flyash and silica fume are two common pozzolans), metakaolin reacts with the calcium hydroxide(lime) byproducts produced during cement hydration.

Water is an important ingredient in mixing of concrete, as it actively participates in the chemical reaction with cement. Portland cement is a mixture of complex compounds, the reaction of which with water leads to setting and hardening of cement. All the compounds present in cement are anhydrous but when brought into contact with water they get decomposed forming hydrated compounds. Since water helps to form the strength and setting properties of cement and aggregate is exercised, but the control on the quality of water is often neglected.

This subject deals with the effect of neutral salts present in water on strength and setting properties of O.P.C .

In this present experimental investigation an attempt is made to the strength behaviour of metakaolin, superplasticiser and chemicals on high performance concrete.Cement is replaced by 0%,20% Metakaolin by volume of concrete, thus resulting in the increase in strength. Superplasticiser is added to increase the workability of concrete.Dosage of superplasticiser is 1.5% by weight of cement.

INTRODUCTION

High performance of concrete (HPC) widely been used in recent years, not only for its increased compressive strength, improved durability and economic benefits, but also for its positive impact on the environment.
Cement and concrete are key components of both commercial and residential construction in worldwide, the cement and concrete industries are huge.

Worldwide, cement production totalled 1.25 billion tons in 1991, according to the U.S Bureau of mines.
Concrete tends itself to a variety of innovative designs due to its many desirable properties. Not only can it be cast in diverse shape but it also possess high compressive strength, stiffness. Low thermal and electrical conductivity and low combustibility and toxicity. Two characteristics how ever have limited its use, its briule and weak in tension and develops cracks during curing and due to thermal expansion and contraction over a period of time recently, however the development of fiber reinforced concrete(FRC) in various fields has provided a technical basis for

improving these defieleneies. This describes the general properties and application of METAKAOLIN reinforced concrete used in construction the thinner and stronger elements spread across entire section, when used in low dosage arrests cracking.

The performance of concrete in both short and long terms is being subjects to greater research and security in the recent years. The ordinary concrete may fail to exhibit the required quality or desirability. In such cones admixture is used to modifying the properties of ordinary concrete so as to make it more suitable for any situation.

An admixture can be defined as a chemical products, which is added to the concrete mix by weight of cement. It is added to the batch immediately before or during mixing for the purpose of achieving a specific modification, or modification to the normal properties of concrete. Admixture may be organic or inorganic in composition but their chemical character is an essential feature.

These are many technologies who highly command and faster the use and development of admixtures as they impact many desirable characteristics and effect economy in concrete construction.

Further it will be slightly difficult to products the effects and the Rersult of using admixture, Because every time the change in the bond of cement, aggregate grading mix proposition and richness of mix, after the properties of concrete. Sometime many admixtures effect more than one property of concreate and sometimes they effect the durable properties adversely therfore one must be cantions in the selection of admixture in concrete.

Strength of concrete primarily depends upon the cement paste and in more the strength of paste increases with the fineness of cement contents Hence as the W/C Ratio decreases the concrete gets higher Strength but concrete become unworkable.

Certain organic compounds are used in the concrete. A new admixture called METAKAOLIN. Used to the two different grade of concrete. Designed with different percentage of Metakaolin and then its effects are observed in improving of tensile strength and also compressive strength of concrete at the same reducing of cost for the concrete.

High Performance Concrete

In recent years, the terminology "High-Performance Concrete" has been introduced into the construction industry. The American Concrete Institute (ACI) defines high-performance concrete as concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely when using conventional constituents and normal mixing, placing and curing practices. A commentary to the definition states that a high-performance concrete is one in which certain characteristics are developed for a particular application and environment.

Examples of characteristics that may be considered critical for an application are:
• Ease of placement
• Compaction without segregation
• Early age strength
• Long-term mechanical properties
• Permeability
• Density
• Heat of hydration
• Toughness
• Volume stability
• Long life in severe environments

Because many characteristics of high-performance concrete are interrelated, a change in one usually results in changes in one or more of the other characteristics. A high-performance concrete is something more than is achieved on a routine basis and involves a specification that often requires the concrete to meet several criteria. For example, on the Lacey V. Murrow floating bridge in Washington State, the concrete was specified to meet compressive strength, shrinkage and permeability requirements. The latter two requirements controlled the mix proportions so that the actual strength was well in excess of the specified strength. This occurred because of the interrelation between the three characteristics.

A high-strength concrete is always a high-performance concrete, but a high-performance concrete is not always a high-strength concrete. ACI defines a high-strength concrete as concrete that has a specified compressive strength for design of 6,000 psi (41MPa) or greater. Other countries also specify a maximum compressive strength, whereas the ACI definition is open-ended.

The specification of high-strength concrete generally results in a true performance specification in which the performance is specified for the intended application, and the performance can be measured using a well-accepted standard test procedure. The same is not always true for a concrete whose primary requirement is durability.

Durable concrete Specifying a high-strength concrete does not ensure that a durable concrete will be achieved. In addition to requiring a minimum strength, concrete that needs to be durable must have other characteristics specified to ensure durability. In the past, durable concrete was obtained by specifying air content, minimum cement content and maximum water-cement ratio. Today, performance characteristics may include permeability, deicer scaling resistance, freeze-thaw resistance, abrasion resistance or any combination of these characteristics. Given that the required durability characteristics are more difficult to define than strength characteristics, specifications often use a combination of performance and prescriptive requirements, such as permeability and a maximum water-cementitious material ratio to achieve a durable concrete. The end result may be a high-strength concrete, but this only comes as a by-product of requiring a durable concrete.

Concrete materials most high-performance concretes produced today contain materials in addition to Portland cement to help achieve the compressive strength or durability performance. At the same time, chemical admixtures such as high-range water-reducers are needed to ensure that the concrete is easy to transport, place and finish. For high-strength concretes, a combination of mineral and chemical admixtures is nearly always essential to ensure achievement of the required strength.

Most high-performance concretes have a high cementitious content and a water-cementitious material ratio of 0.40 or less. However, the proportions of the individual constituents vary depending on local preferences and local materials. Mix proportions developed in one part of the country do not necessarily work in a different location. Many trial batches are usually necessary before a successful mix is developed. High-performance concretes are also more sensitive to changes in constituent material properties than conventional concretes. Variations in the chemical and physical properties of the cementitious materials and chemical admixtures need to be carefully monitored. Substitutions of alternate materials can result in changes in the performance characteristics that may not be acceptable for high-performance concrete. This means that a greater degree of quality control is required for the successful production of high-performance concrete.

Salient Features of HPC

- High Compressive strength
- Low water-binder ratio
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content

• Endogenous shrinkage
• Powerful confinement of aggregates
• Little micro-cracking until about 65-70% of fck
• Smooth fracture surface

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for green house effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact.

Considering the grade of cements high strength of cement of grades 43 & 53 are desirable for design of High strength concretes. To achieve the quest of high performance concrete we should accentuate on the replacement of OPC with industrial by-products. The utilization of pozzolanic materials in concrete as partial replacement of cement is gaining immense importance today, mainly on account of the improvements in the long-term durability of concrete combined with ecological benefits. Fly ash (a waste product from coal thermal power plant), ground granulated blast furnace slag, silica fumes (a waste by-product of the manufacture of Silicon or Ferro-silicon alloys from high purity quartz and coal in a submerged-arc electric furnace), rice husk ash (waste by-product from co-generation electric power plant burning rice husk), high reactive metakaoline (HRM) as partial replacement for cement which are largely available in India. To study the effect of partial replacement of cement by these pozzolanic materials, studies have been conducted on concrete mixes with 350 to 500 kg/cum cementitious material at 30%, 40%, and 50% replacement levels of fly ash; 50% and 60% replacement levels of GGBS and 7.5% and 10% replacement levels of HRM.

MATERIALS USED IN CONCRETE

Materials Used In Cement Concrete

The quality of concrete can be achieved by the selection of suitable materials, admixtures, the choice of mix preposition, water cement ratio and use of proper methods of mixing, placements, curing. All these aspects depend upon materials and admixture selection.
Usually the materials used in concrete are cement, aggregate, water and admixtures.

Cement

Cement is a material that has cohesive and adhesive in the properties in the presence of water. Natural cement is obtained burning and crushing the stones containing clay, carbonate of lime and some amount of carbonate of magnesium. Natural cement resembles very closely hydraulic lime. it sets very quickly after addition of water. It is not strong as artificial cement. the artificial cement was invented by a MANSION JOSEPH ASPDIN of England and therefore, some time Portland cement these basic ingredients of cement are calcium and argillaceous products usually contain following ingredients.

Blended cement

Portland cement containing a mineral additive becomes blended or composite cement. Blended cement is a hydraulic, cementitious products, similar to ordinary Portland cement, but has certain improved properties owing to the presence of the blending material in it.

The use of blended cement improves the properties of both fresh and hardened concrete. This can happen as a result of the extended hydration of the cement pozzolana mixture, the reduced water demand, and the improved cohesion of the paste. Another important benefit is the improvement in durability resulting from the lower permeability and improved microstructure of concrete. This arises from the reduction in pore size and the refinement of the pore structure of the cement paste as well as from improved in the properties of the "interfacial zone" between the cement 'paste as well as from improvements in the properties of the 'interfacial zone' between the cement 'paste and the aggregate surface.

Aggregates

The aggregate like sand, brick and stone are inert materials. Their properties greatly influence the behavior of concrete since they occupy about 70- 80% of total volume of the concrete. It is logical to us maximum of aggregate since they are expensive then cement and are widely are available in nature. The aggregates are classified as two types and comply with the requirements of IS 383-1970 Fine aggregate are material passing through an IS Sieve that is less than 4.75 mm gauge beyond which, they are known as coarse aggregate.

Types of Aggregates:

(1) Fine aggregate

(2) Course aggregate

Fine Aggregate

Concrete is a composite material, the workability and the development of strength depend upon the age, the properties of the constituent materials and their combined action. The role of fine aggregate on strength and workability has to be deciphered before examining the possibility of total replacement of fine aggregate.

The purpose of mix proportioning is to produce the required properties in both plaster and hardened concrete by the most economical and practical combination of material available they has been very little use reported of vast quantities of waste have generated by mixing and quarrying industries only small amount of this waste are used in road making and in manufacture of building materials such as light weight aggregate bricks and autoclave cd bricks an attempt is made to study the affect of rock dust as fine aggregate on the strength and workability aspects of concrete mixes.

It is evident that the concrete strength development depends upon the strength of the cement motor and its synergetic with coarse aggregate. Pebbles as coarse aggregate, due to smooth surface texture impart lower mortar aggregate bond strength than that imparted by crushed coarse aggregates. In the present work, fine aggregate consisting of natural sand conforming to grading zone II of IS 383-1970 is used.

Properties of fine aggregate:

Properties	Results Obtained
Specific gravity	2.74
Water absorption	0.6%
Fineness Modulus	2.47

Coarse Aggregate

For maximum strength and durability, the aggregate should be packed and cemented as compactly as possible for this reason the gradation of particle sizes in aggregate to produce close packing is of considerable importance. It is necessary that aggregate have good strength, durability and weather resistance, their surface is free from impurities such as loam, silt and organic matter which may weaken the bond with the cement paste and that no unfavorable chemical reaction takes place between them and cement.

The coarse aggregate used here with having maximum size is 20mm. We used the IS 383:1970 to find out the proportion of mix of coarse aggregate, with 60% 10mm size and 40% 20mm.

Properties of coarse aggregate

Specific gravity	2.74
Water absorption	0.4%
Fineness Modulus	4.01

Description Of Metakaolin

Metakaolin is a calcined product of the clay mineral kaolinite. The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume. When kaolinite, a layered silicate mineral with a distance of 7,13 Å between the layer of SiO2 and Al2O3 is heated, the water contained between the layers is evaporated and the kaolinite is activated for action with cement.

Metakaolin is refined kaolin clay that 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) byproducts produced during cement hydration.

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.

Metakaolin, it is very fine and highly reactive, gives fresh concrete a creamy, non sticky texture that makes finishing easier.

Advantages

• Increased compressive and flexural strengths
• Reduced permeability (including chloride permeability)
• Reduced potential for efflorescence, which occurs when calcium is transported by water to the surface where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue.
• Increased resistance to chemical attack
• Increased durability
• Reduced effects of alkali-silica reactivity (ASR)
• Enhanced workability and finishing of concrete
• Reduced shrinkage, due to "particle packing" making concrete denser
• Improved color by lightening the color of concrete making it possible to tint lighter integral color.

Chemical composition (%) of METAKAOLIN

SiO_2	39.18
Al_2O_2	10.18
Fe_2O_3	2.02
CaO	32.82
MgO	8.52
Na_2O	1.14
K_2O	0.30

DISCUSSIONS OF TEST RESULTS

The present investigation reports a part of comprehensive study intend to decrease the contribution of Metakaolin on concrete mixes M 30 and M40 with a w/c ratio of 0.4 and 0.36 and cement replacement levels from 0 to 20% the optimum Metakaolin replacement level and strength improvement of high performance of concrete have been decreased.

COMPRESSIVE STRENGTH OF CONCRETE

The test was carried out conforming to IS 516-1959 to obtain compressive strength of M30 and M40 grade of concrete. The compressive strength of high performance of concrete with OPC and metakaolin concrete at the age of 28 days and presented. There is significant Improvement in the strength of concrete because of the high pozzolanic nature of the METAKAOLIN and its void filling ability.

It can be seen from the compressive strength of two mixes M30 and M40 at 28 days age, with replacement of cement by METAKAOLIN was increased gradually

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

up to an optimum replacement level of 20% and then decreased.

The maximum 28 day cube compressive strength of M30 grade with 20% of metakaolin was 50.65Mpsa and of M40 grade with 20 % was 68.91 MPa. The compressive strength of M30 grade concrete with partial replacement of 20% replacement shows10% greater than the control concrete. The maximum compressive strength of concrete in combination with METAKAOLIN depend on two parameters namely the replacement level, water content ratio. Results Showing Tables No: 4.5, 4.9.

Table No. 3.3.Physical Properties of METAKAOLIN

Fineness	390 m^2/kg
Specific gravity	2.875

Table 3.4 Chemical properties of Cement

S.L. No	Characteristics	Result (0% by Mass)
1	Loss of ignition	3.15
2	Silica (sio_2)	2.27
3	Alumina (Al_2o_3)	4.42
4	Iron (fe_2o_3)	11.38
5	Calcium (cao)	58.51

Table No. 3.6 Chemical properties of METAKAOLIN:

Oxide name	Oxide compound	Percentage
Calcium	Cao	36
Silica	Sio2	34
Alumna	Al2o3	18.5
Iron oxide	Fe2o3	2.5
Magnesium oxide	Mgo	11.5
Sulphate	SO3	0.65
Others	(Alkalis)	----

Table 3.7. Properties of fine aggregate:

Properties	Results Obtained
Specific gravity	2.74
Fineness Modulus	2.73

Table 3.8. Properties of coarse aggregate:

Properties	Results Obtained
Specific gravity	2.73
Fineness Modulus	7.61

Table 3.9 sieve analysis of Fine aggregate (Weight of sample 1000g)

S.L No	IS Sieve Size	Weight Retained (g)	Cumulative weight retained	Cumulative % weight retained (g)	Cumulative % Passing
1	10mm	0.00	0.00	0.00	100.00
2	4.75mm	10.00	10.00	1.00	99.00
3	2.36mm	46.50	56.50	5.65	94.35
4	1.18mm	188.00	24.50	24.45	75.55
5	600mm	288.00	532.50	53.25	46.75
6	300mm	358.00	890.50	89.005	10.95
7	150mm	109.00	1000.00	100.00	0.00

Fineness modulus of sand $= \Sigma g/100$
$= 273.35/100$
$= 2.73$

Table 3.10. Sieve Analysis of coarse Aggregate (Weight of sample 5000 g)

S.L No	Is Sieve Size	Weight retained (g)	Cumulative weight retained	Cumulative % weight retained (g)	Cumulative % passing
1	80mm	0.00	0.00	0.00	100.00
2	40mm	0.00	0.00	0.00	100.00
3	20mm	3376.50	3376.50	67.52	32.48
4	10mm	1385.00	4761.00	95.22	4.78
5	4.8mm	169.00	4930.00	98.60	1.40
6	2.4mm	70.00	5000.00	100.00	0.00
7	1.18mm	0.00	5000.00	100.00	0.00
8	600mm	0.00	5000.00	100.00	0.00
9	300mm	0.00	5000.00	100.00	0.00
10	150MM	0.00	5000.00	100.00	0.00

Fineness modulus of Coarse aggregate $= \Sigma g/100$
$= 761.1/100$
$= 7.61$

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

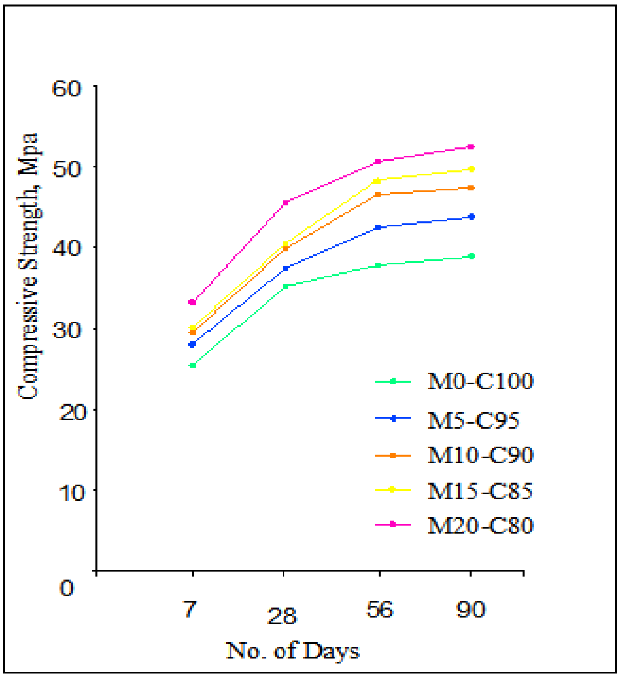

Fig. compressive strength for different percentages of Metakaolin M30

Fig.Cement

Fig.Metakaolin

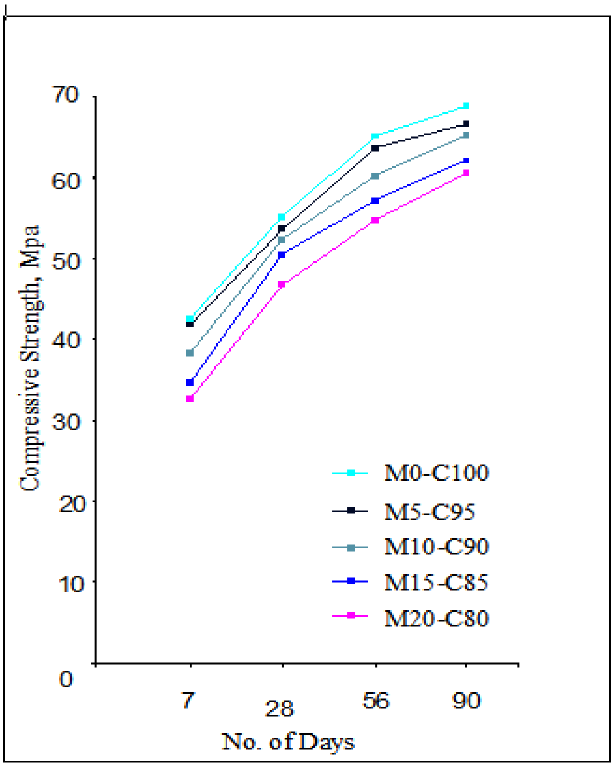

Fig. compressive strength for different percentages of Metakaolin M40

Fig. Concrete Mixer

Fig. Slump test apparatus

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal


Fig. Slump test


Fig.Vibrating machine


Fig.Tests for compressive strength of concrete

CONCLUSION

Based on experimental investigations the following conclusions are drawn.

• Cement replacement by adding METAKAOLIN leads to increase in compressive strength upto 20% replacement for both M30 and M40 grades of concrete. Beyond 20% replacement compressive strength decreased.

• There is a decrease in workability as the replacement level increases, and hence water consumption will be more for higher replacements.

• From the present study it is concluded that the optimum replacement level of cement by Metakaolin is 20% for M30 and M40 grade of concrete.

• The 28 days strength in respect of both grades of concrete with 20% replacement of cement by Metakaolin is maximum.

• The addition of METAKAOLIN has further increased intial 7 day and 28 day, 56 days strength as evident from the tables.

These METAKAOLIN are causing 5-10% of increases in the 7,28,56 days compression in the presence of Metakaolin. The maximum strength at 28 days is observed with 0.20% METAKAOLIN and 20% replacement of cement Metakaolin

REFERENCES:

Text Books

1) N.Krishna Raju,” Design of Concrete Mixes”,Year 2005

2) A.M.Nevile,” Properties of concrete”ELBS with Longman 1987

3) M.S.Shetty,” Concrete Technology”, Year 2008

4) A.R.Santhakumar,” Concrete Technology”, Year 2011

5) M.L.Gambhir,” Concrete Technology Theory and Practice”, Year 2012

Author Details

Annadanam Sudhakar
M Tech (Structural Engineering),

Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions-
Integrated Campus-9L,
C.Gollapalli, Tirupati Rural, Chittoor Dist,
AP-517505

Prof. K.Rajasekhar
Principal & HoD,
Department of Civil Engineering,
Siddartha Educational Academy Group of Institutions-
Integrated Campus-9L,
C.Gollapalli, Tirupati Rural, Chittoor Dist,
AP-517505