International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 6, June-2014, pp: (176-181), Impact Factor: 1.252, Available online at: www.erpublications.com

A study of Metakaolin and Silica Fume used in various Cement Concrete Designs

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Abstract: In the present study, effect of pozzolanic material (Metakaolin and Silica fume) is studied through compressive and Flexural strength in cement concrete. Metakaolin and silica fume area used as cement replacement materials at 5%, 10% and 15% by mass keeping water–cement ratio as 0.42 Compressive and Flexural strength were observed after 7 and 28 days of curing. Silica fume is a by products resulting from the reduction of high – purity quartz with coal, coke and wood chips in an electric arc furnace during the productions of silicon metal or silicon alloys , Silica fume is known to improve both the mechanical characteristics and durability of cement concrete. Finally, the Compressive and Flexural strength performance of Metakaolin-concrete is compared with the performance of concrete blended with silica fume. The test results indicated that the Metakaolin when used in optimum quantity increase the compressive and Flexural strength of the concrete mix when compared with plain cement concrete and cement concrete with Silica fume. It was observed the optimum replacement dose of Metakaolin is 10% by weight of cement. At this percentage of Metakaolin, maximum compressive strength is achieved in the cement concrete.

1. INTRODUCTION

Metakolin is one of the innovative clay products developed in recent years, it is produced by controlled thermal treatments ofkaolin, and Metakaolin can be used as a concrete constituent, replacing part of the cement contact since it haspozzoloanic properties The use of Metakaolin as a partial cement replacements material in mortar and concretes has been studied in recent years , despite of numbers of studies , use of Metakaolin is still not popular in practice , A study is carried out to determine the contributions of Metakaolin in the performance if cement concrete.

Concrete is one of the most common material used in the construction industry In the past few years, many research and modifications has been done to produce concrete with desired characteristic’s. There is always a search for concrete with higher strength and durability. In this natter, blended cement concrete has been introduced to suit the current requirements. The use of supplementary cement materials is fundamental in developing low coast construction materials for use in developing countries. Concrete is the most widely used and versatile building material having high compressive strength ,by additions of some pozzolanic materials, the various properties of concrete viz, workability, durability ,strength resistance to cracks and permeability can be improved. Addition of many admixture cement concrete improve the microstructures of the cement concrete as well as decrease the concentrations o calcium hydroxide through pozzolanic reaction.

The subsequent modifications of the microstructures of cement composites improve the mechanical properties durability and Increase the services life properties. When fine pozzolana particles are dissipated in the past. They generate a large number of nucleation sites for the precipitations of the hydrations products. Therefore, this mechanism makes paste mores homogeneous. This is due to the reactions between the amorphous silica of the pozzolanics and calcium hydroxide produced during the cement hydrations reactions (sabir et al. 201, Rojas and Cabrera 2002, antonovich and Goberies 2003).

Silica fume is known to improve both the mechanical characteristics and durability of concrete. The principal physical effect of silica fume in concrete is that of filler which because of its fitness can fit into space between cement grains in the same way that sand fill the shape between particles of course aggregates and cement grain fill the space between sand grains. In the present study effort is made to find out him compressive and tensile strength of concrete by using silica fume and Metakaolin as practically replacements (5 %, 10 % and 15%)of cement. The results were compared in the form of graphs Results show that he maximum compressive and tensile strength is achieved at 10% of Metakaolin.

2. Standard Specification and Literature Review

2.1 PAVMENT

The upper surface of a road is known as pavement. The surface of roadways should be stable and non-yielding to allow the heavy wheel loads of road traffic to movewith least possible rolling resistance. Road surface should alsobe even along thelongitudinal profile to enable the fast vehicles to move safely and comfortably at the design speed. in order to provide a stable and even surface for the traffic , the roadways is provided with a suitably designed and constructed pavement structurethe pavement carries the wheel loads and transfer the load stresses through a widerarea on the soil sun grade below. the reduction in the wheel load stress due to pavement depends both on its thickness and the characteristics of pavement layers.one of the objectives of a well designed and constructed pavement is therefore to keep those elastic deformation of the pavement within the permissible limits, so thatpavement can sustain a large number of repeated load applications during the design life.
Based on the structural behavior, pavements are generally classified into two Categories:

(i) Flexible pavement
(ii) Rigid pavement

2.2 FLEXIBLE PAVEMENT

Flexible pavements are so named because the total pavement structure deflects or flexes under loading. a flexible pavement structure is typically composed of several layers of materials as shown in figure 2.1 the flexible pavement layers transmit the vertical or compressive stresses to the lower by grain to grain transfer through point of contact in the granular structure. Thus the stresses will be reducedwhich are maximum at the top layer and minimum on the top of sub-grade. Inorder to take maximum advantage of this property, layers are usually arranged in the order of descending load bearing capacity with the highest load bearing capacity material on the top and the lowest load bearing capacity material on the bottom
A typical flexible pavement consists of 4 components. They are as follows:

1. Soil sub-grade
2. Sub-base course
3. Base course
4. Surface and binder course

2.3 RIGID PAVEMENT

Rigid pavements are so named because the pavement structure deflects very little under loading due to the high modulus of elasticity of their surface course. The load is not transferred from grain to grain to the lower layer as in the case of flexible pavement layers. The load is distributed by the slab action, and the pavement heaves like an elastic plate resting on a viscous medium. A rigid pavement structure is typically composed of a PCC surface course built on top ofeither (a) the sub grade or (b) an underlying base course. Because of its relative rigidity, the pavement structure distributes loads over a wide area with only one. Or at most two, structural layers. Rigid pavement can have reinforcing steel, Which is generally used to handle thermal stresses to reduce or eliminate joints and maintain tight crack widths? A typical rigid pavement structure consists of the surface course and the underlying base and sub-base courses (if used) as shown in figure 2.2. The surface course made of PCC is the stiffest and provides the majority of strength. Providing a good base or sub-base course layer under cement concrete slab, increases the pavement life considerably and therefore works out moreeconomical in the long run. The underlying layers are in order of magnitude less stiff but still make important contribution to pavement strength as well as drainage and frost protection.

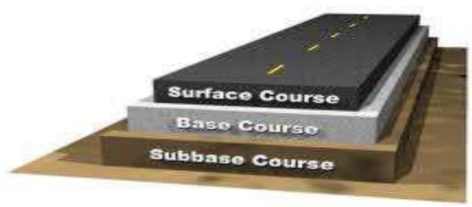

Figure 1

2.4 Concrete containing pozzo lanic materials such as silica fume and metakaolin

Yogendran et al.(1987) made an attempt to modify the properties of concrete with respect to its strengthand other properties by using silica fume and chemical admixtures. They concluded that optimum replacement of cement by silica fume for high strength is found to be 10% for a water cement ratio of 0.42 at all age. The results show some interesting trends with respect to acid resistance. Substitutions of SF, MK or FA under certain conditions have been shown to increase the chemical resistance of such mortars over with plain Portland cements.

3. Experimental Work and Methodology

3.0 INTRODUCTION

This chapter describes the materials used. The preparation of the test specimens and the test procedure Also, the properties and chemicals compositions were listed down in this section.
In order to achieve the stated objectives, this study was carried out in few stages. On the initial stage. All the materials and equipment's needed was procured. Metakaolin and silica fume are used in the concrete mixes according to the predefined proportions. Concrete samples were tested in laboratory in the form of cube and beam. Finally, the results obtained were analyzed to draw out conclusion.

3.1 MATERIALS USED

The materials used in this study were cement, Metakaolin, silica fume (SF), sand, aggregates and water. The description of each of the materials is described In the following sections.

3.1.1 Cement

Ordinary Portland cement available in local market of standard brand was used in the investigations. Procurement of cement is made in single batch to avoid variations and stored in moistures free locations, the specific gravity was 3.15 and fineness was 3200 m2 / kg.

3.1.2 Silica fume (SF)

Silica fume is a byproduct resulting from the reductions of high purity quartz with coal in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. The fume has a high content of amorphous silicon dioxide form the gases escaping from the furnaces.

3.1.3 METAKAOLIN

Metakaolin is another pozzolanic material which is manufactured form selected kaolins, after refinements and calcinations under specific conditions.it is a highly efficient pozzolanic and reacts rapidly with the excess calcium hydroxide resulting from OPC hydrations, via a pozzolanic reaction, to produce calcium silicate hydrates and calcium alumino silicate hydrates(Luc Courade et el. 2003). It is quite useful for improving concrete quality, by enhancing strength and reducing setting time, and may thus prove to be a promising material for manufacturing high performance concrete (Li and Ding 2003).

The details properties of ordinary Portland Cement (OPC), Metakolin and Silica Fume are given in table 1.

Table: 1: Properties of OPC, Metakaolin, and silica fume (Srivastava et al.2012)

PORPERTIES	OPC	SILICA FUME	METAKAOLIN
Physical			
Specific gravity	3.15	2.2	2.5
Means grains size (um)	22.5	0.15	2.54
Color	Ivory to Cream	Dark to light gray	Dark gray
specific area cm2 / gm	3250	150000-300000	150000-180000
Chemicals compositions (%)			60.65
Silicon dioxide (sio2)	20.25		30-34
Aluminum oxide (AL2O3)	5.004	85	100

Iron oxide (Fe2 O3)	3.16	-	1
Calcium oxide (CaO)	63.61	-	2.08
Magnesium oxide(MgO)	4.56	0.2.08	02.0.8
Sodium oxide (Na2O)	0.08	0.2.008	02.08.2014
Potassium Oxide(K2O)	0.51	0.5.12	5.12
Loss on ignition	3.12	<6.0	1.4

3.1.4 Coarse Aggregate

The coarse aggregate material was collected from the crusher placed on the river or Raipur Rani Village, near Naraingarh (Panchkula). Crushed aggregate nominal size of 20mm and 10mm retained on 4.75mm I.S. size confirming to IS: 383-1970 was used in the present investigation. It is ensured that It is free from impurities such as dust, clay particulars and organic matter etc. the specific gravity is found to be 2.7[for both coarse aggregate (10& 20mm)]. The gradations are given in Table 2.

Table: 2: Sieve Analysis of coarse Aggregate (20MM) (Total Weight=3982gm)

Sieve Size (mm)	weight retained (g)	cumulative wt. retained g)	%age retained	%age finer
20	66	66	1.65	98.34
16	2244	2310	58.01	41.98
12.5	1411	3721	93.44	6.56
10	100	3821	95.95	4.04
4.75	83	3904	98.04	1.95
2.36	24	3928	98.7	1.3

Table 3: Sieve Analysis of coarse Aggregate (10MM) (Total Weight=3536gm)

Sieve Size (mm)	Weight retained (g)	cumulative wt. retained g)	%age retained	%age finer
12.5	142	142	4.015	95.98
10	599	741	20.95	79.04
4.75	2170	2911	82.32	17.67
2.36	580	3491	98.72	1.27

3.2 MIXING PROCEDURE

The mixing procedure was divided in to three stages. In the first stage. Cement, Metakaolin and silica fume are measures / weighed as per and mixed thoroughly by hand prior to mixing it with aggregates and sand. This was to make sure that all the binders were mixed thoroughly to produce a homogenous mix. The second stage involves mixing the binders with the aggregates for about 5 minutes. At the final stage, measured water was added in to the concrete mix. This step was crucially important to make sure that the water was distributed evenly so that the concrete have uniform for every cube. After that, the concrete was poured into the mould. Mixing of concrete is shown in below figure 2.

Figure 2 : Mixing of concrete

3.3 CASTING TEST CUBES

Six cubes of 150mmx150mmx150mm were casted for each concrete mix. The concrete was poured into the mould in three layers where each layer was compacted using a steel temping rod after that it was placed on vibrator to remove voids and for proper compaction. The cubes were removes from the moulds after 24 hours and cured Ina water rank. Preparations of cubes are shown in figure 3.

Figure 3: Preparations of Cubes

3.4 10% REPLACMENT WITH METAKAOLIN AND SILICA FUME (BEST REPLACEMENT)

For 10% replacement of cement with Metakaolin, the blended concretes exhibit higher strength than concrete with no replacement at all ages .on the seventh day, the cubes with 10% replacement have a exceeded the compressive strength of the concrete is 34.94 Mpa compared to 32.83 Mpa of the control. On the twenty eight day, the strength of the blended concrete has achieved 38.26Mpa compared to 36.21 Mpa of the control. And on the twenty eight day. The beans with 10% replacement have exceeded the flexural strength of concrete 7.320Mpa compared to 6.210Mpa of the control. From the results, it is clear that among different replacement levels, the used of Metakaolin at the replacement level of 10% performed the best which resulted in the highest compressive and flexural strength.

For 10% replacement of cement with the silica Fume, the blended concretes exhibit higher strength than the concrete with no replacement at all ages. On the seventh day, the cubes with 10% replacement have exceeded the compressive strength of the concrete is 32.73 Mpa. On the twenty eight day, the strength of the blended concrete has achieved 38.02Mpa compared to 36.21Mpa of the control. And on the twenty eight day, the beans with 10% replacement have exceeded the flexural strength of concrete 6.650Mpa compared to 6.210Mpa of the control. Form the results it is clear the among different replacement levels, the use of silica at the replacement level of 10% performed the best, which resulted in the highest compressive and flexural strength. The concrete cubes compressive strength and beams flexural strength with the 10% replacement exhibits the best strength performance in this study.

CONCLUSION

The present study has been carried out to check the compressive and flexural strength of concrete. Both compressive and flexural of plain cement concrete are compared with modified concrete obtained by partially replacement of cement with Metakaolin and Silica Fume separately. Cement is replaced with and silica Fume by 5% and 10% and 15% in different concrete mixes. The main conclusion drawn from the study are:

1. Replacement of Metakaolin increase the Compressive Strength at all ages of curing. However optimal replacement does is 10% at which 7 and 28 days Compressive Strength is maximum i.e. 34.49 Mpa and 38.26 Mpa about 1.66 to 2.05% high than plain concrete.

2. Replacement of Silica Fume increase the Compressive Strength with 10% at which 7 and 28 days compressive strength is maximum i.e. 32.73 Mpa i.e. 32.73 Mpa and 38.02Mpa up to 1.75% high than plain concrete.

3. Replacement of Metakaolin increases the Flexural Strength at all ages of curing. However optimal does is 10% up to 1.5% higher than plain concrete.

4. Replacement of Silica Fume increases the Flexural Strength at all ages of curing However optimal dose is 10% up to 1.5% higher than plain concrete.

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