Strength Development in Concrete by Using Metakaolin

Jamshed Alam[1], Raju Ranjan[2]

[1]PG Student, Department of Civil Engineering, Galgotias University, Gr. Noida, Uttar Pradesh.
[2]Assistant Professor, Department of Civil Engineering, Galgotias University, Gr. Noida, Uttar Pradesh.

Abstract – *Cement concrete is the most widely used material for the various constructions. Properly designed and prepared concrete mixes results in good strength and durability properties. Even such well-designed and prepared cement concrete mixes under controlled conditions also have certain limitations because of which the properties of concrete are found to be inadequate for special situations and for certain special structures. Hence variety of the admixtures such as fly ash, Silica fume, rise husk ash and stone dust etc., are used along with the cement in certain percentages to enhance properties of the regular cement concrete.*

Hence an attempt has been made in the present investigation by the replacement of cement with recent new pozzolanic material of Metakaolin up to certain percentages. To attain the setout objectives of the present investigations, the grade of concrete M35 mix concrete have been taken as reference concrete. Hardened concrete is tested for strength properties such as Cube Compressive strength, Split Tensile Strength. The variations of above strengths with variation in different percentages of Metakaolin have been studied.

Keywords: Pozzolanic Material, Metakaolin, Compressive strength, Split Tensile Strength.

1. INTRODUCTION

General: Concrete is one of the most extensively used construction material in the world with an approximate of about two billion tones placed throughout the world per year. It is attractive in many applications because of its considerable strength at a relatively low cost value. Concrete can generally be produced of locally available constituents and can be cast into a wide variety of structural configuration and requires minimal maintenance during the service. However environmental concern is that the emission of CO_2 associated with cement manufacturing and hence has brought the pressure to reduce the cement consumption with the, inventions and usage of Admixtures.

Metakaolin: Metakaolin (MK) is classified as a Mineral Admixture in IS 456:2000 in clause 5.2.1.4.

About metakaolin: Metakaolin is produced by heat treating of Kaolin, one of the most abundant natural minerals to a temperature of 600-800 degree Celsius. Kaolin is a white fine clay mineral that has been traditionally used. Metakaolin is produce under carefully well controlled conditions and hence its composition, white appearance and performance are relatively consistent. It reacts rapidly with the calcium hydroxide in the cement paste, converting it into a stable cementitious compounds thus refining the microstructure of concrete thereby reducing its permeation properties. Due to its high surface area and high reactivity, relatively small addition rates of MK produce relatively large increases in strength, impermeability and also the durability while its light colour gives it an aesthetic advantage.

Metakaolin is a cementitious material which is used as admixture to produce high strength concrete. In Korea, the utilization of this material remained mainly limited to fireproof walls but began recently to find applications as a replacement for silica fume in manufacturing of high performance concrete. In order to evaluate and compare the mechanical properties and durability of the concrete using metakaolin, the following tests were conducted on concrete specimens using various replacements of metakaolin; mechanical tests such as compressive, tensile and Split Tensile Strength tests. Strength tests shows that the most appropriate strength was obtained for a substitution rate of metakaolin to binder is approximately 10%. The filler effect resulting from the fine powder of binders was seen to ameliorate substantially the resistance to the chemical attacks in the comparison with ordinary concrete. The tests implemented in this study confirmed that the metakaolin constitutes a promising material as a substitute for the cost prohibitive silica fume.

As stated above that the Metakaolin is produced by burning kaolin at a temperature of 600°C-800°C. The main constituent, kaolinite is a hydrous aluminium silicate of the approximate composition $2H_2O.Al_2O_3.2SiO_2$.

Metakaolin is one of the innovative clay products developed in the recent years. It is produced by controlled thermal treatment of kaolin. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has the pozzolanic properties. The use of metakaolin as a partial cement replacement material in mortar and concrete has been studied widely in the recent years. Despite of the recent studies, there are still many unknowns with the uses of metakaolin. Study is needed to determine the contribution of

metakaolin to the performances of the hardened concrete. There are great concerns on the strength and durability of metakaolin-concrete when used as the construction materials in the construction industries. If it is proven that the concrete is durable and strong, this will lead to the uses of metakaolin to replace the part of the cement. Metakaolin is not a by-product which means its engineering values are carefully well controlled. Therefore, using metakaolin should promise some advantages compared to the other cement replacement materials. In this case, studies are needed to study the performances of the concrete using metakaolin.

Objective: The main objective of this study is to achieve the high strength concrete by using Metakaolin admixture and its durability. This study also includes the performance of concrete by using Metakaolin with respect to compressive strength, and its Split Tensile Strength – a first of its kind.

2. MATERIALS USED

1.1 Cement: Ordinary Portland cement of 43-grade cement which is conforming to IS: 8112 – 1970 was used throughout the work. The specific gravity is 3.11 and fineness modulus is 4.54.

1.2 Fine aggregate: Locally Available natural river sand confirming to the grading zone – II of table of IS: 383 – 1970 has been used as fine aggregate. The specific gravity is 2.72, and fineness modulus is 3.73.

1.3 Coarse aggregate: Machine crushed granite confirming to IS: 383 – 1970 consisting 20mm maximum size of aggregate have been obtained from the locally available place. It has been tested for specific gravity i.e., 2.71.

1.4 Metakaolin: The Metakaolin is obtained from Kaolin Techniques pvt ltd, Vadodara, Gujarat. The Metakaolin is conformity with general requirements of pozzolana.

Table-1: Manufacturer's specification of metakaolin:

Origin	India
Mineralogical composition:	Kaolinite-($Al_2O_3SiO_2$)
Packaging:	Powder 25 kg
Physical properties	**Typical**
Pozzolanic reactivity mg $Ca(OH)_2$/gm	900-1050
BET surface area m^2/gm	12-18
Average particle size	1.5-2.5 micron
Residue (> 45 micron)(max%)	0.5-2%
Brightness	75±1
Bulk density (gm/ltr)	300 to 320
Specific gravity	2.5

1.5 Super Plasticizer: Conplast P211 used is a chloride free – water reducing admixture based on selected sugar reduced lignbosulphonates. It is supplied as a brown solution which instantly disperses in water. This admixture produces higher levels of workability for the same water content. Allowing benefits such as the water reduction and increased strengths to be taken. The specific gravity is 1.18 to 1.19 at 25^0C; fluoride content is less than 0.05% by weight.

1.6 Water: Potable water has been used in this experimental study for the mixing and curing processes.

3. EXPERIMENTAL WORK AND TEST

In the present study M35 grade concrete has been used. The mix of concrete is designed as per the guidelines of IS 10262, subsequently mixes were prepared with a partial replacement of cement by Metakaolin at percentages of 5, 10, 15, 20 and 25 for cubes and cylinders, by weight of cement water ratio of 0.50 and constant dosage of 200 ml suerplasticizer for 1 bag of cement is used.

Manual mixing is adopted throughout this experimental work. First of all, all the materials that is cement, Metakaolin, fine aggregate and coarse aggregate are weighed exactly, cement and Metakaolin are mixed first. Then to coarse aggregate (C.A.) & fine aggregate (F.A.), cement Metakaolin mixture is added and thoroughly mixed.

A solution is prepared by adding the required dosage of suerplasticizer to about 10%of water required for the concrete mix to be used at the added and mixed it well. The balance of water is then added to the concrete in small quantities and mixture is uniformly mixed with water. After that, the solution containing suerplasticizer is added to the concrete and is again thoroughly mixed until there is uniform color.

The cubes are casted in the steel moulds (150x150x150mm) and cylinders (150 mm dia and 300 long) are also casted. The specimens are demoulded after curing which is done for a period of 7 days and 28 days. The cube specimens are tested for compressive strength, the cylinder specimens are tested for Split Tensile Strength.

3.1 Mix Design: Mix design carried out for M35 grade of concrete by IS 10262:2009, resulting to a mix proportion of 1:1.69:2.28 with water cement ratio of 0.5. The replacement of cement by Metakaolin was 5% to 25% at increment of 5% each.

Table-2: Different combinations of mixes

Mix Designation	Mix details (cement+MK)
S-1	100%Cement+0% MK
S-2	95%Cement + 5%MK
S-3	90%Cement +10%MK
S-4	85%Cement + 15%MK
S-5	80%Cement+20%MK
S-6	75%Cement+25%MK

3.2 Compressive and Split Tensile Strength test: Concrete prepared with different percentage replacement of cement by metakaolin at increment of 5% each up to 25% was cured under normal condition and were tested at 7 days and 28 days for determining the compressive and Split Tensile Strength and compared those with the results of conventional concrete.

4. RESULTS AND DISCUSSION

4.1 Tables:

Table-3: Cube compressive strength of concrete with partial replacement of cement by metakaolin

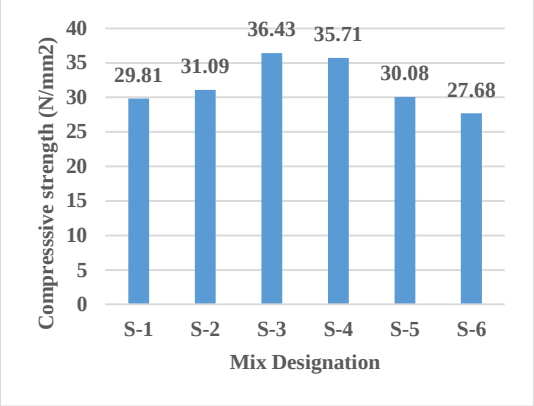
Mix Designation	% replacement of cement by metakaolin	Compressive Strength @7days (N/mm²)	Compressive Strength @28days (N/mm²)
S-1	0	29.81	45.52
S-2	5	31.09	47.41
S-3	10	36.43	53.71
S-4	15	35.71	50.08
S-5	20	30.08	44.38
S-6	25	27.68	43.11

Table-4: Split Tensile Strength of Concrete with % of Metakaolin

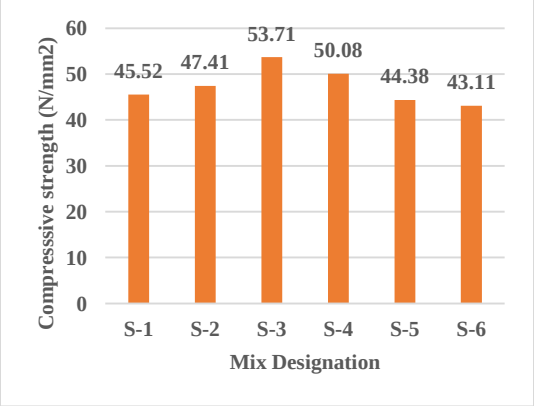
Mix Designation	% of Metakaolin	Split Tensile Strength @7days (N/mm²)	Split Tensile Strength @28 days (N/mm²)
S-1	0	3.811	3.986
S-2	5	4.015	4.357
S-3	10	4.319	4.783
S-4	15	3.961	4.531
S-5	20	3.273	3.567
S-6	25	2.876	2.985

4.2 Graphs:

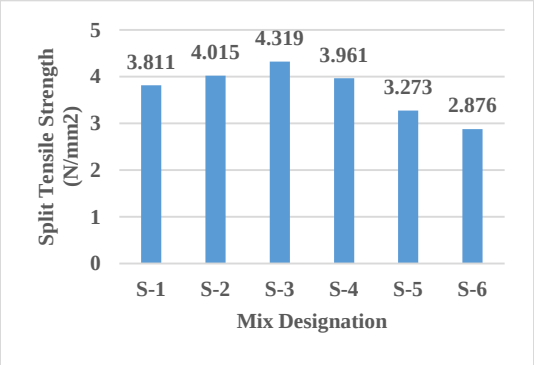
Graph-1: Cube Compressive Strength of Concrete with % of Metakaolin at 7days curing period



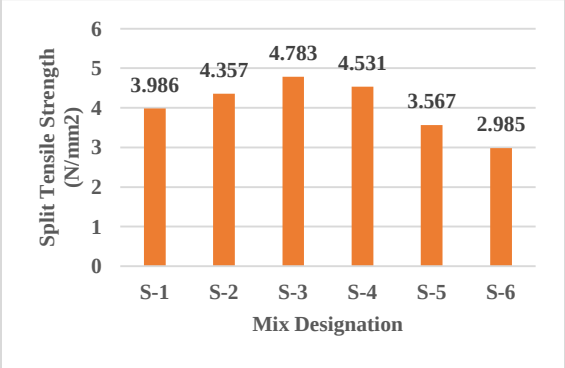
Graph-2: Cube Compressive Strength of Concrete with % of Metakaolin at 28 days curing period



Graph-3: Split Tensile Strength Of Concrete With % Of Metakaolin at 7 days curing period



Graph-4: Split Tensile Strength Of Concrete with % of Metakaolin at 28 days curing period



4.3 Discussion:

A. Influence of Metakaolin percentages on Compressive strength of concrete

The compressive strength (Table-3, graph 1 and 2) of the mix M35 i.e. without mixing of Metakaolin is 29.81N/mm^2 and 45.52N/mm^2 for 7 days and 28 days respectively. In the present investigation the Metakaolin has been used as replacement to cement up to a maximum of 25%. When Metakaolin is used as admixture in different percentages the strength is increased.

For e.g., with 5% replacement of cement by Metakaolin the compressive strength at 28 days is 47.41N/mm^2 and there is an increase of compression strength by 4.15 %.Considering 10% replacement, the compressive strength is 53.71 N/mm^2 there is an increase in compressive strength by 13.28%. With 15% replacement, the compressive strength is 50.08 N/mm^2, and the decrease in compressive strength by 6.75%. With 20% replacement, the compressive strength is 44.38 N/mm^2, and the decrease in compressive strength by 11.38%. From this strength it is clear that there is no advantage in using Metakaolin beyond 10%. Hence, 10% Metakaolin can be taken as the optimum dosage, which can be mixed as a partial replacement to cement for giving maximum possible compressive strength at any stage.

B. Influence of Metakaolin percentages on Split Tensile strength of concrete

In the case of split tensile strength (Table-4 and graph 3 and 4) the 28 days value without Metakaolin is 3.986N/mm^2. When 5% replacement is used the split tensile strength is 4.357 N/mm^2. There is increase in strength by 9.30%. The split tensile strength at 28 days with 10% replacement is 4.783 N/mm^2 showing an increase of strength by 9.77%. With 15% replacement the tensile strength for 28 days is 4.531 N/mm^2. There is decrease in strength by about 5.26% only. Hence, it is advisable to use 10% as- replacement. Hence the optimum percentage of Metakaolin is again 10% even in the case of split tensile strength.

CONCLUSIONS

Based on the present experimental investigation, the following conclusions are drawn:

1. 10% Metakaolin can be taken as the optimum dosage, which can be utilized by using super plasticizer. Mixed as a partial replacement to cement for giving maximum possible compressive strength at any stage.

2. The optimum percentage of Metakaolin is again 10% in the case of Split Tensile Strength.

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