EXPERIMENTAL STUDY OF STRENGTHENING PROPERTIES ON CONCRETE BY USING POZZOLANA MATERIALS

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Abstract: Recent days the partial replacement of ordinary Portland cement with pozzanals has been increasing widely. Most commonly used pozzanals are fly ash, silica fume, metakaoline, ground granulated blast furnace slag. A pozzolan is a material which, when combined with calcium hydroxide, exhibits cementitious properties. Pozzolans are commonly used as an addition to cement concrete and in some cases to reduce .The material cost of concrete. Recent research aimed at energy conversation in the cement and concrete industry has in part, focused on the use of less energy intensive materials such as fly ash, slag and silica fume. Of the late some attention has been given to the use of natural pozzolans like metakaoline as possible partial replacement for cement. Amongst the various method used to improve the durability of concrete, and to achieve high performance concrete, the use of metakaoline is a relatively new approach, the chief problem with its extreme fineness and high water requirement when mixed with cement. The present work focus on investigating the mechanical and durability properties of M20 grade concrete with the partial replacement of metakaoline (10%,20%,30%), flyash (5%,10%,15%), silica fume (2%,4%,6%). the cubes, cylinders and prisms are tested for compressive strength.
Keywords: Metakaoline, Flyash, Silica Fume. Mix Design

I. INTRODUCTION

Metakaoline is a manufactured pozzolanic mineral admixture which significantly enhances many performance characteristics of cement based mortars, concrete and related products. The use of pozzolanic materials in the manufacture of concrete has a long, successful history. Most pozzolans used in the world today are by products from other industries, such as coal flash, blast furnace slag, rice husk and silica fume. As such there has been relatively little work done with regard to manufactured, optimized and engineered pozzolanic materials which are specially intended for use in Portland cement based formulations, The use of Metakaoline and various chemical admixtures have become staple ingredients in the production of concrete with designed strength in excess of 7500psi (>50Mpa)or where service environments, exposure or life cycle cost considerations dictate the sue of High performance concrete (HPC). Among the various methods used to improve the durability of concrete, and to achieve high performance concrete the use of Metakaoline is relatively a new approach. The partial replacement of ordinary Portland cement with pozzolanic materials can be advantageous in increasing the durability of paste, mortar or concrete if the proper curing regime is adopted. This is due to the fact that the Calcium Hydroxide produced by the cement hydration reacts with the pozzolana and produces additional gel which has a pore blocking effect and therefore alters the pore structure and the strength. In addition there is a reduction in Calcium Hydroxide (CH) which leads to improved resistance to sulphate attack and alkali-silica reaction. Recently Metakaoline which is an ultra fine pozzolan produced form clacined clay that has been added to the list of pozzolanic materials.

METAKAOLINE :

Metakaoline is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaoline is smaller than cement particles, but not as fine as silica fume. Metakaoline is a high quality pozzolanic material, which is blended with Portland cement in order to improve the strength and durability of concrete and mortars. The Meta prefix in the term is used to demote change. It is a borrowing from Greek meaning after, along with, beyond. It is used, and is recognizable, in the formation of compound words metabolic, metamorphosis. The scientific use of the prefix is used for a combining form denoting the least hydrated of a series. In the case of Metakaoline, the change that is taking place is dehydroxylization, brought on by the application of heat over a defined period of time.

STRENGTH PARAMETERS :

Metakaoline contains similar range of silica and alumina oxides. Metakaoline contain high silica and super fineness, its reactivity is more, comparative to other pozzolanic admixtures. As a result, it contributes to strength improvement. Compressive strength of Metakaoline concrete continuous to increase with replacement levels at all ages u to optimum dosage. Ultra high strength concrete of the order of 40 to 120N/mm2 is now possible for field placeable concrete with Metakaoline admixture. Such high strength concrete has increased modulus of elasticity, lower creep and drying shrinkage. Another strength parameter of Metakaoline is its gain in strength.

ADVANTAGES:

- Increased compressive and flexural strengths
- Reduced permeability.
- 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 colour by lightening the colour of concrete making it possible to tint lighter integral colour.
- 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.

Fly ash:
Flyash is “the finely divided residue resulting from the combustion of ground or powdered coal, which is transported from the fire box through the boiler by flue gases “. Flyash is a by-product of coal-fired electric generating plants. There are about 70 thermal power plants in the country, which are currently producing about 100 million tons of flyash per annum. Out of this huge quantity of flyash, hardly less than 5% is being put for gainful purposes like brick making, cement manufacture, void filling in tunnels, backfill, sludge stabilization, glass manufacture agriculture, soil stabilization etc., leaving a massive portion of the ashis mixed with a measured amount of water and pumped into lagoons from where it can be later reclaimed. In spite of some inherent problems associated with flyash utilization, the encouraging engineering properties of the material prompted engineering community to utilize it in bulk quantities for construction purposes, which not only helps to dispose it off but also to preserve the top fertile soil from using it for several purposes.

Silica fume:
It also known as microsilica, (CAS number 69012-64-2, EINECS number 273-761-1) is an amorphous (non-crystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. The main field of application is as pozzolanic material for high performance concrete

Properties:
Silica fume is an ultrafine material with spherical particles less than 1 µm in diameter, the average being about 0.15 µm. This makes it approximately 100 times smaller than the average cement particle. [1] The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method.

II. MATERIAL PROPERTIES

The materials used in the experimental work namely cement, metakaoline, fine aggregates and coarse aggregate(20mm, 10mm)have been tested in the laboratory for use in mix designs. the detail are presented below.

CEMENT
Ordinary Portland cement of 53 GRADE(deccan) was used in the investigation.
THE DETAILS OF TESTS CONDUCTED ON CEMENT ARE DESCRIBED BELOW.

Specific Gravity of Cement
Specific gravity is calculated by using Le-Chatlier’s flask method or by specific density bottle method.
Cement specific gravity:
Fineness Test on Cement
Fineness test on cement can be calculated by sieve test or air permeability method, in commercial cement it is suggested that there should be about 25to 30% of particles less than 7 microns in size.
Fineness of cement:

Initial and Finial Setting Time Test on Cement
Initial and finial setting time test on cement is obtained by vicat’s apparatus, for initial setting time of cement vicat’s needleshould penetrate to a depth of 33 to 35mm from the top, for setting time the vicat’sneedle should pierce through the paste more than 0.5mm. we to calculate the initial and finial setting time as per IS:4031 (PART 5)-1998.
Initial setting time of test cement:
Finial setting time of test cement:

Standard Consistency Test
The standard consistency test of a cement paste of cement paste is defined as that consistency which will permit vicat’s plunger having the 10mm diameter and 50mm length to penetrate to a depth of 33 to 35 from the top of the mould. The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS:4031(Part 4)-1988.
Standard consistency of test cement:

FINE AGGREGATE
Aggregates smaller than 4.75 mm and up to 0.075mm are considered as fine Aggregates .
The Details of test conducted on fine aggregate are described below.

Fineness Modulus
The standard definition of fineness modulus is as follows: ” An empirical factor obtained by adding the total percentages of samples of aggregate retained on each of a specified series of sieves, and dividing the sum by 100.”
Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS:2386(part 1)-1963.

i) A set of IS sieves of sizes – 80mm, 40mm, 20mm,16mm, 10mm, 4.75mm, 2.36mm, 1.18mm, 600um, 300um, 150um.
ii) 80mm to 4.75 mm IS sieves are used for coarse aggregate analysis and from 4.75 mm to 150um IS sieves are used for analysis of fine aggregates.

sl.no	Is. Sieve DESIGNATION	% OF WEIGHT RETAINED (KG)	CUMULATIVE % OF WEIGHT RETAINED (C1)	% OF PASSING
1	10	-	-	-
2	4.75mm	0.5	0.5	99.5
3	2.36mm	1.5	2	98
4	1.18mm	8	10	90
5	600µ	24	34	66
6	300µ	46	80	20
7	150µ	18	98	2

Table 2.1 Sieve analysis of fine aggregate

COARSE AGGREGATE
Aggregate greater than 4.75mm are considered as coarse aggregate.
Specific Gravity
The specific gravity of coarse aggregate is
Fineness Modulus of coarse Aggregate

IS sieve designation	% of weight retained (kg)	Cumulative percentage weight retained	cumulative percentage passing
80mm	-	-	100
40mm	-	-	100
20mm	30.84	30.84	69.16
10mm	68.70	99.54	.46
4.75mm	0	99.54	0
2.36mm	0	99.54	0
1.18mm	-	100	0
600 µ	-	100	0
300 µ	--	100	0
150 µ	-	100	0

Finess Module=7.27

Table 2.2 sieve Analysis of coarse Aggregates

METAKAOLINE
Properties of Metakaoline
In the present investigation Metakaoline marketed by specially Minerals, Vadodara, Gujarat, is used. The results furnished by manufacturer are presented in table its specific gravity as found is 2.65 and bulk density is 710 kg/m^3

Average particle size , µm	1.5
Specific gravity	2.65
Bulk density(kg/m ^{3})	710
Physical form	Off –white powder

Table 2.3 Physical Properties of Metakaoline

Sl.no	Characteristics	Result metakaoline(%weight)
1	Loss of ignition	4.52
2	Silica	60.45
3	Alumina	16.23
4	Iron	8.56
5	Calcium	3.73
6	Magnesium	2.14

Table 2.4 Chemical properties of Metakaoline

III. TEST RESULTS

Replacement of cement with METAKAOLINE of M20 grade concrete :
Calculate the mix proportion with partial replacement of OPC with 0%,10%,20%and 30% of metakaoline.
Mix proportions for M20 Grade Concrete:

Conventional concrete -1:1.9:3.62:0.55
10% replacement -0.9:1.9:3.62:0.55
20%replacement -0.8:1.9:3.62:0.55
30%replacement -0.7:1.9:3.62:0.55

WORKABILITY TESTS:

sl.no	Description for M20	Slump cone test	Compaction factor test	Vee-bee consistometer test
1	Plain concrete	40mm	0.95	8sec
2	Metakaoline 10%	30mm	0.89	9sec
3	Metakaoline 20%	26mm	0.873	6sec
4	Metakaoline 30%	19mm	0.87	6sec

Table 3.1 metakaoline workability tests values for M20

sl.no	Description for M20	Slump cone test	Compaction factor test	Vee-bee consistometer
1	Plain concrete	40mm	0.95	8sec
2	Fly ash5%	26mm	0.85	9sec
3	Fly ash10%	24mm	0.83	11sec
4	Fly ash 15%	22mm	0.81	13sec

Table 3.2 Fly ash workability tests values for M20

sl.no	Description for M20	Slump cone test	Compaction factor test	Vee-bee consistometer
1	Plane concrete	40mm	0.95	8sec
2	Silica fume2%	36mm	0.90	16sec
3	Silica fume 4%	32mm	0.85	14sec
4	Silica fume4%	30mm	0.80	13sec

Table 3.3 Silica fume workability tests values for M20

COMPRESSIVE STRENGTH:
Metakaoline:

Sl.no	Percentage of metakaoline(%)	Compressive strength 28 days
1	0	33.3
2	10	35.57
3	20	37.49
4	30	34.37

TABLE 3.4 COMPRESSIVE STRENGTH OF CONCRETE FOR M20

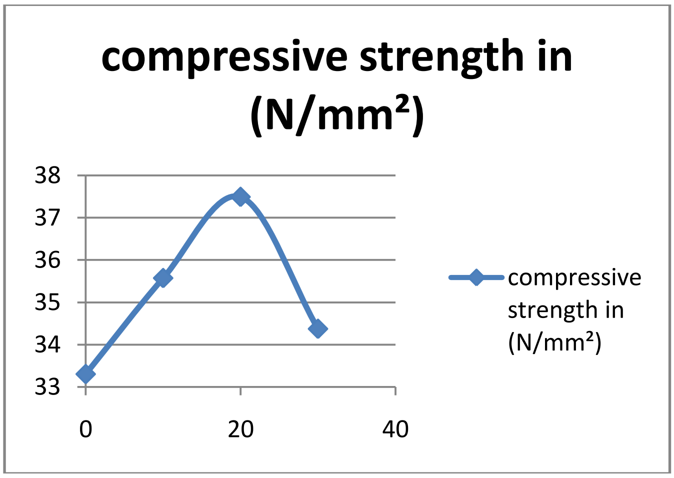

Figure 1. Graph between compressive strength of concrete M20 VS percentage of Metakaoline

fly ash :

Sl.no	Percentage of fly ash	Compressive strength(N/mm²) 28days
1	5%	30.38
2	10%	33.33
3	15%	30.3

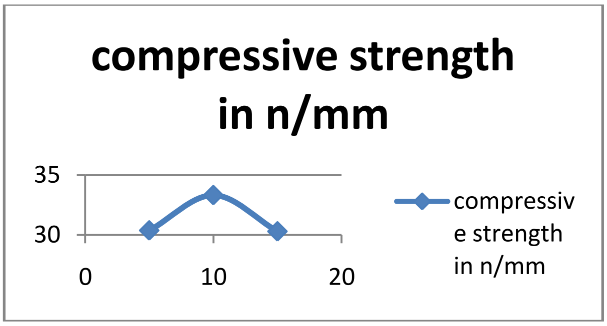

Figure2. Graph Between compressive strength of concrete for M20 VS % of fly ash

Silica fume :

Sl.no	percentage of silica fume	Compressive strength (N/mm²) In 28days
1	2%	30.95
2	4%	32.90
3	6%	33.54
4	8%	31.5

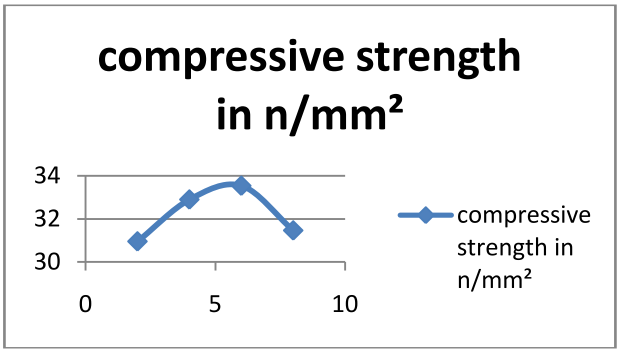

Figure 8. graph between compressive strength of concrete for M20 VS percentage of silica fume

IV. VI. CONCLUSION

Based on the analysis of experimental results and discussion there upon the following conclusions can be drawn.

- The compressive strength of concrete increased when cement is replaced by metakaoline for M20 at 20% replacement of cement by metakaoline
- The compressive strength of concrete increased when cement is replaced by fly ash for M20 at 15%replacement of cement by fly ash
- The compressive strength of concrete increased when cement is replaced by silica fume for M20at 6% replacement of cement by silica fume
- Workability of concrete decreases with increase in fly ash replacement level.
- Workability of concrete decreases with the increase in metakaoline replacement level.
- Workability of concrete decreases with the increases in silica fume replacement level

REFERENCES

[1] Badiogiannis. E.V.G Papadakis, E.chaniotakis, s.Tsivillis(2004) “Exploitation of poor greekkaoils strength development of metakaoline concrete and evaluation by means of K-value, cement and concrete research 34, 2004,pp 1035-1041

[2] Bai.j.m., ,kunitha, j.,wild and sabir,b.b(1999) “Workability of concrete incorporating pulverized fuel ash and metakaoline”, magazine of concrete research, V.51,no. 3,1999,p.207-216

[3] Bai j.,s.Wild,B.B>sabir and J.M.kinuthi,(2000) “strength development in concrete incoperating pulverized fuels and metakaoline” in the magazine of concrete research No.3,2000,pp 53-162

[4] A. Bilodeau, V. Sivasundaram, K.E. Painter and V.M. Malhotra, Durability of concrete incorporating high volumes of fly ash sources in the USA, ACI Mater.J. 91(1) (1994)3 – 12.

[5] A. Bilodeau and V.M. Malhotra, concrete incorporating high volumes of ASTM class F fly ashes: USA, 1992, PP. 319 – 349.

[6] C.S. Poon, study on high strength concrete prepared with large volume of low- calcium fly ash, Cem. Concr. Res. 30 (3) (2000) 447 – 455.

[7] D. Ravina and P.K. Mehta, Properties of fresh concrete containing large amount of fly ash, Cem. Cem. Res 16(2) (1986) 227 – 238.

[8] G..M. Giaccio and V.M. Malhotra, Concrete incorporating high volumes of ASTM Class F fly ash, Cem, Concr. Aggregates 10 (2) (1988) 88 – 95.

[9] K.R. Hwang, T. Noguchi and F . Tomosawa, Effects of fine aggregate replacement on the rheology, compressive strength and carbonation properties of fly ash and mortar, ACI Spec. Publ. SP – 178 (1998) 401 – 410.

[10] M. Maslehuddin, Effect of sand replacement on the early – age strength gain and long – term corrosion – resisting characteristics of fly ash concrete, ACI Matter. J.86 (1) (1989) 58 - 62.

[11] West, J.M. (1981) Fatigue endurance of glass fiber reinforced cement, Journal of materials science 16(9).

[12] Rayment, D. L. (1978) Determination of the planar distribution of glass fibers in opaque matrix composites. Journal of Material Science13(4).

[13] ASTM C617 – 98 Standard Practice for Capping Cylindrical Concrete Specimens, USA, 1998.

[14] ASTM C469 – 94, Standard Test Method for static modulus of elasticity and poisson’s ratio of concrete in compression. 1994.

[15] William Gibert.r.(1974), “ the effect of steel fibers on the compressive strength of concrete”, fiber

reinforced concrete, sp44, ACI. PP195 – 207.

[16] Murty, A.V.S.R. (1998): “Flyash in construction of Roads and Embankments”, Experience sharing meet on use of Flyash in Roads and Embankments, CRRI, New Delhi.Indian Concrete Journal(ICJ)

[17] Shah S.P Rangan B.V. (1997), “ Fiber reinforced concrete properties”, ACI journal, vol 75, pp 102 – 115. [15] P.J. Tikalsky, P.M. Carrasquillo and R.L. Carrasquillo, Strength and durability considerations affecting mix proportions of concrete containing fly ash, ACI Mater.J. 85 (6) (1988) 505 – 511.

[18] T.R. Naik, B.W. Ramme and J.H. Tews, Use of high volume of class C and class F fly ash in concrete, cem. Concr. Aggregates 16 (1) (1994) 12 – 20 fig. 8. Depth of wear versus abrasion time at 365 days. R. Siddique/ cement and concrete Research 34 (2004) 487 – 493.

[19] T. R. Naik, S.S. Singh and B.W. Ramme, Mechanical properties and durability of concrete made with blended fly ash, ACI Mater. J. 95 (4) (1998) 454 – 462.

[20] V.G. Papadakis, Effect of fly ash on Portland cement system: Part 1. Low – calcium fly ash, cem. Concr. Res. 29 (11) (1999) 1727 – 1736.

[21] N. Krishna Raju,” Design of Concrete Mixes” , Year 2005 .

[22] M.S.Shetty, “Concrete Technology”.

[23] IS 12269-1987 Specification for OPC 53 grade.

[24] IS 10262-2009 recommended guide line for concrete mix design page no 38.

[25] IS 9103-1999 Concrete admixture-specifications. Page no 38.

[26] IS 9013-1978 Accelerating curing.

[27] IS 383-1970 Specification for coarse aggregate and fine aggregate from natural sources page no 38.

[28] IS 650-1966 Specification for standard sand for testing of cement.

[29] IS 456-2000 “Recommendation for plain & Reinforced concrete”.

