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Characteristic Evaluation of Blended Cement Concrete

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Abstract— This paper summarized the research work on evaluation of ternary blended cement containing Metakaolin &Fly ash .compaction factor test, slump cone test, flow table test was carried out on fresh concrete to check the workability while compressive strength, flexural strength, split tensile strength, impact strength was carried out on hardened concrete. A concrete mix of grade M40 was investigated by keeping water-binder ratio as 0.4. Initially workability and strength characteristics of binary blend was carried out by replacement intervals of 5%, 10%, 15%, 20%. Similarly workability and strength characteristics of Ternary bend was found out by replacement intervals of 5%, 10%, 15%, 20%[1]. Result states that by increasing percentage of fly ash, workability goes on increasing while by increasing percentage of metakaolin workability goes on decreasing [1]. It was observed that, percentage change in strength of concrete when fly ash is used is varying for various duration. But when Metakaolin was used, the percentage change in strength for various durations is almost constant [2]. Thus from above conclusions we get an idea about using both the materials i.e. fly ash and metakaolin, as a replacement in concrete together. It was evident from the tests of workability as well as on strength, that combination of 5% FA and 20% MK increase strength as well as makes the concrete more workable[3].

Keywords— Metakaolin, Fly-Ash, Binary, Ternary Blend, workability, Compressive strength, split tensile strength, impact value.

INTRODUCTION

Concrete is mostly used material worldwide because of its certain advantages such as general availability of ingredients, mouldability of fresh concrete and durability of hardened concrete[3]. But this popularity of concrete causing the adverse effect on environment. The main constituent of concrete is cement which causes about 7% of global warming And CO_2 emission and which require huge amount of energy for its production. Also problem of disposal of waste generated due to combustion of coal. Flyash is major waste product of thermal power plant. So there is need to replace the cement by any other cementitious material which overcomes above disadvantages. There are various types of supplementary cementitious material like silica flume, fly ash , GGBFS, Metakaolin, In this work, an extensive study using metakaolin and fly as binary mix its combinations as ternary mix has been carried out. Use of Portland cement construction is one of the major resons for Co_2 emissions. Metakaolin is obtained by thermal activation of kaolin clay which reduces Co_2 emissions & reduce heat of hydration caused due to Portland cement, while fly ash is waste generated by thermal power plant used as partial replacement of cement as well as additive to provide environmental consistent way of its disposal & reuse[12].

1. To find the optimum proportion of metakaolin that can be used as a replacement/ substitute material for cement in concrete.
2. To find the optimum proportion of Fly Ash that can be used as a replacement/ substitute material for cement in concrete.
3. To evaluate compressive and tensile strength of metakaolin and fly ash replaced concrete specimens.

II. MATERIALS AND METHODOLOGY

A.Metakaolin

Metakaolin is classified as a new generation of supplementary cementitous material[5]. Supplementary cementitious materials (SCMs) are finely ground solid materials that are used to replace part of the clinker in a cement or cement in a concrete mixture. Use of metakaolin in cement-based systems, provides technical as well as environmental benefits. Metakaolin is unique in that it is not the by-product of an industrial process nor is it entirely natural; it is derived from a naturally occurring mineral, and is manufactured specifically for cementing applications[2]. Metakaolin is usually produced by thermal treatment, i.e., calcination of kaolin clays within a definite temperature range. The main process important for production high reactivity pozzolana from kaolin clay is calcination. The heating process drives off water from the mineral kaolinite (Al_2O_3+$2SiO_2$+$2H_2O$), the main constituent of kaolin clay, and collapses the material structure, resulting in an amorphous alumino-silicate ($Al_2O_3.2SiO_2$), meta-kaolinite.

TABLE.I. PHYSICAL PROPERTIES OF METAKAOLIN

PHYSICAL PROPERTIES	METAKAOLIN
Physical form	Powder
appearance	Dark grey
Specific Gravity	2.5
Mean grain size (μm)	2.54

Specific area cm2 /gm	150000-180000

TABLE.II. CHEMICAL PROPERTIES OF METAKAOLIN

CHEMICAL COMPONENT	PERCENTAGE %
SiO2	60-65
Fe2O3	1.00
Al2O3	30-34
CaO	0.2-0.8
Na2O	0.5-1.2
K2O	0.5-1.2
Mn2O3	0.22

B.Fly Ash

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases [15]. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants, and together with bottom ash removed from the bottom of the furnace is in this case jointly known as coal ash[16]. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO_2) and calcium oxide (CaO). There are basically two classes of fly ash as defined by ASTM C618 as:-

1. Class F Fly ash
2. Class C Fly ash.

Differences between these two classes are based on the amount of Calcium, Silicon, Aluminum, & Iron content in ash. Chemical property is largely influenced by the chemical content of fly ash.

Physical properties help in classifying the coal ashes for engineering purposes and other engineering properties. Some of the properties are specific gravity, grain size distribution, index properties, free swell index and specific surface.

TABLE.III. CHEMICAL COMPOSITION OF FLY ASH

CHEMICAL COMPOSITION	PERCENTAGE (%)
Silica (SiO2)	49-67
Alumina (Al2O3)	16-29
Iron Oxide (Fe2O3)	4-10
Calcium Oxide (CaO)	1-4
Magnesium Oxide (MgO)	0.2-2
Sulphur (SO3)	0.1-2
Loss of Ignition	0.5-3.0

Other than the above substitute materials; Cement, fine and coarse aggregates were used and tested for various properties.

C. Concrete Mixes

In this study, the early age properties of fresh concrete and mechanical performance and tensile strength of hardened concrete were examined[10]. All tests were conducted using the following sample groups:

1. Conventional concrete,
2. Cement is replace with 5%, 10%, 15%, 20% FA.
3. Cement is replace with 5%, 10%, 15%, 20% MK
4. Cement is replace with combination of fly ash and MK by 5% ,10%,15%,20%
5. Each of the above samples was tested for compressive strength, split tensile strength and workability tests.

D. Workability

The workability of various mixes was assessed by determining the compacting factor, Slump value and flow percentage as per the IS-1199:1959 specifications.

III. RESULTS & DISCUSSION

A. Workability:

Freshly mixed concrete for various proportions were tested for workability by three methods, viz. compacting factor, flow percentage and slump value[9]. It was observed that, the workability increases with increase in fly-ash content in the mix. The mix with cement as the only binder, the workability was medium. An attempt has been made to correlate the increase in workability as a function of fly-ash content in the fly ash concrete. The variation of each workability measure with fly-ash content is presented in Table IV. From table, the values of compaction factor, flow percentage and slump value has shown increase with increase in fly-ash addition. But with increase in Metakaolin content the workability reduces to make concrete poor in workability and handling.

TABLE.IV. WORKABILITY OF CONCRETE MIXES:

SR NO	MIX	SLUMP OF CONCRETE (mm)	COMPACTION FACTOR	FLOW (%)	WORKABILITY
1.	PCC	89	0.887	70	Medium
2	5 % FA	90	0.86	70	Medium
3	10 % FA	95	0.89	77	Good
4	15 % FA	107	0.92	90	High
5	20 % FA	121	0.97	92	High
6	5 % MK	78	0.85	75	Medium
7	10 % MK	75	0.8	68	Low
8	15 % MK	67	0.76	65	Low
9	20 % MK	58	0.75	59	Poor

TABLE.V. WORKABILITY OF TERNARY BLENDED CEMENT CONCRETE

SR. NO.	MIX COMBINATION	SLUMP (mm)	C.F.	FLOW TEST (%)	WORKABILITY
1.	Conv. Concrete	89	0.887	70%	Medium
2	5%FA+5%MK	66	0.87	79%	Medium
3	5%FA+10%MK	58	0.85	73%	Medium
4	5%FA+15%MK	50	0.77	65%	Low
5	5%FA+20%MK	42	0.75	58%	Poor
6	10%FA+5%MK	79	0.89	69%	Medium
7	10%FA+10%MK	68	0.83	74%	Medium
8	10%FA+15%MK	61	0.80	74%	Medium
9	10%FA+20%MK	45	0.76	62%	Low
10	15%FA+5%MK	113	0.92	89%	High
11	15%FA+10%MK	104	0.95	92%	High
12	15%FA+15%MK	89	0.86	73%	Medium
13	15%FA+20%MK	81	0.84	70%	Medium
14	20%FA+5%MK	120	0.97	94%	High
15	20%FA+10%MK	109	0.97	95%	High
16	20%FA+15%MK	93	0.90	76%	Medium
17	20%FA+20%MK	87	0.85	75%	Medium

Fig.1. reveals that the value of slump decreases with increase in %of MK in blend and slump increases with increase in the % of FA in the blend.
This may be because the pozzolonic activity of MK is higher than that of FA, hence on addition of water MK uses it faster than the FA.

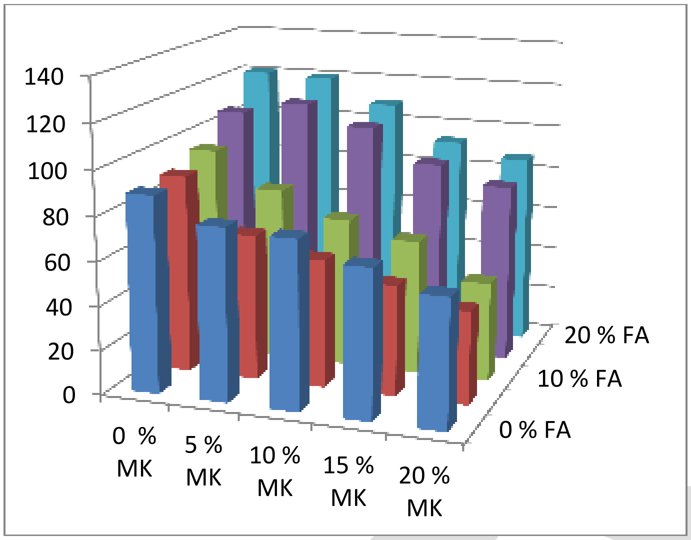

Fig.1. Graph of slump showing ternary blend cement replacement

It is evident that from fig. 2 that the value of compaction factor decreases with increase in %of MK in blend and compaction factor increases with increase in the % of FA in the blend.
This may be because the particle size distribution of the substitution materials used are finer than that of cement, hence they are denser and occupies more surface area, also due to workability there is good response in compaction of concrete

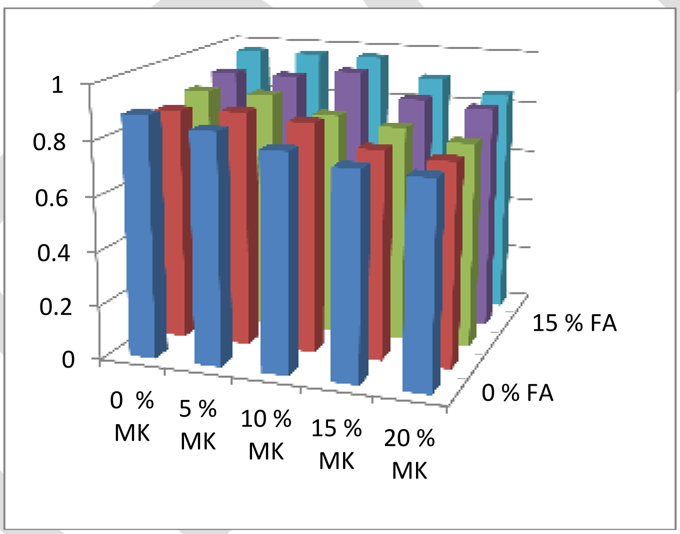

Fig.2. Graph of compaction factor showing ternary blend replacement

It is evident that from fig.3 that the flow value initially shows trend of increment upto 5% and then decreases with increase in %of MK in blend and flow value increases with increase in the % of FA in the blend.

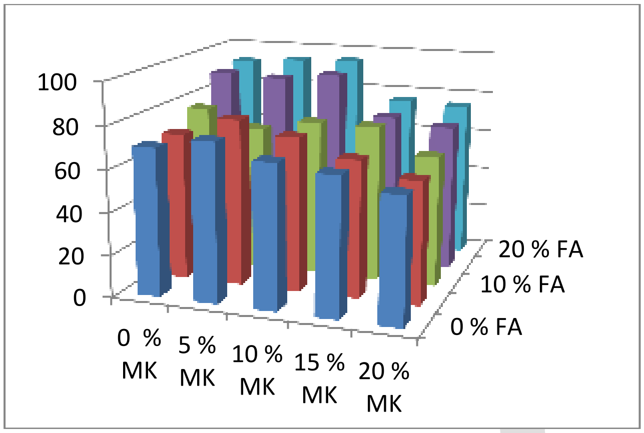

Fig.3. Graph of flow value showing ternary blend cement replacement

B.Compressive Strength behaviour of blended cement concrete.

TABLE.VI. COMPRESSIVE STRENGTH TEST RESULTS

REPLACEMENT LEVELS (%)	COMPRESSIVE STRENGTH (MPA)		
	3 DAYS	7 DAYS	28 DAYS
PCC	25.78	32.44	41.78
5 % FA	23.56	35.56	41.33
10 % FA	22.89	34.22	40.44
15 % FA	21.78	32.22	38.67
20 % FA	20.89	30.67	37.78
5 % MK	25.56	33.33	42.22
10 % MK	27.11	35.11	44.89
15 % MK	28.22	36.44	47.11
20 % MK	27.33	35.56	43.46

The table shows results of compressive strength for various replacements in cement.

Fig.4 reveals that when cement is replaced the compressive strength has reduced this might be because the FA is good in workability and might have hampered the water cement ratio to reduce the strength. When MK is used there has been a substantial rise in the strength upto 20%.

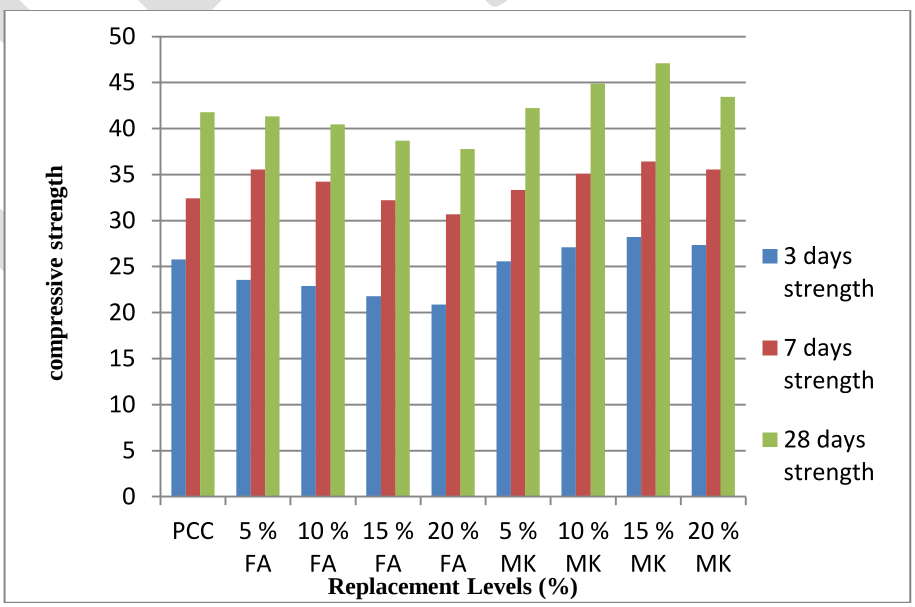

Fig.4. Graph of compressive strength for individual replacement

C. Split-tensile strength behaviour of blended cement

TABLE.VII. SPLIT-TENSILE TEST RESULTS

SR. NO.	REPLACEMENT LEVELS		SPLIT TENSILE STRENGTH
	FA FOR CEMENT	MK FOR AGGREGATE	28 DAYS
1	0	0	4.53
2	5	0	4.84
3	10	0	4.73
4	15	0	4.56
5	20	0	4.10
6	0	5	3.75
7	0	10	4.74
8	0	15	4.46
9	0	20	3.96

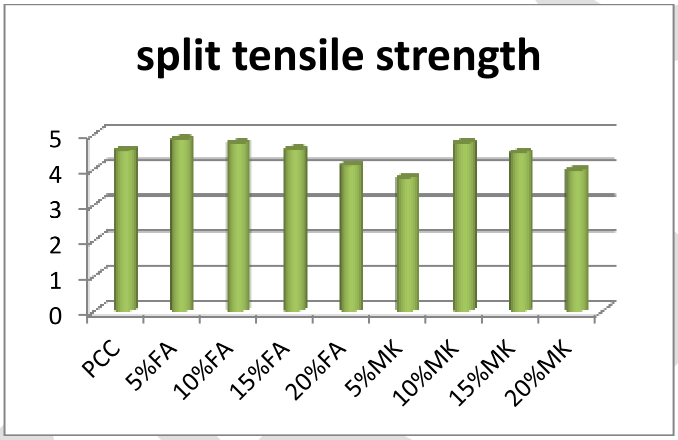

Fig.5. Graph of Split tensile strength for individual blend replacement

As shown in the fig.5, PCC strength is better than FA replacement but lesser than MK replacement.

As FA is only an admixture which improves the workability, it helps in increasing and maintaining the tension upto 15% replacement and again drops moderately in comparison of PCC. Whereas MK addition shows reduction in tension capacity of concrete. Only at 10% MK addition split tensile capacity has increased.

TABLE IX. 28 DAYS FLEXURAL STRENGTH FOR VARIOUS REPLACEMENTS

SR. NO.	MIX COMBINATION	AVERAGE FLEXURAL STRENGTH
1.	Conv. Concrete	6.39
2	5 % FA	5.49
3	10 % FA	5.46
4	15 % FA	5.44
5	20 % FA	4.7
6	5 % MK	6.59
7	10 % MK	6.93
8	15 % MK	7.20
9	20 % MK	6.39

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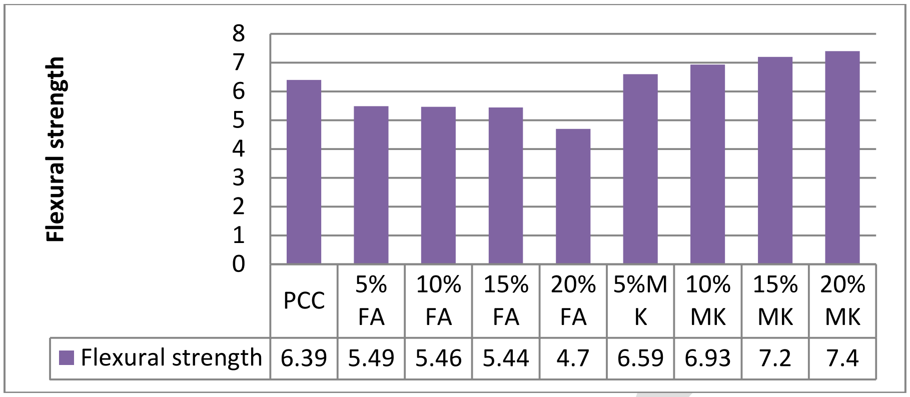

Fig.6. Graph of flexural strength for various replacement

TABLE NO. VIII. COMPRESSIVE STRENGTH & SPLIT TENSILE STRENGTH VALUES FOR TERNARY MIX REPLACEMENTS

SR. No.	REPLACEMENT LEVELS		COMPRESSIVE STRENGTH	SPLIT TENSILE STRENGTH
	FA FOR CEMENT	MK FOR CEMENT	28 DAYS	
1	0	0	41.78	4.53
2	5	5	41.78	3.89
3	5	10	43.11	4.13
4	5	15	49.78	4.67
5	5	20	45.89	5.77
6	10	5	41.33	5.45
7	10	10	42.67	4.97
8	10	15	46.34	6.23
9	10	20	43.56	5.67
10	15	5	41.45	4.89
11	15	10	41.67	5.13
12	15	15	45.12	4.45
13	15	20	42.56	4.05
14	20	5	40.67	3.97
15	20	10	41.34	3.78
16	20	15	44.67	4.35
17	20	20	43.11	3.77

Fig. 7 shows that for ternary blend the compressive strength increases to certain limit and finally decreases beyond that limit. This might be for the addition of MK which is a good pozzolonic additive and to certain extent FA improves the workability hence it also adds to the concrete strength.

Fig.8 shows the graph of flexural strength. The variation in reading is observed as trend showing increase in flexural strength upto 15 % of combinations and then decrease in values of strength.

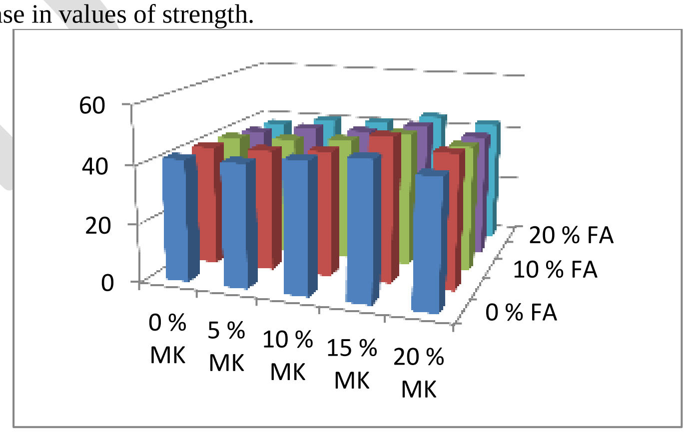

Fig.7. 28 Days compressive strength of ternary blended cement concrete

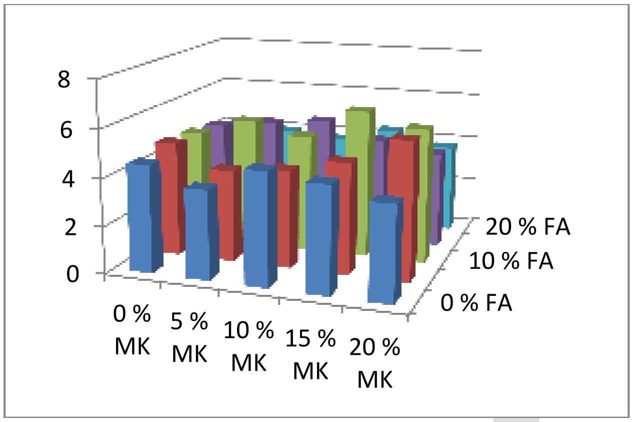

Fig.8. 28 Days flexural strength of ternary blended cement concrete

TABLE NO .X. 28 DAYS IMPACT STRENGTH FOR VARIOUS REPLACEMENTS

SR. NO.	MIX COMBINATION	FIRST CRACK STRENGTH (BLOWS)	FAILURE STRENGTH (BLOWS)
1.	Conv. Concrete	22	31
2	5 % FA	24	35
3	10 % FA	28	41
4	15 % FA	32	47
5	20 % FA	31	47
6	5 % MK	38	56
7	10 % MK	47	76
8	15 % MK	63	82
9	20 % MK	63	84

From the water absorption test values in table below it can be concluded that conventional concrete weighs heavier than others as it absorbs much water than the others. The minimum water is absorbed by the MK blend as it fills up the pores within the concrete making it denser and harder for absorption.

TABLE NO. XI. WATER ABSORPTION TEST RESULTS FOR VARIOUS REPLACEMENTS

MIX DESIGNATION	INCREASE IN MASS OF CONCRETE (%)
Conv. Concrete	7.085
5%FA	3.931
10%FA	4.439
15%FA	4.126
20%FA	4.223
5%MK	4.439
10%MK	4.302
15%MK	4.152
20%MK	3.529

V. CONCLUSION

- From the above results it is very clear that, as the fly ash percentage by weight goes on increasing, the strength of the concrete goes on decreasing. And as the Metakaolin percentage by weight goes on increasing, the strength of concrete also increases.
- It is also been observed that, percentage change in strength of concrete when fly ash is used is not constant for various durations.
- But when Metakaolin is used, the percentage change in strength for various durations is almost constant.
- Thus from above conclusions we get an idea about using both the materials i.e. fly ash and metakaolin, as a replacement in concrete together.
- From the results of individual replacement, it is also clear that strength of cubes can be further improved by using a fair combination of two materials to get blended concrete.

- It is evident from the workability as well as strength graphs that combination of 5% FA and 20% MK may prove to increase strength as well as makes concrete more workable.

REFERENCES:

[1] M. Nazeer and R. Arun Kumar, "Strength Studies on Metakaolin Blended High-Volume Fly Ash Concrete" International Journal of engineering and advanced technology , Volume3, issue-6, August 2014.

[2] Kannan, V. and Ganesan, K., "Effects of Binary and Ternary Cementitious Blends on the Mechanical Properties of Self Compacting Concrete", Australian Journal of Basic and Applied Sciences 8(3) March 2014, Pages: 283-291..

[3] Pacheco Torgal, Arman Shasavandi and Said Jalali, "Using metakaolin to improve the compressive strength and the durability of fly ash based Concrete", International Seminar, Innovation & Valorization In Civil Engineering & Construction Materials, Morocco – Rabat / November 23-25, 2011

[4] M. Si-Ahmed, A. Belakrouf, and S. Kenai Influence of Metakaolin on the Performance of Mortars and Concretes International Journal of Civil, Architectural, Structural and Construction Engineering Vol:6 No:11, 2012

[5] Bini M J and Shibi Varghese "Ternary Blended Concrete with Bagasse Ash and Metakaolin", International Journal of Engineering Research & Technology, Vol. 3 Issue 10, October- 2014.

[6]. Dr.K.Srinivasu, M.L.N.Krishna Sai and Venkata Sairam Kumar.N, "A Review on Use of Metakaolin in Cement Mortar and Concrete", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 7, July 2014

[7] Dr Sravana, Sarika.P, Dr.Srinivasa Rao, Dr.Seshadri Sekhar Tand Apparao.G, " Studies on Relationship Between Water/Binder Ratio And Compressive Strength Of High Volume Fly Ash Concrete", American Journal of Engineering Research, Volume-02, Issue-08, pp-115-122 2013

[8] Jayraj Vinodsinh Solanki and Jayeshkumar Pitroda, "Flexural Strength of Beams by Partial Replacement of Cement with Fly Ash and Hypo Sludge in Concrete", International Journal of Engineering Science and Innovative Technology, Volume 2, Issue 1, January 2013

[9] Mohammed Azhar and Mohammed Mohsin Ali Qureshi, "Strength Development in Concrete By Incorporating Metakaolin", International Journal of Advanced Trends in Computer Science and Engineering, Vol.2 , No.1, Pages : 634 – 639 (2013)

[10] B. B. Patil1, P. D. Kumbhar, "Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin", International Journal of Modern Engineering Research, Vol.2, Issue.3, May-June 2012 pp-1099-1104

[11] Nabil M. Al-Akhras "Durability of metakaolin concrete to sulfate attack" Cement and Concrete Research 36 (2006), pp.1727–1734

[12] Joy M. Justice, "Evaluation of Metakaolins for use as Supplementary Cementitious Materials" Phd thesis report, Georgia Institute of Technology, April- 2005

[13] Justice J.M, Kennison L.H, Mohr B.J., Beckwith S.L, McCormick L.E, Wiggins B Zhang Z.Z, and Kurtis K.E, "Comparison of Two Metakaolins and a Silica Fume Used as Supplementary Cementitious Materials" SP- 228(Volume1& 2) Seventh International Symposium on Utilization of High-Strength/High Performance Concrete, June(2005),SP228-17

[14] Badogiannis E, Papadakis V.G., Chaniotakis E, Tsivilis S, "Exploitation of poor Greek kaolins: Strength development of metakaolin concrete and evaluation by means of k-value" Cement and Concrete Research 34 (2004), pp.1035–104 [11] Hemant Chauhan and Bhavna K. Shah, "Effect of Activated Flyash in Metakaolin based cement", Proceedings of National Conference on Recent Trends in Engineering & Technology, B.V.M. Engineering College, V.V.Nagar, Gujarat, India

[15] Sabir B.B, Wild S, Bai J, "Metakaolin and calcined clay as pozzolans for concrete: a review Cement and concrete composite 23,(2001), pp.441-454.

[16] N. Bouzoubaâ1*, M. H. Zhang1, and V. M. Malhotra Mechanical properties and durability of concrete made with high-volome fly ash blended cement using a coarse fly ash Cement and Concrete Research, Vol. 31, No. 3, Oct. 2001, pp. 1393-1402.