iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: V Month of publication: May 2021

DOI: https://doi.org/10.22214/ijraset.2021.34019

Combined Impact of Fly Ash and Metakaoline on Mechanical Properties of Concrete

Swagatika Nayak[1], Nagarampalli Manoj Kumar[2]
[1]Student, [2]Guide, Department of Civil Engineering, GIET University, Gunupur, Odisha-765022

Abstract: Concrete is probably the most extensively used construction material in the world. The addition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. Nowadays there is an increasing trend of utilization of waste/non-conventional materials in cement and concrete matrices. These materials are often used as a part replacement of cement reducing the cost of construction and help to overcome the deficiencies associated with the use of Ordinary Portland Cement (OPC) alone in which damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Metakaoline is a waste/non-conventional material which can be utilized beneficially in the construction industry. From the recent research works using Metakaoline is a evident that it is a very effective pozzolanic material and it effectively enhances the strength parameters of concrete. However, the workability is slightly compromised and durability of concrete is increases. In the present work, an experimental investigation was carried out, replacing cement with Flyash. For improving the mechanical and durability properties of concrete by adding the metakaoline.
Keywords: Fly ash (FA), Metakaoline (MK), compressive strength, split tensile strength, flexural strength

I. INTRODUCTION

The application of concrete in construction is as old as the days of Greek and roman civilization. But for numerous reasons, the concrete construction industry is not sustainable. It consumes a lot of virgin materials and the principal raw material of concrete i.e. cement is responsible for green house gas emissions causing a threat to environment through global warming. Therefore, the industry has seen various types of concrete in search of a solution to sustainable development. Infrastructural growth has witnessed many forms of concrete like High Strength Concrete, High Performance Concrete, and Self Compacting Concrete.

The history of cementing material is as old as the history of engineering construction. Some kind of cementing materials were used by Egyptians, Romans, and Indians in their ancient constructions. It is also believed that the early Egyptians mostly used cementing materials, obtained by burning gypsum.

The story of the invention of Portland cement is, however, attributed to Joseph Aspdin, a Leeds Builder and brick layer, even though similar procedures had been adopted by other inventors.

Joseph Aspdin took the patent of Portland cement on 21st October 1824. The fancy name of Portland was given owing to the resemblance of this hardened cement to the natural stone occurring at Portland in England. In his process Aspdin mixed and ground hard lime stones and finely divided clay into the form of slurry and calcined it in a furnace similar to a lime kiln till the CO_2 was expelled. The mixture so calcined was then ground to a fine powder.

Roman builders used volcanic tuff found near Pozzuoli village near Mount Vesuvius in Italy. This volcanic tuff or ash mostly siliceous in nature thus acquired the name Pozzolona. Later on, the name Pozzolona was applied to any other material, natural or artificial, having nearly the same composition as that of volcanic tuff or ash found at Pozzuoli.

The word Pozzolona was derived from Pozzuoli, a town in Italy a few miles from Naples. The materials are of volcanic region containing various fragments of pumice, obsidian, feldspars,and quartz etc. The name Pozzolona was first applied exclusively to this material. But the term has been extended later to diatomaceous earth, highly siliceous rocks I and other artificial materials. Thus, the pozzolanic material is natural or artificial having nearly the same composition as that of volcanic tuffs or ash found at Pozzuoli.

Concrete is an artificial material in which the aggregates both fine and coarse are bounded together by the cement when mixed with water. The concrete has become so popular and indispensible because of its inherent characteristics and advantages either when green or hardened.

The use of reinforcement in concrete has brought a revolution in applications, design and construction techniques. Its great versatility and relative economy in filling wide range of needs has made it a very competitive building material.

II. LITERATURE REVIEW

The present work is drafted after referring the following previous researches:

BAI, JIPING, GAILIUS, ALBINAS Development of a multivariate statistical model for consistency parameter prediction including slump, compacting factor and vebe time for concrete incorporating FA and MK is described. The models constructed provide an efficient, quantitative, and rapid means for obtaining optimal solutions to consistency prediction for concrete mixes using PC-FA-MK blends as binder. Based on the experimental data, comprehensive regression analysis and significance tests were performed and the best-fit models for predicting consistency parameters were found. Values of consistency were calculated by the proposed models and gave a good agreement with observed experimental data. It indicates that the models are reliable, accurate and can be used in practice to predict the consistency of PC-FA-MK blends.

A.K.MULLCK (2007) Described among the many factors that govern the durability and performance of concrete in service, type of cement receives greater attention. In his paper he describes the characteristics of cementitious systems required to meet the diverse requirements of strength and durability of concrete and highlights the advantages of part replacement of OPC by fly ash, granulated slag and silica fume- either singly or in combination in ternary blends.

JELICA ZELI, IVANA RADOVANOVI, DRA`AN JOZI Investigated the deterioration of concrete structures due to the presence of sulfate in soils, groundwater and marine environments is a well-known phenomenon. The use of blended cements incorporating materials such as natural pozzolona, fly ash, or silica fume have an important role in the long- term durability of concrete exposed to sulfate attack.

R. D. NEVES AND J. C. O. FERNANDES DE ALMEID, conducted an experimental study to investigate the influence of matrix strength, fiber content and diameter on the compressive behavior of steel fiber reinforced concrete is presented. Two types of matrix and fibers were tested. Concrete compressive strengths of 35 and 60 MPa, 0.38 and 0.55 mm fiber diameter, and 30 mm fiber length, were considered. The volume of fiber in the concrete was varied up to 1.5%. Test results indicated that the addition of fibers to concrete enhances its toughness and strain at peak stress, but can slightly reduce the Young's modulus.

Simple expressions are proposed to estimate the Young's modulus and the strain at peak stress, from the compressive strength results, knowing fiber volume, length, and diameter. An analytical model to predict the stress–strain relationship for steel fiber concrete in compression is also proposed. The model results are compared with experimental stress–strain curves.

ELAHI, P.A.M. BASHEER, S.V.NANUKUTTAN, Q.U.Z KHAN (2009), Conducted an experimental investigation was carried out to evaluate the mechanical and durability properties of high performance concretes containing supplementary cementations materials in both binary and ternary systems.

The mechanical properties were assessed from the compressive strength, whilst the durability characteristics were investigated in terms of chloride diffusion, electrical resistivity, air permeability, and water absorption. The test variables included the type and the amount of supplementary cementitious materials (silica fume, fly ash, and ground granulated blast-furnace slag). All the ternary combinations can be considered to have resulted in high performance concretes with excellent durability properties.

ROLAND BLESZYNSKI, R.DOUG HOOTON, MICHAEL D.A. THOMAS, ANCHRIS A. ROGERS (1998) Investigated the Durability of Ternary cementitious systems. Seven concrete mixtures, including three ternary concrete mixtures consisting of various combinations of silica fume, blast-furnace slag, and Portland cement were studied. In this paper they describe the project in detail and presents field observations and laboratory findings up to 2 years. A comparative summary revealed that the ternary blend concretes tested have a greater durability performance than the other mixtures tested.

III.MATERIALS USED

A. Cement

Locally available Ordinary Portland Cement of 53 grade of BIRLA Brand confining to ISI standards has been procured, and the tests have been carried out according 15:8112- 1989.

B. Fine Aggregate

The locally available Natural river sand conforming to grading zone II of table 4 of IS 383-1970 has been used as Fine aggregate.

C. Coarse Aggregate

Machine Crushed granite confining to IS 383-1970 [23] consisting 20 mm maximum size of aggregates have been obtained from the local quarry. It has been tested for Physical and Mechanical Properties such as Specific Gravity, Sieve Analysis, Bulk Density, Cushing and Impact values.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue V May 2021- Available at www.ijraset.com

D. Fly Ash

The fly ash obtained from Hyderabad Industries, Andhra Pradesh is used in the present experimental work. The chemical composition of flyash is rich in silica content which react with calcium hydroxide to form C-S-H gel. This gel is responsible for the strength mortar or concrete. The fly ash used to the specification of grade 1 flyash.

E. Metakaoline

The Metakaolin is obtained From the 20 MICRONS LIMITED Company at Balanagar in Hyderabad. The specific gravity of Metakaolin is 2.4. The metakaolin is in conformity with the general requirement of Pozzolona.

F. Crimped Steel Fibers

Galvanized Crimped Iron Fibers with 0.6 mm dia and 32 mm in length are used. The Aspect ratio of the fibers is 53.3.

G. Admixture

Super Plasticizers are new class of generic materials which when added to the concrete causes increase in the workability. They consist mainly of naphthalene or melamine sulphonates, usually condensed in the presence of formal dehyde.

H. Water

Tap water has been used in this experimental program for mixing and curing.

IV. RESULTS & DISCUSSIONS

A. Effect of Percentage Replacement of Cement by Metakaolin on Compressive strength of Concrete at 7 and 28 days Curing

Table 1 – Cube Compressive strength of Metakaolin Blended Concrete at 7 days in N/mm2

% of MK	0%	5%	10%	15%	20%
0% Fi	57.35	60.05	61.09	58.62	57.91
0.25% Fi	58.39	60.77	64.95	59.17	59.93
0.50% Fi	56.85	64.13	63.06	62.45	60.32
0.75% Fi	59.53	65.24	65.91	64.3	61.22
1.0% Fi	53.55	61.90	62.37	59.94	58.53

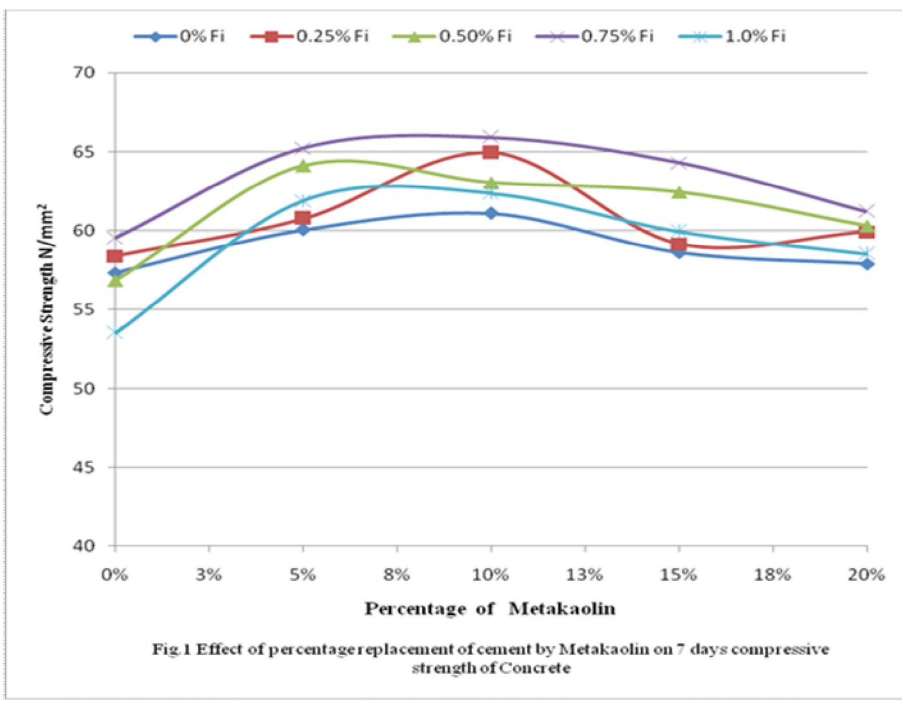

Fig.1: Cube Compressive strength of Metakaolin Blended Concrete at 7 days in N/mm2

Table 2 –Cube Compressive strength of Metakaolin Blended Concrete at 28 days in N/mm2

% of MK	0%	5%	10%	15%	20%
0% Fi	81.13	87.70	91.89	90.29	89.07
0.25% Fi	83.94	91.72	96.10	94.32	90.87
0.50% Fi	84.50	94.20	96.41	95.28	92.16
0.75% Fi	87.30	95.62	99.70	97.09	95.99
1.0% Fi	82.76	90.70	94.43	92.61	92.26

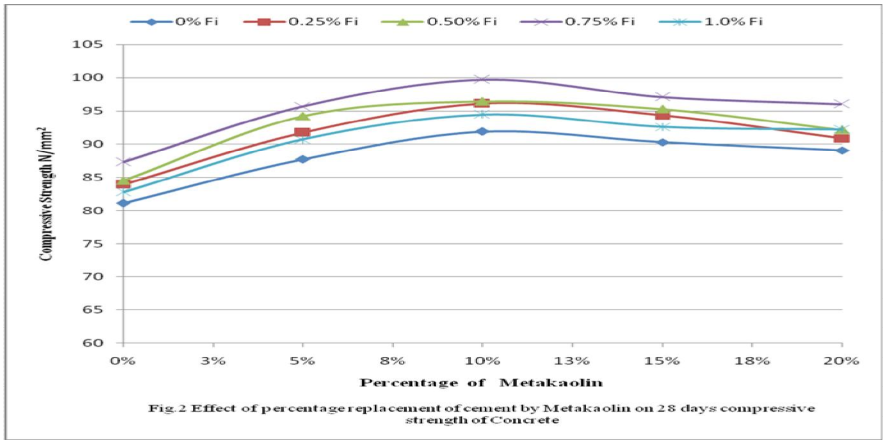

Fig. 2: Cube Compressive strength of Metakaolin Blended Concrete at 28 days in N/mm2

1) *Discussions:* From the graph and table, it can be observed that maximum compressive strength has been attained for mixes containing 10% Metakaolin along with 0.75% of fibers at 28 days. As the percentage replacement increases beyond 10% the 28 days compressive strength of Metakaolin Blended Concrete started decreasing when compared to plain Concrete. The slight decrease in strength of mixes containing 1% of fibers is due to the improper blending of fibers in concrete due to the balling effect of the fibers.

B. Effect of Percentage Replacement of Cement by Flyash on 7 days & 28 days Compressive Strength of Concrete

Table 3 – Cube Compressive strength of flyash blended concrete at 7 days in N/mm2

% of FA	0%	5%	10%	15%	20%
0% Fi	54.85	50.52	49.47	48.08	48.67
0.25% Fi	55.85	52.11	51.72	50.28	47.60
0.50% Fi	54.38	51.02	50.50	51.17	48.80
0.75% Fi	56.94	55.25	54.57	53.06	52.41
1.0% Fi	51.22	47.56	49.25	47.80	46.73

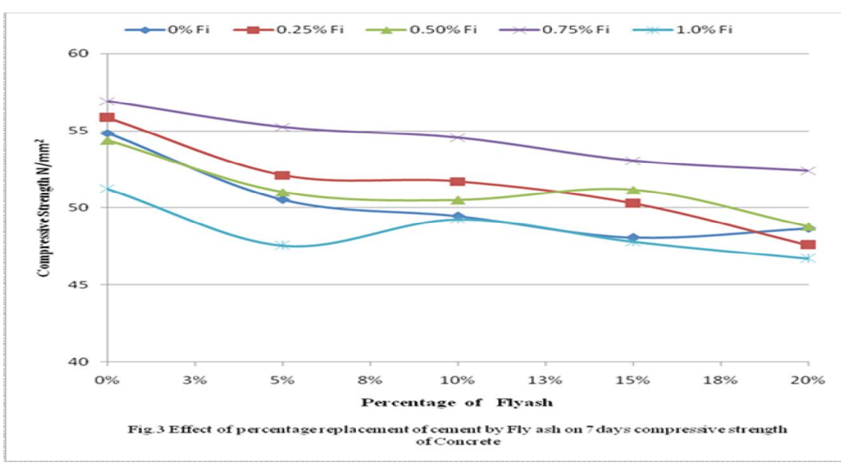

Fig. 3: Cube Compressive strength of flyash blended concrete at 7 days in N/mm2

Table 4– Cube Compressive strength of Fly ash Blended Concrete at 28 days in N/mm2

% of FA	0%	5%	10%	15%	20%
0% Fi	81.13	83.88	85.41	86.83	89.32
0.25% Fi	83.94	84.89	86.73	87.66	90.54
0.50% Fi	84.5	85.19	85.48	85.76	87.94
0.75% Fi	87.3	88.48	89.28	89.42	91.58
1.0% Fi	82.76	86.58	86.37	85.79	88.63

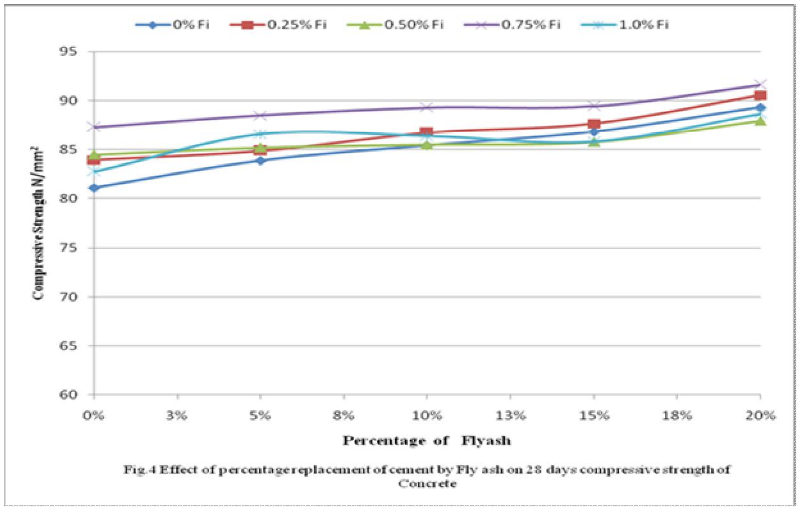

Fig.4 Effect of percentage replacement of cement by Fly ash on 28 days compressive strength of Concrete

Fig. 4: Cube Compressive strength of Fly ash Blended Concrete at 28 days in N/mm2.

1) *Discussion:* From the graph and table, it can be observed that maximum compressive strength has been attained for mixes containing higher percentage of Flyash along with 0.75% of fibers at 28 days. As the percentage replacement increases beyond the 28 days compressive strength of Flyash Blended Concrete started decreasing when compared to plain Concrete. Whereas, the compressive strength of flyash blended concrete at 7 days deceased as the percentage of flyash started increases, this is due to the slow reactivity of flyash particles in the chemical hydration process, but, as the age of concrete starts increasing the gain in strength of concrete is evident due to the slow forming of c-s-h gel, the strength of flyash blended concrete will increase till 90 days, so the overall strength will be higher than the present values. The slight decrease in compressive strength of mixes containing 1% of fibers is also due to the improper blending of fibers in concrete due to the balling effect of the fibers. Fibers with lower aspect ratio exhibit less balling effect.

C. *Effect of Percentage Replacement of cement by Flyash and Metakaolin on 28 days Compressive strength of Concrete*

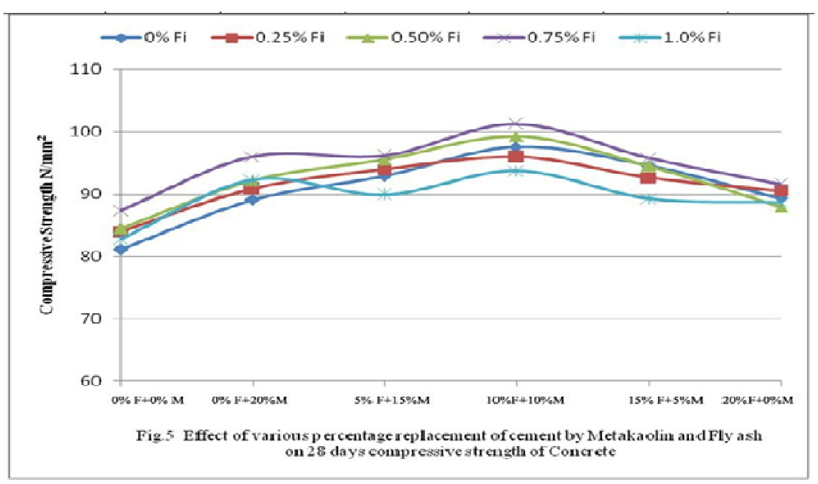

Fig.5 Effect of various percentage replacement of cement by Metakaolin and Fly ash on 28 days compressive strength of Concrete

Fig. 5: Cube Compressive Strength of Ternary Blend of fly ash and metakaoline at 28 Days in N/mm2

1) *Discussions:* From the graph and table, it can be observed that the strength of ternary blended concrete increases as the percentage of metakaolin increases till 10% and starts reducing beyond 10% addition of metakaolin. The minimum strength obtained by all the mixes is greater than the target strength of the mix design. The maximum compressive strength has been attained for mixes containing 10 % of Flyash and 10% of metakaolin along with 0.75% of fibers at 28 days. As the percentage replacement of flyash increases beyond 10%, the 28 days compressive strength of ternary Blended Concrete started decreasing. This is due to the slow rate of gain of strength of fly ash induced c-s-h gel in the concrete, the compressive strength containing higher flyash percentages is likely to increase by some more extent till the age of 90 days and beyond, thus resulting in overall gain of strength of the ternary blended concrete. The slight decrease in compressive strength of mixes containing 1% of fibers is also due to the improper blending of fibers in concrete due to the balling effect of the fibers. Fibers with lower aspect ratio exhibit less balling effect.

D. Effect of Percentage Replacement of Cement by Flyash & Metakaolin on 28 days Split Tensile Strength of Concrete

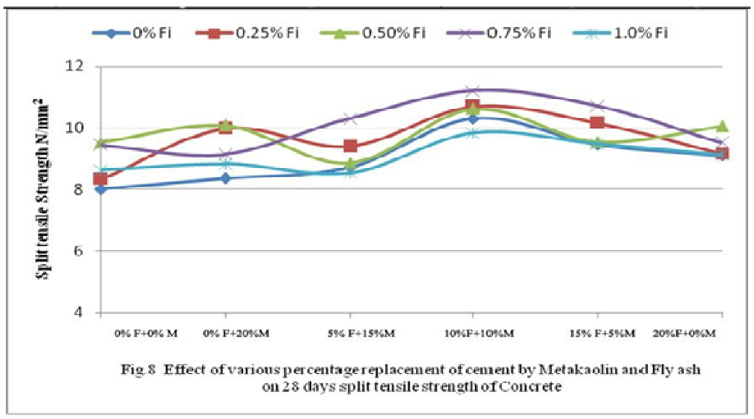

Fig. 6: Split Tensile Strength of Ternary Blend of fly ash and metakaoline at 28 Days in N/mm2

1) *Discussions:* From the graph and table, it can be observed that maximum split tensile strength has been attained for mixes containing 10% Metakaolin & flyash along with 0.75% of fibers at 28 days. As the percentage of fibers increases, the 28 days compressive strength of Flyash Blended Concrete started increasing when compared to plain Concrete.

E. Effect of Percentage Replacement of cement by Flyash & Metakaolin on 28 days Flexural Strength of Concrete

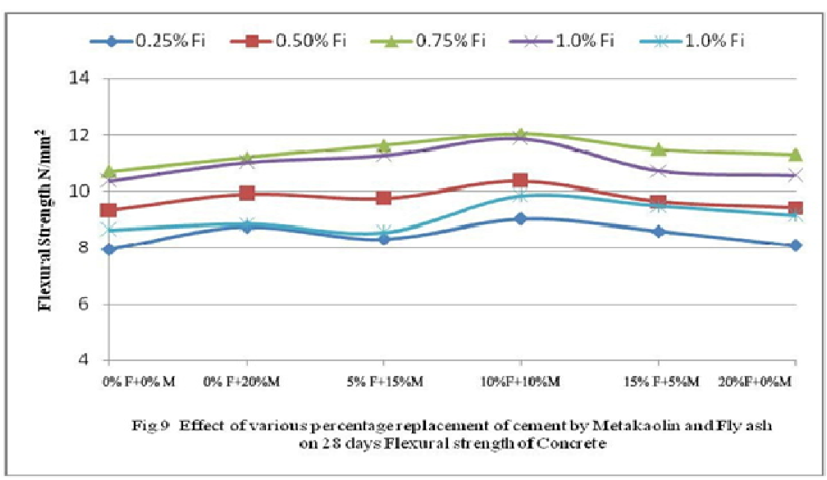

Fig. 7: Flexural Strength of Ternary Blend of fly ash and metakaoline at 28 Days in N/mm2

1) *Discussions:* From the graph and table, it can be observed that the flexural strength of ternary concrete increases drastically with the addition of fibers, this is due to the bond between the concrete and the fibers which results in higher flexural strength, it can be also concluded that the flexural strength increases slightly due to the effect of metakaolin and flyash.

V. CONCLUSIONS

The following conclusions have been arrived from the study:

A. Metakaolin is an effective pozzolona and results in enhanced early strength and ultimate strength of concrete.
B. The compressive strength of young concrete, i.e., 7 days is improved by blending the OPC with 10% of metakaolin by weight.
C. The 10% replacement with metakaolin is the most optimum replacement, enhancing the concrete's compressive strength at all ages.
D. The 28-days compressive strength of concrete was improved by partial replacements of OPC by metakaolin in the range up to 10% by weight, and was at the 20% level still maintained. The highest 28-days strength improvement of concrete can be expected at partial replacements in the 10-15% range.
E. The combined use of metakaolin and a super plasticizer allowed increasing the aforementioned partial replacement levels, i.e. to 20% in the case of maintaining strength.
F. Ternary blending by Metakaolin in combination with Fly Ash was found leading to further technical improvements to concrete strength. Especially, blended concrete mixtures with Metakaolin / Fly Ash -ratio to 50/50 by weight revealed higher efficiency for improving strength at older ages.
G. Addition of flyash results in economy of the mix because of low cost of fly ash.
H. Addition of fibers to all the mixes clearly indicate improvements in all the properties such as compressive strength, split tensile strength, and most importantly increased flexural strength, this property is very useful in arresting the cracks to a large extent.

REFERENCES

[1] Antiohos, S.; Maganari, K.; and Tsimas, S., "Evaluation of Blends of High and Low Calcium Fly Ashes for Use as Supplementary Cementing Materials," Cement and Concrete Research, Vol. 27, 2005, pp.349 356.
[2] A.Sadr Momtazi, M. M. Ranjbar, F. Balalaei, R. Nemati, "The effect of Iran's metakaolin in enhancing the concrete compressive strength"
[3] A.K. Mullick. "Performance of Concrete with Binary and Ternary cement blends." The INDIAN Concrete Journal, January 2007.
[4] A.Elahi, P.A.M.Basheer, S.V. Nanukuttan, Q.U.Z.Khan." Mechanical and Durability properties of high performance concrete containing Supplementary cementitious materials." Construction of Building materials 24(2010) Pg 292-299.
[5] Bai, Jiping; Gailius, Albinas, "Consistency of fly ash and metakaolin concrete" Journal of Civil Engineering and Management 2009
[6] Dhir, R.K. and Jones, M.R, "Development of Chloride-Resisting Concrete Using Fly Ash" Fuel, Vol. 78, 1999, pp.137-142.
[7] Jelica Zelic, Ivana Radovanovic, Drazan Jozic. "The Effect of silica Fume additions on the Durability of Portland Cement Mortars Exposed to Magnesium Sulphate Attack". Materials and Technology 41 (2007), Pg 91-94
[8] Lane, D.S.; and Ozyildirim, C., "Preventive Measures for Alkali-Silica Reactions (Binary and Ternary Systems)", Cement and Concrete Research, Vol. 29, 1999, pp.1281-1288.
[9] Moser, Robert D, Jayapalan, Amal R, Garas, Victor Y And Kurtis, Kimberly E, Assessment of Binary and Ternary Blends of Metakaolin and Class C Fly Ash for Alkali- Silica Reaction Mitigation in Concrete, Cement and Concrete Research, pp. 1664-1672.
[10] Ong, Chee Huat (2006) Performance of concrete containing metakaolin as cement replacement material.
[11] R. D. Neves and J. C. O. Fernandes de Almeida, Compressive behavior of steel fiber reinforced concrete, pp 2-3
[12] Roland Bleszynski, R. Doug Hooton, Michael D.A Thomas, and Chris A. Rogers " Durability of Ternary Blended concrete with Silica Fume and Blast-Furnace Slag: Laboratory and Outdoor Exposure Site Studies". ACI materials journals September- October 2002.