ISSN No: - 2456- 2165

STRENGTH CHARACTERISTICS OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH FLY-ASH & METAKAOLIN

K.Anantha Lakshmi
PG Student ,
Structural Engg.
Layola Institute of Tech & Management
Dhulipalla, Guntur ,
A.P , India
lakshmi.anantha220@gmail.com

I.S. Anvesh Reddy
Asst Prof & HOD ,
Dep of Civil Engg.
Layola Institute of Tech & Management
Dhulipalla , Guntur ,
A.P , India

A.V.S Sai Kumar
Asst Prof & HOD , Dep of Civil Engg.
Princeton College of Engineering & Tech,
Ghatkesar, Hyderabad, T.S, India
avssaikumar@gmail.com

***Abstract*— Cement is the most costly and energy intensive component of concrete. The unit cost of concrete can be reduced as much as possible by partially replacing cement with fly-ash and metakaolin. Fly-ash is a waste obtained during thermal industries. As fly-ash is a waste material leaving into the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized. Therefore scientific study should be made towards reuse both at an experimental phase and in practical application. In the present study M25 grade of reference concrete was prepared without any replacement in cement. The same grade was partially replaced by 20% of fly-ash and 0%, 5%, 10% and 15% of metakaolin in cement. Investigation was carried out for fresh concrete properties and hardened concrete properties on specimens cured for 7, 28 & 90 days.**

***Index Terms*—** Concrete, fly-ash, metakaolin, fresh concrete, compressive, split tensile, flexural.

I. INTRODUCTION

The cement industry is one of the two primary product producers of carbon dioxide(CO_2),creating up to 5% of worldwide man –made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The CO_2 emission from the concrete is directly proportional to the cement content used in the concrete mix; 900 kg of CO_2 are emitted for the production of every ton of cement. Metakaolin is in widespread use all over the world in the concrete industry. The advantages of metakaolin are not only the many concrete performance benefits, both in mechanical and durability properties, but also the environmental benefits. While the production of portland cement is associated with high CO_2 emissions. Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Metakaolin can be produced by primary and secondary sources containing kaolinite are high purity kaolin deposits, kaolinite deposits or tropical soils of lower purity, paper sludge waste which contains kaolinite, oil sand tailings contains kaolinite. From the previous observations it is proved that use of waste product namely Metakaolin increased compressive and flexural strengths, increases durability. Metakaolin usage helps in developing high performance and high strength in concrete. Fly ash is the finely divided mineral residue resulting from the combustion of ground or powdered coal in electric power generating thermal plant.

Fly ash is a beneficial mineral admixture for concrete. It influences many properties of concrete in both fresh and hardened state. Moreover, utilization of waste materials in cement and concrete industry reduces the environmental problems of power plants and decreases electricity generation costs. Cement with fly ash reduces the permeability of concrete and dense calcium silicate hydrate (C–S–H). Research shows that adding fly ash to concrete, as a partial replacement of cement, will benefit both the fresh and hardened states. While in the fresh state, the fly ash improves workability.

II. LITERATURE REVIEW

S, Prince Arulraj G, Dilip C in 2013 examined a review on use of metakaolin in concrete. This paper reviews the use of metakaolin as supplementary cementitious material in concrete. From the recent research works using Metakaolin, it is evident that it is a very effective pozzolanic material and it effectively enhances the strength parameters of **Aiswarya** concrete.

A. Sadr Momtazi, Ranjbar. M. M, Balalaei. F, Nemati. R examined the effect of Iran's metakaolin in enhancing the concrete compressive strength. This paper presents the performance of metakaolin (F-M) on compressive strength and durability of concrete. Fired (Calcinated) F-M has a very good pozzolanicity, which could be partially replaced with Portland cement. It can decrease permeability, increase compressive strength and concrete durability. In this study, four different type of metakaolin which one of them was made in UK and the others were from different part of Iran were used. The results indicate that the replacing F-M up to 20% has noticeable effect on compressive strength in comparing with mixture without metakaolin.

B. B. Patil1, P. D. Kumbhar examined that " Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin" the present paper deals with the study of properties namely workability, compressive strength and durability of M60 grade HPC mixes incorporating different percentages of high reactivity metakaolin by weight of cement along with some suitable super plasticizer. The results of the study indicate that the workability and strength properties of HPC mixes improved by incorporating HRM up to a desirable content of 7.5% by weight of cement. HPC mixes have also indicated better resistance to the attacks of chemicals such as chlorides and sulfates when the HPC mixes were exposed to theses chemical for 180 days period.

Nova John in 2013 examined the Strength properties of metakaolin admixed Concrete. This paper presents the results of an experimental investigations carried out to find the suitability of metakaolin in production of concrete. In the present work, the results of a study carried out to investigate the effects of Metakaolin on strength of concrete are presented. The referral concrete M30 was made using 53grade OPC and the other mixes were prepared by replacing part of OPC with Metakaolin. The replacement levels were 5%, 10%, 15% up to 20 %(by weight) for Metakaolin. The various results which indicate the effect of replacement of cement by metakaolin on concrete are presented in this paper to draw useful conclusions. The results were compared with reference mix. Test results indicate that use of replacement cement by metakalion in concrete has improved performance of concrete up to 15%.

Sanjay N. Patil, Anil K. Gupta, Subhash S. Deshpande is examined the Metakaolin- Pozzolanic Material for Cement in High Strength Concrete. This paper deals with the use of Metakaolin which is having good pozolanic activity and is a good material for the production high strength concrete, which is getting popularity because of its positive effect on various properties of concrete.

Vikas Srivastava, Rakesh Kumar and V.C. Agarwal in 2012 examined the Effect on mechanical properties of concrete by inclusion of metakaolin reported that metakaolin inclusion increases the compressive, tensile, flexural and bend strength and modulus of elasticity of concrete considerably; however, the workability is slightly compromised. This paper presents the review of investigations carried out to find the suitability of metakaolin in production of concrete.

Canon has stated that by adding fly ash to the extent of 15% by weight of cement in lean concrete (W/C=0.8) strength equal to the corresponding plane concrete within 90days was achieved.

C.Marthong, T.P.Agrawal in 2012 examined the Effect of Fly Ash Additive on Concrete Properties. This paper reports a comparative study on effects of concrete properties when OPC of varying grades 33, 43, 53 were partially replaced by fly ash. The main variable investigated in this study is variation of fly ash dosage of 10%, 20%, 30% and 40%. The compressive strength, durability and shrinkage of concrete were mainly studied. Test results shows that, inclusion of fly ash generally improves the concrete properties upto certain percent or replacement in all grades of OPC.

Deepa A. Sinha and Elizabeth George have designed M25 and M30 concrete mixtures with different percentages of ash substitution without any addition of chemical admixtures. It was found that not only the 28 and 90 days compressive strength but also the flexural strength and durability of fly ash concrete was satisfactory up to 50% fly ash substitution for cement.

Dhuraria has recorded that earlier strengths could be achieved in fly ash concrete by adjusting the various ingredients in such a way that the quantity of cement and fly ash in the final mix is more than the quantity of cement replaced. Fly ash concrete mix appeared drier than normal concrete mix but gets satisfactorily compacted with adequate vibrations.

Hanh H. Pham1, Kien T. Tong1, Thanh T. Le1,2 examined the result of high strength concrete using fly ash for the structures in Vietnamese marine environment for sustainability reported that the research results of a high strength concrete (compressive strength of above 80 MPa) which has up to 35% cement content replaced by fly ash to be used for the structures in Vietnamese marine environment. The use of this concrete probably helps extend the service life of the infrastructures and also helps reduce a large amount of an industrial waste (fly ash) discharged from Vietnamese thermal power plants. This will be able to improve all three aspects of a sustainable construction which comprises economy, natural resource and environment.

Lovewell and Washa has stated that flyash concrete may develop some compressive strength as the corresponding plain concrete at earlier ages by over dosing the fly ash suitability.

M. Collepardi examined the result of Concrete durability in a Marine Environment reported that this model is adopted to examine the durability of reinforced concrete structures exposed to a marine environment. At least three aggressive agents in sea water can cause deterioration of the reinforced concrete structures chloride, sulphate and alkali ions. The specific aggressive action of each aggressive agent is examined corrosion of the metallic bars caused by chloride ions, damage of the cement paste carried out by sulphate attack, and swelling disruption of concrete if alkali-reactive aggregates are present in the concrete. In order to prevent the damage of concrete structures exposed to a marine environment the following measures should be adopted: to reduce the water cement ratio by using super plasticizers; to employ cementations binders based on the combination of Portland cement with mineral addition such as fly ash and/or blast furnace slag.

III. MATERIALS AND IT'S PROPERTIES

A. *Cement:*

The following tests as per Indian standard codal are done to ascertain the physical properties of the cement. The results of the tests are compared to the specified values given table.

Table No: 1 Properties of cement

S. No	Property	Test results
1	Normal consistency	29%
2	Specific gravity	3.13
3	Initial setting time	92 minutes
4	Final setting time	195 minutes
5	Compressive strength at 3days 7days 28days	 27.40 N/mm^2 29.23 N/mm^2 41.62 N/mm^2

B. Metakaolin:

Metakaolin is brought from Vadodara having 50%-55% of SiO_2 is used all through the study.

Table No: 2 Physical properties of metakaolin

Properties	Value
Density (gm/cm^3)	2.17
Bulk density (gm/cm^3)	1.26
Particle shape	Spherical
Colour	Grey
Specific gravity	2.1

C. Fly ash:

Fly ash is a finely divided residue that results from the combustion of ground (or) pulverized coal and is transported from boilers by flue gases are known as "fly ash". It is an industrial waste from thermal power stations on very scale. It is brought from

Table No: 3 Physical Properties of Fly ash

S. No	Properties	Range
1	Percentage passing 75 micron I.S sieve	71.4 to 95.90
2	Percentage passing 45 micron I.S sieve	45.0 to 88.80
3	Fineness(Blain's air method) (cm^2/gm)	3300 to 6250
4	Limereactivity (kg/cm^2)	50 to 62.40

Table No: 4 Chemical composition of fly ash

Constituents	Values (% by weight)
Loss on Ignition	0.87
Silica as Sio_2	62.93
Iron Oxide as Fe_2O_3	3.56
Alumina as Al_2O_3	22.61
Manganese as Mn	0.14
Titanium Oxide as TiO_2	0.53
Calcium Oxide as CaO	4.58
Magnesium Oxide as MgO	0.60
Sodium Oxide as Na_2O	0.89
Potassium Oxide as K_2O	1.74
Phosphorus as P	0.32
Sulphate as SO_3	1.23

D. Fine aggregate:

The fine aggregate used is natural sand obtained from the river Godavari conforming to grading zone-II of table 3 of IS: 10262-2009. The results of various tests on fine aggregate are given in table.

Table No: 5 Properties of fine aggregate

S. No	Property	Value
1	Specific gravity	2.57
2	Fineness modulus	2.46
3	Bulk density: Loose Compacted	 15kN/m^3 16kN/m^3
4	Grading	Zone-II

E. Coarse aggregate:

Coarse aggregate obtained from local quarry processing units has been used for this study.

Table No: 6 Physical properties of coarse aggregate

S. No	Property	Value
1	Specific gravity	2.78
2	Fineness modulus	8.83
3	Bulk density Loose Compacted	 14 kN/m^3 16 kN/m^3
4	Nominal maximum size	20 mm

F. Water:

Ordinary potable tap water available in laboratory was used for mixing and curing of concrete.

Table No: 7 Physical properties of water

S. No	Property	Value
1	pH	7.1
2	Taste	Agreeable
3	Appearance	Clear
4	Turbidity(NT units)	1.75

G. Mix design procedure:

In present study M25 grade concrete was designed as per IS: 10262-2009. The weight ratio of mix proportion is 1: 1:2 keeping water cement ratio 0.4. It was proposed to investigate the properties of concrete, cast with partial replacement of cement with 20% of fly-ash and 0%, 5%, 10% and 15% of metakaolin proportions and cured in water.

In this experimental work, physical properties of materials used in the experimental work were determined. M25 grade of reference concrete was mixed and cured in potable water.

IV. RESULT AND DISCUSSIONS

According to IS:516-1964 conforming 9 cubes, 9 cylinders and 9 beams are casted After 24 hours the moulds were de-moulded and subjected to water curing. Before testing the cubes were air dried for 2 hours. Crushing loads, split tensile strength and flexural strength were noted and average of 3 specimens was determined at 7days, 28days and 90days. The results are tabulated below

S. No	Mix Id	Compressive strength(N/mm^2)		
		7 days	*28 days*	*90 days*
1	NCC	21.35	32.62	37.21
2	F-M0	23.42	42.6	45.80
3	F-M5	30.13	44.25	46.23
4	F-M10	35.34	47.58	49.26
5	F-M15	30.8	44.6	46.17

Table. No:8 compressive strength test results

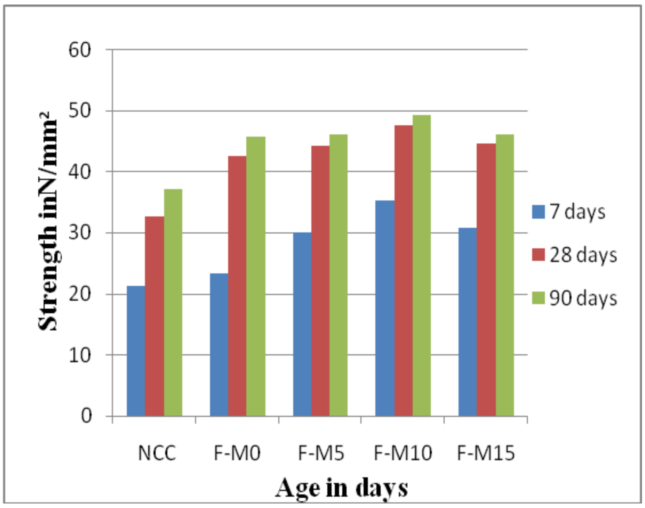


Table. No: 9 Split tensile strength test results

S. No	Mix Id	Split tensile strength(N/mm^2)		
		7 days	*28 days*	*90days*
1	NCC	1.45	2.0	2.23
2	F-M0	2.0	2.4	2.9
3	F-M5	2.3	2.8	3.01
4	F-M10	2.9	3.03	3.3
5	F-M15	2.4	2.9	3.02

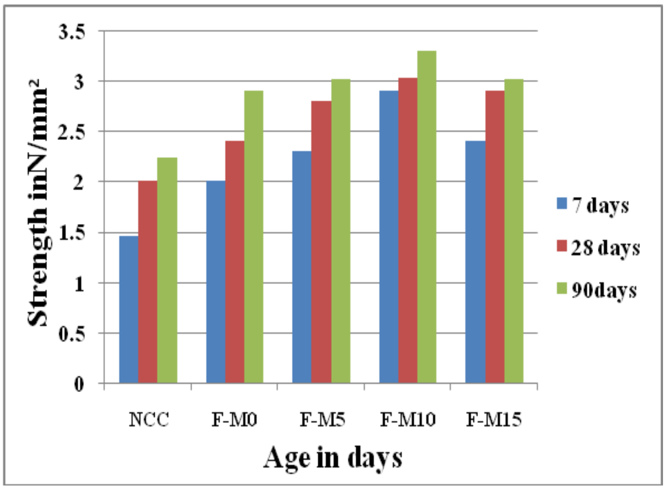
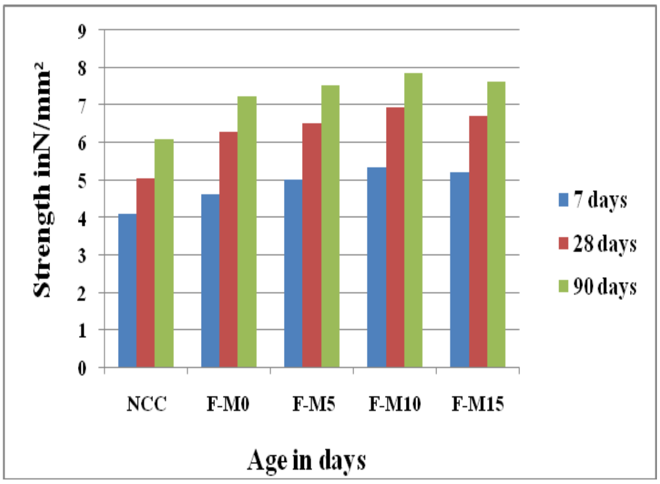


Table. No:10 Flexural strength test results

S. No	Mix Id	Flexural strength(N/mm^2)		
		7 days	*28 days*	*90 days*
1	NCC	4.1	5.05	6.08
2	F-M0	4.63	6.28	7.23
3	F-M5	5.02	6.50	7.54
4	F-M10	5.34	6.93	7.85
5	F-M15	5.21	6.70	7.62



V. CONCLUSIONS

It was observed that the compressive strength of F-M0, F-M5, F-M10, and F-M15 at the age of 28 days has reached its target mean strength however it was observed that the compressive strength increased by 30%, 36%, 45% and 36.7% respectively when compared with NCC. It was observed that the compressive strength of F-M15 has reduced by 6% respectively when compared with F-M10 at the age of 28 days. Flexural strength (At 28 days) of F-M0, F-M5, F-M10 and F-M15 has increased by 24%, 28%, 37% and 32% respectively when compared with mix NCC. Flexural strength (At 28 days)

ISSN No: - 2456- 2165

of NCC has reduced 24% by respectively when compared with mix F-M0. Flexural strength (At 28 days) of mix F-M5, F-M10 and F-M15 has increased by 3%, 10% and 6% respectively when compared with mix F-M0. Flexural strength (at 28 days) of mix F-M15 has reduced by 6% respectively when compared to F-M10. The split tensile strength(at 28 days) of mixes F-M0, F-M5, F-M10 and F-M15 has increased by 20%,40%, 51% and 45% respectively when compared with mix NCC. The split tensile strength of mix NCC has reduced by 20% respectively when compared to F-M0. The split tensile strength of mixes F-M5, F-M10 and F-M15 (at 28 days) has increased by 16%, 26% and 20% respectively when compared with mix F-M0. The Split tensile strength of mix F-M15 has reduced by 4% respectively when compared with mix F-M10.

Cement can be replaced with metakaolin up to 10% without much loss in compressive strength. Considerable decrease in compressive strength was observed from 15% cement replaced with metakaolin.

REFERENCES

[1] Aiswarya S, Prince Arulraj G, Dilip C in 2013 examined a review on use of metakaolin in concrete. IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: 2250-3498, Vol.3, No.3, June 2013.

[2] A.V.S.Sai. Kumar, Krishna Rao B, “A Study on Strength of Concrete With Partial Replacement Of Cement With Quarry Dust And Metakaolin” , International Journal of Innovative Research in Science, Engineering and Technology Vol. 3, Issue 3, March 2014

[3] A. Sadr Momtazi, M. M. Ranjbar, F. Balalaei, R. Nemati examined the effect of Iran's metakaolin in enhancing the concrete compressive strength.

[4] B. B. Patil1, P. D. Kumbhar examined that “ Strength and Durability Properties of High Performance Concrete incorporating High Reactivity Metakaolin” International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol.2, Issue.3, May-June 2012 pp-1099-1104 ISSN: 2249-6645

[5] Beulah M., Prahallada M. C. “Effect Of Replacement Of Cement By Metakalion On The Properties Of High Performance Concrete Subjected To Hydrochloric Acid Attack Beulah M. Asst Professor, Prahallada M. C. Professor” International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 2, Issue 6, November- December 2012, pp.033-038 33

[6] Jiping BAI, Stan WILD, Albinas GAILIUS in 2004 examined the accelerating Early Strength Development of Concrete Using Metakaolin as an Admixture. ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 10, No. 4. 2004.

[7] M. Si-Ahmed, A. Belakrouf, and S. Kenai examined that “Influence of Metakaolin on the Performance of Mortars and Concretes”. World Academy of Science, Engineering and Technology 71 2012

[8] Nova John in 2013 examined the Strength Properties of Metakaolin Admixed Concrete. This paper presents the results of an experimental investigations carried out to find the suitability of metakaolin in production of concrete. International Journal of Scientific and Research Publications, Volume 3, Issue 6, June 2013 1 ISSN 2250-3153.

[9] Sanjay N. Patil, Anil K. Gupta, Subhash S. Deshpande is examined the Metakaolin- Pozzolanic Material for Cement in High Strength Concrete. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN: 2278-1684, PP: 46-49

[10] Tasnia Hoque, Muhammad Harunur Rashid, MD. Rokon Hasan, EBNA FORHAD MONDOL in 2013 examined the Influence of Stone Dust as Partially Replacing Material of Cement and Sand on some Mechanical Properties of Mortar. International Journal of Advanced Structures and Geotechnical Engineering ISSN 2319-5347, Vol. 02, No. 02, April 2013. IJASGE 020203 Copyright © 2012 Basha research centre. All rights reserved.

[11] Vikas Srivastava1, Rakesh Kumar2 and V.C. Agarwal in 2012 examined the Effect on mechanical properties of concrete by inclusion of metakaolin J. Acad. Indus. Res. Vol. 1(5) October 2012