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Experimental Study on Concrete Using Metakaolin and Alccofineas Replacement of Cement

Kalidhasan.B, Ms.R.Haripraba, Dr.P.Ragunathapandian,
M.E, StructuralEngineering(Student)ArulmiguMeenakshi Amman College of Engineering, Vadamavandal-604410,ThiruvannamalaiDt.
M.E., (Ph.D) Assistant ProfessorArulmiguMeenakshi Amman College of Engineering, Vadamavandal -604 410,Thiruvannamalai Dt.
M.E., Ph.D, Professorand Head of the DepartmentArulmiguMeenakshi Amman College of Engineering, Vadamavandal-604410,ThiruvannamalaiDt.

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ABSTRACT
A comparative study on high strength concrete by partial replacement of cement by Metakaolin and Alccofine in different percentages and expecting to achieve more strength than conventional concrete mix of M50. Metakaolinamineral admixture obtained by the calcination of kaolin a clay mineral increases the compressive and flexuralstrengthof concrete uptoalimitof 20%.Alccofine isanew generationmicro-fineparticlesizemuchsmaller than other hydraulic materials like cement, silica fume, flyash, GGBS etc. It has the special attributes toenhance the performance of concrete in the fresh stage because of its optimizedparticle size distribution. Specimens of shapes namelycubes, cylinders and prismsor beams are casted in order totest the compressive strength, split tensile strength and flexural strength of concrete at an interval of 7 days, 14 days and 28 days of curing. It is obtained that the percentage of replacement of cementwith 5% Metakaolinand 15%Alccofine givesthebetter resultswhencompared with other percentages.

KEYWORDS-
Metakaolin,Alccofinecompressionstrength,Flexural Strength,Pozzolanicmaterial.

I. INTRODUCTION

In construction the word concrete comes from Latin word "Concretus" which means compact or condensed. concrete is the second most used substance in the world after water and it is widely used for construction building material. Concreteis a composite material composed of coarse aggregate, fine aggregate, cement andwater. Concrete is one of the most durable building materials. A cement is a bindingmaterial for concreteandmortar.Cementisaasubstanceusedforcivilengineeringconstruction that sets, hardens and adhere to other materials to bind them together.The impact of cement on the environment is of concern, as the manufactureofcementisresponsibleforabout2.5%oftotal

globalemissionsfromindustrialsources.Although Portland cement demands are decreasing in industrial nations, it is increasing dramatically in developing countries. Cement production is one of themajor causes of environmental pollution due to release of large amounts of toxic gases. Portland cement production leads to major CO_2 emissions it causes globally environmental pollution. by reducing the usage of cement, we can control the CO 2emissions. For this we are replacing the cement by mineral admixtures such as Metakaolin and Alccofine to check the durability and strength of concrete by replacing of cement. Ordinary Portland cement is composed of four basic chemical compounds i.e., tricalcium silicate, dicalcium silicate, tricalcium aluminate and tetra calcium alumino ferrite whereas the OPC is used in the residential, non- residential and infrastructure buildings. OPC is good for house construction whereas in general OPC 53 grade is used for all RCC structures like footing, column, beam and slabs whenever initial and ultimate strength is the major structural requirement.

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II. LITERATURE REVIEW

1. AaronDuncanetal.,

"Enhanced Metakaolin reactivity in blended cement with additional calcium hydroxide" in the journal of Multidisciplinary Digital Publishing Institute (MDIP), 2022. For replacement ratio of 20 and 30 weight % metakaolin at increase in calcium hydroxide is observed until the 7th day followed bya decrease duringfurther hydrationtime.Forthesampleswithreplacementratioof40% metakaolin the reduction of CHalreadystarts ata first day.

2. RamChandarKarraetal.,

"Experimental and Statistical Evaluations of Strength Properties of Concrete with Iron Ore Tailings as Fine Aggregate" in thejournal of American Society of Civil Engineers (ASCE),2022. Alccofine was usedas a partial replacement for cementby10% consistentlyfor all concrete mixwiththe partialreplacementof fine aggregates with IOT. The workability of concrete decreased with increase in alccofine replacement. This might be due to the high surface area ofthe IOTaggregates,thereforeincreasingthe demand of water contentwiththereference varyingwatertocementratiotheworkabilityofconcreteincreases with referenc to the control concrete.

3. MandalaSheshuKumaretal.,

"InvestigationoftheStrengthandDurabilityof PartiallyReplacing Cement with GGBS and Alccofine " in the journal of International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET), 2021. Alccofine was used as a partial cement replacement,resultinginhighearlystrength.Comparedtoall otherblends,ConcreteofM60gradewith 15%andCompressive,splittensile,andflexuralstrengthwashigher inalccofine and 30% GGBS.

4. AjaySharmaetal.,

"Durabilitystudyof Conventional Alccofine Concrete withutilization of Pondashasthe Partial ReplacementofFineAggregate"inthejournalofInternationaljournalforscientificresearch&development,2021.TheM -40 grade of concrete with pondashasa replacement of fine aggregate using different percentages of Alccofine. M 40 grade achieved 5% of strength by Alccofine at 28 days. that the maximum compressive strength is 44.46 (N/mm2) after 28 days of curing.

5. MThomasetal.,

"Experimentalstudyoneffectsonpropertiesofconcretewithpartiallyreplacementofcementbymetakaolin" in the journal of InternationalJournal of civil engineering and technology IJCIT, 2020. They observed that flexural strength of different concrete mixes, increases at all stages in comparison of the control mix. At 10% replacement of metakaolin strength observed to be maximum and after strength is decreasing at 28 days maximum Flexural strength of M20 & M25 grade of concrete is 4.4 N/□□^{2} and 4.9 N/□□^{2} .

6. DevachanLetal.,

"Thereviewofengineeringpropertiesof metal-basedconcretetowardscombattingchlorideattackincoastal and marinestructures"inthe journal of OA journal advances incivil engineering,2020. This studyexploresthat mechanicalproperties compressive and flexural strength improved as the MKcontent increased. The optimum MK replacement content was determined to fall between 5 and 15%, with a notable reduction in the concrete strength provides properties beyond this replacement level.

7. GKiranKumaretal.,

"Strength of concrete with RHA and metakaolin" in the journal of International research journal of engineering and technology, 2019. By replacing MK by 10% level of OPC get that maximum compressive strength compared to other replacement levels. These concretes have 6.14% split tensile strength of their compressivestrengthat28days'timeandshowsthehighestvaluesat 10% replacement.

8. GiovannaPalumboetal.,

"Fiber Bragg Grating Sensors for Real Time Monitoring of Early Age Curing and Shrinkage of Different Metakaolin BasedInorganic Binders"inthejournalofIEEESensorsJournal,2019underthetopicofFiberBragg Grating Sensors for Real Time Monitoring of Early Age Curing and Shrinkage of Different Metakaolin -Based Inorganic Binders. The proposed systemallows for controlling the rheology of the binding systems made by metakaolintheearly- age behavior recorded by metakaolingeopolymer, which represents an important suitable alternative to traditional cementitious matrix composites especially for their minor environmental impact metakaolingeopolymer.

III. MATERIALS USED.

1. METAKAOLIN

Metakaolin(Meta + kaolin) is an admixture used as a partial replacement of cement in Highstrength concrete (HSC). It is the anhydrous calcined form of theclay mineral kaolinite. A concrete is said t o be high strength if it attains the compressive strength of more than 40Mpa. Metakaolin is prepared by calcination of kaolin it is a clay mineral at a temperature of 650-800◦C for 30-60 minutes and completely evaporating its bound water. The particle size of metakaolin is smallerthancement particles, but notasfineas silica fume.The average size of metakaolinis below 2micron. Metakaolin has a pozzolanic properties. Chemical formula for metakaolinisAl2O3.2SiO2.2H2O. Itreactswithcalciumhydroxide oneofthebyproductsof hydrationreaction of cement and results in additional C-S-H gel which results in increased strength. Metakaolin is in powder form and is generallywhite or greyincolor. It hasthechemicalcomposition ofsilica (54%), Alumina (38.3%),Ferric oxide(4.28%),Calciumoxide(0.39%),Magnesiumoxide(0.08%), Sodium oxide (0.12%) and potassium oxide (0.5%). The use of metakaolin in highperformance concrete increases the compressive strength and flexure strength. It reduces the efflorescence in concrete. It reduces the size of pores in cement paste by transforming finer particlesinto discontinuous pores. Whencement is partiallyreacted with metakaolinit reacts with calcium hydroxide andresults inextra C-S- H gel. Use of 15% metakaolinincreases the workability. Itis economical in the aspects of Durability

Figure1: Metakaolin

Theadvantagesofmetakaolininhighstrengthconcrete areasfollows

- Reducestheheatofhydrationleadingtoshrinkage andcrackcontrol.
- EcofriendlybyreducingamountofCO2emission.
- Increasesthecompressivestrengthofconcreteupto20%.
- Acceleratestheinitialsettingtimeofconcrete.
- Strengthofdurabilityofconcreteincreases.

Themetakaolinasitsvariousapplicationsintheconstructionareasfollows

- Highrisebuildings.
- Nuclearpowerstations.
- Massconcreting.
- DamsandBridges.

2. ALCCOFINE

The mineral admixture **Alccofine**is a new generation micro-fine particle size much smaller than other hydraulic materials like cement, silica fume, fly ash, GGBS etc. For high strength, Alccofine is a new generation microfine concrete material and which is important in respect of workability as well as strength. Also,Alccofine is easy to use and it can be added directly with cement. The ultrafine particle of Alccofine provides better and smooth surface finish. It has the special attributes to enhance the performance of concrete in the fresh stage because of its optimized particle size distribution. Alccofine is produced in completely controlledconditions with special type of instruments to manufacture optimizingparticlesizedistribution which is its unique property. It also improves the rate ofstrength obtained inconcretemixeswithhighpozzolanicmaterialcontent

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slikeflyash, GGBS,etc.Alccofine1203 and alccofine 1101 are two types of alccofine with lowcalcium silicate and high calcium silicate respectively. Alccofine 1200 series is of 1201, 1202, 1203 which represents fine, micro fine, ultrafine particle size respectively. Alccofine1201 isanalccofinewith highcalcium silicate. Alccofine-1203 is aneco-friendlyandlowcalcium silicate- based microfine material that consists of a high amount of glass content with high reactivity

Figure:2 Alccofine

Alccofine-1203 is a highly processed material obtained from GGBS, the waste material generated from the iron ore industriesin India.Alccofine-1203isa fine powder.Duetothecontrolledgranulation. Theperformanceofalccofineis superiorto all other admixtures used in India. Due to its fineness of alccofine 1203 it givesreduced water demand for the workability of concrete even up to 70% substitutionlevel as per requirement.

Fig3Alccofine-1203

Theadvantagesofalccofineare

- Improvesdurabilityparametersofconcretebyrefinedporestructuresandreducespermeabilityofconcrete.
- Improves the rate of strength obtained in concrete mixes with high pozzolanicmaterialscontentslikeflyash,GGBS (Ground Granulated Blast-Furnace Slag).

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IV. DESIGN

1. MIXPROPORTIONBYREPLACEMENTOFMETAKAOLIN5%ANDALCCOFINE15%

Qualityofcement	396kg/m^3
Qualityoffineaggregate	626kg/m^3
Qualityofcoarseaggregate	1124kg/m^3
Qualityofwater	187kg/m^3
QuantityofMetakaolin	24.75kg/m^3
QuantityofAlccofine	74.25kg/m^3
W/Cratio	0.37
Mixratio	1:1.58:2.84

2. MIXPROPORTIONBYREPLACEMENTOFMETAKAOLIN10%ANDALCCOFINE 10%

Qualityofcement	396kg/m^3
Qualityoffineaggregate	616kg/m^3
Qualityofcoarseaggregate	1105kg/m^3
Qualityofwater	186kg/m^3
QuantityofMetakaolin	49.5kg/m^3
QuantityofAlccofine	49.5kg/m^3
W/Cratio	0.37
Mixratio	1:1.55:2.79

3. MIXPROPORTIONBYREPLACEMENTOFMETAKAOLIN15%ANDALCCOFINE5%

Qualityofcement	396kg/m^3
Qualityoffineaggregate	615kg/m^3
Qualityofcoarseaggregate	1104kg/m^3
Qualityofwater	188kg/m^3
QuantityofMetakaolin	74.25kg/m^3

QuantityofAlccofine	24.75kg/m^3
W/Cratio	0.37
Mixratio	1:1.55:2.79

V. RESULT AND ANALYSIS

COMPRESSIVESTRENGTH

Figure3: CompressionTest

- The cubes were casted for size 150bmm × 150 mm × 150 mm with the helpof calculated mix designforM50gradeconcrete.Afterthecuringperiodthetestsweretakenfor7 thday,14thdayand 28th day. The compressive strengthis determined by using the formula
- **STRESS=P/A**

WhereP=load A=areaofthecastedcubes

COMPRESSIONSTRENGTHRESULTSOFCONVENTIONALCONCRETE

DAYS	TRIALS	LOAD,kN	STRESS	AVERAGE
7thDAY	TRIAL1	805	35.78	36.13N/mm^2
	TRIAL2	821	36.49	
	TRIAL3	813	36.13	
14thDAY	TRIAL1	932	41.43	40.98N/mm^2
	TRIAL2	910	40.44	
	TRIAL3	924	41.07	
28thDAY	TRIAL1	1308	58.13	58.21N/mm^2
	TRIAL2	1309	58.18	

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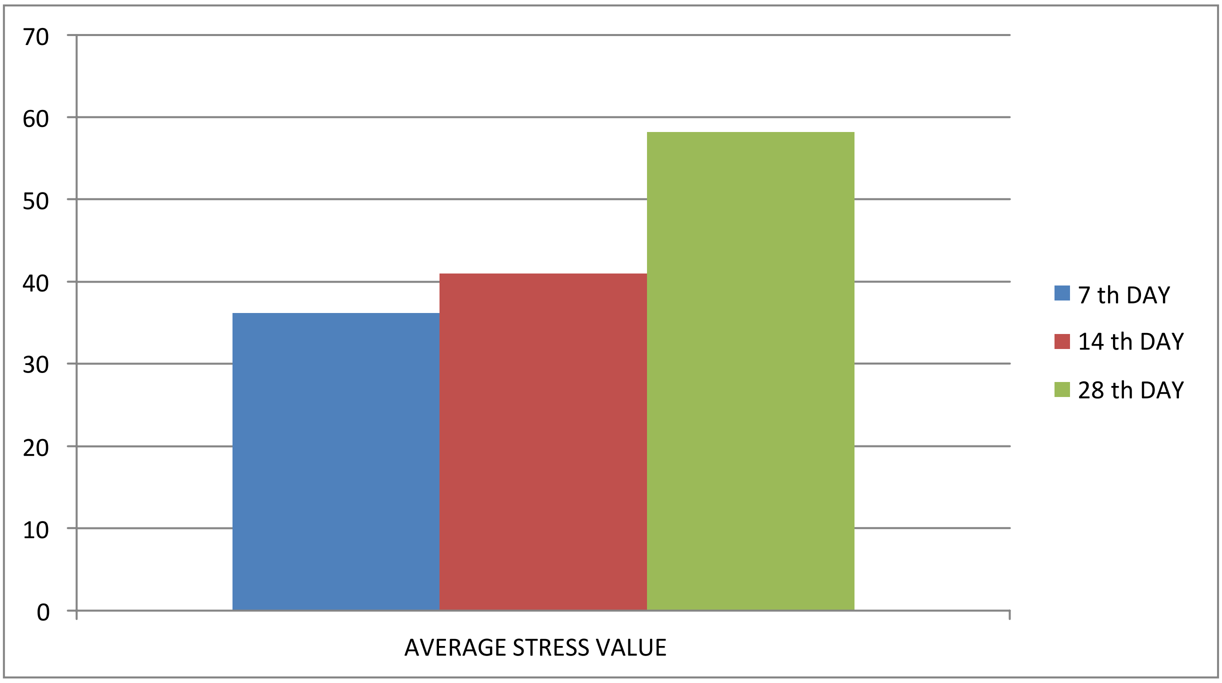
	TRIAL3	1312	58.31	



SPLITTENSILESTRENGTH

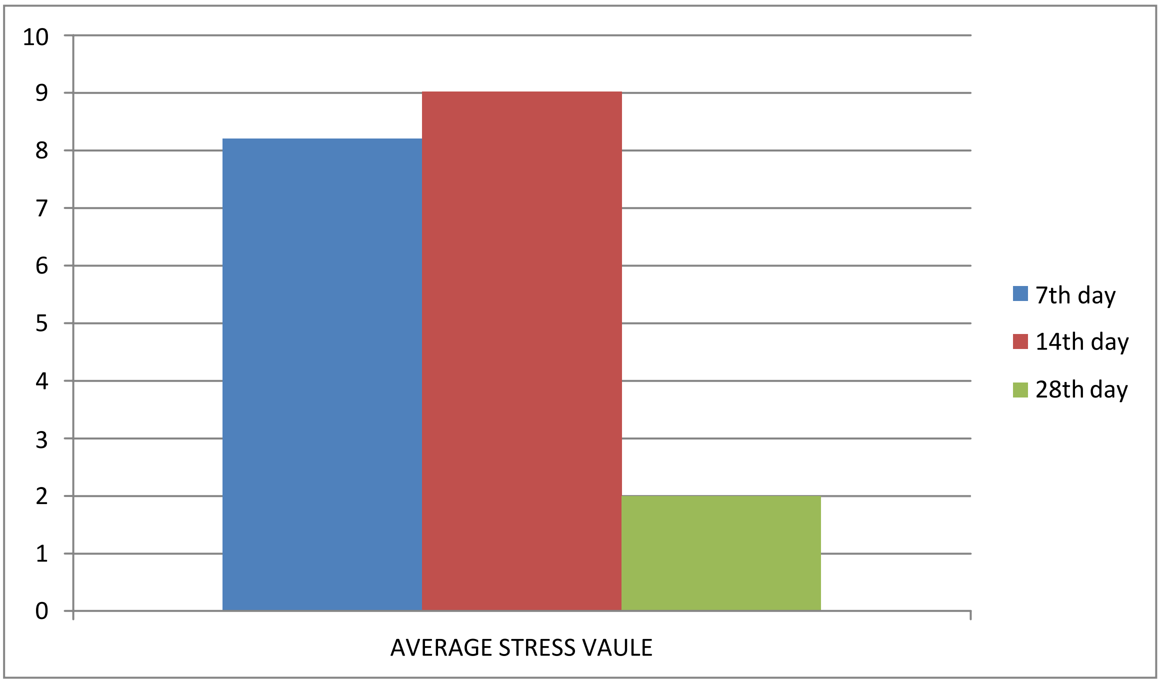
i. Thecylinderwascastedandtestsaretakenfor7thday,14thdayand28thdaybyusingtheformula

ii. Stress=2P/piLD

where,P=Load L=LengthofthecylinderD=Diameterofthecylinder

SplitTensileStrengthValuesforConventionalConcrete

DAYS	TRIALS	LOAD,kN	STRESS	AVERAGE
7thDAY	TRIAL1	152	8.6	8.20N/mm^2
	TRIAL2	140	7.92	
	TRIAL3	143	8.09	
14thDAY	TRIAL1	168	9.51	9.02N/mm^2
	TRIAL2	157	8.88	
	TRIAL3	153	8.66	
28thDAY	TRIAL1	181	10.24	9.96N/mm^2
	TRIAL2	176	9.96	
	TRIAL3	171	9.68	



FLEXURALSTRENGTH

Thebeamwascastedanditistestedfor7thday,14thdayand28thday.Inordertocalculatethe flexural strength, the following formula is used.

STRESS=Pl/bd^2

Where,P=Load

l=Lengthofthebeamorprismb=Breadthofbeamor prism

d=DepthorHeightofthebeamor prism

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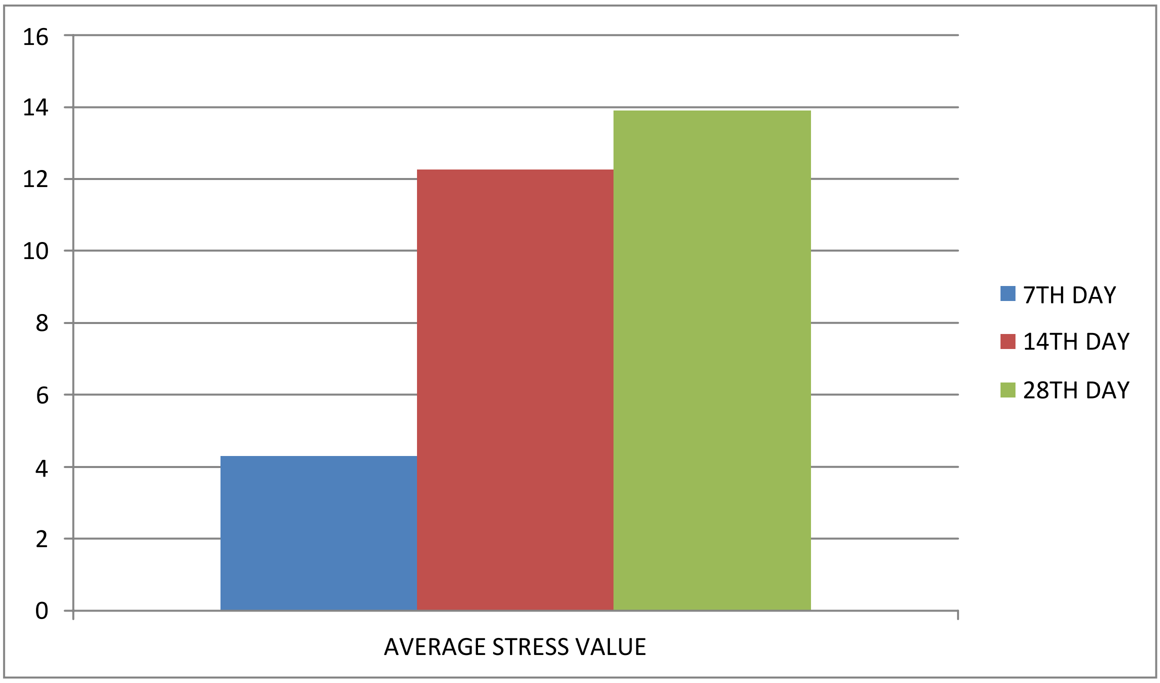
FlexuralStrengthValuesforConventionalConcrete

DAYS	TRIALS	LOAD,kN	STRESS	AVERAGE
7^{th}DAY	TRIAL1	26	10.4	10.4N/mm^2
	TRIAL2	25	10	
	TRIAL3	27	10.8	
14^{th}DAY	TRIAL1	30	12	12.27N/mm^2
	TRIAL2	31	12.4	
	TRIAL3	31	12.4	
28^{th}DAY	TRIAL1	35	14	13.9N/mm^2
	TRIAL2	34	13.6	
	TRIAL3	35	14	



VI. CONCLUSION

Thisinvestigationwasconductedtoevaluatet heperformanceofconcretecontaining different percentages 5%, 10% and 15% of Metakaolin and Alccofine as partial replacement of cement. The compressivestrength, split tensile strength andflexural strength test were conducted on the materials of concrete and the reports were given for different percentages. From the test results taken for 7^{th} day,14^{th} day and 28^{th} day of Compressivestrength,splittensilestrength,Flexuralst rengthofconcreteforvariouspercentages(5%,10% and15%) of Metakaolin andAlccofine the maximum strength attains at the replacement of

5% Metakaolin and15% Alccofine and it was found to be appropriate, economical and gives the best result for the future use.

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