Effect Of Metakaolin and Basalt Fibre on Mechanical Properties Of Conventional Concrete

Sunny A. Jagtap
Assistant Professor, Department of Civil Engineering,
Shri Chhatrapati Shivaji Maharaj College of Engineering Nepti,Ahmednagar, Maharashtra, India.
(email: sunnyjagtap16@gmail.com).

Abstract—**Concrete is one of the well-known construction materials. However, the production of Portland cement, an essential constituent of concrete, leads to the release of significant amount of CO_2, a greenhouse gas; one ton of Portland cement clinker production is said to creates approximately one ton of CO_2 and other greenhouse gases . Environmental issues are playing an important role in the sustainable development of the cement and concrete industry.Today many researches are ongoing into the use of Portland cement replacements, using many waste materials like pulverized fly ash (PFA) and ground granulated blast furnace slag (GGBS). Like PFA and GGBS, a metakaolin is also used as a binder with partial replacement of cement which take some part of reaction at the time of hydration, also it is act as a filler material. Cement replacement by metakaolin in the range 5% to 25% increment of 5% is to be study in addition with basalt rock fibre by volume fraction in range from 0.05% to 0.25% with increment of 0.05%. It was tested for mechanical properties at the age of 7, 28 days and compared with those of conventional concrete.**

Keywords— ***Concrete, Metakaolin, Basalt fibre , Flexural strength.***

I. INTRODUCTION

Concrete is a blend of cement, sand, coarse aggregate and water. The key factor that adds value to concrete is that it can be designed to withstand harshest environments significant role. Today global warming and environmental devastation have become manifest harms in recent years, concern about environmental issues, and a changeover from the mass-waste, mass-consumption, mass-production society of the past to a zero-emanation society is now viewed as significant.

Due to global warming the need to cut down energy consumption has increased. The effect of global warming has impacted everyone on the planet and is a well-recognized concept. The interest of construction community in using waste or recycled materials in concrete is increasing because of the emphasis placed on sustainable construction.

Metakaolin is one of the innovative clay products developed in recent years. It is produced by controlled thermal treatment of kaolin. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has pozzolanic properties. The use of metakaolin as a partial cement replacement material in mortar and concrete has been studied widely in recent years.

Basalt is well known as a rock found in virtually every country round the world. Its main use is a crushed rock in construction, industrial and high way engineering. However, it is not commonly know that basalt can be used in manufacturing and made into fine, superfine and ultrafine fibres. Comprise of single-ingredient raw materials melt basalt fibres are superiors to other fibres in terms of thermal stability, heat and sound insulation properties, vibration resistance and durability.

II. LITERATURE SURVEY

Vermaak and Potgieter[1]Metakaolin is a pozzolanic material obtained throughthermal activation of kaolinite. It has several important advantages when used as anextender for Portland cement. This note describes the strength enhancement observed in mortars containing metakaolin additions between 10 and 30%. It was found thatcompressive strengths increases with increased curing times and depended strongly on theactivation temperature used. They proposed that strength enhancements did notsignificantly depend on the concentration of metakaolin addition. Significantimprovements in compressive strengths of cement mortars, up to 80% or more werefound in selected cases.

Ding and Li[2] studied and compared the effects of metakaolin and silica fume on various properties of concrete. Seven concretes were cast at a water/binder ratio of 0.35 with 0, 5, 10, and 15% cement replaced by either metakaolin or silica fume. Theconcretes were tested for slump, compressive strength, free shrinkage, restrained shrinkage cracking, and chloride diffusivity by ponding. Metakaolin-modified concreteshowed a better workability than silica fume-modified concrete. As the replacement level was increased, the strength of the metakaolin-modified concrete increasedat all ages similarly to that of the silica fume-modified concrete. Both mineral admixturesreduced free drying shrinkage and restrained the shrinkage cracking width. However, thecracking time was earlier for these two concretes. The two admixtures greatly reduced thechloride diffusivity of the concrete.

Singha K (2012)[3]studied A Short Review on Basalt Fiber.The basalt fiber is now being a popular choice for the material scientist for the replacement of steel and carbon fiber due to its high rigidity and low elongation or extension at break. Its supreme tenacity value makes it as a useful reinforcement material in the present and also for the future era to come.

Dr. N. Subramanian (2010)[4] carried out research on Sustainability of RCC Structures Using Basalt Composite Rebarsaccording to his study Basalt composite rebars (BCR) had been introduced recently into the market as an alternative to steel bars. They offer a number of advantages over the conventional steel bars as well as FRP bars. Their light weight combined with non-corrosive nature will result in economic and sustainable reinforced concrete structures. BCR is an ideal choice for applications such as marine structures, off-shore structures, parking structures, bridge decks, highway under extreme environments, and structures highly susceptible to corrosion (paper and chemical industries)and for pervious concrete pavements.

III. EXPERIMENTALWORK

The material details are as follows:

A. *Cement*

For this research, locally available cement which is of the ordinary Portland cement type (53 grade) was used throughout the work. Specific gravity of cement was 3.15.

B. *Fine Aggregate*

Locally available fine aggregate used was 4.75 mm size confirming to zone II with specific gravity 2.66. The testing of sand was conducted as per IS: 383-1970.Water absorption and fineness modulus of fine aggregate was 1.35% and 2.74 respectively.

C. *Coarse Aggregate*

Coarse aggregate used was 20mm and less size with specific gravity 2.70. Testing of coarse aggregate was conducted as per IS: 383-1970. Water absorption and fineness modulus of coarse aggregate was 0.7% and 7.17 respectively.

D. *Water*

The water used was potable, colourless and odourless that is free from organic impurities of any type.

E. *Metakaolin*

Metakaolin is one of the innovative clay products developed in recent years. It is produced by controlled thermal treatment of kaolin. Metakaolin can be used as a concrete constituent, replacing part of the cement content since it has pozzolanic properties

TABLE 3.1 CHEMICAL&PHYSICAL PROPERTIES OF METAKAOLIN

Chemical	**Composition**
SiO	50% - 55%
Al2O3	38% - 42%
CaO	1%-3%
TiO2	0.8-1.2
Na2O	<1%
Fe2O3	0.2-0.5
K2O	<1%
MnO	<0.5%
MgO	<0.1%
Loss on Ignition	Max 1.5%
Physical	Properties
Bulk Density (g/cc)	0.5461 (When packed)
Color	White
Specific Gravity	2.30

F. *Basalt fibre*

Basalt is well known as a rock found in virtually every country round the world. Its main use is a crushed rock in construction, industrial and high way engineering. However, it is not commonly know that basalt can be used in manufacturing and made into fine, superfine and ultrafine fibres.

TABLE 3.2 CHEMICAL & PHYSICAL PROPERTIES OF BESALT FIBRE

Chemical Composition Of Basalt Rock	**Percentage (%)**
SiO_2	52.8
Al_2O_3	17.5
Fe_2O_3	10.3
MgO	4.63
CaO	8.59
Na_2O	3.34
K_2O	1.46
TiO_2	1.38
P_2O_5	0.28
MnO	0.16
Cr_2O_5	0.06

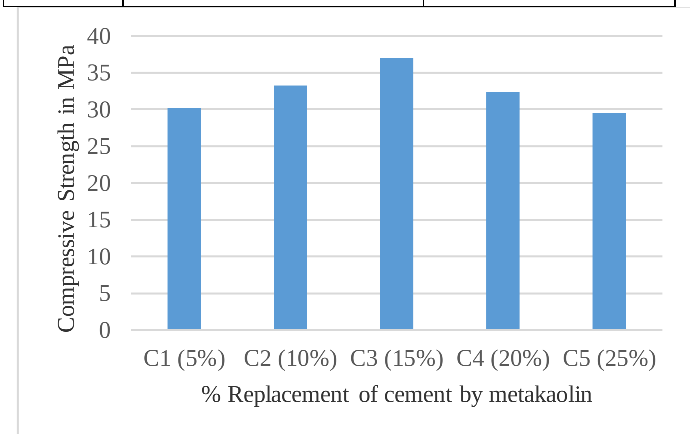
IV. RESULTS&DISCUSSION

A. *Compressive Strength (7 Days):*

Three cubes of size 150x150x150 mm were casted to work out the 7th and 28th day's compressive strength of all the proportions. The table III gives the results of test conducted on hardened concrete with 0-25% metakaolin powder for 7 days.

TABLE 4.1
EXPERIMENTAL TEST RESULTS FOR COMPRESSIVE STRENGTH

Mix Notation	**% replacement of cement by metakaolin powder**	**Compressive Strength in MPa (7 Days)**
A1	5 %	30.25
A2	10%	33.24
A3	15%	36.97
A4	20%	32.40
A5	25%	29.52



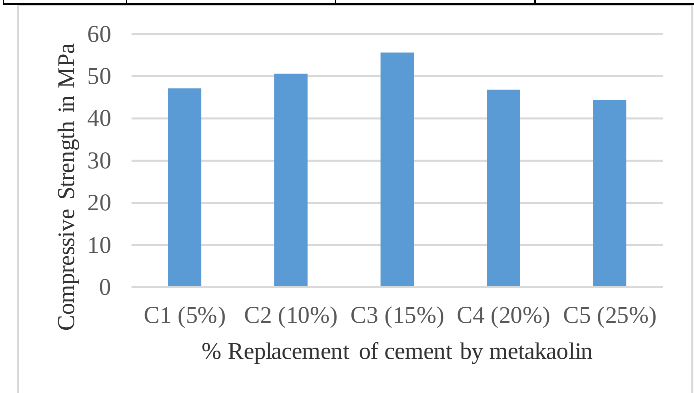
Graph 4.1: Comparative compressive strength of concrete with cement replacement with metakaolin for 7 days

It is clear from table III compressive strength obtained for concrete with 15% replacement by metakaolin powder showed a higher value by 30% compared to control concrete for 7 days. Above results shows that 15% metakaolin replacement is feasible as strength point of view, so further work will carried out with 15% replacement of metakaolin in addition with basalt fibre

The table IV gives the results of test conducted on hardened concrete with 0-25% metakaolin powder for 28 days.

TABLE 4.2

Mix Notation	% replacement of cement by metakaolin powder	% Addition of basalt fibre by volume fraction	Compressive Strength in MPa (28 Days)
C1	15%	0.05%	47.08
C2	15%	0.10%	50.71
C3	15%	0.15%	55.64
C4	15%	0.20%	46.87
C5	15%	0.25%	44.45



Graph 4.2: Comparative compressive strength of concrete with cement replacement with metakaolin for 28 days.

B. *Flexural Strength:*

Three beam section of size 100x100x500mm were casted and cured for 28 days. The flexural strength is determined by the

Formula:

$$fcr = P_f L / bd^2 \quad \text{or} \quad 3P_f a / bd^2$$

Where,

fcr = Flexural strength, MPa

P_f = Central load through two point loading system, N

L = Span of beam, mm

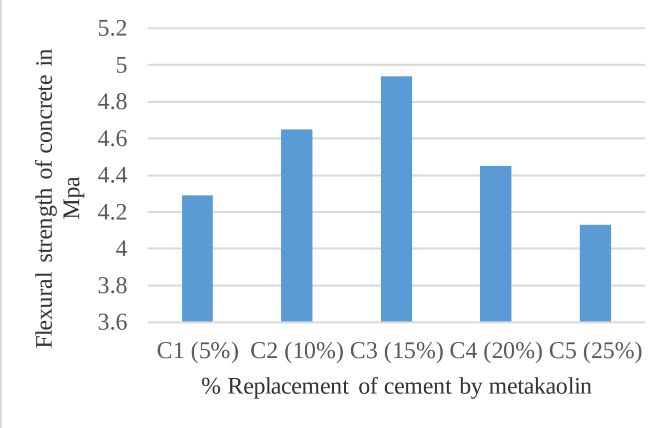
b = Width of beam, mm

d = Depth of beam, mm

a = distance between line of fracture to the nearest support, mm.

TABLE 4.3 EXPERIMENTAL TEST RESULTS FOR FLEXURALSTRENGTH

Mix Notation	% replacement of cement by metakaolin powder	% Addition of basalt fibre by volume fraction	Flexural Strength in MPa (28 Days)
C1	15%	0.05%	4.29
C2	15%	0.10%	4.65
C3	15%	0.15%	4.94
C4	15%	0.20%	4.45
C5	15%	0.25%	4.13



Graph 4.3: Comparative flexural strength of concrete with cement replacement with metakaolin for 28 days

C. *Spilt Tensile Strength:*

Three cylindrical sections of diameter 150 mm and length 300 mm were casted and cured for 28 days. The split tensile strength of cylinder is calculate by the following formula:

$$fcys = 2P_{sp} / \pi D L$$

Where,

fcys = Split Tensile strength, Mpa

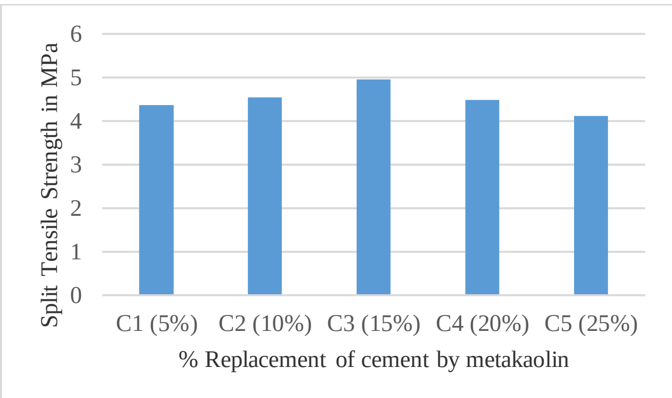
P_{sp} = Load at failure, N

L = Length of cylinder, mm

D = Dia. Of cylinder, mm

TABLE 4.4 EXPT. TEST RESULTS FOR SPLITE TENSILE STRENGTH

Mix Notation	% replacement of cement by metakaolin powder	% Addition of basalt fibre by volume fraction	Split Tensile Strength in MPa (28 Days)
C1	15%	0.05%	4.36
C2	15%	0.10%	4.54
C3	15%	0.15%	4.96
C4	15%	0.20%	4.49
C5	15%	0.25%	4.11



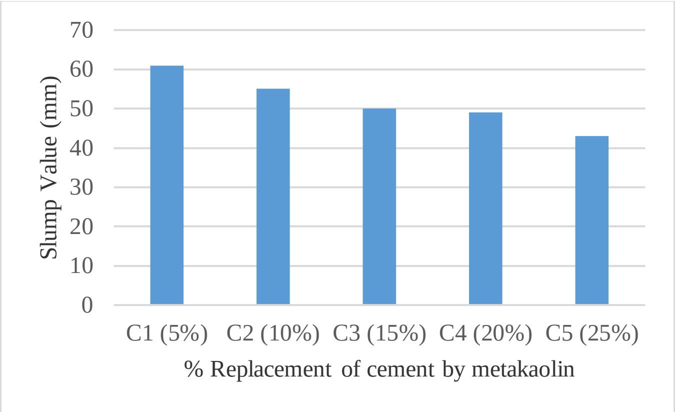
Graph 4.4: Comparative Split tensile strength of concrete with cement replacement with metakaolin for 28 days

D. *Workability Test:*

Slump Cone test was conducted for investigation of workability of fresh concrete. Following Table VII shows the slump value for all proportions.

TABLE 4.5SLUMP VALUE FOR ALL PROPORTIONS

Mix Notation	% replacement of cement by metakaolin powder	Slump Value (mm)
C1	5 %	61
C2	10 %	55
C3	15 %	50
C4	20 %	49
C5	25 %	43



Graph 4.5: Comparative slump value of concrete with cement replacement with metakaolin for 28 days

VI. RESULTS AND DISCUSSION

The influence of metakaolin powder & basalt fibre on the Properties of concrete such as the compressive strength, slump are studied. An appreciable increase in the compressive strength is observed with the increase in the percentage replacement of cement by metakaolin powder from 5 % to 15 %. With 15% replacement the increase in strength is approximately 30%. Also the experimental results shows that the addition of basalt fibre up to 0.15% improved considerable post cracking flexural strength. It means addition of basalt fibre made the concrete more tough and ductile. The test results of flexural strength of metakolin concrete containing basalt fibre were found to increasing upto 0.15% addition of basalt fibre than the conventional concrete.

Slump test was carried out and the slump was found to be 50 mm with 15% replacement. Considering the strength criteria, the replacement of cement by metakaolin powder is feasible up to 15%.

VII. CONCLUSION

Based on experimental observations, following conclusions can be established:

1. The strength of concrete increases with increase in metakaolin content upto 15% replacement of cement.
2. The strength models developed for BFMC predicts the results of various strengths which are in good compliance with experimental results.
3. The strength of BFMC has increased in flexure and split tensileup to addition of 0.15% of basalt fibre.
4. As the Percentage of metakaolin powder in concrete increases, workability of concrete decreases. As metakaolin content increases, cement paste available is less for providing lubricating effect per unit surface area of aggregate which reduces the workability of concrete.

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