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Partial Replacement of Cement with Metakaolin and Silica Fume inConcrete

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Abstract- *Cement is an essential ingredient of concrete and it is composed of lime and silica. During the production of cement, large quantity of raw material is utilized and which are burnt to produce the clinkers which result in the emission of CO2 in the environment. Global emission from the manufacture of cement stood at 1.7 billion metric tons of (CO2) in 2021.In 2021, cement consumption was expected to reach 4.4 billion tons and its production was expected to generate 450 kg/m3 of CO2 emission, representing 25% of total annual global manufacturing emission. The main aim of this project is to investigate the mechanical behavior of concrete as partial replacement of cement with metakaolin, silica fume. In this project the mix proportion of M30, M35 grade of concrete is adopted in accordance with 10262:2019 & IS 456:2000 and cement of 53 grade PPC is used. The concrete is tested for strength parameter of conventional concrete & in this concrete we add silica fume and metakaolin are replaced by weight of cement in different proportion 7% (silica fume) and 5%, 10%, 15% (metakaolin). Metakaolin (MK) and silica fume (SF) have been used in concrete separately. MK has (+) effect on workability but SF has (-) effect on workability so we adopt co-addition of MK + SF gives higher strength than sole addition of MK and SF. Compressivestrength test are conducted for 7, 14,28 days.*

Key Words: concrete, metakaolin, silica fume.

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I. INTRODUCTION

Concrete is a most commonly used building material and water. It is used for construction of multi-story buildings, dams, road pavement, tanks, offshore structures, canal lining. The method of selecting appropriate ingredient of concrete and determining their relative amount with the intention of producing a concrete of the necessary strength durability and workability as efficiently as possible is termed the compressive strength of harden concrete is commonly considered to be an index of its extra properties depends upon a lot of factors e.g worth and amount of cement water and aggregates batching and mixing placing compaction and curing. Concrete is the very basic and important construction material used widely. On the concrete is cement is the important material. In the past few years, many research and modification has been done to produce concrete which has the desired characteristics. The addition of some pozzolanic materials were reduces the usage of cement on concrete considerably and also increases the strength and f characteristics of the concrete. Some of the pozzolanic materials like metakaolin, silica fume is used instead of cement at certain percentages Concrete is made from cement, fine aggregate, coarse aggregate and water. This hard and alkaline material along with steel is an excellent composite material used in the construction. The cement and water form glue or cream, which coats the sand and aggregate. When the cement is chemically reacted with the water, it is hardened and binds the whole mix. The setting ofd takes place usually within a few hours. It takes some more weeks for concrete to get a full hardening and gain strength. So, the time elapse the compression strength of concrete keep on increasing. With addition of pozzolanic materials such as metakaolin, GGBS etc. in certain proportions it is noticed that the compressive strength of concrete is improved. Much research carried out for the betterment of concrete and its properties. In recent times concrete researchers are concentrating on secondary cementitious materials for the improvement of concrete and its strength etc. Hydraulic cement, a primary binder is produced on an average of two billion tons per year amounting to 2.5 tons of per capita consumption. Concrete structures got a perennial problem of contribution to CO2 emission and as a result greenhouse effect. A method to reduce the cement content in concrete mixes is the use of some pozzolanic concrete materials.

II. METHODOLOGY

2.1 Cement

Pozzolana Portland Cement of Ambuja brand of 53 grade confirming to IS 1489(part 1 and 2) 1991 was used in the present study. The various properties of cement are shown in Table below:

Table1.1.1: Properties of Cement

Sr.No	Property	Result
1	Normal Consistency	31%
2	Initial SettingTime	30 min
3	Specific Gravity	3.15
4	Fineness ofcement	3.5%
5	Specific Area	3000 cm2/gm
6	Soundness ofcement	1.0mm

2.2 Fine Aggregate:

Natural river sand locally available confirming to IS 2386-1999 was used of grading zone II. The properties of fine aggregate are shown in table below:

Table: Properties of Fine Aggregate

Sr.No	Property	result
1	Bulk density	1625 kg /M 3
2	Specific Gravity	2.69
3	Fineness Modulus	2.873
4	Water absorption	1.15

2.3 Coarse Aggregate:

Coarse aggregate of size 10mm & 20 mm of crushed stone locally available confirming to IS 2386 1999 was used:

Table1.3.1: Properties of Coarse Aggregate

Sr. No	Property	Result
1	Bulk density	1525 kg /M 3
2	Specific gravity	2.76
3	Fineness Modulus	6.56
4	water absorption	0.46%

2.4 Water

The canal water used in this study was free ofalkalis, acids, salts, organic materials & other

2.5 Silica Fume

Silica Fume also known as condensed silica fume or micro silica is very fine, non-crystalline produced in electric arc furnaces as a by-product of the production ofelemental silicon o silicon allows. The specific gravity ranges from 2.2 to 2.3. Silica fume is added to Portland cement concrete to improve its properties, in particular compressive strength, bond strength and abrasion resistance impurities.

Table1.5.1: Physical & Chemical Properties of Silica Fume

Physical State	Solid- Non-Hazardous
Specific Gravity	2.23
Mean grain size (µm	0.15
Color	Light grey to black
Odour	Odour less
Silicon dioxide (Sio_2)	85

Aluminum Oxide (Al_2O_3)	1.12
Iron Oxide (Fe_2O_3)	1.46
Calcium Oxide (Cao)	0.2-0.8
Magnesium Oxide (MgO)	0.2-0.8
Sodium Oxide (Na_2O)	0.5-1.2
Potassium Oxide (K_2O)	0.5-1.2

2.6 Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as China clay or kaolin, traditionally used in the manufacture of porcelain. It is a product that is manufactured for use rather than a by-product and is formed when China clay, the mineral kaolin, is heated toa temperature between 600 and 800ºC. Its quality is controlled during manufacture, resulting in a much less variable material than industrial pozzolans that are by- products The particle size of metakaolin is smaller than cement particles, but not as fine as silica fume usually 8% - 20% (by weight) of Portland replaced by metakaolin. Such a concrete exhibits favorable engineering property.

Table:1.6.1 Physical & Chemical Properties of metakaolin

Physical State	Solid- Non-Hazardous
Specific Gravity	2.6
Mean grain size (μm)	1-2
Color	Light Creamy White
Odour	Odorless
Silicon dioxide (Sio_2)	53
Aluminum Oxide (Al_2O_3)	43
Iron Oxide (Fe_2O_3)	1.2
Calcium Oxide (Cao)	0.5
Magnesium Oxide (MgO)	0.4
Sodium Oxide (Na_2O)	-
Potassium Oxide (K_2O)	2.43

2.CONTROL MIX DESIGN

mix design properties were designed as per IS 10262 2019 code book guide lines, 1:1.88:2.82 (Cement: Fine Aggregate (FA): Coarse Aggregate (CA)) From the mix percentage the weight of silica fume and metakaolin required is tabulated and calculated.

Weight of material used

CEMENT (Kg/m3)	FINE AGGREGATE (Kg/m3)	COARSE AGGR E G AT E (Kg/m3)	WATER (lit/m3)
356	637	1250	0.43

Table 2.1:Weights of cement, silica fume andmetakaolin required for M30 GRADE

CEMENT	Replacement % of cement bySilica Fume and Metakaolin (SF + MK)	(SF + MK) (2.5 + 2.5) = 5%	(SF + by Silica MK)Fume and (5 + 5) Metakaolin n =10%	(SF + MK) (7.5 + 7.5) =15 %

	Silica Fume(Kg/m3)	27	27	27
	Metakaolin (Kg/m3)	19	39	58
	Cement (Kg/m3)	340	320	301

III. RESULT AND DISCUSSION

Compressive strength

For M30 grade of concrete the test result is the average of at-least three standard cured strength specimens made from the same concrete sample and tested at the same age. The dimensions of the cube are 150mm X 150 mm X 150 mm. At first, the cube mold is prepared by connecting it properly with nuts and bolts. Then, it is thoroughly appliedwith grease in all nuke and corner of the mold. Now the prepared concrete is kept in three layers then thecompaction or vibration are ignored. Finally leveling is done in the mold. It is allowed to set for 24 hours and thendemolded. The load was applied without shock and increased continuously at a rate of approximately 140 Kg/cm2 /min until the resistance of the specimen to the increased load broke down and no greater load could be sustained. It is done on curing of cubes after 7, 14 and 28days. This process is repeated for the percentages 5%, 10%, 15%.
Compressive Strength Test
Compressive Strength (fc) = P/A
Where P – Load at Failure in Kg and
A – Surface area of bearing cube in mm2

Figure 1: CUBE CASTING

Fig -1: cube casting

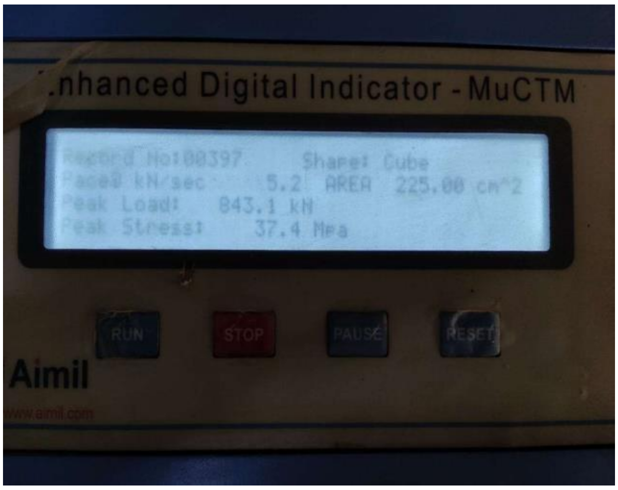
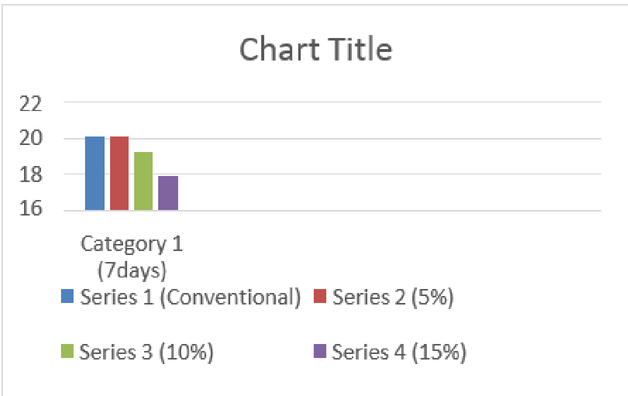


Fig-2: Result

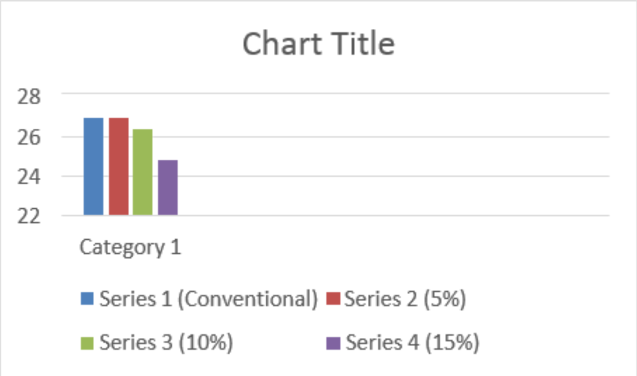
Fig-3: Block Testing Compressive strength of concrete (7 days)

S.N.	SPECIMEN	COMPRESSIVE STRENGTH (N/mm2)
1	Conventional	20.1
2	(SF + MK) 5%	20.1
3	(SF + MK) 10%	19.2
4	(SF + MK) 15%	17.9



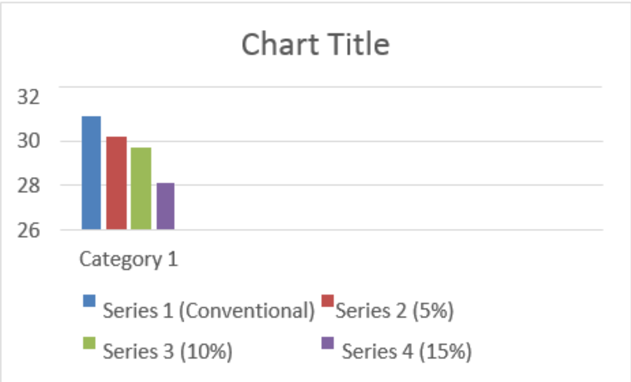
Compressive strength of concrete (14 days)

S.N.	SPECIMEN	COMPRESSIVE STRENGTH (N/mm2)
1	Conventional	27
2	(SF + MK 5%)	27
3	(SF + MK 10%)	26.4
4	(SF + MK 15%)	24.8



Compressive strength of concrete (28 days)

S. N	SPECIMEN	COMPRESSIVE STRENGTH (N/mm2)
1	Conventional	31.1
2	(SF + MK) 5%	30.2
3	(SF + MK) 10%	29.7
4	(SF + MK) 15%	28.1



IV. CONCLUSION

Following conclusion can derived on the basis of testing of concrete cube with partial replacement as cement with silica fume and metakaolin.

1. The 28 days compressive strength of normal concrete cube is less or compared with concrete made with replacement of cement with SF+MK 5% whereas this strength of concrete reduce we increase the percentages of SF+MK.

2. The 7 days compressive strength of concrete comparatively same with 5% increasing metakaolin and silica fume content but compressive strength of concrete for 10% and 15%. generally, they decrease with increasing.

3. Optimum dose of silica fume and metakaolin in combination is found 5% 10% ,15% (by weight) respectively at 7 days,14 days ,28 days compressive strength.

4. The slump is found to decreases with increases in metakaolin content at silica fume content considerably.

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