Experimental Investigationon Partial Replacement of Cement by Metakaolin and Silica fume

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Abstract -A normal concrete is useful for general applications which is generally brittle in nature and feeble in tension. For special purpose, special concrete with modified compositions are used. We decided to go with special concrete in which cement is replaced partially by metakaolin as major replacement and silica fume as minor replacement. Mineral admixtures tend to have greater strength at later age, by using mineral admixture in concrete provides greater sustainability in construction industry. The material used as the replacing component for cement have pozzolanic property. This paper d determines the special characteristics of admixture used in concrete.Metakaolin is an admixture which is used as replacing component in this project. Steel scrap waste from lathe machine is used as fibres to achieve good flexural strength. Steel scrap prevents micro crack in concrete. Cement is replaced partially by 7% of silica fume, it has been obtained from studying the literature. Metakaolin is added to the mix of about 5% incremental order of 5%, 10%, 15%, 20% and strength and physical properties will be studied. 1.5% of steel scrap is added to the total cement volume.

Index Terms – Silica fume, metakaolin, steel fiber, partial replacement,

1 INTRODUCTION

Concrete is a durableconstruction material composed of certain proportion of water, m-sand, aggregates and cement. There are numerous factors that affect the strength and durability of the concrete, by selecting an appropriate alternative material for the replacement of materials used in concrete will increase the strength properties of the concrete. This type of concrete comes under the category of special concrete. Special concrete comprises of mineral admixtures and fiber particles whichincreases the structural strength of the concrete. Scrap metal is the waste material produced from lathe industries. In India nearly tons of metal scrap are generatedyearlywhich makes the dumping difficult by using this scrap in concrete, the dumping of these wastes can be reduced. By using steel scrap in concrete flexural strength can be increased. Metakaolin is amost effective material, cement can be partially replaced by metakaolin. It has pozzolanic property. Metakaolin is prepared by calcination process of kaolin at a temperature of 650-800°C.Silica fume is a derivative of silica metal, it is a reactive pozzolanic material. It is efficient in influencing the strength of concrete. Main component present in silica fume is silicon dioxide (Sio2). Silica fumeusage in concrete mix results in the reduction of water percentage in concrete and it is highly impervious to chloride ion penetration this will reduce the salt settlement in concrete and thus makes it as durable concrete.Silica fume addition is essential to some extend for obtaining high strength in the concrete.

2 MATERIAL USED

2.1 Cement

Ordinary Portland Cement of Grade 53 as per code provision of IS: 12269:1993 was used in this project. It is the important component in the preparation of concrete mix. This helps to bind the materials together. The initial and final setting time of cement was found to be 30mins and 560minutes respectively. Fineness test was done by using 90μ sieve.

TABLE 1
PROPERTIES OF CEMENT

S.No	Physical Properties	Value
1.	Consistency	30%
2.	Specific gravity	3.18

2.2 Fine aggregate

Instead of river sand as fine aggregate manufactured sand was used in this project. The sieving process of the sand is done using 4.75mm sieve. The fineness modulus and specific gravity of fine aggregate are 2.83 and 2.53. The properties of the sample taken was determined by the provision of IS 2386: 1999. Sand tested was compatible to Zone-3.

TABLE 2
PROPERTY OF FINE AGGREGATE

S. No	Physical Properties	Value
1	Specific gravity	2.53
2	Fineness	2.83

2.3 Coarse aggregate

The crushed stone aggregate of 20mm sizeobtained from crushing plants are used in this project.The specific gravity and fineness modulus of coarse aggregate are 2.67and 5.1 respectively. The properties were determined as per IS 2386-1999.

TABLE 3
PROPERTY OF COARSE AGGREGATE

S.No	Physical Properties	Value
1.	Water absorption	0.70%
2.	Specific gravity	2.67
3.	Fineness	5.1

2.4 Silica fume

Silica fume haspozzolanic properties which can be used as admixturein concrete. Silica fume is an airborne fine material spherical in shape. It is very fine particle of size less than 1μ. The fineness modulus is obtained as 0.465. The specific gravity of silica fume obtained as 2.206.

TABLE 4
PROPERTY OF SILICA FUME

S.No	Physical Properties	Value
1.	Specific gravity	2.206
2.	Fineness modulus	0.465

2.5 Metakaolin

Metakaolin is an unpurified natural pozzolanic material. It is manufactured thermally activated ordinary clay and kaolinite clay. The mineral is heated to a temperature between 600°c and 800°c. Metakaolin is usually used as an alterative replacement of silica fume. By using appropriate amount of metakaolin as a replacement of cement will increase the strength of the concrete. The fineness modulus and specific gravity ofmetakaolin are 0.5 and 2.162 respectively.

TABLE 5
PROPERTY OF METAKAOLIN

S.No	Physical Properties	Value
1.	Specific gravity	2.162
2.	Fineness	0.5

2.6 Steel scrap

Steel scrap is attained from lathe industries. It is a waste product obtained in the process of manufacturing steel product. Fiber addition will increase the flexural strength of the concrete. The length of steel scrap is of about 25-40mm. Thespecific gravity of steel scrap is 7.85.

TABLE 6
PROPERTY OF STEEL SCRAP

S.No	Physical Properties	Value
1.	Diameter(mm)	0.3-0.75mm
2.	Length(mm)	25-40mm
3.	Specific gravity	7.85

2.7 Water

Water is one of the major constituents of concrete. Water will help to enhance the chemical reaction in concrete with cement. The amount of water to be added in concrete has to becalculated before using that in concrete and also the quality should be tested so that it canbe a factor of increasing the strength of the concrete. The PH value of water lies between 6 and 8 that indicate the water is free from organic matters.

2.8 Super plasticizer

Super plasticizer addition will increase the workability of the concrete. The super plasticizer added to this project is Conplast SP430(NE). Super plasticizer should be used to achieve water reduction in the concrete. The amount of super plasticizer used in this project is about 2%.

3 MIX DESIGN

3.1 Mix Proportion

The concrete grade M35 is used in this project. Calculation of the materials is done using code book.

TABLE 7
MIX PROPORTION

S. No	Materials	Quantity
1	Cement	414.7 kg/m^3
2	Fine Aggregate	672.59 kg/m^3
3	Coarse Aggregate	1177.91kg/m^3
4	Water	157.7kg/m^3
5	Super plasticizer	4.97 kg/m^3
6	Water-cement ratio	0.38

3.2 Replacement and Addition for Cement

Silica fume and metakaolin is partially replaced with cement. Steel fiber is added to the volume of cement in concrete.

TABLE 8
REPLACEMENT AND ADDITION FOR CEMENT

Mix	Mix Description	Cement %	Silica Fume (%) + Metakaolin (%)	Addition for Cement (Steel Fibre) %
M1	Conventional	100	0	1.5
M2	SF 7% + Metakaolin 5%	88	7 + 5 = 12	1.5
M3	SF 7% + Metakaolin 10%	83	7 + 10 = 17	1.5
M4	SF 7% + Metakaolin 15%	78	7 + 15 = 22	1.5
M5	SF 7% + Metakaolin 20%	73	7 + 20 = 27	1.5

4 TESTS ON FRESH CONCRETE

4.1 Slump test

Slump test can be performed both in laboratory and in field.Concrete slump test is carried out for various mix proportion.

TABLE 9
SLUMP TEST

S. No	Mix proportion	Slump value(mm)
1	M1	123
2	M2	100
3	M3	85
4	M4	70
5	M5	50

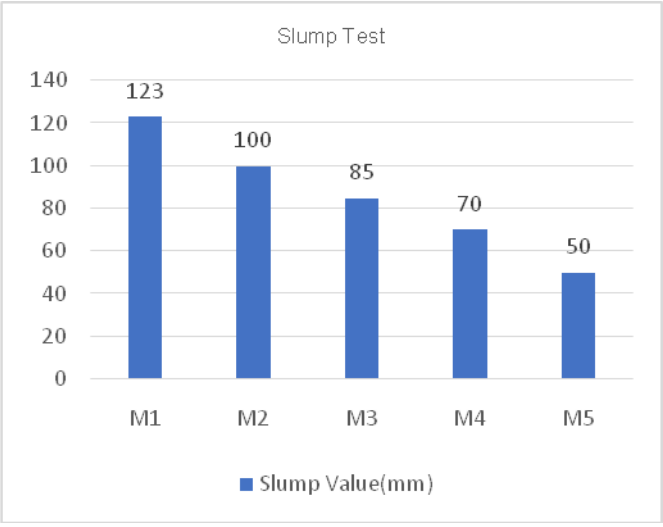

Fig 1 Slump test

4.2 Compaction factor test

Compaction factor test canbe performed in laboratory it can also be done in field. This experiment is done to determine the degree of compaction of the concrete.

TABLE 10
COMPACTION FACTOR

Sl.no	Mix proportion	Compaction factor
1	M1	0.90
2	M2	0.93
3	M3	0.89
4	M4	0.86
5	M5	0.83

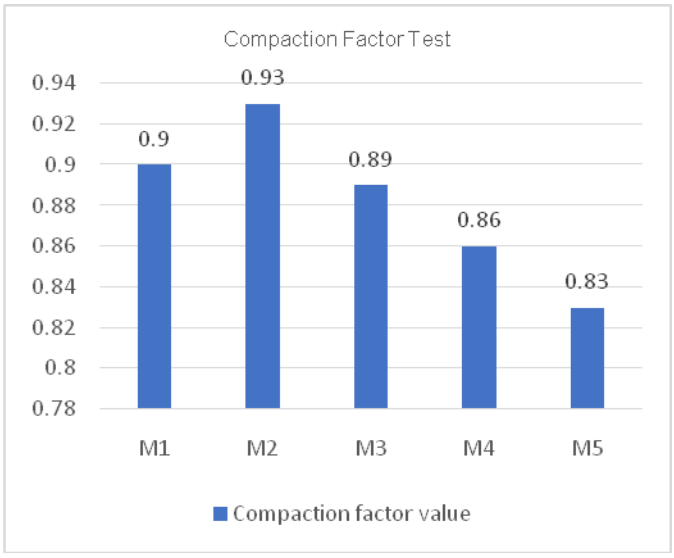

Fig 2 Compaction Factor test

5 TESTS on HARDENED CONCRETE

5.1 Compressive strength

Compression test is performed using compression testing machine (CTM). The cube specimen is of size 15×15×15cm. The size of aggregate should not exceed 20mm.

TABLE 11
COMPRESSION STRENGTH TEST

Sl.no	Mix proportion	Compressive strength		
		7 days	14 days	28 days
1	M1	29.1	38.29	41.62
2	M2	25.38	33.35	36.26
3	M3	27.42	36.11	39.26
4	M4	29.87	39.26	42.68
5	M5	27.28	35.86	38.98

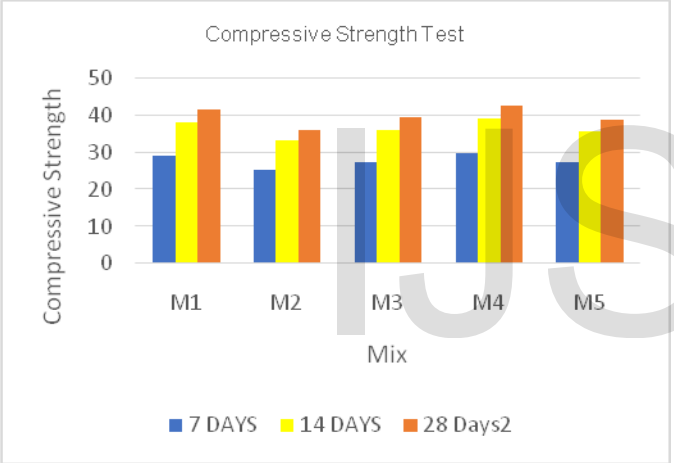

Fig 3 Compression Test

5.2 Split tensile strength

To determine the tensile stress of concrete split tensile strength is carried out. This test is performed in laboratory. Cylinder specimen dimension of height 30cm, diameter 15cm is used to proceed the test.

TABLE 12
SPLIT TENSILE STRENGTH

Sl.no	Mix proportion	Tensile stress		
		7 days	14 days	28 days
1	M1	5	6.44	7
2	M2	6.55	7.3	8.04
3	M3	7.61	8.3	9.12
4	M4	8.71	9.74	10.59
5	M5	6.6	7.63	8.3

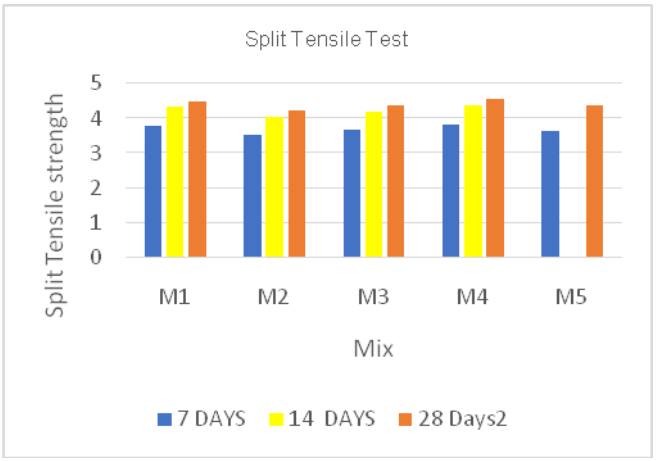

Fig 4 Split Tensile test

5.3 Flexural strength

Flexural strength of concrete test is used to determine the flexural characteristics of the concrete. Prism of size 150×150×700mm is used to find out the flexural strength.

TABLE 13
FLEXURAL STRENGTH

Sl.no	Mix proportion	Flexural strength		
		7 days	14 days	28 days
1	M1	3.77	4.33	4.5
2	M2	3.52	4.04	4.21
3	M3	3.66	4.2	4.38
4	M4	3.82	4.38	4.57
5	M5	3.65	4.19	4.37

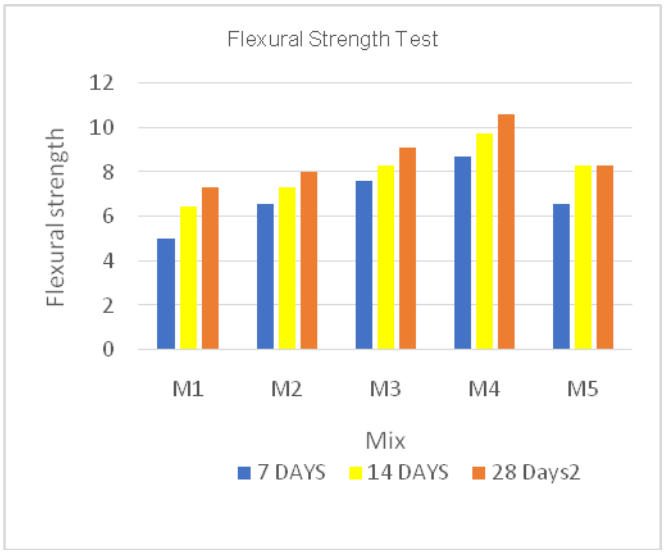

Fig 4 Flexural Strength Test

6 CONCLUSION

- Compressive strength increases by replacing metakaolin by 15%, Silica fume by 7%, steel scrap 1.5% on both 7 days,14 days and 28 days.
- Flexural strength of the concreteincreases by 74.2% of conventional concrete by replacing metakaolin by 15%, silica fume by 7% and 1.5%steel scrap added.
- Tensile strength increases by 1.3% of conventional concrete by replacing metakaolin by 15%, silica fume by 7% and 1.5%steel scrap added.
- Steel scrap addition enhances flexural strength in concrete.

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