Experimental Study on Concrete with Partial Replacement of Cement by Mineral Admixtures

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Abstract – The production of 1 tons of cement liberates 755 kg of carbon-dioxide has leads to increase in global warming, the usage of cement is keep on increasing due to the construction of structures, which is necessary for a country to improve it's infrastructures. The usage of cement should be reduced by replacing it, now a day's industries are developing in a rapid manner and the by- products from it are disposing as a waste in dumping yards. Mainly three major mineral admixtures of fly ash, blast furnace slag, silica fume are treated as waste products. Fly ash material has been using in construction field for replacement of cement up to 35%. This project is to increase that percentage of replacement by a suitable waste material. To achieve all the three by products mentioned above are mixed in a proportion of 60%, 30%, 10% of blast furnace slag, fly ash, silica fume respectively. This combination will give better properties like standard cement then the individual replacement of by-products. Then the cement manufacturing process is adapted for mixture by heating the mixture at a temperature of 1400ºC, the clinker will form then the clinker is crushed and grained to get the fineness of cement. The mixture is tested for standard cement tests like specific gravity, consistency, initial and final setting time, loss on ignition, and chemical composition. The cement in concrete is replaced by obtained mixture by increment of 20% up to 100%. Then the concrete is tested for compression, split tensile, flexural strength test to find the performance of mixture in concrete.

Index Terms – Cement, Silica Fume, Ground Granulated Blast Furnace Slag, Fly Ash, Compressive Strength, Split Tensile Strength, Flexural Strength.

1. INTRODUCTION

Concrete is a composite material composed of coarse aggregate bonded together with fluid cement which hardened over time. Most concrete used are lime based concretes such as Portland cement or concrete made with other hydraulic cements.

In Portland cement concrete (other hydraulic cement concretes) when the aggregate is mixed together with the dry cement and water. They form a fluid mass that is easily molded in to any shapes. The cement reacts chemically with water and the other ingredients to form a hard matrix which binds all the materials together into a durable stone like materials that has many uses.

Often additives such as pozzolanas or super plasticizers are included in the mixture to improve the physical properties of wet mix or the finished material.

Most concrete is poured with reinforcing material such as rebar. Embedded to provide tensile strength, yielding reinforced concrete. Today, large concrete structures such as Dams, Multi storied car parking are usually made with reinforced concrete.

A.CEMENT

Cement is a binder substance is used in construction that sets and hardens and can bind other material together. Cement used in construction can be characterized as being either hydraulic or non-hydraulic, depending up on the ability of the cement to set in the presence of water.

Non-hydraulic cement will not set in wet conditions or under water; rather, it sets as dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals are after setting.

Hydraulic cements set become adhesive due to a chemical reaction between the dry ingredients and water. The chemical reaction results in mineral hydrates that are not very water soluble so are quite durable in water and safe from chemical attack. This allows setting in wet conditions or underwater and further protects the hardened materials from chemical attack.

The most important uses of cement are components in the production of mortar in masonry, and of concrete, a combination of cement and aggregate to form strong building materials.

The cost of cement is about as 12 -15% of total construction cost. So, this experimental study suggests the use of by products as a replacement material which reduces the cost of cement. So, that the cost of binding material can be saved.

This study begins with the searching of waste products which has the similar properties like cement. And this study extended up to testing of properties of available by products. After that the available of by products are mixed with the proportions of 60% of GGBS, 30% of fly ash and 10% of silica fume. At the end of the testing, the mixture had the important properties for good binding material as 40% of Lime, 25% of silica, 6% of Alumina and 5% of iron oxide.

Then the mixture is used for replacement instead of cement in concrete as percent of 20%, 40%… up to 100%... Then the samples are tested for compression, tension and flexural tests. And the results were obtained is compared with the cement and the mixture is suggested for use. Then the Fresh concrete is tested for slump to determine the workability and area of usage of concrete in different environmental conditions. At last the results are analyzed and tabulated. Based on the results suggestions are given to make use of this study results.

2. OBJECTIVE AND SCOPE

A. OBJECTIVE

1. To compare the properties of materials with cement this has similar properties of cement.

2. To find the proportions of mix.

3. To find low cost materials or by products.

B. SCOPE

1. Fly ash is a very fine particulate material that looks and feels like talcum powder and can be a tan to gray colour, depending on its source. It is classified as a pozzolan and with its high silica content is used by concrete produces as a component in the range of 10 to 25% of the cementitious portion of concrete mixtures.

2. Silica fume is added to Portland cement concrete to improve its properties, in particular its strength, bond, and abrasion resistance. These improvements stem from both the mechanical improvements resulting from addition of a very fine powder to the cement paste mix as well as from the pozzolana reactions between the silica fume and free calcium hydroxide in the paste.

3. If power plant, Industry waste is suitable, it can be used in concrete production. This will reduce the waste material from construction as GGBS waste can be recycled for concrete production purposes.

3. STUDY MATERIAL

A.CEMENT

The ordinary Portland cement of 53 grade whose specific gravity of cement is 3.14, normal consistency of the cement was found as 28% and the initial and final setting times were found as 120 min and 238 min respectively was used.

A.1.FINENESS TEST

Fig.1. Fineness Test

So, we need to determine the fineness of cement by dry sieving as per IS: 4031 (Part 1) – 1996.The principle of this is that we determine the proportion of cement whose grain size is larger than specified mesh size. The apparatus used are 90µm IS Sieve, balance capable of weighing 10g to the nearest 10mg, A nylon or pure bristle brush, preferably with 25mm to 40mm, bristle, for cleaning the sieve. Sieve shown in figure below is not the actual 90µm sieve.

Report the value of R, to the nearest 0.1 percent, as the residue on the 90µm sieve.

Trials	**Water/cement ratio**	**Slump value for Cement in mm**	**Mixture in mm**
1	0.25	12	10
2	0.30	36	25
3	0.35	65	52
4	0.40	84	70

A.2.SOUNDNESS TEST

Soundness of cement is determined by Le-Chatelier method as per IS: 4031 (Part 3) – 1988. Apparatus – The apparatus for conducting the Le-Chatelier test should conform to IS: 5514 – 1969. Balance, whose permissible variation at a load of 1000g should be +1.0g and Water bath.

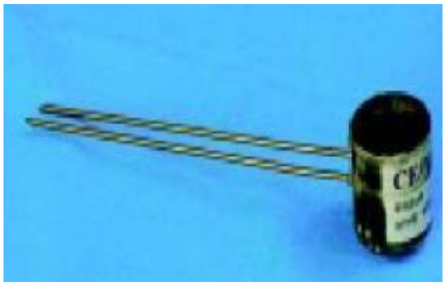

Fig.2. Soundness Test

TABLE 1

CEMENT TESTING REPORT

Sl.No	Test	Results
1	Specific gravity	3.15
2	Consistency	28
3	Initial setting time	30 Min
4	Final setting time	600 Min

B.COARSE AGGREGATE

The coarse aggregate with 40 mm nominal size having specific gravity 2.76 was used. The impact value is 20.5%. And the water absorption of the coarse aggregate is 0.54%.

TABLE 2

COARSE AGGREGATE TESTING REPORT

Sl.No	Test	Results
1	Specific gravity	2.76
2	Water absorption %	0.54
3	Impact value	20.5%
4	Fineness modulus	2.596

C.FINE AGGREGATE

Locally available river sand is used. As per IS 383:1970, sand is confirming to Zone I to IV. Specific gravity of the sand used is 2.69. And the water absorption value is 0.45%.

TABLE 3

FINE AGGREGATE TESTING REPORT

Sl.No	Test	Results
1	Particle shape	Irregular
2	Appearance	Brownish yellow
3	Type	River sand
4	Specific gravity	2.64
5	Water absorption %	1.24
6	Fineness modulus	2.73

4. PROPORTIONS OF MIX

M1 = Conventional concrete

M2 = 20% of mix + 80% of cement

M3 = 40% of mix + 60% of cement

M4 = 60% of mix + 40% of cement

M5 = 80% of mix + 20% of cement

M6 = 100%of mix + 0% of cement

5. MIX DESIGN

M20 grade of concrete was designed by following the specification given in the IS 10262: 2009. Water – Cement ratio (w/c) was selected as 0.40 based on conducting slump tests for different design trails. Mix proportion obtained for M20 mix is 1:2.3:3.1.

6. RESULTS AND DISCUSSIONS

A. SLUM TEST

The above graph show the results of slump test of cement and Mix. Good workability of cement concrete is achieved at the water/cement ratio of 0.4. The graph shows that Workability of cement concrete in normal since the slump values are up to 80mm. and this water/cement ratio shall be used for plain concrete structures. Whereas the mix obtains the workability of 70 mm at the same water cement ratio. Hence it can also be used for normal concrete works.

B. COMPRESSIVE STRENGTH

The strength compressive strength of concrete cubes was tested of size 150mmx150mmx150mm for different proportion of replacement. And at the end of tests the results were compared with conventional concrete to check the strength obtained.

TABLE 4

Results of Compressive Strength Test

Sl. No	Trials	Compressive Strength Test In N/mm^2		
		7 DAYS	14 DAYS	28 DAYS
1	M1 = Conventional Concrete	15.30	22.44	25.10
2	M2 = 20% Mix + 80% Cement	15.10	22.41	25.10
3	M3 = 40% Mix + 60% Cement	15.10	22.21	24.80
4	M4 = 60% Mix + 40% Cement	14.40	21.80	24.22
5	M5 = 80% Mix + 20% Cement	12.20	18.24	20.18
6	M6 = 100% Mix + 0% Cement	9.78	14.20	16.67

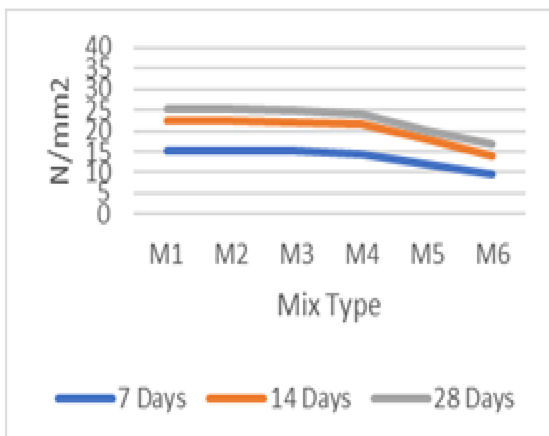

Fig.3. Comparison of Compressive Strength of Mix

Since the results of M1, M2, M3 and M4 mixes are same this can be allowed for any RC works. But the remaining mixes are decreased gradually, though it has the strength up to 18 N/mm2

C. FLEXURAL STRENGTH

The flexural strength of concrete was found out by a concrete beam of size 50cmX10cmX10cm. The samples molded and casted for different proportions and tested for different day. Generally, 7 days, 14 days and 28 days tests are conducted to find the concrete flexural strengths. So, in this project the samples are tested for 7, 14 and 28 days of curing.

TABLE 5

Results of Flexural Strength Test

Sl. No	Trials	Flexural Strength Test In N/mm^2		
		7 DAYS	14 DAYS	28 DAYS
1	M1 = Conventional Concrete	0.138	0.225	0.265
2	M2 = 20% Mix + 80% Cement	0.138	0.225	0.250
3	M3 = 40% Mix + 60% Cement	0.138	0.218	0.250
4	M4 = 60% Mix + 40% Cement	0.125	0.213	0.238
5	M5 = 80% Mix + 20% Cement	0.113	0.200	0.225
6	M6 = 100% Mix + 0% Cement	0.100	0.187	0.213

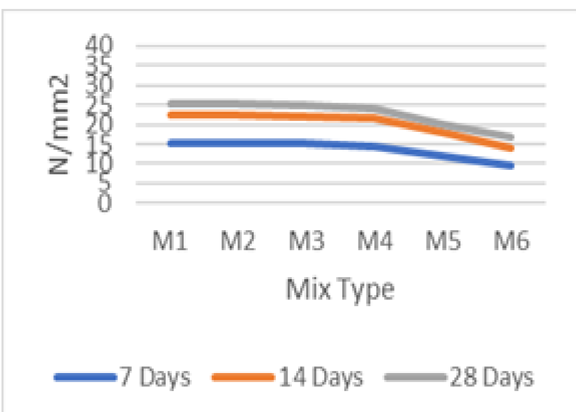

Fig.4. Comparison of Flexural Strength of Mix

In the above graph the flexural strengths were deceasing gradually toward increase in replacements. But up to 60% replacement it is acceptable.

D. SPLIT TENSILE STRENGTH

The Split tensile testing of concrete, samples of different proportions are casted of 10cm in diameter and 20cm in length of a cylinder. Then the usual compression testing machine to apply loads. During the test the sample ie the cylinder should be placed horizontally. This arrangement allows the cylinder to split up. That load required to split up the concrete cylinder called split tensile force or load. At the end of the results one can able to find the split tension of concrete cylinder.

TABLE 6

Results of Tensile Strength Test

Sl. No	Trials	**Tensile Strength Test In N/mm^2**		
		7 DAYS	14 DAYS	28 DAYS
1	M1 = Conventional Concrete	1.43	2.07	2.387
2	M2 = 20% Mix + 80% Cement	1.43	2.07	2.228
3	M3 = 40% Mix + 60% Cement	1.27	1.91	2.228
4	M4 = 60% Mix + 40% Cement	1.27	1.75	2.070
5	M5 = 80% Mix + 20% Cement	0.79	1.11	1.270
6	M6 = 100% Mix + 0% Cement	0.64	0.79	1.110

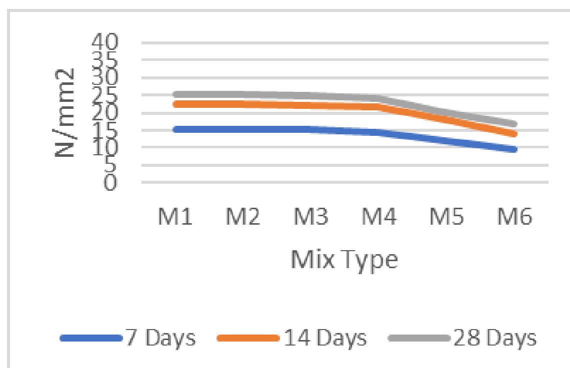

Fig.5. Comparison of Tensile Strength of Mix

From the graph, the split tensile strength of cylinder is more or less equal for the samples M2, M3 and M4. But after that the tensile strength is getting reduced to 1.11 N/mm2.

7. CONCLUSION

According to our experimental study, strength of concrete in compression, tension, and flexure will keep on increasing by increase in replacement percentage up to 60% after that it loses its strength gradually. So, we can use the mixture in concrete by an optimum replacement of 60%. Since M1, M2, M3 and

M4 mixes have similar strength it can be used for any RC works. Its shows that the cost towards the purchasing of cement can be reduced up to 60% without any compromises in strength. We can use the 60% replacement of cement by mixture in any reinforced concrete section without any loss in strength. Since the M5 mix have 20% lesser strength when compared to conventional or up to M4 mix it can be used for any single storied or comparatively lesser loads bearing structures. But 81-100% of mixture is not suitable for reinforced concrete section where the section has to carry more loads. For the replacements 81% to 100% is suggests for plain concrete structures like concrete wall, compound wall, etc. And the same replacement can be used for floor slabs, flooring works, and as a mortar for plastering. And coming to the flexural strength of concrete it shows the same results up to M4 mix. And the deviations of M5 & M6 mix from the conventional concrete are gradually increased which indicates that's the flexural strength is decreasing keep on increasing in replacement above 80%. So that this experimental study suggests that the replacement of cement shall be increased up to 60% to achieve the same strength of conventional concrete with reduction in cost.

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