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Study on Compressive Strength Properties of Concrete Using Aluminium Powder and Steel Fibers

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Abstract- *The purpose of this work is to investigate the compressive strength of concrete by including aluminium powder and steel fibres. For this reason, aluminium powder was used to partially replace the cement, and steel fibres were used to partially replace the coarse aggregates. The aluminium powder when comes in contact with the cement particles tend to react with the calcium hydroxide present in the cement to produce hydrogen gas which is responsible to give a cellular kind of matrix to the concrete making it light in weight as compared to the conventional concrete which is helpful in reduction of the dead load of the structure. On the other hand, the steel fibers provide resistance to cracking in the concrete improving its ability to withstand high impact loading improving the strength and durability of the concrete. The main objective of this work is to utilize the waste product in to the concrete to improve its engineering properties. Replacement of aluminium powder and steel fibers 1% and 0.5%, by weight of cement and coarse aggregate respectively. The result obtained shows that the aluminium powder and the steel fibres improve the workability and the compressive strength of the concrete.*

Keywords: *aluminium powder, steel fiber, lightweight concrete*

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I. INTRODUCTION:

With the increase in construction activities, the focus of engineers has shifted to the use of light-weight and sustainable construction structures and hence various attempts are being made to develop low density and light-weight concrete with the use of various waste materials. Lightweight concrete is developed by induction of an expansive agent which increases the volume of the mixture as well as provides improved mechanical and durability properties, while making the concrete light-weight, thereby decreasing the dead load on the structure [1-3]. Light-weight concrete was first used by Romans for the construction of “The Pantheons”, using pumice stone. Since then, it has been widely used in various structures in countries like USA, UK, Europe etc [4]. Light-weight concrete has various advantages over conventional structures such as reduced dead load, faster construction, improved mechanical and durability properties, high thermal conductivity etc [2-6]. To achieve the lightweight in the structure mostly the aggregates are replaced with light-weight aggregates such as pumice stone, clay pebbles, light-weight expanded clay aggregates (LECA) etc [7-8]. In addition to this light-weight can also be achieved with the use of expansive agents like aluminium powder, hydraulic cements, calcium sulfoaluminate etc [9]. Out of which aluminium powder is most widely used in the concrete due to its easy availability [10].

Aluminium powder has been extensively used in concrete to produce a cellular concrete and auto-clave aerated concrete by generating a chemical action in the mortar which leads to the formation of large number of gas bubbles [10-12]. It has proven to be the best solution as a foaming agent in the autoclave aerated concrete. The aluminium powder is available in the market in three varieties: atomized, flake and granules. For the production of light-weight concrete generally the aluminium powder made from foil scrap in the form of microscopic granules with the size less than 100micrometer- 1 nanometre is generally used [10-13]. Many researchers have found that the concrete with aluminium powder has lower density (800-2000kg/m3) as compared to conventional concrete. However, aluminium powder tends to decrease the compressive strength and modulus of elasticity of the concrete of the concrete by making it more brittle and leading to the development of more cracks on the concrete surface [14]. For the purpose of filling up the gaps stated above, steel fibres have increasingly been employed in conjunction with aluminium powder in recent years [15]. In concrete, the steel fibres are isotropic components that act as a crack arrester, resulting in an increase in the mechanical strength, ductility, and longevity of the concrete mix. There have been several studies conducted that have discovered that the addition of steel fibres to lightweight concrete often enhances the tensile and compressive strength of the concrete [16-18]. Balendran et al. [19] investigated the influence of steel fibres on the compressive strength, flexural strength, and modulus of elasticity of lightweight concrete with aluminium powder and steel fibres and compared the results with conventional concrete. They concluded that the density of the concrete could be reduced by 30 percent by incorporating aluminium powder into the concrete mixture. Aside from that, the introduction of steel fibres in the concrete raised the compressive strength of the concrete from 91MPa to 115MPa, which is a significant improvement. Moreover, they observed an increase in the flexural strength of the concrete, indicating that steel fibres and aluminium powder may be employed in the concrete to generate a lightweight and high-strength concrete mix. Specifically, the purpose of this work is to investigate the impact of aluminium powder and steel fibre on the compressive strength of concrete when used as substitutes for cement and coarse aggregates, respectively, in concrete. In order to achieve this, a concrete mix design was devised that included the use of aluminium powder as a 1 percent substitute for cement and steel fibres as a 0.5 percent replacement for coarse aggregate in concrete. The slump and compressive strength of the concrete were tested after seven, fourteen, and twenty-eight days.

II. MATERIALS AND METHODS

A. *Materials*

Cement: The cement employed in this investigation was Ordinary Portland Cement (OPC) 53 grade, which had standard strengths at 3, 7, and 28 days that were larger than 27, 33, and 53 MPa, respectively. The specific gravity of cement was found to be 3.06, and the soundness of the cement was found to be 0.5mm. The fineness of the cement was found to be 2300 cm2/gm, which is rather high. The consistency of the cement, as well as the beginning setting time and the ultimate setting time, were all found to be 30 percent, 30 minutes, and 486 minutes, respectively. In accordance with IS 12269: 1987 and IS 4031: 1968, all of the measurements were within the required limits.

Fine Aggregate: River Sand (4.75mm-0.015mm) with a specific gravity of 2.65 was utilised in the proportioning of the concrete mix, which had a specific gravity of 2.65. According to IS 2386(Part III):1963, the loose bulk density of the sand was detected to be 1.55 grammes per cubic centimetre of volume, and the moisture content was discovered to be 0.1 percent. Table 1 shows the results of the sieve analysis as well as the fineness modulus of the river sand.

Coarse aggregate**:** The coarse aggregate used in the concrete mix was basalt boulders (20mm and 10mm in size) with a specific gravity of 2.65, which were employed in the proportioning of the concrete mix. According to IS 2386(Part III):1963, the loose bulk density of the sand was detected to be 1.55 grammes per cubic centimetre of volume, and the moisture content was discovered to be 0.1 percent. Table 2 shows the results of the sieve analysis as well as the fineness modulus of the river sand.

Aluminum Powder (Aluminum Oxide): The aluminium powder utilised in this investigation had a particle size of 125 microns and a purity of 99.7 percent. It was divided into two groups: 0.5 percent and 1 percent. Table-3 shows the consistency, initial setting time, and final setting time of aluminium powder as a partial substitute for cement (0.5 percent and 1 percent), as determined by the experiments. Steel fibre: Steel fibre was used as a partial replacement for cement. Aspect ratio of 64 was employed in this investigation to create the steel fibre material. The supplier said that the density of steel fibre obtained was 7,800 kg/m3.

Water: For this investigation, portable water in accordance with IS456:2000 was utilised.

B. *Mix proportion*

The mix design for M-25 grade concrete was completed in accordance with IS 10262:2009. For the purposes of this investigation, two different mix proportions were created. One was a normal mix, and the other was made by substituting cement with 1 percent aluminium powder and coarse aggregate with 0.5 percent steel fibres by weight, respectively, in place of cement and coarse aggregate. It was decided to keep the weight-to-content ratio same (0.5) for both combinations. Table-4 depicts the final mix proportion that was produced.

TABLE I:
SIEVE ANALYSIS OF RIVER SAND

Sieve Size	Weight retained (grams)	Cumulative weight retained (grams)	% Cumulative weight retained	% Passing through
4.75mm	7	7	0.35	99.65
2.36mm	21	28	1.4	98.60
1.18mm	140	168	8.4	91.60
600µ	332	500	25	75.00
300µ	1110	1610	80.50	19.50
150µ	250	1860	93.00	7.00
<150µ	140	2000	208.65	
Fineness Modulus				=2.086

TABLE II
SIEVE ANALYSIS OF COARSE AGGREGATE

Sieve Size	Weight retained (grams)	Total weight retained (grams)	% cumulative weight retained	% Passing through
80mm	0	0	0	100
40mm	0	0	0	100
20mm	0	0	0	100
10mm	3.207	3207	64.14	35.86
4.75mm	1707	4914	98.28	1.72
2.36mm	25	4939	98.78	1.22
1.18	5	4944	98.88	1.12
600µ	0	4944	98.88	1.12
300µ	0	4944	98.88	1.12
150µ	0	4944	98.88	1.12
<150µ	56		98.88	1.12
	5000		656.72	
Fineness Modulus			=656.72/100	= 6.567

TABLE III
CONSISTENCY AND SETTING TIME OF ALUMINIUM POWDER AS A PARTIAL REPLACEMENT TO CEMENT

%Age of cement replaced by aluminum	Normal Consistency (%age)	Initial Setting time (Min.)	Final Setting time (Min.)
0.5	35.00	30	586
1	34.00	30	570

TABLE IV
MIX PROPORTION FOR M-25 GRADE OF CONCRETE

Mix Proportion	Mix-1	Mix-2
Cement	19.5kg	19.25kg
River Sand	20.25kg	20.25kg
Coarse Aggregate	40.2kg	40.1kg
w/c ratio	0.5	0.5
Water content	8.66lit	8.66lit
Aluminium powder	-	1kg
Steel Fibers	-	0.4kg

C. Testing Procedure

The fresh qualities of the concrete mixes, as well as their density and compressive strength, were evaluated. The slump cone, in accordance with IS 516:1959), was used to evaluate the fresh qualities of the concrete mix. Using the IS 516:1959 standard, the compressive strength of the mixtures was determined. Compressive strength of the mix was tested using standard cubes of 150mm by 150mm by 150mm that were cast and then cured for 7, 14, and 28 days in the curing tank as indicated in Figure-1 before being subjected to the test. The results of the test are provided in Table 1. In order to acquire the findings, an average of three cube samples were examined for each test.

Figure-1: Curing Tank for the cube specimens

III. RESULTS AND DISCUSSION

A. Fresh Properties:

The slump test was conducted to check the fresh properties of the concrete. Very flowable and pumpable slump was obtained for the both the mixes. The slump as obtained for the mix-2 is as shown in Figure-2. Fibre generally tends to decrease the workability of the concrete by affecting its mobility and thus impacting the compaction processes, however in this case the workability of the concrete improved which was due to the presence of aluminium powder. Aluminium powder reacts with the cement particles making more water available and hence tend to improve the workability of the concrete. Sababar and colleagues [10] observed results that were similar to theirs. They found that increasing the proportion of aluminium powder in the concrete enhanced the slump of the concrete as well as the density of the concrete, making the concrete more pumpable, as stated by the researchers. Maaze et al [11] reported that the aluminium powder produces heat when in contact with the water which travels to the surface of the concrete thus improving the slump of the concrete.

Figure-2: Slump of mix-2 with aluminium powder and steel fibers

B. Compressive Strength:

Table 5 depicts the relationship between the compressive strength of the concrete and the presence of steel fibre and aluminium powder. It can be seen in the table that the inclusion of steel fibres and aluminium powder increased the compressive strength of the concrete. In the 14-day and 28-day tests, an improvement in compressive strength of almost 6.36 percent and 8.23 percent, respectively, was found by substituting 1 percent of the cement with aluminium powder and 0.5 percent of the coarse aggregate with steel fibres, respectively. The addition of steel fibres to the concrete has resulted in a significant improvement in the compressive strength of the concrete. Gao et al. [20] obtained results that were similar to these. They hypothesised that the insertion of steel fibre into concrete would result in an improvement in ultimate compressive strength by slowing the progression of fractures and improving the bonding between the mortar and the steel fibres. According to Maaze et al. [11], the use of aluminium powder causes the concrete to expand due to the heat generated by it, causing water to collect on the surface of the concrete. This causes the slump of the concrete to increase, but it also causes the concrete to become weak, resulting in a reduction in the compressive strength of the concrete. Even though aluminium powder was present in the concrete, its compressive strength did not decrease as a result of the presence of steel fibres in the concrete, which was a surprise to the researchers. However, the steel fibre gives the material its compositeness, which increases the compressive strength of the concrete [12]. The aluminium powder has a tendency to reduce the density of the concrete. From this study it can be noted that the combination of steel fiber with aluminium powder in the concrete helps to improve the workability and the compressive strength of the concrete in addition to reducing the dead load of the concrete.

TABLE V
AVERAGE COMPRESSIVE STRENGTH OF THE CONCRETE

Mix Proportion	Average Compressive Strength in MPa at		
	7 days	14 days	28 days
Mix-1	18	22	26
Mix-2	18.36	23.40	28.14

IV. CONCLUSION

According to the findings of the study, the inclusion of steel fibres and aluminium powder in concrete can assist to improve the pumpability and compressive strength of the concrete. At 14 and 28 days, an increase in compressive strength of nearly 6.36 percent and 8.23 percent was observed, respectively, when 1 percent cement was replaced with aluminium powder and 0.5 percent coarse aggregate with steel fibres, indicating that they can be successfully used as replacements for cement and coarse aggregate, respectively, in concrete, resulting in concrete that is lighter in weight, more workable, and with improved mechanical strength.

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