THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Green Concrete for Green Building

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Abstract:
Concrete mixture can be made clean, green and economic. This research intends to find out the effect on the strength and economy of concrete as a result of substituting cement and sand with fly ash and bottom ash respectively. Fly-ash and bottom ash are waste of thermal power plant and they are hazardous to environment but they can be utilized in concrete mixture for construction. Fly ash's role in concrete is as a substitute for cement because of its pozzolanic properties thus reducing the cost of concrete. Bottom ash has specific gravity less than sand so, its replacement results in reduction of concrete's weight. In this study, detailed experimental investigation is done to study the effect of partial replacement of cement with fly ash and fine aggregate with bottom ash for the mix design of M20 grade concrete. Components were replaced by 5% weights of cement and fine aggregate and continued by incrementing one percentage point till 30%. Destructive test were carried out on hardened concrete cubes. The samples were cured for 7days, 14days and 28 days by ponding method and tested by universal testing machine. The replacement of these components in concrete has improved the workability of concrete. The strength of the concrete cubes also increased up to a certain percentage replacement and then decreased gradually. The research model may be replicated in construction industries to save cost, reduce concrete weight and make concrete green by saving natural resources.

Keywords: *economic, strength, partial replacement, workability*

1. Introduction

Concrete accounts for a bulk of construction material. A building can be made green from the first phase by using eco-friendly construction materials. A detailed experimental investigation is done to study the effect of partial replacement of cement with fly ash and fine aggregate with bottom ash for the mix design of concrete grade M20. Components were replaced by 5% weights of cement and fine aggregate and continued by incrementing one percentage point till 30%. The slump tests are performed at each percentage replacement to find the workability of the concrete mix. The tests on hardened concrete are destructive test done using Universal Testing Machine cube for size (150 x 150 x 150) mm. The concrete samples are to be cured for 7days, 14days and 28 days in ponding method to arrive at the compressive strength testing process. Partial replacement of the concrete components has resulted in a concrete that is economic, increases the workability to desired limits and enhances strength of concrete.

G	G_s (cm^2/gm)	Retained on 0.09 mm sieve (%)	Retained on 0.032 mm sieve (%)
3.13	3670	0.70	18.2

Table 1(a): Physical properties (cement) from company.
G: Specific gravity;
G_s: Specific surface area;

Normal Consistency (%)	Initial setting time (min.)	Final setting time (min.)
32	40	-

Table 1(b): Physical properties (cement) from laboratory test

2. Chemical Properties

Chemical composition of OPC generally suggests the possible applications. Loss on ignition is generally equal to the carbon content. The probable range of chemical composition of the cement is presented in the table.

Chemical composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	SO_4	LOI
OPC	18.62%	4.75%	3.02%	61.42%	3.21%	1.51%	1.42%	2.29%	3.55%

Table 2: Chemical properties (cement) from company
LOI: Loss on ignition.

2.1. Fine Aggregate

The gradation of the fine aggregate was done as per the IS 383-1970, Table 4. The sand was found to be from zone III. The specific gravity of the sand was found to be 2.65.

2.2. Coarse Aggregate

The coarse aggregate used were of good quality which is obtain from the crushing quarry in different sizes. The various tests were performed to determine the quality of the aggregate for the study.

The gradation of the coarse aggregate is done for both 20mm and 10mm individually. The gradation of the aggregate were done as per IS 383-1970. The impact value of the aggregate was found to be 24.33%

2.3. Flyash and Bottom ash

The physical and chemical properties of the fly ash and bottom ash were referred from the factory data.

3. Experimental Works

3.1. Sample Preparation and Curing

In this test sample, concrete is prepared as per the target strength of M20 with the mixture ratio of 1:1.5:3 of cement, fine aggregate and course aggregate respectively with the required component replacement and it is filled in the mould of size 15cm x 15cm x 15cm where top of mould is strike off. A total number of eighteen cubes are casted so that six numbers of cubes can be tested for different percentage replacement for 7^{th} day, 14^{th} day and 28^{th} day compressive strength. Fly ash is added in place of cement and bottom ash is added in place of fine aggregate in concrete in different percentages and kept for 24 hours. The sample is then removed from the mould and kept inside the water tank for curing till its required day for testing. At the end of curing period sample is removed from the curing tank and it is dried for removing the surface water. Then the cubes are tested immediately and the results of cube strength are noted. The testing is done using Universal Testing Machine.

3.2. Slump Test

This test is performed to check the workability of the concrete in a laboratory or construction site. It is instant and economic process. Slump cone mould in the form of frustum of a cone of height 300mm, bottom diameter 200mm, top diameter 100mm is fixed on a platform. The inner surfaces are properly greased and then concrete is gauged in three different layers by tamping each layer for 25 times with a tamping rod 16mm in diameter, 600mm long and rounded head at one end. After striking off the top of the cone, the cone is lifted gently and the deduction in height of concrete is measured which gives the slump value.

3.2.1. Observation Table for Slump Test.

The value of the slump test was noted for each mixture and the result is given below.

Sl. no	Percentage replacement (%)	Water cement ratio	Slump value(mm)
1	0	0.5	96
2	6	0.5	105
3	9	0.5	100
4	12	0.5	110
5	15	0.5	125
6	18	0.5	130
7	21	0.5	125
8	24	0.5	120
9	27	0.5	115
11	30	0.5	110

Table 3: Slump test

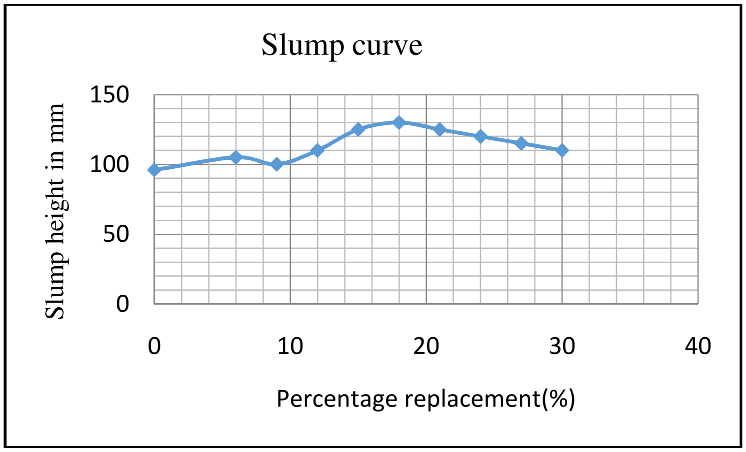

Figure 1: Graph for slump

3.3. Compressive Strength

The compressive strength of 7th day, 14th day and 28th day cubes for different percentage of replacement of components are represented with the help of table and graph. It is observed that the compressive strength of the cubes increases from 7th to 28th days up to a certain limit of percentage replacement and then it decreases below the standard value as follows.

The average compressive strength of the cubes of each 7th day, 14th day and 28th day are tabulated in the table below.

Percentage replacement (%)	7th Day (N/mm^2)	14th Day (N/mm^2)	28th Day h(N/mm^2)
0	9.81	14.35	20.11
5	10.06	14.47	18.39
6	10.06	14.59	19.01
7	10.3	14.72	19.87
8	10.67	14.96	20.97
9	10.79	15.21	21.58
10	10.91	15.45	22.07
11	11.04	15.7	22.44
12	11.16	15.94	22.81
13	11.28	16.19	22.81
14	11.53	16.31	22.93
15	11.77	16.43	23.3
16	11.89	16.68	23.3
17	12.02	16.8	23.67
18	12.26	17.04	24.03
19	12.02	16.8	23.3
20	11.89	16.55	22.44
21	11.53	16.43	21.21
22	11.16	16.19	20.97
23	11.04	15.94	20.85
24	10.79	15.7	20.11
25	10.55	15.45	19.37
26	10.3	15.21	18.76
27	10.06	14.72	18.52
28	9.81	14.47	17.41
29	9.81	14.22	16.55
30	9.81	13.98	15.7

Table 4: compressive strength

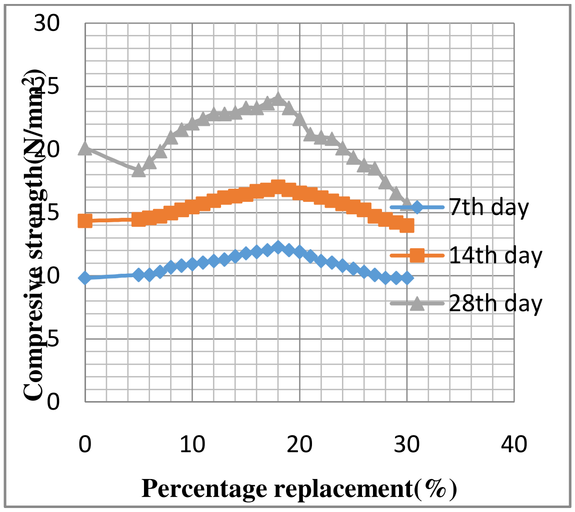

Figure 2: Graph for compressive strength

The compressive strength and the slump value of the concrete were found to be higher than the value required for nominal M20 grade of concrete. So the use of fly ash and bottom ash in concrete proved to be effective.

3.4. Cost vs. Strength of the Concrete

The cost per strength of the concrete is computed to know the cost effective production of the concrete. The cost of the concrete is computed by considering the cost of the materials at source and the transportation charges. The cost of labour are also included as they are important and different for varying location. The strength of the concrete for the computation was taken for each percentage replacement and the cost of production was taken per unit volume of concrete. The details are presented in table 5

The cost of the concrete was found to be reducing with increase in the strength of the concrete for certain percentage replacement. The economic achievement of the concrete production was studied and found that cost effective concrete can be produce at 18% replacement of the flyash and bottom ash. The same can be observed from the graph in figure 3

Replacement by %	Total cost per cum (Rs)	28th day strength(N/mm^2)	% Cost reduced
0	6784.98	20.11	0.00
5	6627.32	18.39	2.32
6	6595.78	19.01	2.79
7	6564.25	19.87	3.25
8	6532.72	20.97	3.72
9	6501.18	21.58	4.18
10	6469.65	22.07	4.65
11	6438.11	22.44	5.11
12	6406.58	22.81	5.58
13	6375.05	22.81	6.04
14	6343.51	22.93	6.51
15	6311.98	23.3	6.97
16	6280.45	23.3	7.44
17	6248.91	23.67	7.90
18	6217.38	24.03	8.37
19	6185.85	23.3	8.83
20	6154.31	22.44	9.30
21	6122.78	21.21	9.76
22	6091.25	20.97	10.22
23	6059.71	20.85	10.69
24	6028.18	20.11	11.15
25	5996.64	19.37	11.62
26	5965.11	18.76	12.08
27	5933.58	18.52	12.55
28	5902.04	17.41	13.01
29	5870.51	16.55	13.48
30	5838.98	15.7	13.94

Table 5: Cost versus strength

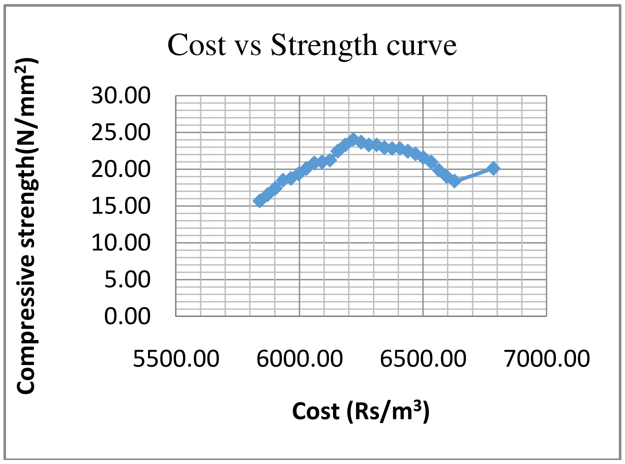

Figure 3: Graph of cost versus strength

The strength has increased to the limits of 20% compared to the conventional M20 grade of concrete. The partial replacement of 18% is found to be optimum from economy as well as strength. The detail of the comparison is shown in the table below.

Percentage replacement (%)	28th day strength (N/mm^2)	Strength achieved (N/mm2)	Percentage strength achieved (%)
0.00	20.11	0.00	0.00
5.00	18.39	-1.72	-8.54
6.00	19.01	-1.10	-5.49
7.00	19.87	-0.25	-1.22
8.00	20.97	0.86	4.27
9.00	21.58	1.47	7.32
10.00	22.07	1.96	9.76
11.00	22.44	2.33	11.59
12.00	22.81	2.70	13.41
13.00	22.81	2.70	13.41
14.00	22.93	2.82	14.02
15.00	23.30	3.19	15.85
16.00	23.30	3.19	15.85
17.00	23.67	3.56	17.68
18.00	24.03	3.92	19.51
19.00	23.30	3.19	15.85
20.00	22.44	2.33	11.59
21.00	21.21	1.10	5.49
22.00	20.97	0.86	4.27
23.00	20.85	0.74	3.66
24.00	20.11	0.00	0.00
25.00	19.37	-0.74	-3.66
26.00	18.76	-1.35	-6.71
27.00	18.52	-1.59	-7.93
28.00	17.41	-2.70	-13.41
29.00	16.55	-3.56	-17.68
30.00	15.70	-4.41	-21.95

Table 6: Percentage of strength achieved

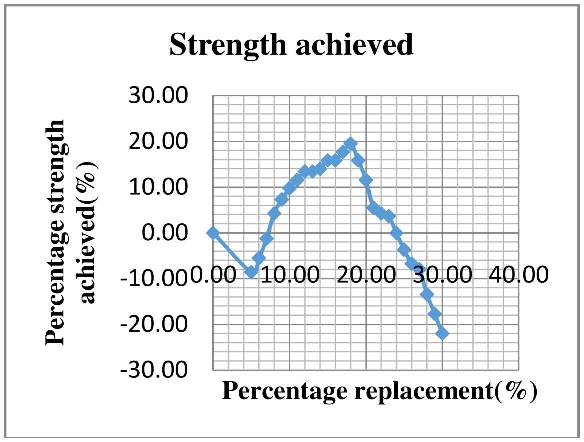

Figure 4: Graph of strength achieved

4. Result

4.1. Workability

Spherical shape of fly ash helps to reduce the water requirement for a given slump by reducing the friction between particles resulting in increased workability. Bleeding can be reduced by the use of fly ash and bottom ash due to its increased fines volume. Slump value of 96 mm was obtained with no replacement by keeping water/cement ratio as 0.5 and keeps gradually increasing. A maximum slump of 130 mm was achieved at 18 % replacement of the components with constant water/cement ratio of 0.5. The workability can be decreased to desired limits by decreasing the water/cement ratio.

4.2. Strength Development

The strength development of the concrete was gradual and un satisfactory for the 7^{th} day test but there was good strength development for 14^{th} and 28^{th} day test when the percentage replacement of the fly ash and bottom ash were increased for certain limit. The strength increment was observed till around 20 % replacement of the fly ash and bottom ash to the concrete produced. From the graph for strength versus number of days, it is clear that the strength of the concrete can be improved till certain limit as around 20% replacement. Initially the strength developed is below the strength developed for zero percentage replacement, but as the concrete gets mature, the strength of the concrete increased drastically.

4.3. Strength versus Cost of Concrete

From this study it has been observed that the cost of the concrete can be reduced to certain limit depending on the following:
Location: When the location of the site is near the location of the available materials of concrete like cement, aggregate and by product of thermal plant, the cost of producing the concrete is low without affecting its strength.

4.4. Amount of the Concrete Produce

Cheaper concrete can be produce when the amount of production of concrete is huge. If the amount of concrete production is small in quantity then the by-product replacement will not affect the cost reduction by much as that of normal concrete. The result can be verified from the cost analysis table.

4.5. Percentage Replacement

The cost of production of the concrete can be reduced by replacing the cement and fine aggregate with thermal plant by-product in till 18% percentage without the strength being compromised.

4.6. Quality of Materials

The quality of materials also plays an important role in strength development of the concrete. If the quality of the materials is not good, the strength of the concrete will be affected which will increase the cost of production as the concrete will be unfit for the construction and new concrete mix has to be made.

5. Conclusion

There is reasonable gain of compressive strength for certain percentage replacement of the fly ash and bottom ash. The present study shows the gain of strength of 20% at 18% replacement in comparison to zero percent replacement. On further increment of the replacement, the strength decreases from its maximum value, but giving the strength above the nominal strength till 24% replacement. Therefore, use of fly ash and bottom ash in the concrete increase the strength of concrete above the nominal value

The slump value of the concrete were increased to certain limit when the cement and fine aggregates were replaced with fly ash and bottom ash respectively in a given proportion of the concrete mixture. For the fixed water cement ratio of 50%, the slump value increased from 96mm for zero percent replacement to maximum of 130mm at 18% replacement and then decreased to 110mm at 30% replacement. So use of fly ash and bottom ash increase the workability.

The overall cost of the concrete can be reduced by use of fly ash and bottom ash in concrete. Nearly 12% of the cost of the concrete can be reduced by using fly ash as replacement of cement and bottom ash as replacement of fine aggregate.

This research can be further validated and can be implemented to large scale construction firms to change the face of construction.

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