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PERFORMANCE OF CONCRETE BY REPLACING COARSE AGGREGETE AND FINE AGGREGATE WITH BLAST FURNACE SLAG AND CRUSHER DUST

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Abstract: The basic objective of this study was to identify alternative source of good quality aggregates which is depleting very fast due to the fast pace of construction activities in India. Use of slag a waste industrial by-product of iron and steel production provides great opportunity to utilize as an alternative to normally available aggregates. The present Investigation has been undertaken to study the effect of blast furnace slag and crusher dust on the mechanical properties of concrete, when coarse aggregates is replaced by blast furnace slag and crusher dust is replaced with fine aggregate in different percentages i.e. 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%. The main parameters investigated were cube compressive strength, split tensile strength and flexural strength. The tests were conducted on concrete with ratio 1:1.86:3.77.In this work, M20 grade concrete mix was developed using IS method of mix design. Specimens of dimensions of 150 x 300mm cylinders for split tensile strength and 100 x 100 x 500mm prisms for flexure strength and 150 x 150 x 150mm cubes were cast for compressive strength of concrete specimens. The test results indicate that with the use of blast furnace slag by fully replacing coarse aggregates and fully replacing crusher dust by fine aggregates in different percentages i.e. 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%,. For evaluation of strength parameters each grade of concrete for each proportion in the form of cubes, cylinders and prisms were casted for testing at 7 days and 28 days periods. The compressive strength, split tensile strength and flexural strength increases with the increase in percentage of blast furnace slag and crusher dust up to 30%.

Keywords: Concrete, partial replacement, Blast furnace slag, crusher dust, compressive strength

I. INTRODUCTION

Concrete is a widely used material in the world. Based on global usage it is placed at second position after water. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. Whose continued use has started posing serious problems with respect to its availability, cost and environmental impact. In such a situation the crusher dust can be an economic alternative to the river sand. Crusher Dust can be defined as residue, tailing or other non-voluble waste material after the extraction and processing of rocks to form fine particles less than 4.75mm. Usually, Crusher Dust is used in large scale in the highways as a surface finishing material and also used for manufacturing of hollow blocks and lightweight concrete prefabricated Elements. Use of Crusher dust as a fine aggregate in concrete draws serious attention of researchers and investigators. Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. Over a period of time, waste management has become one of the most complex and challenging problem in the world which is affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste by products which are environmentally hazard and creates problems of storage. Always, construction industry has been at forefront in consuming these waste products in large quantities. Blast furnace slag is a non-metallic material consisting of silicates and aluminosilicate of calcium and magnesium together with other compounds of sulphur, iron, manganese, and other trace elements. The utilization will also reduce the strain on supply of natural fine aggregate, which will also reduce the cost of concrete. Rapid urbanization in developing countries such as India is creating a shortage of adequate housing in cities. Using artificial aggregates for quality concrete is a natural step to mitigating this problem. The world wide consumption of fine aggregate in concrete production is very high, and several developing countries have encountered difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasing needs of infrastructural development in recent years. To overcome the stress and demand for river fine aggregate, researchers and practitioners in the construction industries have identified some alternative materials such as fly ash, slag, limestone powder and siliceous stone powder. In India attempts have been made to replace river sand with crusher dust.Blast furnace slag is a non-metallic material consisting of silicates and alumina-silicates of calcium and magnesium together with other compounds of sulphur, iron, manganese, and other trace elements. It is produced from a molten state simultaneously with pig iron in a blast furnace. The solidified product is further classified according to the process by which it was brought from the molten state. Blast furnace slag (BFS) is produced through relatively slow solidification of molten blast furnace slag under atmospheric conditions, resulting in crystalline mineral formation. BFS is one of the most commonly utilized reclaimed construction materials, being used as coarse aggregate in Portland Cement Concrete (PCC) (also referred to simply as concrete in this report), aggregate in hot-mix asphalt, road base material, and fill. According to the U.S. Geological Survey (USGS) 2009 Minerals Yearbook (van Oss 2009), approximately 5.071 million tons (4.6 million metric tons) of BFS were used in the United States in 2009, having a value of about $33 million. This number is down from 7.606 million tons (6.9 million metric tons) of Blast Furnace Slag produced in 2008, having a value of about $53 million, reflecting the dramatic downturn in the U.S. economy. The successful utilization of crusher dust as fine aggregate and blast furnace slag as coarse aggregate would turn this waste materials that causes disposal problem into a valuable resource. The utilization will also reduce the strain on supply of natural fine aggregate, which will also reduce the cost of concrete. The main objective of the present investigation is to evaluate the possibilities of using crusher dust as a replacement to fine aggregate and blast furnace slag as a replacement to coarse aggregate. Present investigation aimed at to study, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of traditional fine aggregate was replaced with quarry dust and coarse aggregate was replaced with Blast furnace slag. Compressive strength, split tensile strength and flexural strengths were found after 7 days and 28 days of curing.

II. METHODOLOGY

In this study, concrete of M20 grade is considered for a W/C ratio is 0.50 with the targeted slump of 100±25 for the replacement of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 % of replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust. The Compressive Strength, Split Tensile Strength and Flexural Strength of concrete specimens are obtaining by replacing the blast furnace slag with coarse aggregates and crusher dust replaced with fine aggregates by varying percentage (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100%) after 7 days and 28 days. To evaluate the strength characteristics in terms of compressive strength, split tensile strength and flexural strengths were tried with different percentages of both blast furnace slag and crusher dust (0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% 90% & 100%).

The parameters studies were:

In M20 design mix, the percentage of crusher dust replaced by fine aggregate and blast furnace slag replaced by coarse aggregate in proportions of 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% 90% & 100%.

6 Cubes of size 150 x 150 x 150 mm and 6 cylinders of 150 mm diameter & 300 mm height and 6 flexural beams of size 500 x 100 x 100 mm were cast and tested for each percentage of replacement.

A. Material used

Cement:

Ordinary Portland Cement (53 grade) with specific gravity of 3.13 was used for this experimental investigation.

Coarse aggregate:

Natural granite aggregate having density of 1500 kg/m3 and fineness modulus (FM) of 6.65 was used. The specific gravity was found to be 2.78 and maximum size of aggregate was 20mm.

Fine aggregate (Natural river sand):

Locally available river sand having density of 1550 kg/m3 and fineness modulus (FM) of 2.55 was used. The specific gravity was found to be 2.67 the fine aggregate was found to be confirming to zone – II as per IS 383:1970. Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.

Blast Furnace Slag:

Blast furnace slag is a nonmetallic material consisting of silicates and aluminosilicates of calcium and magnesium together with other compounds of sulfur, iron, manganese, and other trace elements. It is produced from a molten state simultaneously with pig iron in a blast furnace. The solidified product is further classified according to the process by which it was brought from the molten state. Fineness modulus (FM) of 2.93 was used. The specific gravity was found to be 3.18.

Crusher Dust

Crusher Dust is very fine and is sometimes called tailings. It is used mostly for walkways as it is very easy to walk on. Bike trails and paths are usually finished with crusher dust. It can also be used as the final layer between crusher run and the top pavers or patio stones. Crusher dust is fine rock particles. When boulders are broken into the small pieces crusher dust is formed. It is gray in color and it is like fine aggregate.

Water

Potable fresh water, which is free from concentration of acid or organic substances, was used for mixing the concrete. Concrete specimens were casted using 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of replacement fine aggregate with crusher dust and coarse aggregate with blast furnace slag.

Number of specimens required for the experiment:

No of cubes casted for compression test is 66

No of cylinders casted for split tensile strength is 66

No of prisms casted for flexure strength is 66

B. TESTS CONDUCTED ON CEMENT

Specific Gravity Test: According to IS 2720 – part – 3

Specific gravity is the ratio of the density of a substance compared to the density (mass of the same unit volume) of a reference substance. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always water for liquids or air for gases.

Fineness Test: According to IS 4031-1968

Fineness is defined as the surface area of cement particles per unit weight, means more number of particles per unit weight. If the percentage of fineness is more than 90 % the cement is supposed to be fresh, if it is less than 90 % than that Cement should be avoided to use.

Standard consistency Test: According to IS 4031 (Part 4) 1988

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger to penetrate to a depth of 5 to 7mm from the bottom of the vicat mould.

Initial Setting and Final Testing Time Test

According to IS 4031 (Part 5) 1988 The time period elapsed between the time of adding water to the cement to the time when the needle fails to pierce the mould for 5 + 0.5mm. The time period elapsed between the time of adding water to the cement to the time when the annular ring fails to make the impression on the mould is called the final setting time.

Compressive Strength of Cement: According to IS 8112-1989

Compressive strength of cement is determined from mortar cubes of size 7.07 X 7.07 X 7.07c.m and cement to sand ratio 1:3. The strength is obtained for 3,7,28 days. The strength obtained on 28th day is called compressive strength of cement.

C. TESTS CONDUCTED ON COARSE AGGREGATE

Water Absorption of coarse aggregate

(IS: 2386- PART- 3).Water absorption gives an idea of strength of aggregate. Aggregates having more water absorption are more porous in nature and are generally considered unsuitable unless they are found to be acceptable based on strength, impact and hardness tests.

Specific Gravity

(IS: 2386- PART- 3).The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. The specific gravity test helps in the identification of stone.

Sieve Analysis

(IS: 383- 1970) A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common method.

Crushing Value

(IS: 2386 -PART- 4) the aggregate crushing value provides a relative measure of resistance to crushing under a gradually applied compressive load. To achieve a high quality of concrete, aggregate possessing low aggregate crushing value should be preferred. The aggregate crushing value gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load . With aggregate crushing value 30 or higher' the result may be anomalous and in such cases the ten percent fines value should be determined instead.

Fineness modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation. It is an empirical number relating to the fineness of the aggregate. The higher the FM is, the coarser the aggregate.

D. TESTS CONDUCTED ON FINE AGGREGATE

Sieve Analysis

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the particle size distribution (also called gradation) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

Fineness modulus

Fineness Modulus (FM) is used in determining the degree of uniformity of the aggregate gradation. It is an empirical number relating to the fineness of the aggregate. The higher the FM is, the coarser the aggregate.

E. CASTING

According to IS 516-1959

The cubes were casted in steel moulds of having dimensions 150 x 150 x 150mm, the cylinders having dimensions of 150mm diameter and 300mm height and finally, the flexural beams were casted in 500 x 100 x 100 mm.

For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds in three layers simultaneously vibration was effected by table vibrator. The moulds were removed after twenty four hours and the specimens were kept immersed in clean water tank. After curing the specimens in water for a period of 7and 28 days the specimens were taken out and allowed drying under shade. Six cubes, six cylinders and six flexural beams were casted for each mix.

F. MIX DESIGN PROCEDURE

Test results of mix design

(a)Characteristic Comp. Strength required in the field at 28 days = 20 Mpa

(b)Max. size of aggregate= 20 mm

(c)Degree of workability (specified or not)= 50 –80 mm

(d)Type of exposure = Moderate

(e)Min. Cement (if specified) = 300kgs

Test data for materials:
(a)Cement Used =OPC 53Grade
(b)Specific Gravity of
1) Fine Aggregate = 2.58
2) Coarse Aggregate – 20mm = 2.81
Specific Gravity of Cement= 3.13
(a)Sand corresponds of Zone= Zone II
(b)The target mean strength is determined using following relation
$f_t = f_{ck} + (t * S)$
Where f_t = Target Mean Strength@ 28 days f_{ck}=Characteristic Compressive Strength @ 28 days t=A Statistical value depending upon the results and no. of tests.
S = Standard deviation shown from IS: 10262-2009
Assuming not more than 5% results are expected to fall below the characteristic compressive strength. In which cases the value of 't' is 1.65. Standard deviation for M20 Grade of concrete is 4.
f_t = 20 + (1.65*4) = 26.6 Mpa

- Target mean Strength of Concrete = 26.6 Mpa
- Selection of w/c ratio corresponding to the target mean Strength of 26.6 Mpa = 0.50(From Table 5 of IS 456, maximum water-cement ratio = 0.55)
- From Table-2 IS: 10262-2009 for nominal maximum size of aggregate 20mm, the maximum water content is 186 liters per cubic meter.
- From Table-3 IS: 10262-2009 Volume of coarse aggregate per unit volume of concrete for zone–II fine aggregate is 0.62.
- For change in value of w/c ratio the following adjustments are required according to IS: 10262-2009 in water content and percentage of sand in total aggregate.
- Selection of water and sand content water per cubic meter for 20mm maximum size aggregate and sand of zone II water content per cubic meter of concrete is 170 kg and sand content(as % of total aggregate) = 37%Therefore required Sand content as percentage of total aggregate by absolute
- Volume = 37- 2.00 =35%
- Determination of Cement content :

Water / Cement ratio = 0.50
Required Water content = 170 Lts /m³
Cement content = 340 Kgs
This Cement is adequate for moderate exposure condition.
e. Determination of Coarse and Fine Aggregate content:
For 20mm Maximum size of aggregate the amount of entrapped air in the fresh concrete is 2 percent.
0.98 = [170 + 340/3.13 + ((1/0.35) x Fa/2.58)] x 1/1000
Fa = 633.34 Kg/m³
0.98 = [170 + 340/3.13 + ((1/0.65) x Ca/2.81)] x 1/1000
Ca = 1282 Kg/m³
Mix proportion by weight:
Comp. Strength of Concrete Cubes at 7 days with the above proportions were
1)16.00MPa 2)16.50MPa 3)16.25MPa
Comp. Strength of Concrete Cubes at 28 days with the above proportions were
1)22.50MPa 2)22.60MPa 3)23.00MPa
Slump observed is 75mm. Hence the Mix Proportion of above trail is recommended.

III. EXPERMENTATION

Concrete specimens were casted using 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% of replacement fine aggregate with crusher dust and coarse aggregate with blast furnace slag.

Figure 3.1: compression test of cube


Figure 3.2: After testing the specimen


Figure 3.3: split tensile strength

Figure 3.4: flexural strength test

Figure 3.5: After testing the specimen.

Figure 3.6: Flexural Failure Pattern

IV. RESULTS AND DISCUSSION

The cubes were placed in the compression testing machine and the loads are applied gradually at a rate of 16.3 N/mm^2/min. The average value of the compression strength of three cubes was taken as the compression strength. The compressive strength of conventional concrete was found to be 27.63 N/mm^2

Table 4.1 Average Compressive Strength of Concrete with Crusher Dust and blast furnace slag.

%of replacement C.A with blast furnace slag and F.A with crusher dust	Average Compressive strength of the concrete at different ages(N/mm2)	
% of replacement	7days	28days
0	16.3	27.63
10	16.25	27.04
20	16.32	27.38
30	16.57	27.98
40	11.24	20.36
50	9.19	17.04
60	7.63	14.96
70	5.82	12.37
80	4.15	8.37
90	2.1	4.15
100	1.41	3.52

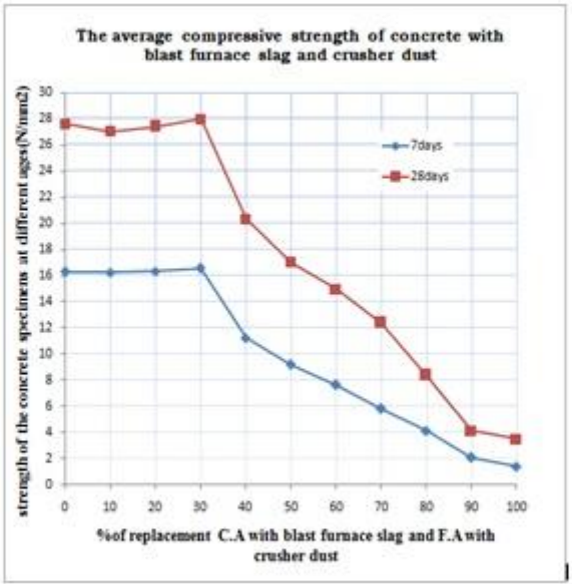


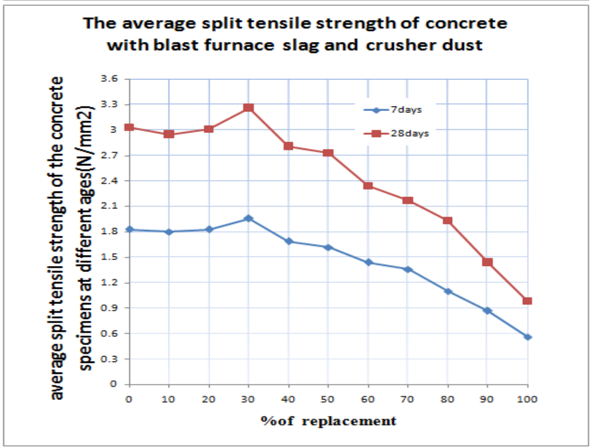
Figure 4.1 average compressive strength of concrete with blast furnace slag and crusher dust

From the table 4.1 and figure 4.1, it can be seen that at 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust there is no reduction in compressive strength

Three cylindrical specimens were tested for each percentage of replacement. The cylinders were placed in the machine horizontally. Load was applied gradually at a uniform rate until the specimens failed. Split tensile strength was taken as the average strength of three specimens. The split tensile strength of concrete with both crusher dust and blast furnace slag are given in Table 4.2 and figure 4.2.

Table 4.2 Average split tensile strength of Concrete with Crusher Dust and blast furnace slag.

%of replacement C.A with blast furnace slag and F.A with crusher dust	Average split tensile strength of the concrete at different ages(N/mm2)	
% of replacement	7days	28days
0	1.83	3.03
10	1.8	2.95
20	1.83	3.01
30	1.96	3.26
40	1.69	2.81
50	1.62	2.73
60	1.44	2.34
70	1.36	2.17
80	1.1	1.93
90	0.87	1.44
100	0.56	0.98



.Figure 4.2 average split tensile strength of concrete with blast furnace slag and crusher dust

From the table4.2 and figure4.2, it can be seen that at 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust that shown only marginal increase in split tensile strength.

Flexural strength was taken as the average strength of three specimens. The flexural strength of conventional concrete was found to be 5.61N/mm^2. The average flexural strength of concrete with crusher dust and blast furnace slag are given in Table 4.3 and figure 4.3.

Table 4.3 Average flexural strength of Concrete with Crusher Dust and blast furnace slag.

%of replacement C.A with blast furnace slag and F.A with crusher dust	Average Flexural strength of the concrete at different ages(N/mm2)	
% of replacement	7days	28days
0	2.96	5.61
10	2.89	5.6
20	2.92	5.66
30	3.02	5.68
40	2.96	5.49
50	2.81	5.45
60	2.55	5.19
70	2.5	5.01
80	2.21	4.38
90	2.09	3.98
100	1.88	3.67

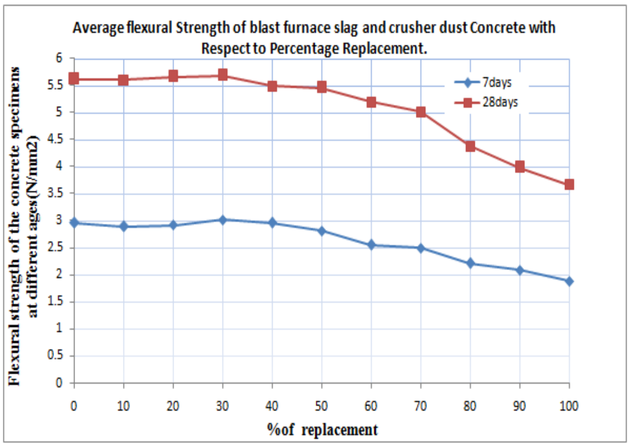


Figure 4.3 average flexural strength of concrete with blast furnace slag and crusher dust.

From the table and figure, it can be seen that similar to flexural strength only marginal increase was observed at 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust.

V. CONCLUSIONS

The physical properties of crusher dust and blast furnace slag are satisfying the requirements of fine aggregate and coarse aggregate. The cost of concrete made with blast furnace slag and crusher dust is less than conventional concrete because the crusher dust and blast furnace slag which were less cast.At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust there is no reduction in compressive strength and beyond 30% there is steep decrease in the compressive strength. At 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust that shown only marginal increase in split tensile strength was observed whereas beyond 30% replacement of coarse aggregate and fine aggregate there is a steep decrease in split tensile strength. Flexural strength is also similar to split tensile strength only marginal increase was observed at 30% replacement of coarse aggregate with blast furnace slag and fine aggregate with crusher dust. Based on this experimental investigation, it is found that crusher dust can be used as an alternative material to the natural river sand and blast furnace slag can be used as an alternative material to the coarse aggregate.

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