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RESEARCH ARTICLE

EFFECT OF WASTE WATER ON GROUND GRANULATED BLAST FURNACE SLAG BASED CONCRETE.

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Abstract

Water is a natural resource on which entire kingdom of flora and fauna depends. In recent decades depletion, wastage and pollution of this natural resource has been done on a large scale. Due to this, some areas had encountered with extreme drought conditions. This affects the construction industry and thus affects the economy of the country. Hence use of this water in efficient way has become a need. Thus Water in both form polluted and fresh water should be used to overcome the problem of water shortage.

The other problem is disposal of waste generated from the industries. The waste such as GGBS is generated from the steel industry. So use of this waste is also an important issues. In this paper comparative study has been made between, concrete casted by using waste water and tap water with GGBS in varying proportion as a replacement for cement.

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Introduction:-

Water being a natural resource is being polluted by domestic waste, industrial waste etc. Hence study of the pollutants available in the polluted water is also very important. On the other hand GGBS, which is a pozzalonic material having ingredients similar to that of ordinary portland cement, but in little variation. In this paper GGBS has been used as a partial replacement for cement in concrete (M35), and concrete has been casted by using waste water and tap water. And comparison has been made between its strength parameters and other properties of concrete.

Objectives of investigation:-

Experiments were conducted on concrete prepared by partial replacement of cement by GGBS, ranging from 10% to 50% with an increment of 10%. Thus replacing cement by GGBS concrete is casted by using tap water and waste water. The main objective of this investigation was to find out the effect of waste water on GGBS based concrete (i.ethe compressive strength, tensile strength and flexural strength) as well as to evaluate the possibility of using GGBS in concrete as a partial replacement for cement along waste water without sacrificing its strength.

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Following are the main objectives of the study:
1. To use GGBS as partial substitute for ordinary Portland cement along with waste water.
2. To determine the percentage of GGBS along with waste water which gives maximum strength when compared to the control mix concrete.
3. To study the effect of waste water on other properties of concrete such as its chemical properties of concrete.

Materials used:-

The material details are as follows:

Cement:-

Cement may be defined as binding substance capable of holding of solid matter together so as to act as a solid structure. The four major potential components are normally termed as tri-calcium silicate, Di-Calcium Silicate, Tri Calcium Aluminates and tetra calcium alumina ferrate.Cement used for the work was 53 grade (Birla) Ordinary Portland Cement confirming to IS 8112-1989.

Fine aggregate:-

Locally available sand from Mula River confirming to zone II with specific gravity 2.66 was used. All the test on fine aggregate was conducted as per Indian Standard Specification IS: 383-1970.

Coarse aggregate:-

Coarse aggregate used was 20 mm and less size having specific gravity 2.70. All the tests on coarse aggregate was conducted as per Indian Standard Specification IS: 383-1970.

GGBS:-

In this experiment GGBS is partially used as replacement for cement in M35 grade concrete. Chemical composition of GGBS is given as follows:

Table 1:- Physical Properties of GGBS.

Physical Property of GGBS	**Value**
Specific Gravity	2.43
Color	Off – White
pH	8.5

Table 2:- Chemical Properties of GGBS

Composition	**Percentage (%)**
CaO	30 – 50
SiO_2	28 – 38
Al_2O_3	8 – 24
MgO	1 – 18
Fe_2O_3	0.9 – 1.2

Water:-

Sample 1 - The water used was potable, colorless and odorless that is free from organic impurities of any type (Tap Water)

Sample 2 - The water used was waste water obtained from natural stream polluted due waste discharged into it.

Table 3:- Properties of Waste Water:

Property of Water	**Value**	
	Waste Water	**Tap Water**
Hardness	712 ppm	0.3 mg/lit.
Alkalinity	620 ppm	29 mg/lit
Chloride Content	157.27 ppm	0.7 mg/lit
Total Dissolved Solids	166 mg/lit.	82 mg/lit
Dissolved Solids	90 mg/lit.	35 mg/lit
Suspended Solids	56 mg/lit.	0.56 mg/lit

Volatile Solids	20 mg/lit.	-
BOD	52 mg/lit	0.9 mg/lit
COD	122 mg/lit	-
Sludge Volume Index	178.57	-
Sulphate Content	129 mg/lit	25 mg/lit
Fluoride Content	8.46 mg/lit	0.2 mg/lit

Experimental work and test:-

Mix Design:-

Mix designwas carried out for M35 grade of concrete by using IS 10262:2009, which resulted to a mix proportion of 1:1.52:2.04 with water cement ratio of 0.42. The replacement of cement by GGBS was 10% to 50% at an interval of 10% each, casted by using waste water and tap water.

Preparation of Test Specimens:-

Concrete mixture was done according to the mix design. The total mixing time was 10 minutes then the samples were casted and left for 24 hours. After that, samples were demoulded and placed in the curing tank 7 days and 28 days.

Table 4:- Specimens Dimensions.

Properties studied	**Specimen shape**	**Sizes of specimens (mm)**
Compressive strength	Cube	150×150×150
Flexural strength	Beams	100×100×500
Split tensile strength	Cylinders	150×300
Pull out Strength	Cube	150×150×150
Water absorption test	Cube	150×150×150

Results and Discussion:-

In this study, testswere conducted on harden concrete by using Compressive Testing Machine(CTM) of capacity 3000 KN and Universal Testing Machine (UTM) of capacity 600 KN as per IS 516:1959.

Compressive Strength Test results (IS 516:1959):-

According to IS: 516:1959, the cubes of size 150 mm x 150 mm x 150 mm were prepared for the compression test. According to IS: 10086-1982, this cubes were placed in machine in such a manner that the load is applied perpendicular to the surface . The rate of loading is uniform and failure (crushing) load is noted.

Table 6:- Experimental Test Results For Compressive Strength.

% replacement of cement by GGBS	**Compressive Strength in MPa (28 Days)**	
	Tap Water	**Waste Water**
0	41.28	-
10	43.87	45.77
20	50.43	55.63
30	53.54	44.58
40	50.711	43.23
50	37.19	35.76

It is clear from table 6, compressive strength for 30% replacement of GGBS casted using tap water showed good results as compared to conventional mix concrete. In case of Waste water 20% replacement showed better results.

Results of Spilt Tensile Strength Test:-

Split tensile strength of cylinder specimens is determined by placing between the two plates of Compression Testing Machine, Plywood strips of 3 mm thick, 25 mm wide and 300 mm long, were placed between the plates and surface of the concrete specimens.

According to IS: 5816:1999 for determining split tensile strength cylinder specimens of size 150 mm in diameter and 300 mm in are horizontally placed between the two plates of Compression Testing Machine. In these tests, compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses induced in the specimen.

It is clear from table 7 (given below), Split Tensile strength for concrete casted using tap water along with 40% replacement of cement by GGBS showed good value as compared to control concrete for 28 days. In case of waste water 20% replacement showed good values as compared to conventional concrete.

Table 7:- Experimental Test Results For Split Tensile Strength.

% Replacement of cement by GGBS	**Spilt Tensile Strength in MPa (28 Days)**	
	Tap Water	**Waste Water**
0	4.16	-
10	4.341	3.60
20	4.78	4.286
30	4.68	3.92
40	4.19	3.68
50	3.78	3.25

Results of Flexural Strength Test: (IS: 516:1959):-
Beams of size 100 mm X 100 mm X 500 mm were prepared and cured for 28 days and tested under two-point loading in beam reaction apparatus. The load as increased until the specimen failed and the failure load is recorded. The test results obtained are as follows:

Table 8:- Experimental Test Results For Flexural Strength.

% Replacement of cement by GGBS	**Flexural Strength in MPa (28 Days)**	
	Tap Water	**Waste Water**
0	4.04	-
10	4.31	4.25
20	4.36	4.58
30	4.57	4.336
40	4.16	4.01
50	3.88	3.92

It is clear from table 8, flexural strength for concrete casted using tap water along with 20% replacement of cement by GGBS showed good value as compared to control concrete for 28 days. In case of waste water 20% replacement showed good values as compared to conventional concrete.

Results of Alkalinity Test:-
For conducting the alkalinity test specimen are cured for 60 days are taken. The specimens were oven dried at 105°C for 24 hours. Mortar was separated from the dry concrete by breaking down the dry specimen. The mortar was grinded into powder form. The powdered mortar sieved in 90µ and 10gm of sample was diluted in 50ml distilled water and stirred it completely. Then with pH paper was immersed, with the help of pH scale, pH was noted. Then in same solution glass electrode was immersed and with the help of pH meter the pH value was noted.

Table 9:- Experimental Test Results for Alkalinity Test.

% Replacement of cement by GGBS	**pH Value (pH Paper)**		**pH Value (pH Meter)**	
	Tap Water	**Waste Water**	**Tap Water**	**Waste Water**
0%	10	-	9.46	-
10%	10	10.5	9.84	10.46
20%	10	10.5	10.06	10.53
30%	10	10.5	10.19	10.67
40%	10	10.5	10.34	10.76
50%	10	10.5	10.42	10.81

It is clear from table 9, alkalinity of GGBS based casted by using tap water ranges from 9 – 10.5. In case of waste water casted concrete pH value is more as compared to tap water casted concrete.

Results of Water Absorption (Porosity) Test:-
Water absorption test or the porosity test was carried to find out the percentage water absorption. The test results obtained are as follows:

Table 10:- Experimental Test Results for Water Absorption Test.

% Replacement of cement by GGBS	% Water absorption	
	Tap water	Waste Water
0	4.16	-
10	3.89	3.94
20	3.54	3.75
30	3.33	4.26
40	4.085	4.53
50	4.33	4.81

It is clear from table 10, water absorption of concrete reduces as the percentage of GGBS in concrete increases. For tap water casted concrete along with GGBS, 30 % replacement showed less value. For waste water casted concrete along GGBS, 20% replacement showed less value.

Results of Carbonation Test:-
Carbonation test is carried out to determine the depth of concrete affected due to combined attack of atmospheric carbon dioxide and moisture causing a reduction in level of alkalinity of concrete. A spray of 0.2% solution of phenolphthalein is used as indicator of concrete. The change of color of concrete to pink indicates that the concrete is in good health.

Results of Rebound Hammer test:-
This test is used to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part II)-1992. The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. The rebound value is read from the graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of hammer or with the help of digital display which gives compressive strength. 3 cubes of each variation were casted for the conduction of test and cured for 28 days under water. Rebound Hammer test results obtained are given as follows:

Table 11:- Experimental Test Results for Rebound Hammer Test.

% replacement of cement by GGBS	Compressive Strength (MPa)	
	Tap Water	Waste Water
0 %	42.98	-
10 %	43.52	43.75
20 %	46.33	45.42
30 %	49.5	41.17
40 %	42.28	40.38
50 %	40.75	39.99

Results for Ultrasonic Pulse Velocity Test:-
This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part I)-1992. This method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. The ultrasonic pulse velocity depends on the density and elastic properties of material being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity; homogeneity etc. 3 cubes of each variation were casted for the conduction of test and cured for 28 days under water.

Table 12:- Experimental Test Results for Ultrasonic Pulse Velocity Test (Tap Water).

% replacement of cement by GGBS	Pulse Velocity (Km/sec.)	Concrete Quality
0 %	3.52	Good to very good, slight porosity may exist
10 %	3.56	
20 %	3.63	
30 %	3.78	
40 %	3.56	
50 %	3.43	Satisfactory but loss of integrity is suspected

Table 13:- Experimental Test Results for Ultrasonic Pulse Velocity Test (Waste Water).

% replacement of cement by GGBS	Pulse Velocity (Km/sec.)	Concrete Quality
10 %	3.35	Satisfactory but loss of integrity is suspected
20 %	3.51	Good to very good, slight porosity may exist
30 %	3.23	Satisfactory but loss of integrity is suspected
40 %	3.22	
50 %	3.19	

Conclusion:-

Based on the experimental work conducted, the following conclusions are drawn.

1. 30 % replacement of cement by GGBS in concrete casted by using tap water, strength increases by 29 %, for waste water casted concrete 20 % replacement is the optimum replacement of GGBS for cement in concrete. The strength increases by 34%.
2. 30 % replacement of cement by GGBS in concrete casted by using tap water, split tensile strength increases by 12.5 %, for waste water casted concrete 20 % replacement is the optimum replacement of GGBS for cement in concrete. The strength increases by 3%.
3. 40 % replacement of cement by GGBS in concrete casted by using tap water, flexural strength increases by 3 %, for waste water casted concrete 30 % replacement is the optimum replacement of GGBS for cement in concrete. The strength increases by 7%.
4. The pH of concrete along with GGBS and casted using tap water shows pHvalue ranging between 9 – 10.5. In case of GGBS based concrete casted by using waste water shows pH value ranging from 10 – 10.81. The specimens were more alkaline hence has more resistance for corrosion.
5. For Water absorption test, in case of tap water casted concrete as percentage of GGBS increases water absorption reduces up to 30% as the concrete is more dense. In case of GGBS based concrete casted using waste water up to 20% replacement value of water absorption is less.
6. Increases of GGBS in concrete increases the workability of concrete. As GGBS gives out water (GGBS doesnot absorb water).
7. For carbonation test the color of concrete surface after spraying phenolphthalein indicator changed purple - pink which indicated that concrete was not affected by the atmospheric carbon dioxide.
8. For ultrasonic pulse velocity test, 30% replacement has pulse velocity is greater than 3.5 Km/sec in case of tap water casted concrete. In case of waste water casted concrete 20 % replacement GGBS partially replaced for cement pulse velocity is greater than 3.5 Km/sec, but for rest of specimen, pulse velocity is less than 3.5 Km/sec.
9. Hence from the above results we can conclude that 30% is the optimum replacement of GGBS in case of tap water casted concrete. In case of GGBS based concrete casted by using waste water with the specifications given above give optimum results for 20% replacement. So GGBS along with waste water can be used for 20% replacement
10. Use of waste water and GGBS in concrete is a good option for eco-friendly development.

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