INTERNATIONAL RESEARCH JOURNAL IN ADVANCED ENGINEERING AND TECHNOLOGY (IRJAET) E - ISSN: 2454-4752 P - ISSN : 2454-4744
VOL 4 ISSUE 3 (2018) PAGES 3867 – 3878
RECEIVED : 05.05.2018 PUBLISHED : 10.06.2018

June 10, 2018

Concrete Using Industrial Waste as a Fine Aggregate Replaced by Chittam Slag

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Abstract:

Engineering is a professional art of applying science to the efficient conversion of natural resources for the benefit of man. Engineering therefore requires above all creative imagination to innovative useful application for natural phenomenon. The main objective of this project is to investigate the mechanical behaviour of new concrete type obtained by adding aluminium waste(chittam slag) which is an impure aluminium mixture that results from metals melting and mixing with flux. The main advantage of this type of concrete over the conventional ones is the reduction in the quantity of raw materials. The results of this study indicate that aluminium slag can be used as an ingredient in the range of certain limits to improve strength of concrete/mortar. The most interesting finding was that aluminium slag accelerates the setting time of concrete/mortar. Because of these findings it is suggested that aluminium slag added concrete/mortar may be used in the manufacturing of buildings subfloors, panels, blocks etc.The project deals about addition of Chittam slag (CS) to concrete in order to study the compressive and tensile strength properties by adding a Chittam slag as a concrete. The strength characteristics are studied for various Chittam slag in concrete proportions of 10%, 20% and 30% by weight of Natural sand (NS) for M30 mix.

Keywords: aluminium waste(chittam slag), mechanical behaviour, concrete proportions, compressive strength

1. INTRODUCTION

The natural sand is a fine aggregate which is utilized for construction activities. The term 'natural sand' is used to identify the material traditionally recovered from geologically recent deposits of sand-sized materials. Typically these deposits are from Quaternary deposits in streams, rivers, estuaries, lakes, lagoons or dunes. This leads to the depletion of the natural resources, therefore to overcome this problem we go for the utilization of Chittam slag (Aluminium waste) in place of river sand. The chittam slag is the waste product of aluminum industry. Chittam slag is defined as a manufacturing of aluminium products by wastage of impurity aluminium waste.

CHITTAM SLAG

Aluminium is one of the widely used construction materials in the world, and during the aluminium production, the huge amount of waste is produced from the aluminium industry. Then the aluminum waste material taken to be heating about high temperature for melting and creating a new structure. The liquid state of aluminum is separating the impurities (flooding materials of aluminium liquid). The waste aluminium impurities are using to recycling process. This waste material is in different shapes and different sizes. The large size materials are again recycling to this same process. When the small sizes are called as “Chittam Slag”, sieves and replacing to sand in concrete. Natural sand is not possible to available all periods, because of natural sand are mostly demanded now a days for construction process. This chittam slag (aluminum waste) useful for the nearest construction in aluminum industries. This modern concrete is give high compression and tensile strength. This slag hazardous waste for the environment and so recycling or locking up of this waste is very crucial from the environmental point of view.

Fig.1 Chittam Slag

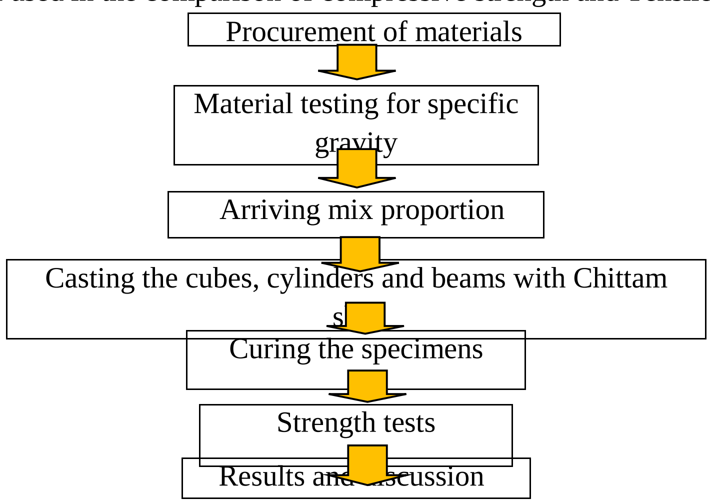
One of the problems often experienced with river sand is the presence of contaminates, which can be very difficult to remove. These contaminants may be silt, organic matters and sometimes, harmful chemicals, such as sulphates and chlorides, all of which can have significant detrimental effects on the performance of structural concrete. Chittam slag, on the other hand, comes directly from aluminium industries, and thus very few, if any contaminates are present.Production generally involves screening and possibly washing. Separation into discrete fractions, recombining and blending may be necessary.

(A) LITERATURE SURVEY

However, in this proposal, it is suggested to use the chittam slag obtained before recycling procedure as the replacement of sand in order to see if the desired mechanical properties will be achieved. Also, Pereira et al. studied the effect of chittam slag on the mechanical properties of Portland cement mortar and demonstrated that aluminium slag can be used as partial replacement material for sand in certain limits to obtain environmental and economic advantages. Moreover, the chittam slag was used to produce the concrete blocks and in this study, it was demonstrated that the permeability of concrete is positively affected by aluminium dross and it accelerates the strength development of concrete. The potential use of aluminium dross as filler in concrete products like concrete bricks and non-aerated concrete is recommended by Brough . Another study based on using new industrial waste streams as secondary aggregates demonstrated that white and black aluminium dross have potential as filler aggregates in concrete production when it is in processed form (<700 µm). The effect of aluminium dross on the setting time, flexural and compressive strengths of concrete has also been studied and suggested to use as a retarder for hot weather concreting. Another study has proved that the use of aluminium dross manufactured from refractory material increases the mechanical properties of concrete when it is used as filler.

2. METHODOLOGY

Concrete cubes of size 15 x 15 x 15 cm , concrete cylinders of 15cm diameter and 30 cm height and concrete beams of size 50x10x10 cm were cast to determine the 3, 7 and 28 days strength using river sand and Chittam slag as fine aggregate in the mix ratio of 100:0, 90:10 ,70:20 and 70:30. The Chittam slag mix which has yield the optimum strength compared to the strength of specimen cast from river sand was selected and used in the comparison of compressive strength and Tensile strength.



A. PRELIMINARY INVESTIGATION ON MATERIALS

Production of good quality concrete requires meticulous care exercised at every stage of manufacture of concrete. In this investigation the mechanical properties of the Replacement of Chittam Concrete (CC) are obtained. The Replacement of Chittam Concrete was prepared by adding the following materials such as cement, fine aggregate, coarse aggregate, Chittam slag and potable water.

(1)Cement:

One of the important criteria for the selection of cement is its ability to produce improved microstructure. Hence selection of proper grade and quality of cement is important for obtaining rich mix. Some of the important factors, which play a vital role in the selection of the type of the cement are compressive strength, fineness, heat of hydration, alkali content, tricalcium aluminates (C_3A) content, tricalcium silicate(C_3S) content, dicalcium silicate(C_2S) content and compatibility with admixtures etc.The cement used in this study is OPC 53 grade. This cement is most widely used in the construction industries.The physical properties are obtained by conducting following tests on cement.

TABLE 1

PHYSICAL PROPERTIES OF CEMENT

Sl.No	Properties	Value	Standard values
1	Specific gravity	3.17	3.10 - 3.20

2	Standard consistency	28%	25 – 35%
3	Initial setting time	45 min	>30 min
4	Final setting time	512 min	<600 min

(2)Fine Aggregate:

Fine aggregate plays a very important role in concrete in both its plastic and hardened state. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 3/8-inch (9.5mm) sieve. Fine aggregate should be properly graded to give minimum void ratio and be free from deleterious materials like clay, silt content and chloride contamination etc. From the test results the physical properties of fine aggregate is tabulated as,

TABLE 2

PHYSICAL PROPERTIES OF FINE AGGREGATE

S.No	Properties	Value
1	Specific gravity	2.52
2	Percentage of voids	24.50%
3	Bulk density	1650 kg/m^3
4	Water absorption	1.20%

TABLE 3

SIEVE ANALYSIS FOR FINE AGGREGATE (SAND)

Sl.no	Sieve size (mm)	Weight retained (gms)	Cumulative weight retained(gms)	Cumulative % retained	% finer
1	10	0	0	0	100
2	4.75	14	14	1.4	98.6
3	2.36	35	49	4.9	95.1
4	1.18	185	234	23.4	76.6
5	0.6	339	573	57.3	42.7
6	0.3	357	930	93	7
7	0.15	56	986	98.6	1.4
8	Pan	14	1000	100	0

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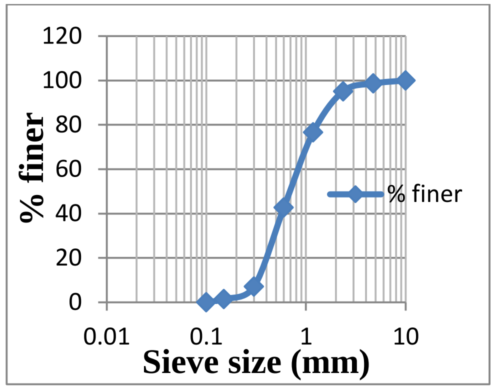

Fig.**2**Sieve analysis chart for fine aggregate

(3)Coarse Aggregate:

Aggregates make up about 75% of the volume of concrete, so their properties have a large influence on the properties of the concrete. Aggregates are granular materials, most commonly natural gravels and sands or crushed stone, although occasionally synthetic materials such as slag or expanded clays or shale are used. The role of the aggregate is to provide much better dimensional stability and wear resistance. Also, because they are less expensive than Portland cement, aggregates lead to the production of more economical concretes. The following tests are carried out on Coarse aggregate as per IS:2386 (Part 3) – 1963 as per IS:2386 (Part 3) - 1963(Reaffirmed 1997). Table 4 shows the physical properties of coarse aggregate. Table 5 shows the Sieve analysis for coarse aggregate. Figure 5 indicates shows the grading curve of coarse aggregate.

TABLE 4

PHYSICAL PROPERTIES OF COARSE AGGREGATE

S.No	**Properties**	**Value**
1	Specific gravity	2.74
2	Finenessmodulus	5.67
3	Bulk density	1507.5 kg/m^3
4	Water absorption	0.80%

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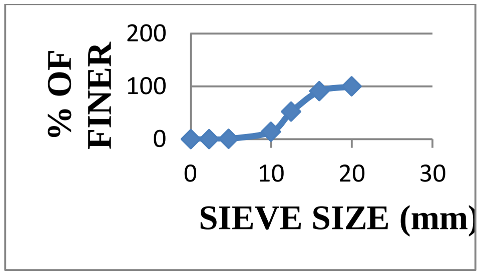

Fig.3 Sieve analysis chart for coarse aggregate

B.EXPERIMENTAL PROCEDURE

1) Mixture Proportions: The concrete mixture proportions of the mixes are given in Table 6. As seen from the table, within the scope of the experimental program five concrete mixtures were prepared. The control mixture included only the Portland cement (PC) as a binder, and named as AS0 which means that there is no aluminum slag. The remaining mixtures had different aluminum slag contents of 10%, 20% and 30% by weight of Portland cement and named as AS10, AS20, and AS30, respectively. For all the mixtures, the total amount of cementitious material (PC+AS) content and slump value were kept constant. Since the slump value was kept constant, water was gradually added to the mixtures and therefore the water to cement ratio (w/c) ranges from 0.45 to 0.5.

TABLE 6 MIX PROPORTIONS

W/C	Cement	Fine aggregate	Coarse aggregate
0.5	**1**	**1.62**	**2.764**

(2)Specimen Preparation: Concrete mixtures were prepared by using mechanical mixer. For all concrete mixture, first of all, the fine and coarse aggregates were mixed for 1 minute and the cementitious materials (cement or cement and aluminium dross) were added and mixed for 1 more minute. Eventually, the water was gradually added.After completing the mixing procedure, the air content, slump and setting time were determined for the fresh concrete properties. From each concrete mixture, fourteen 100x200 mm cylinder specimens and two 15x15x15 cm cube specimens were cast to determine the hardened properties like compressive strength, permeability tests and corrosion test. After 24 hours, the specimens were removed from the molds and cured in water at a temperature of 20±2°C until the date of testing.

(3)Tests on Fresh Concrete: In this study, the slump cone test and compaction factor test of fresh concrete were determined.

(4)Tests on Hardened Concrete: The hardened concrete properties were evaluated by performing compressive strength, Tensile strength,and corrosion resistance tests.

*(5)Curing of specimen:*The test specimens shall be stored on the site at a place free from vibrations under damp matting, sacks, gunny bags or other similar material for 24 hours from the time of adding the water to the other ingredients.The specimens curing time period 7 days, 14 days and 28 days curing time after

testing the specimen on arrival at the testing laboratory specimen should be very dry and clean throughout the specimens.

Fig.4 Specimens curing process

(6)Corrosion: the corrosion rate of the steel rebar within the concrete as the aluminium slag volume percentage increases from 0 to 30%. It can be seen that as the slag content increases from 0% to 10%, the corrosion rate decreases. This behaviour was reversed when the slag content exceeded the 10% threshold where a significant increase in the corrosion rate started to be measured. The reason for this inflection in behaviour might be attributed to the chemical composition of the slag which affects the concrete pore solution. The presence of calcium and aluminium hydroxides and alkali metal ions e.g. Na+ and K+ maintains the pore solution pH at a value around 11 which passivates the steel rebar, i.e. the high pH value decreases the corrosion rate but the presence of Cl-and F- ions increases the localized corrosion rate. The chloride ion concentration, [Cl-] necessary to start the pitting corrosion for steel embedded in concrete is termed critical chloride content or chloride threshold value, abbreviated.

3. RESULT AND DISCUSSION

A. COMPRESSIVE STRENGTH TEST

The compressive strength test is used to determine the characteristics strength of the concrete. The aim of this experimental test is to determine the maximum load carrying capacity of test specimens.The cubes were casted in the size of 150 x 150 x 150 mm. Before filling the concrete the cube moulds were cleaned thoroughly using a waste cloth and then properly oiled along its faces then the concrete is filled in mould and then compacted using a standard tamping rod of 60cm length having a cross sectional area of 25 mm^2.The test is carried out for each cube. The reported compressive strength is the averages of 3 specimens were tested at 7days, 14days and 28 days. All the specimens were loaded to failure and the corresponding failure loads were recorded. The compressive strength of the specimen is calculated by dividing the maximum load applied to the specimen during the test by the cross- sectional area of the specimen. The mean value of the three specimens of each is taken as final compressive strength.

$$\text{COMPRESSIVE STRENGTH} = \frac{\text{LOAD (KN)}}{\text{AREA (mm}^2\text{)}}$$

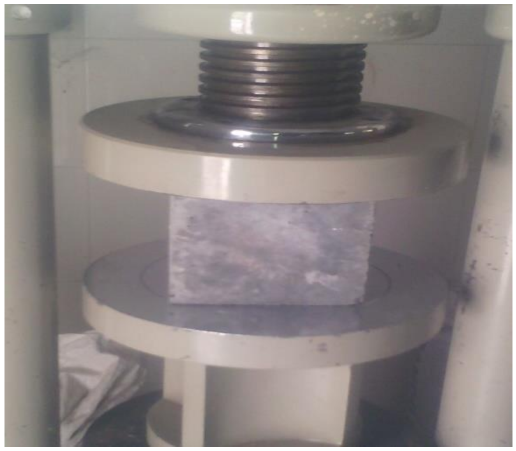

Fig.5 Compressive strength of cube

The average compressive strength and decrease in compressive strength values due to replacement of Natural Fine Aggregate with Chittam slag at varies ages of concrete.

TABLE 7 Compressive Strength Test Results at 7, 14 & 28 days

Specimens	Replacement Of Chittam slag	Average Compressive Strength 7 Days N/mm^2	Average Compressive Strength 14 Days N/mm^2	Average Compressive Strength 28 Days N/mm^2
Conventional	-	27.1	29.21	31.12
TRIAL 1	0 %	25.44	29.92	30.42
TRIAL 2	10 %	23.12	27.57	29.31
TRIAL 3	20 %	21.73	25.92	28.32
TRIAL 4	30 %	19.89	23.92	26.02

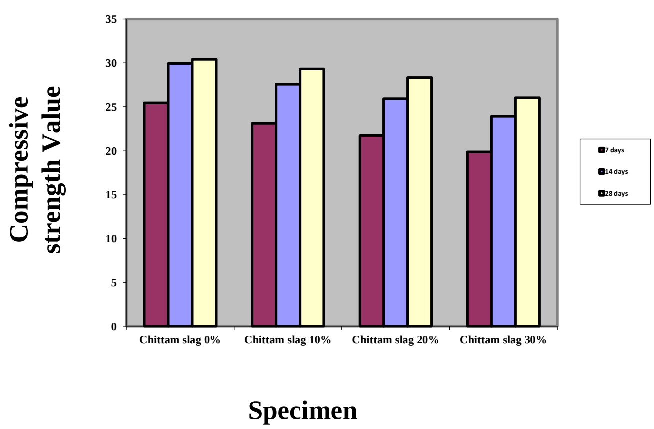

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Fig.6 Flow chart for Compressive Strength Test Results at 7, 14 & 28 days

B. **SPLIT TENSILE STRENGTH TEST**

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist, the direct tension because of its low tensile and brittle in nature. However the determination of tensile strength of concrete is necessary to determine the load at which The concrete members crack. The cracking is a form a tensile failure. The main aim of this experimental test is to determine the maximum load carrying capacity of test specimens during tension. Size of cylinders 150 mm in diameter and 300 mm height were cast for split tensile test. The crude oil was applied along the inner surfaces of the mould for easy removal of cylinder from the mould. Concrete was poured throughout its length and compacted well.The splitting test is well known as indirect test used for determining the tensile strength of concrete. They are sometimes referred as split tensile strength of concrete. The specimen was placed longitudinally on the platform of the compression testing machine and the load was applied along the longitudinal surface at the rate 14N/mm^2/min. until it fails.Due to tensile stress, the specimen fails finally by splitting along the loaded diameter and knowing failure load P, the average split tensile strength can be determined. The failure load divided by the resisted surface area given the split tensile strength of the concrete.

$$\text{SPLIT TENSILE STRENGTH} \quad \frac{2\,P}{\Pi \times d \times L}$$

Where,

P = Compressive load on cylinder in KN
L = Length of the cylinder in 300 mm
d = diameter of the cylinder in 150 mm

TABLE 8 Split Tensile Strength Test Results

Specimens	**Replacement Of Chittam Slag**	**Average Split Tensile Strength 7days N/mm^2**	**Average Split Tensile Strength 14days N/mm^2**	**Average Split Tensile Strength 28days N/mm^2**
Conventional	-	-	-	-
TRIAL 1	0 %	2.65	2.61	2.52

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TRIAL 2	10 %	2.52	2.49	2.48
TRIAL 3	20 %	2.47	2.39	2.35
TRIAL 4	30 %	2.34	2.26	1.99

Fig.7 Split Tensile Strength for cylinder

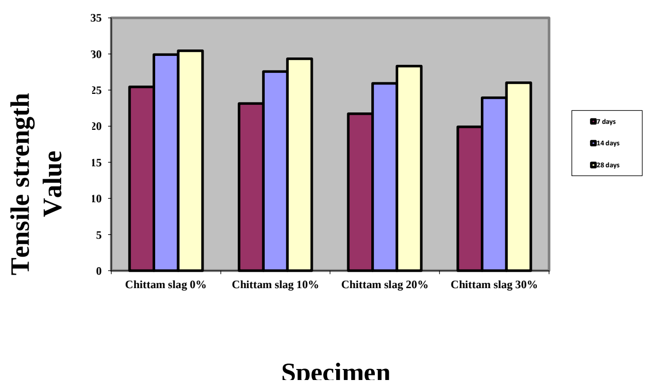

Fig.20 Chart for Split Tensile Strength for cylinder at 7days, 14days, 28days

CONCLUSION

In this project, the objective was to investigate the mechanical and chemical behaviour of new concrete type obtained by adding aluminium slag.. The main tasks performed during the project can be listed as the physical property test and testing of fresh and hardened aluminium slag added concrete.

The following conclusions are drawn as a result of this experimental program:
When aluminum slag is used in the range of certain limits (i.e. up to 15% replacement of cementitious material), increasing aluminium dross content accelerates the hardening which can be understandable since the nano particles of aluminium dross has higher surface area.
(i) High volume aluminium slag replacement is not appropriate because of its high water absorption capacity.
(ii) Since aluminium dross acts as an expanding agent, it can be used in the manufacturing of building subfloors, blocks and pre-molded panels.
(iii) Curing effect on the strength gain of aluminium dross added mortar/concrete should be further studied.
(iv) Increasing the dross volume from 0 to 10% resulted in a decrease of the total halides' ion concentration/hydroxide which is reflected in a decrease in the corrosion rate from 0.44 to 0.2 mpy.
(v) The tensile strength of Chittam slag concrete increases about 5% than river sand concrete.

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