INVESTIGATION AND STRENGTH CHARECTERISTICS OF STEEL SLAG RESIDUE

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ABSTRACT

Use of more and more environment-friendly materials in any industry in general and construction industry in particular Environment of this 'only living' planet is wary of pollution due to emissions of a host of greenhouse gases from industrial processes. Present day construction industry consumes huge amount of concrete and cement is thebindingmaterialusedformakingconcrete.Duringproductionofcementhugeamount ofenergyisneededandabout8%of$CO_2$is released to atmosphere during cement production.

This makes concrete a non eco-friendly material. In consideration of these points, construction industry has devised a substitute for concrete, popularly known as 'Steel Slag Hydrated Matrix'. It consist of steel making slag, ground granulated blast furnace slag, fly ash, lime and water.

The striking feature of this form of concrete is that most of its important ingredients are 100 percent by-products of industries, yet having similar performance record as any other conventional concrete material. Aesthetically also it has good pleasing colour and performance wise it has an excellent resistance to wear and tear. Burning of fossils fuels exclusively for its primary ingredients is not necessary unlike in the cue of cement and also no energy-intensive for cement clinker production. It also utilizes the waste products of industries like fly ash and steel slag which otherwise would pose problem for their safe disposal and sometimes degrades the nvironment.In the present study tests are carried out in two phases. In the first phase of tests, the quantity optimization of raw materials like fly ash and hydraulic lime is made so as to get a best binding material that resembles the conventional binder, the cement. The conventional procedure followed to characterize the quality cement is adopted in this phase of tests and best

raw material composition was arrived at. The lime content in the lime-fly ash mix was varied as 20, 35, 50,

INTRODUCTION

Global warming and environmental destruction have become the major issue in recent years. Emission of host of green house gases from industrial processes and its adverse impact on climate has changed the mind set of people from the mass-production, mass-consumption, mass-waste society of the past to a zero-emission society, utilization of industrial wastes and conservation of natural resources. Preventing the depletion of natural resources and enhancing the usage of waste materials has become a challenge to the scientist and engineers. A number of studies have been conducted concerning the protection of natural resources, prevention of environmental pollution and contribution to the economy by using this waste material. The two major by-products of industry are slag and fly ash. In India, the annual production of fly ash is about 170 million tons, but about 35 percent of the total is being utilized, which is very low. Owing to its ultra fineness, pozzolanic contribution and other properties, the use of flyash makes a cost of disposal and to reduce environmental pollution, it is an imperative to increase the quantity of flyash utilization. Similarly, the Steel industry in India is producing about 24 million tones of blast furnace slag and 12million tones of steel slag.

Concrete is the most preferred and the single largest building material used by the construction industry. Concrete is basically made of aggregates, both fine and coarse, glued by a cement paste which is made of cement and water. Each one of these constituents of concrete has a negative environmental impact and gives rise to different sustainability issues.

LITERATURE REVIEW

In Dec. 1999, JEF Steel's developed the concrete using waste material such as steel making slag, ground granulated blast furnace slag, fly ash &lime dust and 5 t type breakwater blocks approximately 2.0 m in height were manufactured from steel slag hydrated matrix and concrete. These blocks were exposed in the tidal at Mizushima Port, Okayama Pref. in Seto - Inland Sea in Feb. 2000. Square sections of biofouling organisms with an area of 20 cm x 20 cm were cut respectively from four locations on the wave-dissipating blocks and dried at 60°C for24 h. The biomass of the specimens was then measured.

Mathur et al. (1999) looked at the physical properties of blastfurnace slag and steel slag and concluded that both materials were suitable to replace natural stone aggregates in base and sub base road layers, as long as the steel slag was adequately weathered. The study also mixed various slogs together and determined that a mixture of ACBF slag (50%), steel slag (20%), granulate blast furnace slag (20%), fly ash (6%), and lime (4%) would self-stabilize over time and form an adequate bound base or sub base road layer. They have got that the concrete containing above these material better corrosion resistances.

M. Maslehuddi et al. (2003), have particularly worked in areas where good-quality aggregate is scarce. Their research study was conducted to evaluate the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with the crushed limestone stone aggregate concrete. The durability performance of both steel slag and crushed limestone aggregate concretes was evaluated by assessing by water permeability, pulse velocity, dimensional stability and reinforcement corrosion. The results indicated that the durability

H.Matsunaga et al (2000) have taken the mixture proportion of steel slag making ground granulatrd blast furnace slag, fly ash, water and small amount of an activator (calcium hydroxide or lime dust). Cement and natural aggregate were not used. The physical properties of steel slag hydrated matrix were measured. The compressive strength of steel slag hydrated matrix products increases with curing time and exceeds 18N/mm2, which is the general design strength of breakwater blocks. Compared the compressive strength at 91 days and 28 days strength is approximately 1.3 times greater with extended curing. That is the compressive strength of steel slaghydratedmatrix increases with longer curing periods and achieves alevel higherthanthat of an ordinary concrete with long term.

EXPERIMENTAL STUDY

INTODUCTION

In this present study a series of experiments have been done to valuate the characteristic strength of steel slag hydrated matrix. The objective of this study is to prevent the exhaustion of natural resources and enhancing the usage of waste aterials, concern about global environmental issues, and a change over from the mass-production, mass-consumption, mass- waste ociety to a zero-emission society. The hysical and chemical properties of the raw materials have been studied to characterize the raw materials. In addition to this tests have been conducted in two phases. In first phase of tests the optimum percentage of lime is determined by testing mortar cubes prepared from lime+ flyash as binder and GGBFS as fine aggregate in ratio of 1:2 and 1:3 with 20, 35, 50, 65, and80 percent lime in the binder. In the second series of tests concrete specimens were prepared by mixing lime +fly ash binder, GGBFS and steel slag in the ratios of 1:1.5:3. The compressive strength, flexural strength and split tensile strength of these samples were determined after 7 and 28 days.

The Physical properties, chemical properties of materials have been study such as

- ¾ Gradation of fine aggregate and Coarse aggregate
- ¾ Abrasion resistance strength of Aggregate.¾Water absorption of Fine aggregate and coarse aggregate.

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MATERIALS USED

The fly ash used in the present investigation was collected from Rourkela steel plant, Sundargarh, district of Orissa. The fly ash had grayish white colour. The chemical, morphological, mineralogical and physical data for the above flyash is presented as follows.The tests on fly ash were carried out as per IS: 1727-1967. The specific gravity of fly ash is 2.25 and fineness is 8 % (by dry sieving method).

Chemical analysis

Fly ash consists of silica, alumina, oxides of iron, calcium and magnesium and toxic heavy metals like lead, arsenic, cobalt, and copper. The chemical composition of fly ash is given in the Table .The permissible value as per IS: 3812-1981 and ASTM standard also shown here.

Type	**Flyash (Present study) (%)**	**ASTM requirement C-618Class F (%)**	**I.S. specifications (%)**
SiO_2	56.04	-	35(minimum)
Al_2O_3	33.85	-	
Fe_2O_3	3.90	-	
$SiO_2+Al_2O_3+Fe_2O_3$	93.84	70.00 minimum	70.0 (minimum)
CaO	0.73	-	
MgO	0.68	5.00 maximum	5.0(maximum)
K_2O	1.22		
Na_2O	0.19	1.50 maximum	1.5(maximum)
TiO_2	2.69	-	
MnO_2	0.31	-	
SO_3 o	0.05	5.00 maximum	3.0(maximum)
L.O.I(900C)	1.40	6.00 maximum	5.0(maximum)

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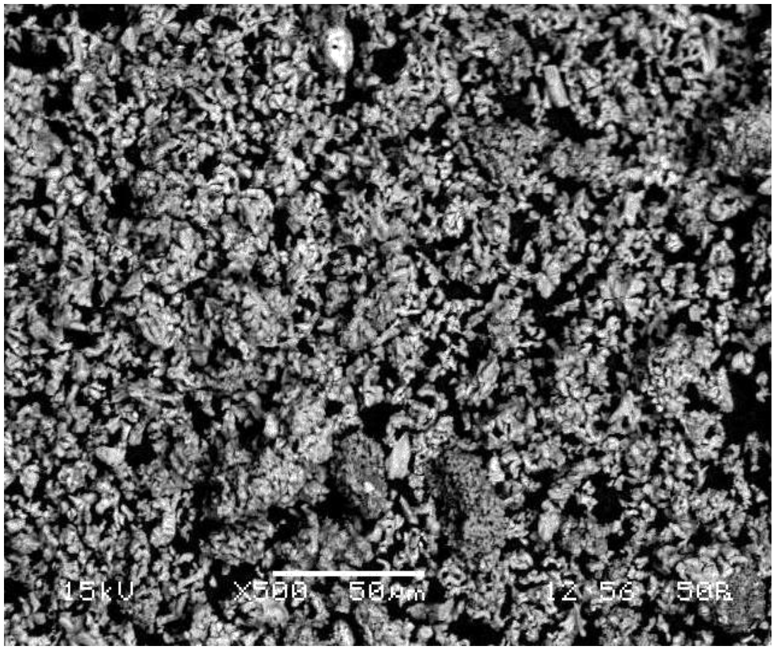

Fig.3.20MicrostructureofLime

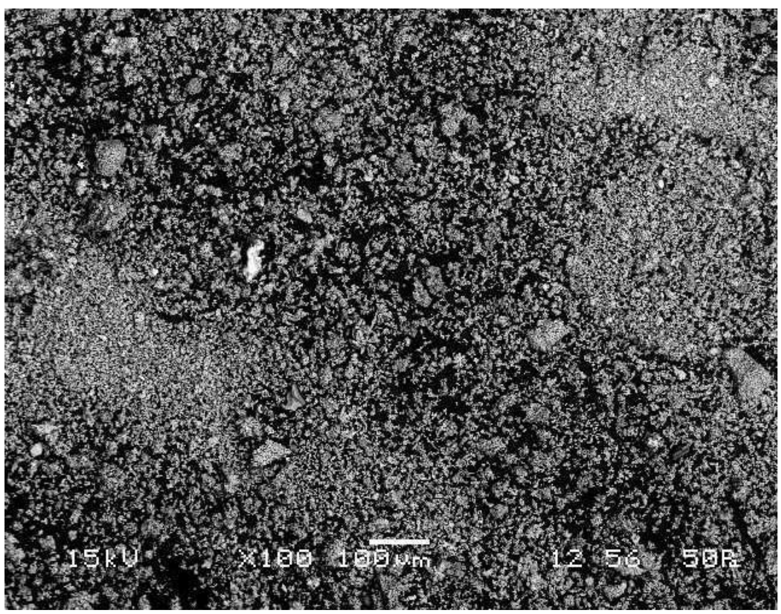

Fig.3.21.MicrostructureofLime

PROPERTIESOFFRESHCONCRETE:

Slump and workability

It generally known that the replacement of Portland cement by fly ash and lime in concrete increase the water requirement is a to obtain a given consistency or water binder ratio. Increases the workability slump for given water content compared to that of concrete without cement.

MECHANICALPROPERTIES

Strength development

The strength development of fly ash concrete is strongly affected by the type of fly as hand the curing temperature. The use of low- calcium fly ashes and lime generally decreases the compressive strength of concrete at early ages (up to 28 days) and increases it at later ages (due topozzolanicreactionofflyash)whencomparedtoPortlandcementwithsimilar28–daycompressive strength. On the other hand, the use of high calcium content has a marginal effect on strength development.

In cool weather, the low temperature generally slows the chemical reaction between cement and water, and thus the strength development of concrete. For flyash concrete, this effect is more pronounced due to reduced Portland cement in the mixture and greater dependence of pozzolanic reaction on temperature.

CONCRETEMIXTUREPROPERTIONS:

The procedure for selection of mix proportions used for Portland cement concrete is also applicable to concrete incorporating fly ash, lime or slag with some modifications. The main steps of procedure are as follows

Selection of water-to compendious materials ratio to meet durability and strength parameters.

¾Calculation of cement contentie. Lime +fly ash

¾Calculation of coarse aggregate content.

¾Calculation of fine aggregate content.

¾Adjustment for aggregate moisture, and;

¾Trial batch adjustments.

The above steps maybe affected depending on the method used for of fly ash lime and GGBS in concrete.

Simple Replacement method

This method consists of direct replacement portion of Portland cement by fly ash or lime by volume or by mass, which mainly consists of modifying an existing Portland cement mix to include fly ash or GGBFS lime without other adjustments. The concrete designed with this method usually has performance compared to that of concrete made with Portland cement.

Modified replacement method

This method consists of developing fly ash /lime concrete mixtures with similar workability and compressive strength to that of Portland cement concrete at a specified age. In general, this concrete has a higher total weight of cementoius materials and higher water cement ratio.

ESTIMATION OF MIXING WATER

As mentioned earlier, the use of fly ash in concrete generally reduces the water demand required to achieve a certain level of workability, while the use of lime GGBS does not

Significantly affect the water demand. Therefore each type of flyash and fly ash content (and the same thing for lime to same extent) data was developed to replace values usually used that provides the approximate mixing water content for different slumps and nominal maximum size of aggregates. Mixing water was also dependent on the GGBFS gradation which was used as sand.

COMPRESSIVESTRENGTH

The compression test is the most important test that can be used to assured the engineering quality in the application of building materials. The optimum lime content in the mixture of lime and flyash were determined by conducting the compression test on mortar specimens as per I.S Code of practice 4301 part-7 (1988).Compressive strength of mortar tests were done in all specimens produced at period of 3, 7, 28 and 56days. Total 12 numbers cube sare produced for each water/ lime + fly ash used in the trial mix. From 12 cubes 3 cubes were tested for 3 days and other 3 cubes at 7 days and remaining 3 cubes at 28 days and 3 cubes at 56 days. The values of all specimens tested 3rd 7th 28th and 56 days were recorded and average value was calculated. The equipment used for the compressive strength test could produced reading which represents the rate of loading. For the Compressive strength there were two series of test done one is for compressive strength for mortar and other is for concrete. For the mortar test the sample were from fly ash with different lime content keeping ground granulated blast furnace slag as fine aggregate. The ratio of powder and GGBS (Ground granulated blast furnace slag) was taken to be 1:2 and 1:3 and six different types of specimen were prepared by varying the lime content (20, 35,50,65,80 and 100%).

To find out the effect of curing period on compressive strength, the samples were cured with curing period of 3 day, 7 day 28day and 56 day. Similarly, to prepare the SSHM (steel slag hydrated matrix), the mix proportion of powder, GGFBS and steel slag was taken as 1:1.5:3. Here also six different types of specimen were prepared by using different lime and fly ash content.

A specimen of normal concrete with the mix of 1:1.5:3 (cement: sand: aggregate) was prepared to compare with the new SSHM. The w/c ratio was taken to be 0.55. Steel slag concrete cubes were prepared taking lime + fly ash binder, GGBFS and steel slag and lime content in lime, flyash mix was varied as 20, 35, 50, 65 and 80 percent. To find the effect of curing period on compressive strength, the samples were cured with curing period 7 day and 28 day.

TENSILEFLEXURALSTRENGTHOFCONCRETE

Flexural test is intended to give the flexural strength of concrete in tension. The testing of concrete to flexural yields more consistent result than those obtained with tension in concrete ; the flexural test also more easily carried out and may have been be more convenient than the test for used in field . It is measured by loading 100 x 100 x 500 mm concrete beam called prism. The flexural strength is expressed as Modulus of rupture and is determined by test method referred in IS 516-1959 by using two points loading method. For testing the specimen is placed in the machine and load is applied and increased continuously at rate of 180 kg/min, until the specimens fails. The maximum load applied to the specimens during the tests are recorded and used to calculate flexural strength of the concrete using the formula.

Flexural strength = $M/Z = Wl/bh^2$

For flexural strength different proportion of lime has taken i.e. (20 %, 35%, 50%, 65%, 80%) with variation of fly ash. It was tested for 7 days and 28 days.

SPLITTENSILESTRENGTH

The splitting tests are well known indirect tests for determining the tensile strength of concrete sometimes referred as split tensile strength of concrete. This tests were carried out in accordance with IS 516-1999 standards conducted on concrete cylinders of 150 mm diameterand 300 mm length. Each cylinder specimen was placed on its side and loaded in compression along a diameter of the tested cylinder specimens. The load was continuously applied at a nominal rate within the range of 1.2N/ (mm2/min) to 24N/ (mm2/min) till the specimens failed. The maximum load applied to specimen during the test were recorded and used to calculate split tensile strength of SSHM concrete. The magnitude of tensile stress is given by the formula RESULT

In this chapter, the results obtained from the testing of mortar prepared from hydrated lime, fly ash and GGBFS and strengths of steel slag hydrated matrix are presented. The conventional procedure followed to characterize the quality of cement is adopted in the first phase of tests and best raw material composition was arrived at. In the second phases, concrete specimens were prepared with taking steel slag as coarse aggregate ground granulated blast furnace slagas fine aggregate and binder that is found to best performance from the test of phase one. The composition of above raw materials was varied to study the effect of raw material compositions on compressive strength, flexural strength and tensile strength adopting conventional testing procedure. The effect of curing period on strength was also studied and reported. Comparison is also made between the Steel slag hydrated matrix and the conventional concrete.

SETTING TIME OF LIME + FLYASH

Setting time

The initial setting and final setting times of various mixes of lime-fly ash is given inTable 4.1.In general it is observed that both the initial and final setting times of fly ash lime mixes are comparably higher than the conventional cement.

With respect to different powder mix (lime+flyash). But the mortar with 35% lime content gives the maximum compressive strength among all six proportions.

The compressive strength of mortar with lime content were given below the graph.

Figure4.4 Variation of Compressive strength of mortar(1:3)with Lime content

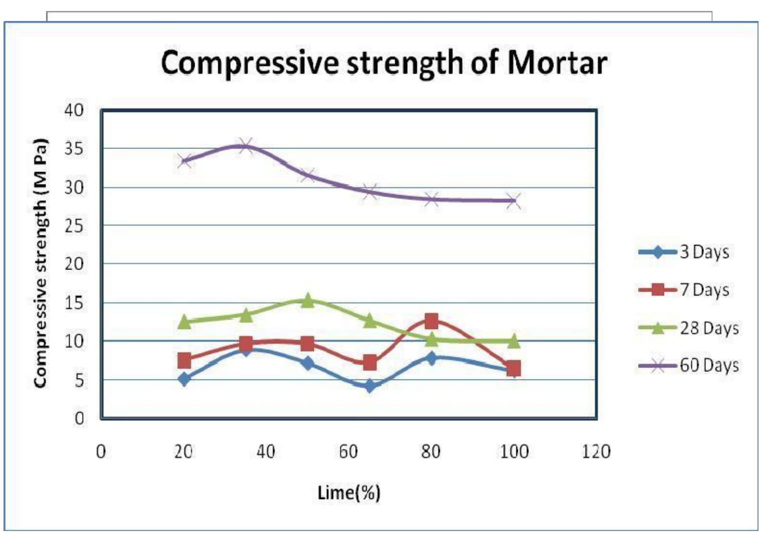

Figure: 4.5 Variation of Compressive strength of mortar (1:2)with Lime content

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COMPRESSIVE STRENGTH OF CONCRETE

The compressive strength of steel slag aggregate concrete decreased with the proportion of lime content. The compressive strength varied from 12.5MPa, for concrete with 20% lime content10MPa, to 12.5MPa for concrete with 35% lime content. The Steel slag Hydrated Matrix Concrete was compared with Normal concrete and the compressive strength of Normal concrete was 24.2MPa. The compressive strength of steel slag aggregate concrete is less than the normal concrete.Thesteelslagwasfullofimpuritiesparticleslikecoal,burntsoillumpsandsomeother materials and also presences of excess lime .These have swelled after coming in contact with waterand consequentlycreatingcracksintheSteelslaghydratedmatrix.Thecrack patterninthe cube was shown below the Figure-4.6. Therefore, the compressive strength of concrete was less than the normal concrete.

Figure 4.6 crack pattern in Cube

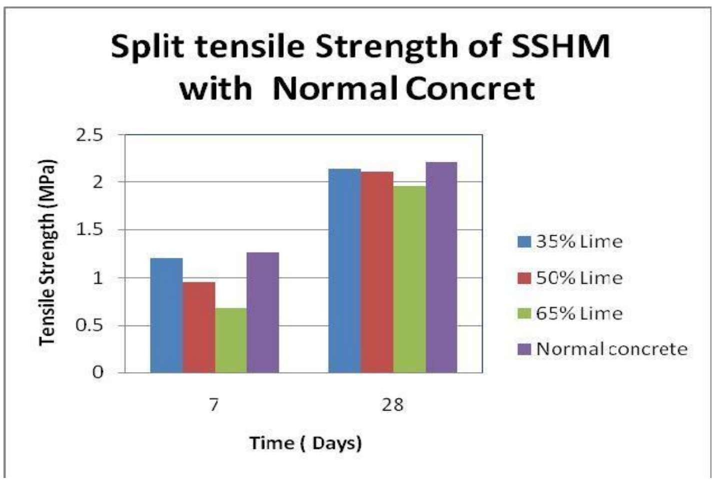
FLEXURAL STRENGTH:

It is increased with proportion of decrease of lime content varying from 2.5 MPa, in the 35%limecontent of concrete is the higher Flexural strength of2.5 MPa Slag aggregate concrete. The flexural strength of Normal concrete was 4.3 MPa. These results indicate that the improvement in the flexural strength, due to the impurities of steel slag aggregate.

SPLITTENSILE STRENGTH:

The split tensile strength of the Normal concrete was 2.22MPawhile it was in the range of 2.1to

2.13MPa in the steel slag aggregate concretes



REASON FOR LOWER STRENGTH

Some other researchers have found the compressive strength of SSHM in the range of 20 N/mm^{2}to30N/mm^{2}after28daysofcurin g.Butinourcasewehavegotcompressives trength

in the range of 9N/mm^2 to 13N/mm^2. This lower strength of SSHM may be due to the following reasons:

¾The steel slag was full of foreign particles like coal, burnt soil lumps and some other materials and excess of lime. These have swelled after coming in contact with water and consequently creating cracks in the SSHM.

¾There were too much dust particles in the steel slag covering the surface of it hence opposing the cohesion and inter locking between the slags and subsequently resulting in low strength.

¾There were foreign particles in the GGBFS. Moreover it was not stored in a confined container rather was exposed to the atmosphere hence decreasing the activity of GGBS.

¾The slaked lime was impure with less CaO content.

¾Though the maximum size of steel slag was 20mm it was a poorly grade done.

¾Use of high water powder ratio which could have been reduced using some admixtures like super plasticizer.

CONCLUSION

From the present studies following conclusions were drawn-

¾ Thecompressivestrengt hofmortarthatislime: flyash: GGBFS in the proportion of (35:65:300) was found to be 15.6 N/mm^2 at 28 days, 38.8N/mm^2 at 56 days.

¾ The mortar proportion (35:65:200)it was found to be 13.53N/mm^2at 28 days, 35.4N/mm^2at 56 days.

¾ Initial setting time, final setting time and consistency of flyash and lime powder (binder) is approximately 30% , 25% and 46% more than the cement.

¾ The compressive strength of mortar Steel slag hydrated matrix was less during earlier stages of curing, but it has achieved almost same strength as normal cement mortar after 56 days.

¾ The 28 days compressive strength of concrete of Steel slag hydrated matrix is found to be less than the normal cement concrete.

¾The compressive strength of SSHM after 28 days of curing was found to vary from9N/mm^2to13N/mm^2.However, other researcher shave found the compressive strength of SSHM in the range of 20 $N/mm^2$to 30 N/mm^2after 28days of curing.

¾ Flexural strength after 28 days

of Steel slag hydrated matrix is lower than normal concrete.

¾ Split Tensile strength after 28 days of Steel Slag hydrated Matrix is approximately same as the normal concrete

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