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Effect of Partial Replacement of Fine Aggregates by Incinerated Sludge Ash on the Mechanical Properties of Concrete

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Abstract: The present work is done so as to study the properties of concrete at fresh and hardened stage containing incinerated sludge ash as a partial replacement of fine aggregates in concrete together in different combinations. An experimental research programme is designed in which controlled concrete (MS1 mix) of grade M20 is designed, casted and tested for various strength parameters such as compressive strength, split tensile strength and flexural strength after 7-days as well as 28-days of curing. Three different mixes were prepared containing 10% (MS2 mix), 20% (MS3 mix) and 30% (MS4 mix) sludge ash as partial replacement of fine aggregates. From the test results, it was observed that the values of all the three strength reduced much for MB4 mix. Based on the analysis of test results, it is observed that with the partial replacement of incinerated sludge ash at 30%, the compressive strength of 28 days is comparable to that of controlled concrete.

Keywords: Fine aggregates, digested sludge, sludge ash, cement, split tensile strength, compressive strength, flexuralstrength.

I. INTRODUCTION

With an increasing population in the cities, the water demand and hence amount of waste water generated has also increased. This waste water when subjected to various treatment techniques results in the formation of digested sludge. Now, this digested sludge has to be disposed of either by dumping it into the ocean or in landfills. However all possible methods of disposal have various degrees of environmental impacts. Therefore there is an alarming need to use alternative measures. One such possible method is to use incinerated sludge in construction as an alternative material. When the digested sludge is incinerated at a high temperature, it results into formation of a hard porous mass of low density, which when properly graded (in appropriate proportion), give same properties as that of fine aggregates. Hence, the incinerated sludge can be used instead of fine aggregates in construction of concrete pavements.Disposal of sludge is a cumbersome problem and it can also contribute to deterioration of the environment. For any waste water management agency sludge disposal is becoming a complex task day by day. The usual ways adopted for disposal of sludge are land filling, agricultural use and ocean dumping. Existing natural sand deposits are being emptied at the same rate as urbanization and new deposits are located either underground, too close to already built-up areas or too far away from the areas where it is needed, that is the towns and cities where the manufacturers of concrete are located. Concrete is the most used construction material in the industrialized countries. However,the concreteproduction needsnaturalresources(water and aggregates)and cement whose production is costly due to the energy required.On the otherhand, Environmental concerns are also being raised against uncontrolled extraction of natural sand. The arguments are mostly in regards to protecting riverbeds against erosion and the importance of having natural sand as a filter for ground water.In this modern world where conservation of environment has become a serious matter of concern for the society .It becomes necessary for each individual to find out ways in order to deal with such problems in a more eco-friendly and conservative manner. An economical way to deal with sludge disposal is to use it as a construction material by replacing the use of fine aggregates with incinerated sludge ash. . With this view in order to tackle this problem of sludge disposal, in the present study reuse of sludge with various percentage replacement are about to be tested.

II. EXPERIMENTAL PROGRAM

The present work is planned to study the properties of concrete at the fresh and hardened stage containing incinerated sludge ash as partial replacement of fine aggregates in differentcombinations.

A. Materials

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Incinerated sludge ash can be used as replacement material for fine aggregates as they successfully meet the durability and gradation standards of fine gradation. It is a non-plastic material as desired for a mineral filler. It may contain minute quantities of biodegradable content which depends on the efficiency of combustion. The concrete produced by replacing fine aggregates is expected to have certain properties such as decrease in density of the mix,improvement of durability and stability. Silica, calcium and iron are prime components of sludge ash and the percentage component of each depends on the additives used during the process of incineration and type of digestion. However, one major reason of not using sludge ash more frequently in concrete mixes is presence of traces of metal ions like lead, cadmium, zinc and copper. Incinerated sludge ash was collected from 21st Century Enviro Engineers Pvt. Ltd, Plot No. 120, Industrial Area Phase 2, Industrial Area Phase I, Chandigarh, 160002. Sufficient quantity of the coarse aggregates, fine aggregate and cement was collected from local market. The cement used in this study was Ordinary Portland cement (OPC 43 grade) of brand Shree ultra, specific gravity of which was 3.13. Coarse aggregate of maximum size 20 mm was used and fine aggregate confined to ZONE II. The specific gravity and fineness modulus of coarse aggregates was 2.66 and 6.68 respectively and that of fine aggregate was 2.63 and 2.53 respectively. Aggregate used are non reactive filler materials accounting to 60-80% volume of concrete. However, it greatly affects the stability and elastic properties of concrete.

B. Methodology

An experimental programme is planned in which controlled concrete of grade M20 mix will be designed, casted and tested for compressive strength after 28-days of curing. Three different mixes will be prepared containing 10%, 20% and 30% sludge ash as partial replacement of fine aggregates. These mixes will be tested for compressive strength, split tensile strength and flexural strength.

C. MixtureProportions

The mixture proportions of various concrete mixes are given in Table I. It shows the detail of concrete mix containing sludge ash as a partial replacement of Fine aggregates. Fixed quantity of coarse aggregate i.e. 200 kg was used in the manufacturing of all the concrete samples. Water cement ratio was kept constant, i.e. 0.60 for all the concrete samples.

Standard grade of concrete M20 has been designed referring to the concepts of "concrete mix proportioning" as mentioned in Indian standard code IS: 10262(2009). The design of concrete grade M20 is as follows: The type of cement which is used in the design is pozzolana Portland cement of grade 43(PPC 43) The maximum nominal size of aggregate used is 20mm. The target strength for mix proportioning can be calculated by using the formula:

$f' = fck + 1.65\sigma$

$= 20 + 1.65 \times 4 \ (\sigma = 4)$

$= 26.6 N/mm^2$

The specific gravity of the coarse aggregate as calculated = 2.68

Water absorption as found out = 1.46%

TABLE 1.
DETAIL OF CONCRETE MIX CONTAINING SLUDGE ASH AS A PARTIAL REPLACEMENT OF FINE AGGREGATES

Mix designation	Sludge Ash (%)	Cement (Kg)	Coarse Aggregate (Kg)	Fine Aggregate (kg)	Sludge Ash (Kg)
MS1	0	50	200	100	0
MS2	10	50	200	90	10
MS3	20	50	200	80	20
MS4	30	50	200	70	30

III. TESTS AND RESULTS

A. Compressive Strength

Using the above methodology for the design of M20 concrete grade by standard procedure, three different concrete mixes are prepared but in all of them the fine aggregate has been replaced by incinerated sludge ash. Three concrete blocks of each mix are cast by using the standard cube size 100×100×100mm as per IS 516 (1959), the hard cube specimens thus prepared are then subjected to compressive strength test using the test machine of 2000 KN capacity being able to operate with a loading rate of 2.5 KN/s.

TABLE 2. COMPRESSIVE STRENGTH VALUES FOR VARIOUS MIXES

Designated mix	7 days compressive strength (N/mm^2)	28 days compressive strength (N/mm^2)
MS1	22.48	32.3
MS2	20.3	29.6
MS3	19.8	27.3
MS4	17.9	25.9

The values of the compressive strength test at various intervals of days are represented with help of bar chart.

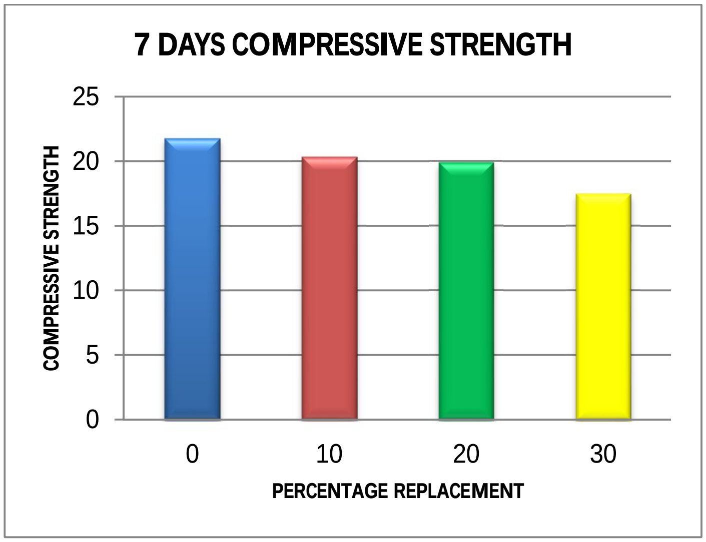

Fig.1 Compressive Strength Results After 7 Day Curing For Different Concrete Mix

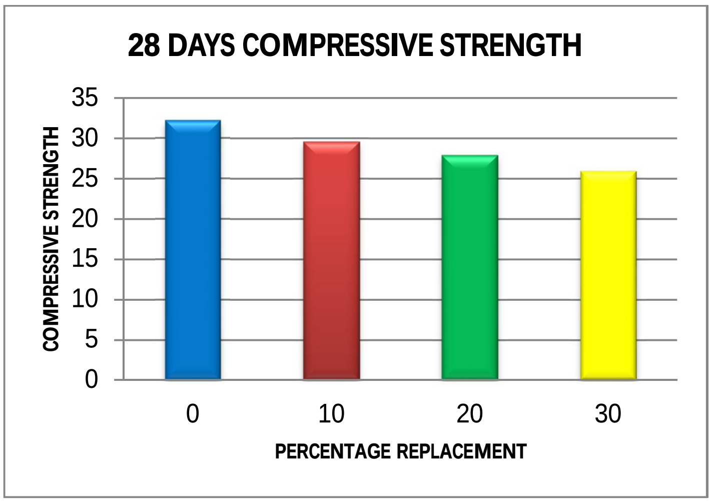

Fig. 2 Compressive strength results after 28 day curing for different concrete mix

B. Split Tensile Strength

Using a cylindrical mould, a cylinder of 300mm in height and 200mm in diameter were casted in order to test the most fundamental and important properties of concrete i.e. its tensile strength, which is tested by split tensile strength test. As concrete is quite brittle in nature therefore it is unable to resist direct tension. Under the influence of tensile forces cracks get developed in the concrete. Therefore it is important to access the maximum load which a particular concrete grade can bear without any signs of cracking, this can be determined by finding out the tensile strength of that particular concrete grade by split tensile strength test.

TABLE 3. SPLIT TENSILE STRENGTH VALUES FOR VARIOUS MIXES

Mix Designation	7 Days Split Tensile Strength(N/mm^2)	28 Days Split Tensile Strength(N/mm^2)
MS1	3.06	3.12
MS2	2.73	2.85
MS3	2.5	2.52
MS4	2.39	2.43

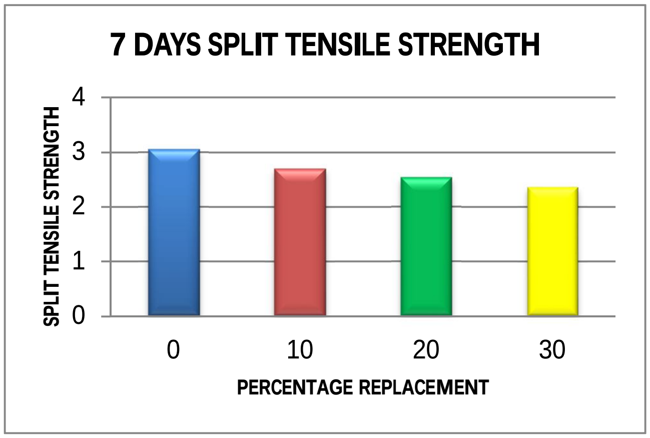

Fig.3 Split Tensile Strength Results After 7 Day Curing For Different Concrete Mix

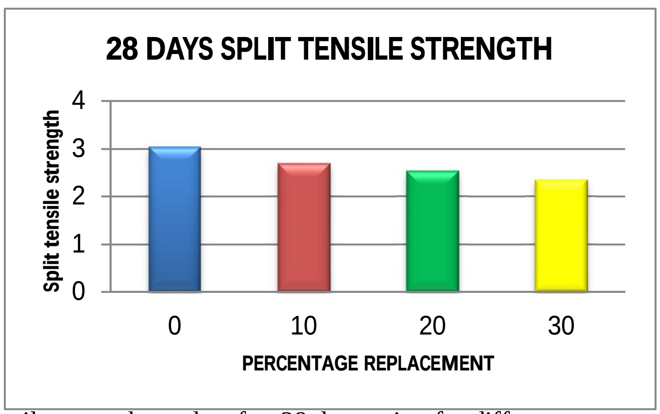

Fig. 4 Split Tensile strength results after 28 day curing for different concrete mix

C. Flexural Strength

Concrete mixes having various replacement percentages of incinerated sludge ash were used for making different prisms having size 100mm×100mm×500mm. Using these prism as sample flexural strength test was carried out in order to determine the corresponding flexural strength values of the samples. The specimens were subjected to load controlled machine (3 point loading system) with a load rate of 2KN/s.

TABLE 4. FLEXURAL STRENGTH VALUES FOR VARIOUS MIXES

Mix Designation	7 Days Flexural Strength(N/mm^2)	28 Days Flexural Strength(N/mm^2)
M1	3.4	4.2
M2	3.2	3.8
M3	2.7	3.5
M4	2.4	3.1

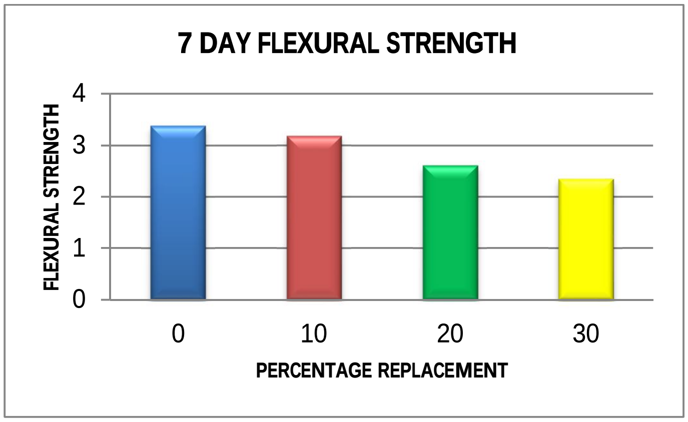

Fig.5 Flexural Strength Results After 7 Day Curing For Different Concrete Mix

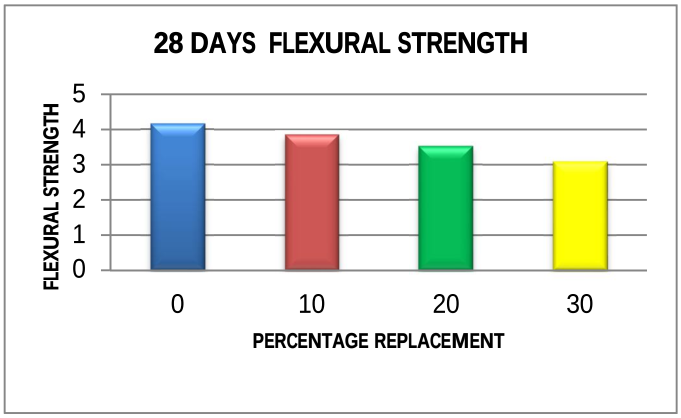

Fig.6 Flexural Strength Results After 28 Day Curing For Different Concrete Mix

IV. CONCLUSION

A. From the results of the compressive strength tests of thecasted cubes, it is observed that with the increase in percentages of incinerated sludge ash upto 30%, the compressive strength of 28 days is comparable to that of controlled concrete.

B. With further increase in replacement percentage of sludge ash, the designed strength is greatly affected and therefore it becomes impractical to use such a replacement in concrete mixes.

C. Hence, as the replacement fraction increases, the properties of the designed concrete mix goes on deviating from that of the controlled mix.

D. It is also observed that the development of compressive strength varies with respect to the curing time

E. Waste aggregates influence strength development at all stages. The rate of strength development of concrete with ash is comparable with controlled mix.

F. The presence of fine material and chemical composition are the two factors which lead to pozzolanic activity of ash. This pozzolanic material having fine silica, reacts with hydrated lime in presence of water and leads to formulation of stable compounds which have properties same as that of compounds formed in control mix setting.

G. In fact, the pozzolonic properties of SSA have an advantage over the natural mix in strength development when curing time is prolonged. However, this is found beneficial only in case of replacement upto 30% for higher replacements low strength of light weight aggregates gives low concrete strength.

V. ACKNOWLEDGEMENT

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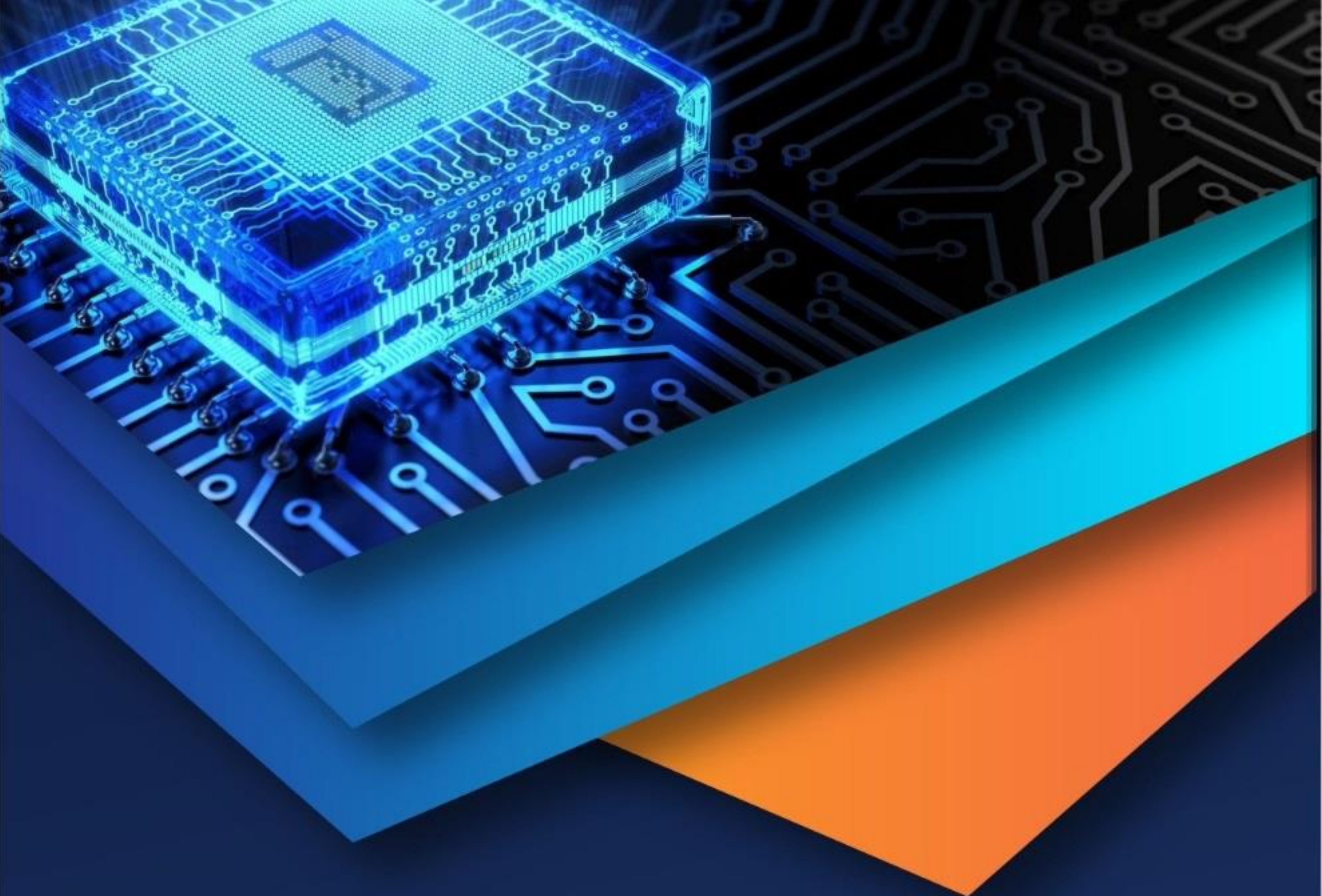

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