EFFECT ON COMPRESSIVE STRENGTH OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY MUNICIPAL SOLID WASTE INCINERATOR ASH

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Abstract - *This paper evaluates the properties of incinerator bottom ash from WTE (waste to energy) Plant, Essel MSW Pvt Ltd, Jabalpur to see what uses the material could be put to after incineration. The properties of the material make it suitable for use as fills, low-cost road sub-grades, sub-bases, and cement concrete. The M20 concrete mix was designed and produced by replacing cement with Municipal solid waste incinerator ash partially. Cement was replaced with 0%, 5%, 10%, 15%, 20%, 25% and 30% with municipal solid waste incinerator ash by weight. The compressive strength test was carried out to evaluate the properties of the M20 grade of concrete mix. The 7 days and 28 days compressive strength were increased by 28.05% and 15.31% in M20 concrete respectively at 10% cement replacement with municipal solid waste incinerator bottom ash (MSWIA).*

***Key Words*: Municipal Solid Waste Incinerator Bottom Ash*, Incinerator ash, MSWI, Cement Replacement, Concrete,* Bottom Ash**

1. INTRODUCTION

The incineration of municipal solid waste has significant benefits as it can reduce the volume and the mass of the waste by about 90% and 70%, respectively. Municipal solid waste is collected and burned in an incinerator; the by-products of the combustion process are collected. Bottom ash typically accounts for 80% of the whole amount of by-products in the MSWI plants.

Municipal solid waste incinerator (MSWI) bottom ash is the ash that is left over after waste is burnt in an incinerator. This ash contains glass, brick, rubble, sand, grit, metal, stone, concrete, ceramics and fused clinker as well as combustive products such as ash and slag.

Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This necessity led to a continuous and increasing demand for natural materials. Parallel to the need for the utilisation of the natural resources emerges a growing concern for protecting the environment and need to preserve natural resources, by using alternative materials that are either recycled or discarded as a waste.

One of the possibilities is to use Municipal Solid Waste Incineration (MSWI) ashes in concrete production. Studies have been carried out to investigate the possibility of utilizing for broad range of material as a partial replacement material for cement & aggregate n the production of concrete.

Concrete has been a major construction material for centuries. Moreover, it would even be of high application with the increase in industrialisation and urbanisation. Concrete construction so far is mainly based on the use of natural resources.

The conservation of natural resources is the need of the hour, and it is essential to have a look at the different alternatives. Among them lies the recycling mechanism. This process gives a two-fold advantage. One is that it can prevent the depletion of the scarce natural resources and the other is the prevention of different used(waste) materials from their severe threats to the environment.

2. MATERIALS

The materials used in the preparation of concrete are cement, sand, coarse aggregates, municipal solid waste incinerator bottom ash, and water.

2.1 Cement: Ordinary Portland Cement (43 Grades) which is available in the market has been used.

2.2 Sand: The natural river sand available in the local market which passes through 4.75mm sieve and having specific gravity of 2.65 (Conforming to Zone II) has been used.

2.3 Coarse Aggregate: Crushed granite conforming to IS 383:1987 and having specific gravity 2.80 has been used.

2.4 Water: Water is an important ingredient of concrete as it actively participated in the chemical reaction with cement. Clean portable water which is available in college campus has been used.

2.5 Municipal solid waste incinerator ash: The subject of study is MSWI ash (Figure-1) collected in the month of September 2016 in a modern incineration facility at WTE Plant, Essel MSW Pvt Ltd, Jabalpur. The incinerator ash has been sieved and metal pieces has been removed manually. The generated ash from incinerator involves a wide range of particles size; only the fraction less than 4.75 mm has been used in this work. The ash has been dried before experiments. The content of major components (in form of oxides) which are found in MSWI ash is presented in Table-1.

Figure-1 MSWI Bottom Ash

Table-1 Content of major oxides found in MSWI Ash

Compound	Percentage in MSWI ash	Percentage in Cement
Silica (SiO_2)	55.7	20.7
Alumina (Al_2O_3)	14.1	6.3
Iron oxide (Fe_2O_3)	8.8	3.6
Lime (CaO)	11.9	63.6
Magnesia (MgO)	2.7	2.4
Sulphur Trioxide (SO_3)	0.7	1.4
Sodium oxide (Na_2O)	1.4	0.1
Potassium oxide (K_2O)	1.2	0.1
Copper oxide (CuO)	0.5	-
Zinc oxide (ZnO)	0.3	-

3. METHODOLOGY

1. Collection of Municipal solid waste incineration ash.
2. Physical tests & Chemical tests conducted on incineration ash
3. Preparation of mix design M20.
4. Replace of cement with MSWI ash as 0%, 5%, 10%, 15%, 20%, 25%, and 30%.
5. Making a number of samples of concrete cubes.
6. Testing of cubes to 7 days, and 28 days.

4. COMPRESSIVE TEST

The Compressive strength test is the most common test conducted on hardened concrete, because it is easy to perform, and also most of the desirable characteristic properties of concrete are related to its Compressive strength.

The Compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist Compressive stresses. In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties.

Compressive strength test is carried on specimens of cubical in shape. The cube specimen is of the size 150mm X 150mm X 150mm. The cube moulds are coated with oil on their inner surfaces and placed on Plate. Concrete is poured into the mould in three layers, each layer is tempered properly so as not to have any voids. The top surface is finished using a trowel. After 24 hours concrete cubes are de-moulded and the specimens are kept for curing under water. These specimens are tested by compression testing machine after 7 days curing or 28 days curing.

5. RESULTS AND DISCUSSION

Table-2 Compressive Strength at 7 days (M20)

S. NO.	Designation Of Mix	Compressive strength (N/mm^2)			Average compressive strength (N/mm^2)
		Cube 1	Cube 2	Cube 3	
1	MSWIA 0%	17	21	19	19
2	MSWIA 5%	22	21	23	22.67
3	MSWIA 10%	22	26	25	24.33
4	MSWIA 15%	20	22	21	21
5	MSWIA 20%	17	14	14	15
6	MSWIA 25%	14	12	13	12.67
7	MSWIA 30%	10	10	11	10.33

Table-3 Compressive Strength at 28 days (M20)

S. NO.	Designation Of Mix	Compressive strength (N/mm^2)			Average compressive strength (N/mm^2)
		Cube 1	Cube 2	Cube 3	
1	MSWIA 0%	28	29	28	28.33
2	MSWIA 5%	31	35	32	31
3	MSWIA 10%	33	30	30	32.67
4	MSWIA 15%	24	25	23	28
5	MSWIA 20%	22	22	23	22.33
6	MSWIA 25%	20	22	18	20
7	MSWIA 30%	15	16	17	16

Compression test carried out on sample cubes by using compression testing machine. The specimens were loaded at a constant strain rate until failure. The compressive strength first increases with increase in the percentage of MSWI ash content up to 10% but start decreasing on further addition of ash content. The results of compressive strength cubes for 7 days curing and 28 days curing are given as in Table-2 and Table-3, and their corresponding graphs are shown in Figure-2 and Figure-3 respectively.

Figure-2

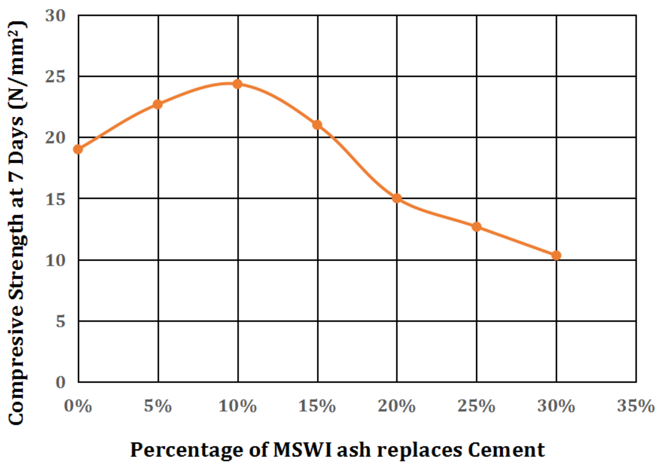
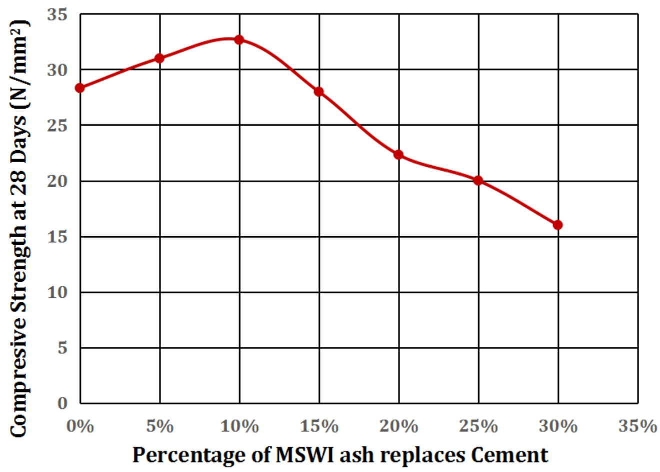


Figure-3



The presence of metallic aluminium in bottom ash causes an evolution of hydrogen gas and the gas is entrapped within concrete by the following chemical reaction (Aubert et al., 2004; Muller and Rubner, 2006; Sorlini et al., 2011)

$$2Al + 4OH^- + 2H_2O \rightarrow 2Al(OH)_3 + H_2\uparrow$$

In addition, concrete expands due to an undesirable increase in the volume of aluminates by the formation of aluminium hydroxide as described by (Muller and Rubner, 2006)

$$Al(OH)_3 + OH^- \rightarrow (Al(OH)_4)^-$$

$$2(Al(OH)_4)^- + 3Ca^{2+} + 4OH^- \rightarrow 3CaO.Al_2O_3.6H_2O\downarrow$$

These reactions cause cracking and spalling of concrete (Bertolini et al., 2004) and eventually lead to a significant increase in permeability and a reduction in strength of hardened concrete. In order for appropriate utilisation of MSWI bottom ash as a sustainable construction material, it is, therefore, essential to develop proper treatment techniques to remove metallic aluminium from the ash. This paper reports experimental investigations on concrete incorporating MSWI bottom ash as a partial replacement of Cement.

6. CONCLUSION

It is observed that the behaviour of compressive strength of cubes changes after a certain point called peak point. The compressive strength increases as the percentage of incinerator ash replacing cement increases, this nature continues to the peak point. After the peak point, the compressive of cubes start decreasing.

Municipal solid waste incineration (MSWI) bottom ash should be given proper chemical treatment to avoid hydrogen gas evolution when used in concrete, which can eventually lead to a significant reduction of the concrete strength.

However, the compressive strength test result shows improvement when ash replaces less or equal to 10% of cement in comparison to the control cube (0% cement replacement), but strength falls when ash replaces more than 10% of cement. The cubes are tested at the 7th and 28th day after they were moulded. Thus, replacement of municipal solid waste incinerator ash up to 10% is suitable for construction of normal buildings.

7. REFERENCE

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