CHAPTER 149

Utilization of Biomedical Incineration Ash by It's Application in Concrete Pavement

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ABSTRACT

Scientific and technological advancements are intimately related to advances in the medical field. The generation of medical waste has sharply increased in tandem with the growth of the global population and the rising use of medical facilities. Because of their hazardous nature, these wastes pose serious environmental and public health risks. Although incineration is a frequently used technique for handling this kind of waste, it produces ash, usually disposed of in landfills. This practice can lead to groundwater pollution due to the leaching of contaminants from the ash, which also consumes large amounts of land. This research aims to explore alternatives to burning incinerator ash in landfills. This study further investigates the potential of utilizing medical incineration ash in concrete road construction to reduce sunlight reflection by repurposing the ash. The research attempts to minimize environmental impacts and contribute to the reduction of urban heat island effects.

Keywords: Concrete pavement; Ash; Environmental impacts.

1.0 Introduction

India has long been a leader in the medical field, and it has also been prominent in infrastructure development. As the population grew, there was a corresponding expansion in the medical sector, and the need for road construction increased to extend the infrastructure network. With the diminishing availability of natural asphalt sources over time, a shortage of asphalt arose, leading to the emergence of concrete roads. These roads are solid, durable, and last significantly longer, which has led to their widespread adoption in a short period. Currently, majority of the highways in India are being constructed with concrete. However, a downside is emerging: the reflection of sunlight from cement roads is causing discomfort to drivers' eyes and increasing the rate of accidents. In addressing this issue, a solution is found in another problem which is growing medical waste in the country and the ash produced from it's controlled incineration. The ash has properties similar to cement and is black, so roads made from it are black and have reduced sunlight reflection.

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This lowers the amount of cement used and, by adding medical waste ash, also contributes to a reduction in soil pollution and costs because of the lower cement content percentage.

2.0 Literature Review

Baghotia (2017) emphasizes the importance of a systems approach to manage biomedical waste effectively, particularly in India, where smaller healthcare facilities often lack adequate waste management practices. The review of regulatory frameworks, such as the Bio-medical Waste Management Rules of 2016, highlights the need for enhanced protocols and infrastructure to mitigate health risks and ensure compliance with environmental laws. The categorization of biomedical waste into healthcare general waste (HCGW) and healthcare risk waste (HCRW) is crucial for effective management. The principles of reduction, reuse, and recycling (the "3Rs") are advocated to minimize waste generation, while proper segregation, storage, transport, and disposal methods are essential to prevent environmental damage and health hazards Research by Kumar *et al.* (2016) explores the potential of using biomedical waste ash as a partial replacement for cement in concrete, indicating that it can improve compressive strength while reducing landfill demand. However, the study also notes that higher ash content may decrease workability and strength, suggesting a balanced approach to its application in construction.

3.0 Specific Objectives

- To evaluate possibility of using medical incineration ash in roads by replacing conventional cement.
- Determine the optimal mix proportions of incineration bottom ash, cement, aggregate, and other additives to achieve desired concrete proportions while minimizing cement content to lesson the sunlight light reflection on roads.
- Conduct road reflection study by field trials to evaluate the actual performance of concrete pavement with incineration bottom ash under real-world traffic and environmental conditions

4.0 Methodology

Problem identification: With the continuous increase in population and increase in the use of medical facilities there is a sharp rise in the generation of medical waste. These wastes are hazardous and have the greatest potential to have an impact on living beings and the environment. One of the important methods of treatment of such waste is incineration but this method also produces ash which is a subject of landfilling. This causes the wastage of large

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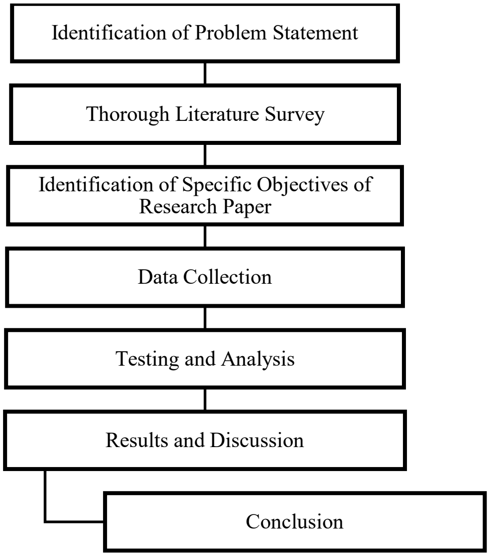
areas of land also leaching contaminants in ashes causes contamination of ground water. The purpose of this project is to find some alternative for landfilling incineration ashes.

Figure 1: Methodology



Collecting the sample of incineration bottom ash: To investigate the use of bottom ash from biomedical incineration in concrete, we took a sample from the Bio Clean Plant, which is situated on Barshi Road in Solapur. Additionally, the process of collecting the sample biomedical incineration ash has been successfully finished. To determine this sample's qualities and appropriateness for usage in concrete applications, analysis will be performed.

Composition of the biomedical incineration bottom ash: To use the biomedical incineration bottom ash in concrete, it was necessary to analyze the composition of the bottom ash so that its suitability could be determined. The following are the major components of the biomedical incineration bottom ash:

- $Si0_2$ - (11.93%)
- Cao - (22.8 %)
- Na_2O - (9.13%)
- Al2O3 - (5.16%)
- Fe_2O_3 - (2.93%)

Replacement of cement by biomedical incineration bottom ash: In this method, cement content is reduced by a certain percentage and is replaced by incineration bottom ash in concrete. The other components of concrete are taken as per the mix design. Three cubes are Casted and their average compressive strength is considered as a result.

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Preparation of mix design of M30: Because of its high calcium oxide (CaO) content (22.8%), which aids in binding and strength characteristics, and its silica (SiO_2) content (11.3%), which promotes pozzolanic activity and increases long-term strength and durability, biomedical incineration ash can be utilized in M30-grade concrete. By recycling waste materials, using this ash in place of some of the cement improves the sustainability of the concrete and lowers production costs and carbon emissions, making it an eco-friendly way to achieve the necessary strength and performance of M30-grade concrete. Optimizing the ratios of cement, fine aggregates, coarse aggregates, and water is part of the mix design for M30 grade concrete that incorporates biomedical incineration ash. The ash is used to partially replace cement or fine aggregates. The physical and chemical characteristics of biomedical incineration ash are described, and replacement percentages usually vary from 5 to 15% based on the ash's reactivity and effect on concrete performance. The mix design has a water-to-cement ratio of 0.4 to 0.45 and complies with IS 10262:2019.

Cube casting of 0.015 cum: In order to cast 0.015 m^3 of biomedical incineration ash (BIA) cubes into concrete, BIA is mixed with aggregates and water, partially substituted for cement, and then poured into a mold. To assess the effect of (BIA) biomedical incineration ash on concrete performance, the cube is cured in water after setting and then tested for compressive strength.

Testing of cubes: When testing cubes that contain bottom ash from biomedical incineration in concrete pavement, the material's mechanical qualities, longevity, and performance under load-bearing circumstances are assessed. By substituting different percentages of bottom ash for conventional aggregates, this method tests the compressive strength of the concrete cubes. The results are examined to ascertain whether using bottom ash in pavement construction is feasible, taking into account elements like long-term performance, resistance to environmental conditions, and structural integrity. Through the reuse of biomedical waste by-products in concrete applications, the study seeks to advance Environmental sustainable construction practices.

Result Analysis: The investigation of biomedical incinerator ash (BIA) and its possible usage in concrete pavement are the main topics of the study. In order to determine whether biomedical incinerator ash BIA can be used as a partial substitute for traditional materials in concrete, the process entails obtaining it from incineration plants and then thoroughly characterizing it both physically and chemically. Different mix patterns were created by substituting biomedical incinerator ash BIA in varying percentages for some of the cement or fine aggregate. Standard tests for workability, durability, and compressive strength were then performed on these mixes. The findings showed that biomedical incinerator ash BIA might improve concrete's strength and environmental sustainability at the right replacement levels, making it a feasible material for environmentally friendly concrete pavements. However, more research is needed to determine the long-term performance and possible leaking of hazardous materials.

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5.0 Materials and Procedures

5.1 Bio-medical Incineration bottom ash collection

To study and use the biomedical incineration bottom ash in concrete, a sample was collected from the Bio clean Plant Barshi Road, Solapur.

Objectives	**Biomedical ash 10% used**					
CONCRETE GRADE	**M30**					
MATERIAL AND THEIR SOURCE					**SPECIFIC GRAVITY**	
CEMENT: OPC/PSC/PCC	OPC : ULTRATECH				3.15	
CRUSH SAND	WAGHOLI : GANRAJ STONE CRUSHER				2.85	
COARSE 1 (10 MM)	WAGHOLI : GANRAJ STONE CRUSHER				2.87	
COARSE 2 (20 MM)	WAGHOLI : GANRAJ STONE CRUSHER				2.9	
W/C RATIO	**0.38**				1.11	
MOISTURE CONTENT ABSORPTION VALUES						
MATERIAL	10MM	20MM	RIVER SAND	CRUSH SAND		
SURFACE MOISTURE	0.00%	0.00%	0.00%	0.50%		
ABSORPTION	1.30%	1.30%	0.00%	3.50%		
CORRECTED	1.30%	1.30%	0.00%	3.00%		
			BATCH VOLUME :- 0.0136 M3			
MIX PROP/UNIT BATCH WEIGHTS/M3			**WEIGHT PER M3**	**CORRECTION**	**CORRECTED BATCH**	**TRIAL BATCH WT**
CEMENT, KG	371		371	0.000	371	5.05
BIOMEDICAL ASH, KG	42		42	0.000	42	0.57
CRUSH SAND, KG	638		638	19.140	618.86	8.42
COARSE : 1 (10MM), KG	347		347	4.511	342.49	4.66
COARSE : 2 (20MM), KG	810		810	10.530	799.47	10.87
WATER IN KGS	155		155	34.181	189.18	2.37
THEROTICAL B.D	**2363.00**		**2363.00**	**68.36**	**2363.00**	**95.82**
HARDENED PROPERTIES						
COMPRESSIVE STRENGTH	AGE	STRENGTH IN MPA	AVERAGE STRENGTH IN MPS			
	7	28.85				
	7	28.4	**28.4**			
	7	27.95				
	28	38.82				
	28	39.17	**38.99**			
	28	38.99				

5.2 Culture and antibiotic sensitivity test on biomedical incineration ash

To better understand microbial contamination and assess the sample's potential health and environmental risks, the bottom ash sample was sent to a pathology lab in Pune for a thorough Culture and Antibiotic Sensitivity Test. The lab carries out microbial culturing, which involves putting the sample in a controlled environment with particular growth media to promote the growth of any bacteria or fungi that are present. This stage is crucial for separating and identifying pathogens potentially dangerous microorganisms that could infect people, animals, or the environment. Furthermore, the observed microbial activity might point to the possibility of toxic leachate formation, which could contaminate groundwater and soil.

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In order to precisely identify the species of microorganisms present, the identification procedure usually takes two to three days and uses sophisticated techniques like Gram staining, biochemical assays, and molecular methods like PCR. Following identification, the pathogens undergo antibiotic sensitivity testing, in which they are exposed to a variety of antibiotics in order to assess their resistance or susceptibility. Finding multidrug-resistant organisms that present serious public health risks, like MRSA or strains that produce ESBL, requires this step.

Figure 2: Sample of Ash for Lab Test

This sample of ash was given for culture and antibiotic sensitivity tests to identify the presence of bacteria or fungi as well as leachate sensitivity. The report states that no organism is isolated in biomedical incineration ash hence it is sterile and leachate-free.

5.3 Composition of the biomedical incineration bottom ash

It is essential to examine the composition and characteristics of bottom ash from biomedical incineration in order to assess its possible application in concrete. An effective method used in this investigation to evaluate the ash's mineralogical and structural properties is X-ray diffraction (XRD). This technique examines the diffraction patterns created when X-rays interact with the material's crystalline phases. The patterns offer important information about the kinds and amounts of crystalline compounds that are present, which has a direct impact on the reactivity and functionality of the ash in concrete applications. XRD analysis is crucial for identifying substances like quartz, calcite, or other silicates and oxides that may affect the structural compatibility of biomedical incineration ash with cement because it frequently contains a mixture of crystalline and amorphous phases. The XRD data is essential for assessing

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whether the ash is suitable for use in construction. Amorphous silica and aluminosilicates are examples of crystalline phases with pozzolanic activity that can improve the strength and durability of concrete, whereas inert or hazardous substances can lessen its efficacy or safety. Through the identification of these phases, XRD analysis aids in the evaluation of the ash's chemical and physical characteristics and directs the improvement of its application and processing. The successful and long-lasting integration of biomedical incineration ash into building materials is made possible by this understanding, which serves as the foundation for additional testing, such as chemical, mechanical, and environmental assessments.

The chemical composition of biomedical incineration ash is highlighted in the provided XRD report, with calcium oxide (CaO) accounting for 22.8%, silica (SiO_2) for 11.3%, and iron oxide (FeO_3) for 2.93%. These elements are important markers of the material's possible application in concrete. The silica content indicates the possibility of pozzolanic reactions, which improve strength and durability, while the high calcium content is consistent with the fundamental binding qualities needed for cementitious materials.

Although small, the iron oxide content is within permissible bounds for concrete applications and does not present a serious problem. The ash's calcium and silica content makes it appropriate for partial cement substitution in concrete. While silica combines with calcium hydroxide to create more calcium silicate hydrates, which gradually increase strength, calcium oxide aids in the setting and hardening process. By recycling waste materials and lowering dependency on natural resources, using incineration ash in concrete also benefits the environment and is consistent with sustainable building methods. Additional tests are advised to assess durability, pozzolanic activity, and compressive strength in order to verify its suitability. Fine grinding is one method of processing ash that can improve its reactivity and cement compatibility. In order to balance performance, cost, and environmental impact, it is also essential to optimize the blend ratio with cement. Ash from biomedical incineration has the potential to be a practical and sustainable ingredient in the manufacturing of concrete with these steps. According to the report, ash from biomedical incineration is rich in calcium, iron, and silicon dioxide, all essential cement ingredients. For strength, Ca_0 and Sio_2 combine to create calcium silicate (Ca_0), and fe_20_3 works as a flux and fortifies the mixture.

6.0 Line of Work

6.1 Replacement of cement by biomedical incineration bottom ash in concrete (5%, 10%, 15%, 20%,25%)

By using this method, the percentage of cement in the concrete is decreased by 5%, 10%, 15%, 20%, and 25% and is replaced with bottom ash from incineration. The other components of concrete are taken as per the mix design. Three cubes are cast of each percentage and their average compressive strength of 7 days and their average compressive strength of 28 days are considered as a result.

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6.2 Preparation of mix design of M30 grade concrete

The concrete cubes were cast in M30 Grade concrete according to the following mix design.

Figure 3: Cube Casting

6.3 Cube casting process

The cube was cast by the mixed design adopted from IS 10262-2009. This sequence of steps can be undertaken.

6.4 Testing of cubes

The following two tests are carried out on cubes:

- Compression test
- Reflection test by lux meter apparatus

6.4.1 Compression test

The ability of a material or structure to resist or tolerate compression is known as its compressive strength. The capacity of a material to withstand failure in the form of fissures and cracks is what determines its compressive strength. The push forces applied to the concrete specimen's two faces during the test, as well as the highest compression the material can withstand without failing, are recorded.

- Compression test following a 7-day healing period
- Compression test following a 28-day healing period

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Figure 4: Concrete Block (Using incineration ash)

6.4.2 Reflection test by lux meter appratus

To gauge how much light is reflected off a specific work surface, use a lux meter. A sensor on the light meter gauges the amount of light shining on it and gives the user a quantifiable reading of the illuminance. The light sensor of the illuminometer satisfies the requirements for this kind of instrument by consisting of a photodiode that transforms light into an electrical signal, an optical filter that guarantees the same sensitivity as the human eye, and a diffusing globe that makes cosine correction easier.

6.4.3 Reflection of sunlight measured by lux meter after 28 days

Because biomedical incineration ash (BIA) significantly alters the material's surface characteristics, there is less reflection in the concrete block that contains BIA. The carbon residues, silica, and other oxides that are commonly found in BIA darken the concrete's surface and increase its propensity to absorb sunlight rather than reflect it. Given that darker surfaces typically reflect less light than lighter ones, this darker coloring is a major contributing factor to the lower reflectivity. Additionally, by adding microscopic roughness, the ash particles may change the concrete's surface texture. The amount of light that is reflected back to the luxmeter is decreased by this roughness, which disperses the sunlight in various directions. The luxmeter reading of 125 LUX, which is less than what would be predicted from conventional concrete 190 LUX, shows that these combined chemical and physical effects significantly reduce the surface's capacity to reflect sunlight. This illustrates how the addition of BIA affects the material's reflective qualities.

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Figure 5: Concrete Block (Conventional)

6.4.4 Reflection of sunlight measured by LUX meter after 28 days

The interaction of the material composition and surface characteristics of a 28-day-old conventional concrete block containing incineration ash can account for a luxmeter reading of 190 LUX. Concrete's texture, color, and density all affect how much sunlight it reflects. The formation of a dense matrix by cement hydration affects surface texture, which in turn affects light reflectivity. A rougher surface scatters light, lowering the lux value, whereas a smoother surface reflects more light. Moderate reflectivity is indicated by the reading of 190 LUX, which is typical for regular concrete that has additional materials like incineration ash added.

The conventional concrete block's luxmeter reading of 190 LUX indicates a substantially higher sunlight reflectivity than the block with biomedical incineration ash, which recorded 125 LUX. This discrepancy can be explained by the fact that biomedical incineration ash has a finer particle size and a darker color, which tends to absorb more light and scatter less, decreasing its reflectivity. Conventional concrete that doesn't contain this kind of ash frequently has a lighter surface and a less absorbent texture, which makes it more capable of reflecting sunlight. The decreased lux reading in biomedical ash concrete emphasizes the material's changed surface characteristics, which include a denser, darker, and less reflective material due to the pozzolanic activity and ash composition. This illustrates how the kind of incineration ash greatly affects concrete's optical properties.

7.0 Result and Discussion

Various tests were carried out and the results of these are as follows:

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Table 1: Compressive Strength of the Concrete Block

Percentage of Ash	Block No.	Compressive Strength after 7 days (N/mm^2)	Average (N/mm^2)	Compressive Strength after 28 days (N/mm^2)	Average (N/mm^2)
	1	42.63		49.97	
5%	2	41.95	42.3	49.83	49.9
	3	42.32		49.90	
	1	28.85		38.82	
10%	2	28.40	28.4	39.17	38.99
	3	27.95		38.99	
	1	27.40		38.44	
15%	2	27.65	27.4	37.35	37.83
	3	27.21		37.69	
	1	25.29		37.70	
20%	2	24.81	25.08	36.03	36.57
	3	25.14		35.98	
	1	23.29		35.24	
25%	2	23.11	2222.84	35.38	3434.96
	3	22.13		34.28	

- From the above results, it is observed that a 5% bio medical ash replacement block gives maximum compressive strength as compared to other percentages.
  i.e. 7 days = 42.3 N/mm^2 and 28 days = 49.9 N/mm^2
- Then the percentage of replacement of incineration ash is taken up to 20% as it gave strength 36.57 N/mm^2 (which is more than the ideal value i.e 30 N/mm^2 according to IS Code) Hence, as per IS code standard one is supposed to get 100% strength but in this study, 115% strength was obtained even after replacement of 20% cement content.

Table 2: Lux Meter Reading

Concrete Block (Normal)	Concrete Block (Incineration Ash)	Reduced Percentage
190 x 100 LUX	125 x 100 LUX	34%

- The above result shows the reflection of the concrete block (normal) is more than the concrete block (incineration ash).
- The reflection is reduced by 34% in concrete blocks (Incineration Ash).

8.0 Conclusion

- The biomedical incineration bottom ash was confirmed to be sterile, with no bacterial growth or toxic substances found in the culture test, making it a safe material for use in concrete

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- The maximum compressive strength was achieved with a 5% replacement of cement by biomedical incineration ash, with concrete showing optimal performance at both 7 and 28 days of curing

Figure 6: Compressive Strength after 7 Days at Different Replacement Ash (%)

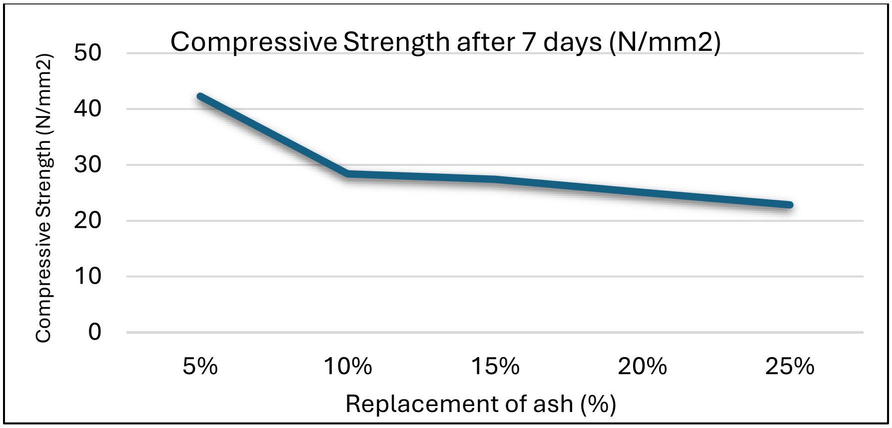
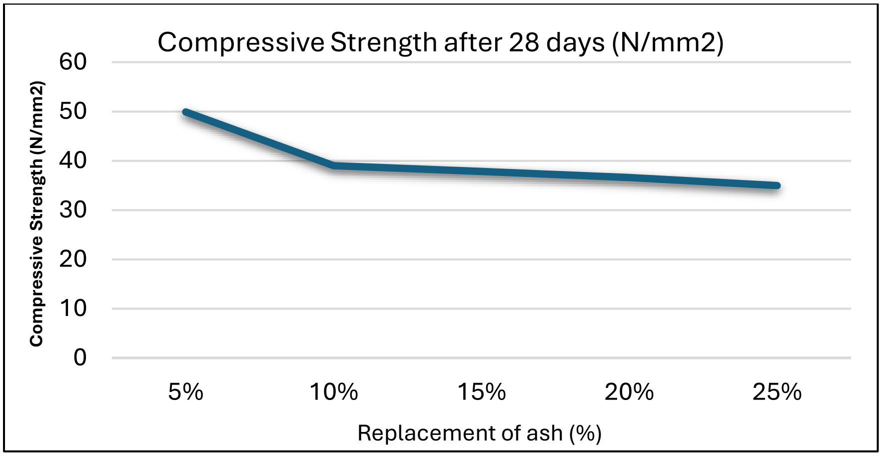


Figure 7: Compressive Strength after 28 Days at Different Replacement Ash (%)



- A 25% replacement of cement with biomedical incineration ash resulted in a compressive strength of 34.96 N/mm² after 28 days, exceeding the IS Code's ideal strength of 30 N/mm², indicating that the ash can significantly contribute to concrete strength.
- The addition of biomedical incineration ash created a darker, asphalt-like surface, reducing sunlight reflection and improving road safety by lowering the risk of accidents caused by glare.

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- The study highlights the environmental benefits of using biomedical incineration ash in concrete, such as reducing landfilling, conserving land resources, and mitigating soil and groundwater pollution, while providing a cost-effective alternative for construction activities

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