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Critical Review on Strength and Durability Properties of Concrete using Incinerated Biomedical Waste Ash

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Abstract: *Waste generation has increased considerably worldwide in the last few decades. Solid wastes encompass the heterogeneous mass of throwaways from the urban community as well as the homogeneous accumulations of agricultural, industrial and mineral wastes. Waste generated from biomedical activities represents a real problem of living nature and human world. A proper waste management system should be required to dispose hazardous biomedical waste and incineration should be the best available technology to reduce the volume of this hazardous waste. The incineration process destroys pathogens and reduces the waste volume and weight but leaves a solid material called biomedical waste incineration ash as residue which increases the levels of heavy metals, inorganic salts and organic compounds in the environment. Disposal of biomedical waste ash in landfill without proper treatment may cause contamination of groundwater due to leachate as metals are not destroyed during incineration. The limited space and the high cost for land disposal led to the development of recycling technologies and the reuse of ash in different systems. There is a scope of utilization of incinerated biomedical waste ash (IBWA) in the production of concrete.This review of literature research paper is intended to evaluate the feasibility of using biomedical waste ash as partial replacement of cement in concrete.*

Keywords: Biomedical waste Ash-Strength and durability properties of Concrete feasibility studiesof using BMWA-Future prospects

I. INTRODUCTION

Biomedical waste is a collection of medical waste from diverse sources that pose a major risk to human, plant, or animal life now or in the future. It cannot be processed or discarded off without proper processing.Bio-medical waste is defined as “any solid and/or liquid waste, including its container and any intermediate product, generated during the diagnosis, treatment, or immunization of humans or animals, or related research activities, or in the manufacturing or testing of biological products in health camps”. Biomedical waste is dangerous for two reasons. The first is infectivity, and the second is toxicity Biomedical waste is often burnt in incineration plants, yielding Incinerated Biomedical Waste Ash (IBMW) which is disposed off in landfills, which are not completely leak-proof. In India, presently biomedical waste is generating 550.9 tons per day, and it is annually increasing by 8%. Biomedical waste management is a basic public health concern and needs to planning for proper collection, safe storage, systematic transportation and disposal. The problem of biomedical waste management needs a safe technology, as also centralized facilities.

Bio Human anatomical waste such as tissues, organs, and body parts, animal wastes generated during research from veterinary clinics, microbiology and biotechnology wastes, waste sharps such as hypodermic needles, syringes, scalpels, and broken glass are all examples of medical waste. discarded pharmaceuticals and cytotoxic drugs, soiled waste such as dressings, bandages, plaster casts, blood-contaminated material, tubes and catheters, and liquid waste from any diseased region Biomedical activities increase waste volume and have a substantial impact because it is mainly fatal. For the treatment and disposal of biological waste, an adequate waste management system is required. To handle hazardous waste, methods such as carbon adsorption, incineration, chemical precipitation, chemical disinfection, biological oxidation, membrane separation, and others have been used, although incineration is the best treatment for biomedical waste .The harmful acid gases such as (CO2, SO2, NO2 etc.) are generated during the burning of biomedical wastes combined with leftover ashes (bottom and fly ash). The qualities of biomedical waste are determined by the source of trash collection. For instance, research laboratories, blood testing laboratories, and so on. Although incineration can reduce waste weight by more than 70%, considerable volumes of combustion leftovers, particularly bottom ash, remain after incineration. According to data from the Government of India's website, the total amount of BMW produced in the country is 484 TPD (tonnes per day) from 1,68,869 HCFs.CPCB reported that the waste handling capacity of incineration plants is approximately 15.01 lakhs MTA, but waste produced from biomedical activities is 27.30 lakhs metric tonnes per year, which is greater than the amount that can be treated at incineration plants. There are various types of incinerators in use. Rotary kiln, fluidized bed, moving grate, liquid injection, multiple hearth, catalytic combustion, waste-gas flare, and fixed grate / direct-flame are some of the more widely employed. The combustion of collected biological waste in the presence of sufficient oxygen is associated with the incineration process. When garbage is incinerated at temperatures above 850^{0}C, it is transformed into ash and harmful gases. The trash is broken down into CO_2 and water. The majority of the ash produced is bottom ash, which is the remnants that remain inside the burner after incineration. Post-burner equipment, such as scrubbers, collects fly ash. When incinerated hospital waste ash is melted at 1,200^{0}C, the ash becomes molten, and the molten ash is transformed to slag by cooling at normal temperature. Metals are not eliminated during incineration and are frequently discharged into the environment with the ash. This biomedical waste ash will be used as partial replacement of cement in concrete manufacturing nowadays to improve the hardened properties of concrete.

II. CRITICAL REVIEW ON THE INVESTIGATION OF INCINERATED BIOMEDICAL WASTE ASH IN CONCRETE

2.1 Udit Kumar et.al investigated that,

Biomedical waste ash can effectively be used in concrete making. Workability of concrete made using biomedical waste ash is lower than that of conventional concrete.

Density of concrete decreased slightly with increase in replacement level.However upto 15% replacement level density was about 99% of that of conventional concrete. Compressive strength of concrete with biomedical waste ash satisfied the requirement of normal concrete.

2.2 Kailash Narayan Katare et.al investigated that,

The addition of IBMW to concrete reduces the slump value, and increases the water absorption and sorptivity. This is due to the expansive nature of IBMW and porosity. Hence, super-plasticizer is essential to improve workability.

The experimental study results suggest that including 7.5% IBMW as a partial cement replacement improves the compressive strength by 20%; improves the split tensile strength by 17% and flexural strength by 14% compared to control mix in 28 days. The addition of IBMW upto 7.5% was found to decrease the voids and provide a dense matrix. Thus, it showed an improved microstructure. The use of IBMW as a partial replacement for sand in concrete solves the problem of limited area and high land disposal costs, resulting in a pollution-free environment.

2.3 M. Anand and Sanjay Chandraet.al concluded that,

The replacement of ash obtained from hospital wastes can be used for the preparation of concrete. The best advantage of this partial replacement is reducing the over dumping of hospital waste to public.

In this research the workability decreased with increasing percentage of proportion of ash. The compressive strength of specimen with 5% ash shows higher than that of control mix.

2.4 Sabo Bala and Hassan Abba Musaet.al discovered that,

Hospital Waste Ash used for the research has about 85.97% of PAI which makes it suitable to be used as a pozzolana since this value exceeds the 70% specified by ASTM.

Also, the slight decrease in the modulus of rapture due to increase in replacement clearly indicated that utilized in concrete production.

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2.5 Lubna K. Hamada, Zainab Z. Ismailet.alinvestigated that,

The recycling of waste medical needles topartially replace the fine aggregate in concretemixes.

Water absorption levels in theWNs- concrete mixes decreased with increasingthe content of the WNs for all curing ages. Compressivestrength of the concrete mixes slightlyincreased with increasing the WNs ratio.

However, the minimum value of compressive strength was (34MPa) for 2% replacement of aggregates at 7 days of curing age but it was higher than the minimum value (17.4MPa) of lightweight concrete for structural application.

2.6 T. Ahmed et.al investigated that,

Heavy metals present in fly ash can be successfully immobilized when it isincorporated incement-mortar matrix albeit having slightly detrimental effects on its engineering properties such as workability, setting times, soundness and compressive strength. But cement with 10% fly ash can still have desirable engineering properties as per ASTM specifications of cement and cement-mortar matrix.

Therefore, medical waste incineration fly ash incorporation into cement appears to be a promising avenue for waste management and successful recycling of waste in the construction material.

2.7 Menker Girma and Belachew Asteray et.al concluded that,

The replacement percentage of BWIA and BA increases the slump, flowability, and compaction factor, and density of fresh concrete decreases.

At an early age of curing, the replacement percentage of BWIA and BA increases compressive strength, and split tensile strength decreases. At 28 days of curing, up to 10% replacement of the BA and BWIA can improve the mechanical properties of highstrength concrete.

2.8 B. Prasanth and V. Ranga Raoet.al investigated that,

M30 grade of concrete in compressive strength and split tensile strength were increased for combination of 20% BMWA and 20% Meta kaolin when compared with that of controlled concrete.

There was a decrease in workability (slump) as the replacement level increases.

For three different loading conditions of three point loading, fourpoint loading, uniformly distributed loading gives better flexural and shear failure resistance compare to control specimens.

2.9 Asefachew Belete Tseganehet.al discussed that,

The stabilizing behavior of the BWIA was demonstrated by the significant reduction of the free-swell index; a 66.7% decrease was obtained when the subgrade was blended with 9% of BWIA.

The UCS increased significantly with the addition of BWIA, up to about 9% by weight. Doubling and tripling the strength of the original subgrade material was observed for uncured and 7 days cured specimens at this optimal addition of the stabilizer.

2.10 Shazim Ali Memon et.al studied on,

Lowcost concrete can be made by utilizing HWA as partial replacement of cement in concrete without compromising the strength parameters.

The setting time increased while the density and water absorption of mixes decreased with the increase in the percentage of HWA in the mix.

The utilization of HWA as partial replacement of cement in concrete solves the problem of it's the disposal thus keeping the environment free from pollution.

2.11 Surinder Gopalrao Wawale et.al investigated that,

For optimizing the biomedical waste management, the new information and communication technology system that is proposed has various advantages. Tracking different types of waste, even hazardous ones in real-time, tracking and locating more thousands of waste items, separation of waste in real-time can be done through this system.

The proposed system also ensures that the BMWM leads to hazard-free environment of the healthcare facilities. It also ensures that an automation of the system proves to be a boon to the facility, to the general public and the environment as a whole.

2.12 Harish T. Mohan et.al investigated that,

Compressive strength of 25 MPa and above is observed in case of composite with lower filler ratios, which shows the potential benefit of the developed composite as a construction material. Gradual crack propagation observed during the failure of the composite justifies the elimination of a catastrophic failure of the structure made of such blocks.

An increased acid resistance justifies the usage of the composite in acid rain prone regions and other acid rich environment like factories. It is also observed that the acid absorption has lower impact on compressive strength.

2.13 M. Kanta Rao and Ch. N. Satish Kumaret.al concluded that,

Fly ash tends to contribute compressive strength when the aluminosilicates present in the fly ash react effectively with calcium aluminosilicates in cement. Due to this reason the early strength of sample containing fly ash resulted in lesser value when compared to the control specimen.

Though the fly ash up to 30% reflected maximum strength gain, considering all mechanical as well as durability properties, optimum value of 40% fly ash replacement was proposed considering superior all round performance in comparison to concrete without fly ash replacement at 28 days.

2.14 Suresh Kumar Aa et.al investigated that,

IBWA enhances the compressive strength of GGBS-based Geopolymer concrete. The strengthened and dense structure of GGBS-based Geopolymer concrete contributes to its increased compressive strength.

Compressive strength was improved by up to 30% by raising the volume of IBWA content in Geopolymer concrete. However, compressive strength was reduced by more than 30% by increasing the volume of IBWA content in Geopolymer concrete.

Split tensile and flexural strength trended in the same trend as compressive strength for 7 and 28 days.

2.15 Apurv kadu and V.K.Gajghateet.al discovered that,

Strength found to be increased for initial replacement of cement with Hypo sludge Ash for instance up to 10% replacement. By using Hypo sludge Ash greener concrete can be produced. Utilization of waste and disposal cost are reduced.

Lowcost houses can be constructed using waste paper ash by reducing the cement content. By using suitable admixture such as superplasticizers, the problem of water absorption can be reduced. Weight of concretse member can be reduced by using paper mill sludge ash which ultimately helps in reducing the dead load of the structure.

2.16 K.Malavan and R.Manju et.al concluded that,

The density of concrete decreased marginally with the increase in the replacement level of BMW. Compressive strength, split tensile strength, Flexural strength of concrete made using BMW is lesser than that of conventional concrete.

It is observed that UPV test for control mix and 10% replacement concrete is termed as good quality concrete.RCPT result show that the chloride penetration is very low upto 30% replacement level.

2.17 O. O. Aderinola et.al investigated that,

The oxide composition analysis shows that POL is a non-pozzolanic material with no calcium oxide (CaO) content and no silicon oxide (SiO2) content, while the plantain peel ash (PPA) is a non-pozzolanic material with a little amount of silica (SiO2) component.

The workability of concrete improved with PPA and POL when added separately, but reduced when combined.The compressive strength of concrete reduces with increasing percentages of PPA, POL and blended PPA/POL content.

2.18 Chithambar Ganesh et.al discussed that,

Workability of the slagbased GC increase with the increase in the utilization of URA owing to the ultrafine size and higher specific surface area of URA. With the incorporation of URA, there is decrease in the value of drying shrinkage strain values across all ages such as 7, 28 and 90 days. Significant reduction of about 7 percent is visible with the addition of URA at 15 % replacement level.

Cost efficiency increases about 19 percent with the inclusion of URA in slag based GC. A gradual decrease in the energy consumption for production is reported with the utilization of URA. Eco efficiency increases by about 18.75 percent with the utilization of URA as a partial substitute of slag in GC.

2.19 Bashir Ahmed Memon et.al investigated that,

Increase in quantity of biomedical waste ash is directly proportional with decrease in the tensile strength except for 1% replacement. For all levels of replacement, the tensile strength of proposed concrete observed with in the specified range of tensile strength for conventional concrete.

Taking 28-day curing as standard, minimum reduction in tensile strength is for 5% replacement of cement with biomedical waste ash. Elongated curing shows increase in tensile strength for all replacements with maximum at 1% replacement of cement.

2.20 Anitha Krishnan et.al concluded that,

The concrete containing 8% Pigeon pea stalk ash has a higher strength than the concrete containing other combinations. The strength gradually increases when the pigeon pea stalk ash is between 2% and 8%, slowly decreasing beyond this percentage.

The split tensile strength of the concrete cylinders of the 8% PPSA replaced concrete is equal to that of the control concrete. On the other hand, the flexural strength of the beams of the 8% pigeon pea stalk ash replaced concrete is better than that of the control concrete.

As a result, the stress value of pigeon pea stalk ash used in concrete is lower, with a smaller modulus of elasticity than conventional concrete. The rebound number value is higher for pigeon pea stalk concrete than conventional concrete.

2.21 P. Srinivas and K. Satish Kumaret.al studied on,

Bricks that were cast with 5 percent of the cement replaced with municipal solid waste have shown best results with considerable strength when compared to standard bricks. The 28 days compressive strength attained by standard brick is 272 N/mm2 and that by specimen 1 is 176 N/mm2. The compressive strength of a traditional mud brick is around 69 N/mm2.

The work has demonstrated a feasible way of using incinerated municipal solid waste ash as a cement replacement material to produce quality bricks. The bricks manufactured did not show any deformation or uneven surfaces and the bricks can be used for construction purposes.

2.22 Junaid Hassan et.al investigated that,

Low cost concrete i.e 2.5% of cost saving can be achieve by utilizing HWAAs partial replacement of cement in concrete Without compromising the strength parameters .The setting time increased while the density and Water absorption of mixes decreased with the Increase in the percentage of HWA in the mix.

The utilization of HWA as partial replacement of Cement in concrete solves the problem of it's the Disposal thus keeping the environment free from Pollution.In future research, further scientific investigation should be carried out to endorse the results.

2.23 MG Pranav et.al investigated that,

A paradigm shift is observed in the production of ordinary Portland cement (OPC) due to its high carbon emission worldwide and the need for adopting sustainability in construction industry. For the same, newer practices have been proposed, which includes the production of sustainable cement whose escalating demand is associated with utilization of different supplementary cementitious materials (SCMs).

These SCMs, act as a key component in sustainable construction by emitting lesser carbon. Cement and concrete are among the major contributors to CO2 emissions in modern society. Researchers have been investigating the possibility of replacing cement with industrial waste in concrete production to reduce its environmental impact.

2.24 Wayan Koko Suryawan et.al concluded that,

Based on its characteristics, bottom and fly ash cannot be disposed in landfills. According to the compressive strength test results, the increase of cement ratio with bottom and fly ash grew. With the ratio of 75:25, the compressive strength was 682 and 772 tons/m2. Toxicity characteristic leaching procedure (TCLP) of stabilization / solidification (S/S) heavy metal leachate can meet the quality standards discharge to landfill.

2.25 Sandeep Singh et.al discussed that,

Concrete mix with 20% GGBS and 15% Metakaolin as replacement of cement and 10% Waste Medicine Wrappers as replacement with fine aggregates is the optimum level as it has been observed to show a significant increase in compressive strength at 28 days when compared with nominal mix

On increasing the percentage replacement of Fine aggregates with waste medicine wrappers beyond 10%, there is a reduction in the tensile strength value. So 10% Waste Medicine Wrappers replacement is optimum for split tensile strength.

2.26 Suresh Kumar A et.al investigated that,

Increasing the addition of Bio-Medical Waste Ash increases the Initial Setting Time of GGBS based GPC. Increasing the addition of Bio Medical Waste Ash increases the strength up to 10% of GGBS based GPC compare to 100% GGBS. The compressive strength has been increased by 13.07% in addition to 7% of BMWA.The compressive strength has increased by increasing the molarity of NaOH up to 13; beyond 13 molarity the compressive strength has been decreased.

2.27 Anita Rajor and Kunalet.al concluded that,

Incineration is the most appropriate alternative for reducing the waste volume but generates a new type of waste in the form of fly ash, bottom ash and molten slag.

The uncontrolled disposal of these ashes and slag causes significant damages as these contaminates the soil as well as surface and underground water due to heavy metal toxicity and presence of dioxins and furans.

Thus to minimize this, several work has been done on utilizing the biomedical waste incinerator ash and slag in cement and concrete and studied the mechanical properties of these building materials. Results of mechanical properties showed that the use of fly ash and bottom ash can be successfully utilized in cement and concrete systems.

2.28 Saman Rahimi Reskati et.al investigated that,

The more BPW addition leads to more reduction in the slump by up to 46.4%, 54.4%, and 48.8% after adding up to 9% hybrid, hard, and soft BPW, respectively. It can be attributed to the flaky and elongated shapes of the BPW particles, affecting the workability factors due to more friction and lower flowability.

Addition of BPW leads the modulus of elasticity to decrease by up to 27.41%, 24.4% and 33.19% for hybrid, hard, and soft BPW containing concrete respectively, which can be attributed to the lower modulus of elasticity of the DWP than natural aggregate and more porous ITZ between the BPW and the cement paste.

2.29 Sari Jaber et.al discovered that,

The ashes are thrown in the municipality dumps and not in certain areas for this purpose, which causes them to spread in the air. It causes serious diseases in the respiratory system. The penetration and oxidation of minerals into landfill soil is a major risk to the soil. It may also reach the groundwater.

For this reason, it is necessary to define areas designated for burying medical waste that differ from those used for municipal waste. Or mixing heavy metals with bricks and cement is an excellent idea for fixing the heavy metals in the cement and are useful in construction operations.

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2.30 Augustine U. Elinwa et.al investigated that,

Hospital waste ash (HWA) has pozzolanic properties and can reduce water absorption by approximately 25% to 54% at 90 days of curing. With this property, the durability of the concrete is enhanced and also the material HWA will perform well as a hydraulic barrier.

Addition of HWA in concrete production reduces the workability of the concrete and therefore, there will be need to use this material in conjunction with a plasticizer that will enhance the workability of the
concrete and encourage higher replacement levels. The compressive strength of HWA concrete decreases with increase in the replacement levels and the best behavior is at 10% replacement.

III. CONCLUSION

Biomedical Waste generation has increased considerably worldwide in the last few decades. Biomedical wastes from hospitals and other healthcare and research centers has become an imperative environmental and public safety problem. So, it is necessary that the biomedical wastes should be disposed in a manner which is least harmful to the human beings. Incineration is the most appropriate alternative for reducing the waste volume but generates a new type of waste in the form of fly ash, bottom ash and molten slag. The uncontrolled disposal of these ashes and slag causes significant damages as these contaminates the soil as well as surface and underground water due to heavy metal toxicity and presence of dioxins and furans. Utilization of biomedical waste incinerator slag as road and asphalt aggregate also showed promising results. Thus, this review of literature paper provides critical information on the proper utilization of biomedical waste incineration ashes and slag as partial replacement of cement in concrete, also there is need to further evaluate the other suitable ways of disposing and utilizing the ashes and slag generated from biomedical waste incinerators.

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