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THE USE OF BOTTOM ASH AND FLY ASH FROM MEDICAL INCINERATORS AS ROAD CONSTRUCTION MATERIAL

Sari Kamel JABER[1], Alaa Aldin ALJAWAD[2], Elena POP[3], Tudor PRISECARU[4], Ionel PISA[5]

In recent years, medical waste has seen continuous growth, especially with the COVID-19 pandemic. Medical incinerators have proven their efficiency in the rapid disposal of medical and other waste. These incinerators produce bottom and fly ash about 30% of the total weight of waste, which contains high concentrations of heavy metals and other elements that negatively affect the soil and the environment. This study is concerned with treating bottom ash after grinding and mixing it with a mixture of asphalt (base layer) according to Marshall's method in different proportions instead of the filler used in the mixture, in proportions of 25%, 50%, 75% and also the fly ash was mixed in the same proportions. The experimental tests were related to: bulk density (g/cm3), stability (kN), flow (mm), and air space (%). It was found that the percentage of 25% for each of the fly ash and the bottom ash is the percentage within the specifications as 90 tests were tested.

Keywords: Medical Waste, Waste Incineration, Ash, Asphalt mixture.

1. Introduction

The world has witnessed rapid development in technology with the increase in the world population. In previous and current years, the spread of the COVID-19 virus has increased the amount of medical waste. This waste, if not properly treated and managed, causes major problems[1]. One such method is incineration in medical incinerators. Due to the fast processing performance, high efficiency, low cost, easy operation, reducing the waste volume to 95% and weight 70%, as well as detoxification, comprehensive disinfection, and resource and energy recovery[2][3][4][5][6]. These incinerators produce two types: gases resulting from

[1] PhD student, Faculty of Mechanical Engineering and Mechatronics, University POLITEHNICA of Bucharest, Romania, mail: enginee.sari@gmail.com
[2] PhD student, Faculty of Mechanical Engineering and Mechatronics, University POLITEHNICA of Bucharest, Romania, mail: Albasri1970@yahoo.com
[3] Assoc Prof, Faculty of Mechanical Engineering and Mechatronics, University POLITEHNICA of Bucharest, Romania, mail: elena.pop@upb.ro
[4] Prof, Faculty of Mechanical Engineering and Mechatronics, University POLITEHNICA of Bucharest, Romania, mail: tudor.prisecaru@upb.ro
[5] Prof, Faculty of Mechanical Engineering and Mechatronics, University POLITEHNICA of Bucharest, Romania, mail: ionel.pisa@upb.ro

the combustion of medical waste with the help of air and burners [7] and ash are two types. Fly ash accompanied by combustion gases can be collected through filter bags[8] and is 3-5% of the total weight of the waste. And bottom ash that is produced at the end of combustion and is at the bottom of the incinerator and is extracted automatically or manually after it cools [9] and is about 20-30% and contains heavy metals Cu, Pb, Cd, Hg, Ag, Mo, Ni, Zn, Sb, Ba. As for fly ash, it contains heavy metals, acids, organic materials, and a high percentage of chlorides, dioxins, and carbon components, and these negatively affect the soil and the environment [10][11]. This ash is treated by burying it in private landfills, but what happens is it is buried in public landfills, and this affects the environment, groundwater and soil, and it can be benefited from by recycling and using it in building materials or cement [12][13][14]. In this paper, bottom ash and fly ash were used and mixed with asphalt mixture in specified proportions instead of filler as a treatment and utilization method.

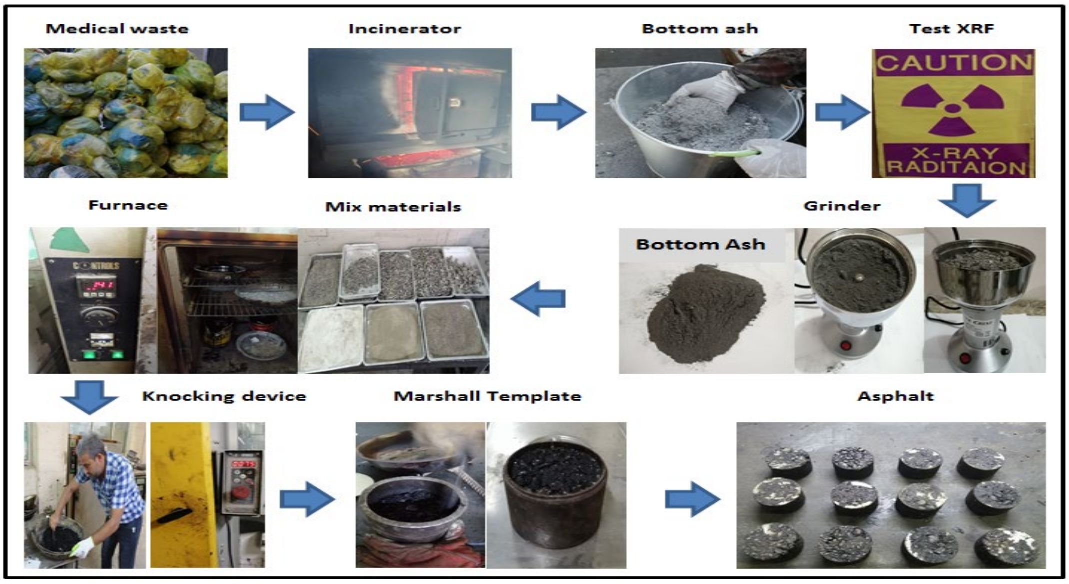


Fig. 1. The stages of converting medical waste into bottom ash and mixing it with the asphalt mixture.

2. Materials and testing methods.

Bottom ash and fly ash samples were taken from burning medical waste in the medical incinerator in the Engineering Department of Medicine City in Baghdad, as shown in Figure 2.

Fig. 2. Ash from the incineration of medical waste

These samples were examined at the Ministry of Science and Technology in an XRF X-Ray Fluorescence device to determine the elements present in the ash, including heavy minerals. Then grind the bottom ash to become as fine as the filler used in the asphalt mixture, as shown in Fig. 3.

Fig. 3. XRF test for bottom ash and its grinding

2.1 Preparation of the asphalt mixture (mixture reference).

Marshall method, which is considered one of the most suitable ways to design the asphalt mixture, according to the scientist Bruce Marshall, who designed it in 1939 in America, relied on the following parameters: density, voids analysis and stability, flow test. In the asphalt mixture, there are three mixtures of (base course, bonding layer and surface layer). The experiment was carried out on the (base layer), which consists of asphalt (40-50), coarse aggregate (19-37.5) mm, coarse aggregate (5-19) mm, crushed sand, river sand and filler. All the above materials were taken from the Salman Pak asphalt plant and they were all within the specifications as in Fig. 4.

Fig. 4. The materials used in the asphalt mixture (base layer).

First, the aggregates are sieved, both according to the specified size, and then dried at 110 degrees Celsius. The two types of aggregates are collected with sand of both types with the filler and in the proportions specified in Table 1 and heated to a temperature of 160 degrees Celsius and the asphalt is heated at (150 degrees Celsius), then the asphalt is added to the Mix the aggregate and mix by hand for two minutes until it covers all parts of the mixture as in Fig. 5.

Table 1

The weight ratios of the asphalt mixture materials.

Lab No.		3523	3524	3525	3526	3527	Mix	Mix limit	Referred to *
Type material		Coarse aggrega-tes (19-37.5)mm	Coarse aggregates (5-19)mm	Crushed sand	Sand	Filler	----	-----	--------
Sieve Measurement		Weight							
in	mm								
1 1/2	31.5	100	100	100	100	100	100	100	100
1	25	64	100	100	100	100	93	90-99	90-100
3/4	19	12	100	100	100	100	82	76-88	76-90
1/2	12.5	2	70	100	100	100	71	65-77	56-80
3/8	9.5	1	36	100	100	100	60	54-66	48-74
No.4	4.75	----	1	93	91	100	45	39-51	29-59
No.8	2.36	----	----	63	67	100	32	28-36	19-45
No.50	0.3	----	----	25	34	100	16	12-17	5-17
No.200	0.075	----	----	10.8	11	96	7.3	5.3-8	2-8
Material mixing percentage by weight		20	32	35	9	4	---	---	----
Asphalt binder percentage %		----	----	----	----	----	4	3.7-4.3	3-5.5

* Mixing ratios according to the specifications of the Iraqi Roads and Bridges Authority

Fig. 5. Asphalt mixture materials in the furnace and mix them manually.

2.2. Additives

In this research, two types of additives were used: bottom ash and fly ash from medical waste incineration, added in different percentages to the mixture as partial replacement of filler. The mineral filler is limestone dust passing through Sieve No. 200 (0.075) mm. It is obtained from factories and is a non-plastic material[15].

2.2.1. Fly ash

Fly ash is the finely residue that results from the combustion of medical waste and which transported with the combustion gases can be collected by bag filters found in the chimneys of medical incinerators. It constitutes 3-5% of the total mass of medical waste entering the incinerator[16]. The use of fly ash is being increased in concrete asphalt paving because it is similar to mineral filler as table 2. The source of fly ash is medical waste from medical waste incineration, and it is available in medical incinerators at no cost. This fly ash has a higher specific gravity compared to limestone as shown in table 2 and a specific surface area 650 m^2/kg[17]. The figure 6 show the fly ash sample used.

2.2.2. Bottom ash

The traditional way to dispose of medical waste in Iraq is incineration. Although the volume of waste is reduced by about 95% and the weight is about 70%, the combustion residue, which is represented by bottom ash, is about 25-30% of the original waste weight As in Figure 6. In some of Iraq's densely populated governorates, the disposal of bottom ash for medical waste has become increasingly difficult due to the decreasing availability of large-area lands far from the population and agricultural areas, as well as due to the high cost. Bottom ash contains high concentrations of heavy metals and mineral elements such as Al, Cu, Fe, Mg, Mn, Pb, Ti, Zn and Cr [18]. The American Environmental Protection confirmed that the bottom ash produced from waste can be recycled, but it must be treated at a high temperature (850-1000°C) to destroy PAHs before or during the recycling process. And since bottom ash is not included as a hazardous waste, it can be recycled, treated and used in infrastructure[13]. This mixture can be described as the recycling of medical waste combustion products(bottom ash) and utilization as building materials according to the mechanical properties[19].

Table 2

Comparison physical characteristics of fillers, bottom ash and fly ash

Properties	Filler	Bottom ash (after grinding it)	Fly ash
Pictures of materials			
Passing sieve 0.075 mm No.200	94%	93 %	98 %
Bulk specific gravity (g/cm^3)	2.617	2.610	2.645
Surface area (m^2/kg)	389	385 after grinding it	650)

2.3. Preparing the asphalt mixture with additives.

Bottom ash and fly ash from medical waste incineration were added to the asphalt mixture in proportions instead of as filler (limestone).

Asphalt mixture (mixture reference).

The comparison with the source of the mixture and the proportions is as follows:
The total weight of the asphalt mixture (reference sample) was 6.25 kg;
Coarse aggregates (19-37.5) mm = 6.25×20% = 1.25 kg from table 4;
Coarse aggregates (5-19) mm = 6.25×32% = 2 kg;
Crushed sand = 6.26×35 % =2.187 kg; Sand = 6.25×9 % = 562.5 g;
Filler = 6.25×4% = 250g; Asphalt = 6.25×4% = 250g

Asphalt mixture with addition of fly ash in proportions of limestone.

4 % Limestone (mixture reference)
25 % Fly Ash from 4% Limestone: fly ash = 62.5g
50 % Fly Ash from 4% Limestone: fly ash = 125g
75 % Fly Ash from 4% Limestone: fly ash = 187g

Asphalt mixture with addition of bottom ash in proportions of limestone

25 % Bottom ash from 4% Limestone: bottom ash =62.5g
50 % Bottom ash from 4% Limestone: bottom ash =125g
75 % Bottom ash from 4% Limestone: bottom ash =187g

Table 3

Proportions of the components of the asphalt mixture

Coarse aggregates 19-37.5 mm	Coarse aggregates 5-19 mm	Crushed sand	Sand	Filler (limestone)	Asphalt binder
20%	32%	35%	9%	4%	4%

2.4. Marshall Specimen's preparation

The sample mold is a cylinder with a height of 63.5 mm and a diameter of 102 mm. It is heated to 120-150 degrees Celsius. A piece of non-absorbent paper with the diameter of the cylinder is placed at the bottom of the mould. The heated asphalt mixture (reference mixture) with a weight of 1210 g is placed in the mould and a piece of non-absorbent paper is placed on top. Twenty-seven samples were tested, including the source mixture and the additions made to the mixture of bottom and fly ash shown in Fig. 6.

Fig. 6. Marshall Specimen with the addition of fly ash and bottom ash.

These moulds are placed in a Marshall hammering device and these moulds are placed on the base of the device and the sample is hammered with 75 strikes on the upper and lower surfaces weighing 4.535 kg and free fall 457.2 mm (ASTM 6926-10). Then we take out the mould and let it cool down to 25° C for 24 hours as in Fig. 7. Then the sample is extracted from the mold with a mechanical jack.

Fig. 7. Marshall mould, Marshall hammer and number strikes.

2.4.1 Determination of Flow and Stability of Specimens.

Asphalt samples are placed in a device (a water bath) filled with water at 60°C for 30 minutes and then placed in a Marshall stability test device (ASTM D6927) as shown in Figure 8 to check the stability and flow of each sample. It was found that when adding bottom or fly ash at 25% of the filler percentage, the stability and flow are within the specifications of the asphalt mixture as shown in Table 4.

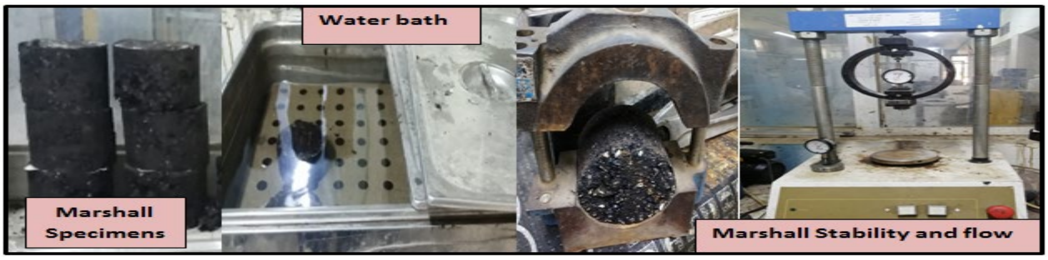
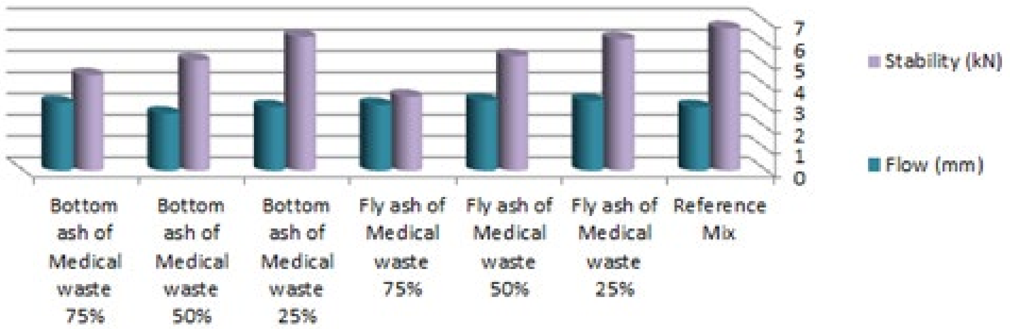


Fig. 8**.** Marshall flow and stability test device

Table 4

Stability and Flow with addition

Test	Reference Mix	Type add and present			Type add and present		
		Fly ash of Medical Waste			Bottom ash of Medical Waste		
		25%	50%	75%	25%	50%	75%
Stability (kN)	6.7	6.2	5.4	3.5	6.3	5.2	4.5
Flow (mm)	3.0	3.3	3.3	3.1	3.0	2.7	3.2



2.4.1 Determination of Flow and Stability of Specimens.

In this test, the density and bulk specific gravity is determined so that the maximum theoretical specific gravity of the mixture with the least air spaces is required. The quantity of asphalt mixture is 1.5 kg and for all samples (the source of the mixture as well as the mixture to which both bottom and fly ash are added) with the maximum size of the aggregate in the mixture as shown in Figure 9 (ASTM D2041).

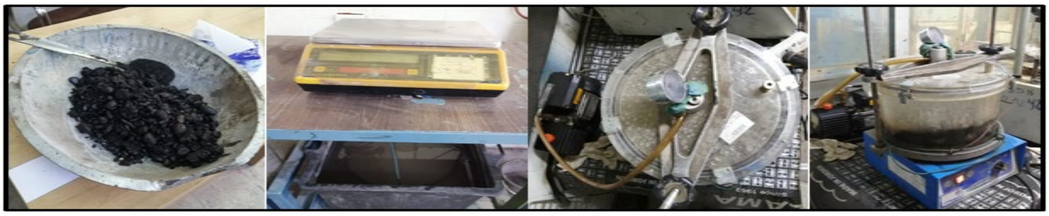
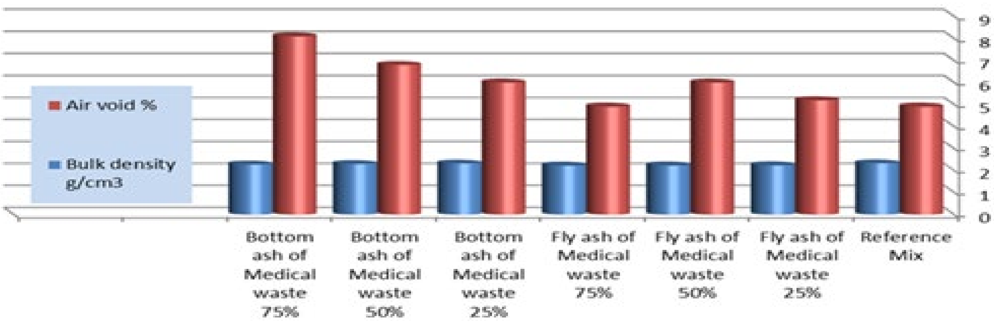


Fig 9. Theoretical specific gravity device

Table 5

Bulk density and Air void with addition.

Test	Reference Mix	Type add and present			Type add and present		
		Fly ash of Medical Waste			Bottom ash of Medical Waste		
		25%	50%	75%	25%	50%	75%
Bulk density (g/cm^3)	2.332	2.240	2.234	2.228	2.323	2.300	2.277
Air void (%)	4.9	5.2	6	4.9	6	6.8	8.1



It was found that when the bottom ash was added at 25%, the bulk density and specific gravity were close to the source of the mixture 2.323 g/cm3 and the air spaces were 6%, and the values started decreasing at 50% and 75%.

As for fly ash, 25% was the same as the ratio of the source of 2.240 g/cm 3 and 50%, and it was found at 75% that the air spaces were equal to the source of the mixture 4% as in table 5.

3. Results and discussion

According to the 2019 statistics, Iraq produces one million kg annually of bottom ash resulting from medical waste, which needs special landfills for burial. This percentage increased annually, especially in the period of Covid - 2019, 2020 and 2021, and with the increase in population growth and demand for residential lands, the necessary need to recycle this ashes to live in a green environment in which generations live with a smile of the future. The importance of using ash from medical waste and comparing it with fly ash from coal and silica fumes in the asphalt mixture with treating ash from waste in other methods was studied in previous researches.

Fly ash and bottom ash used in the experiment are from medical waste. It can be obtained in large quantities and is available 20-30% of the total weight of medical waste [2][3][4][10] and can be recycled, which benefits for the environment, soil and humans, and reduces landfill areas. On the other hand reduces the cost of asphalt by adding ash instead of expensive filler. In previous experiments, coal ash associated with power generation was used by adding it to the asphalt mixture instead of a percentage of the filler. Coal ash is not contained within the maximum for heavy metal and can be buried on any land and obtained from the local market at a cost. The researcher did not specify the source of the ash [17], and it is in limited quantities 3-5% of the total weight [11].

The use of bottom and fly ash from medical waste on the basis of recycling, utilization and disposal at the same time, was studied in many researches from literature. Bottom ash from medical waste was used for the purpose of solidification/stabilization in building concrete and mixing it with cement. This process is considered a recycling of the remaining ash because it contains heavy metals and does not leak to the ground. Note that when 50% of the ash is added, the compressive strength decreases from 38 MPa for 100% cement to 50 % to become 11.3 MPa at 50% cement [19][20] vitrification [9][14], bricks containing clay [21]. Other researchers are using inert municipal solid waste instead of fine aggregate in the mortar cube in different proportions [22], or are using medical waste ash from combustion as an alternative to fine aggregate for concrete based on the strength and penetration of concrete [23].

Fly ash and bottom ash from medicinal incinerators used in our experiment differ in chemical properties. According to the XRF test, it contains more heavy metals than allowed.

The use of silica fumes in the asphalt mixture instead of the weight of the asphalt content with the change of the asphalt content in terms of cracking and fatigue duration as a result of carrying vehicles [15], while in our experiment fly ash and bottom ash from medical incinerators were used in the experiment instead of the percentage of filler in the asphalt mixture based on the basic principles of Marshall method, stability (KN), creep (mm), bulk density (g/cm3) and air voids (%) of the samples. The reference mixing used for the samples in Table 3, which was approved in Table 4 and 5, was within the limits and according to the certificate of the government laboratory in Baghdad No. 13/F/1410 on September 11, 2021 and No. 1334 on October 14, 2021 in which we conducted the experiment.

4. Conclusions

All hospitals produce thousands of tons of medical waste daily, especially in the Corona pandemic and its metamorphoses, as the amount of waste increased. Medical incinerators are considered one of the predominant ways to treat it due to (fast treatment performance, high efficiency, low cost, easy operation) compared to other treatment methods, reducing the waste volume to 95% and weight 70%, in addition to removing poisons, comprehensive disinfection, and recovery of resources and energy. With all these benefits, there are a few negatives aspects to these medical incinerators. One of these is the bottom and fly ash, which annually produces thousands of tons of waste incineration, i.e. 30% of the weight of waste before burning. This ash affects the environment, humans, soil and water because of its containment It contains heavy metals, so it is treated by placing it in forms made of cement and then burying it in the soil. In this experiment, the ashes were mixed after the examination (XFR) in proportions with filler used in the asphalt plant, and the four tests (stability (kN), flow (mm), bulk density (g/cm3) and air void (%)) were carried out, and 90 tests were done in the Ministry of Housing and Construction/National Centre for Construction Laboratories.

When adding 25% of bottom ash and fly ash, the stability was good in both cases, and it seemed to go down at 50% and 75% in both cases due to the increase in the proportions of heavy metals and the increase in heat loss from the mixture due to the distance between the convection furnace in which the materials and the asphalt are heated (Fig. 5) and a hammer device Marshall (Fig. 7) This distance leads to heat loss of the mixture before it is hammered, which reduces the stability and cohesion of the sample. As well as the use of manual mixing of asphalt with the mixture materials leads to heterogeneity between the materials in a correct way and the asphalt agglomeration on heavy metals led to an increase in the air void in small percentages and the most percentages were within the required limit (3-6)%, only at 50% and 75% of the bottom ash exceeded the permissible limit.

We noticed the flow (mm) at all percentages were excellent within the required limit of (2-4) mm because of the rich content of heavy metals in ash. As for the Bulk density all mixtures are within the permissible limits, with best results at 25% with bottom ash recommending its use in paving external roads and its use with asphalt.

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