Use of Municipal Waste in Construction of Bituminous Mixture for Road

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Abstract- Municipal solid waste (MSW) refers to the material discarded in the urban areas for which municipalities are usually held responsible for collection, transportation and final disposal. MSW encompasses household refuse, institutional waste, street sweeping, commercial waste, as well as construction and demolition debris. In developing countries, MSW also contain varying amount of industrial wastemany instances, solid waste is collected in mixed state and is being dumped in environmentally very sensitive places like road sides, marshy lands, low lying areas, public places, forests, wildlife areas, water courses, etc., causing numerous negative environmental impacts.MSW has increased up to 65% since 1980, to the current level of 251 million tons per year with 53.8% landfilled, 34.5% recycled and composted, and 11.7% incinerated with energy recovery. In the process of incineration, MSWI ash is being produced as byproducts; about 80 to 90% of the MSWI ash is bottom ash (BA) and 10 to 20% is fly ash (FA) by weight. The current practice of the U.S. is to combine both BA and FA to meet the criteria to qualify as non-hazardous, and all combined ashes are disposed in landfills. European countries have utilized MSWI BA as beneficial construction materials by separating it from FA. The FA is mostly limited to landfill disposal as hazardous material due to its high content of toxic elements and salts. BA has been actively recycled in the areas of roadbed, asphalt paving, and concrete products in many of European and Asian

Keywords- project, multi objective, optimization

I. INTRODUCTION

As the traffic demand is growing at a rapid rate along with the increase in the axle loads, it is necessary to improve the highway paving materials. The main objective of highway authorities is to provide safe, smooth, imperishable, and economical pavements that are capable of carrying the anticipated loads. To achieve this objective, many specialists, engineers and researchers are anxious and dedicated to select the paving material that can curtail pavement distress and upgrade the performance of asphalt pavements [1]. Filler as one of the constituents in an asphalt mixture, plays a major part in determining the properties and performance of the mixture, especially its binding and interlocking effects. Mineral fillers on adding to asphalt mixtures serve dual purpose [2, 3]. Asphalt cement binder mixes with mineral filler (finer than thickness of as phal film) forms mortar that leads to improved stiffening of the mix. Particles larger than the thickness of the asphalt film act as mineral aggregate and hence contribute to the contact points between distinctive aggregate particles (Puzinauskas 1969; Mohammad Altaf Bhat et.al 2016). Also, they affect the moisture sensitivity, workability stiffness and ageing features of hot mix asphalt (HMA) (Mogawer 1996). Due to variation in gradation, particle shape, surface area, voids content, physico-chemical properties and mineral composition of fillers their influence on the properties of HMA mixtures varies. For various types of fillers, the maximum allowable amount should be different. By increasing the surface area of mineral particles, the filler also influences the optimum asphalt content (OAC) in bituminous mixtures and, simultaneously, the surface properties of the filler particles modify significantly the properties of asphalt such as penetration, ductility, and also of the mixture, such as resistance to rutting. The pavement performance is improved by ensuring that sufficient behavior of the bituminous mixtures is achieved, which essentially depends on their composition. Therefore, selecting the proper type of filler in asphalt mixtures would upgrade the filler's properties and, thus, enhance the mixture's performance (Kandhal 1981). Bituminous mix of good design is expected to result in a mix which is sufficiently (i) durable (ii) strong (iii) resistive to fatigue and permanent deformation(iv) economical (v) environment friendly and so on.

What is bituminous mixture?

The term 'bituminous mixtures' is used to denote all materials in which an aggregate is bound with a hydrocarbon binder. They are most extensively used as surfacing material for road construction, where they are commonly referred to as 'blacktop'. They were first produced in the 1870s and became extensively available by the 1930s.

Roads are built from a number of layers that together are called a pavement. Bituminous mixtures are used in the upper layers of flexible or flexible-composite pavements, as opposed to rigid pavements where the top layers comprise concrete.

1.1 Properties of Bitumen and Filler

Bituminous roads are defined as the roads in the construction of which bitumen is used as binder. It consists of an intimate mixture of aggregates, mineral filler and bitumen. The quality and durability of bituminous road is influenced by the type and amount of filler material is used.

The filler tends to stiffen the asphaltic cement by getting finely dispersed in it. Various materials such as cement, lime, granite powder, stone dust and fine sand are normally used as filler in bituminous mixes. Cement, lime and granite powder are expensive and used for other purposes more effectively. Fines and, ash, waste concrete dust and brick dust finer than 0.075mm sieve size appear to be suitable as filler material. The use of waste powder as filler in asphalt mixture has been the focus of several research efforts over the past few years. Phosphate waste filler [4], Jordanian oil shale fly ash, bag house fines, recycled waste lime, municipal solid waste incineration ash and waste ceramic materials have been investigated as filler. It was proved that these types of recycled filler could be used in asphalt mixture and gave improved performance.

If filler is mixed with less bitumen than it is required to fill its voids, a stiff dry product is obtained which is practically networkable. Overfilling with bitumen, on the contrary, imparts a fluid character to the mixture. The filler has the ability to increase the resistance of particle to move within the mix matrix and/or works as an active material when it interacts with the asphalt cement to change the properties of the mastic. Elastic modulus of asphalt concrete mixture can increase by the addition of mineral filler. But excessive amount of filler may weaken the mixture by increasing the amount of asphalt needed to cover the aggregates. The effects of these fillers are also dependent on gradations. Fillers could improve the temperature susceptibility and durability of the asphalt binder and asphalt-concrete mixture. The effects of these fillers are also dependent on gradations. To have a good mixture, aggregates and filler should bind properly. A strong backbone for the mixture can provided by the good packing of the coarse, fine, and filler aggregates.

The performance of bituminous mix also depends on amount of filler in the mix. The workability of a mix depends, to some extent, on the amount and type of the filler present in the mix. The mixture performance also affected by the interactions between asphalt and filler because of the larger surface area, filler may absorb more asphalt and its interaction with asphalt may lead to different performance of asphalt-concrete mixture. The size distribution, particle shape, surface area, surface texture, voids content, mineral composition, and other physiochemical properties vary for several fillers. Therefore, their effect on the properties of asphalt-concrete mixture also varies.

1.2 Materials

A bituminous mixture is generally composed of aggregate and bitumen. According to the size of the particles, the aggregates are generally divided into coarse aggregates, fine aggregates and filler fractions. The following sections covers the description of the coarse aggregate, fine aggregate, bitumen and mineral fillers used in the study.

A. Coarse Aggregate: The coarse aggregates should have good abrasion value, impact value and also crushing strength. The function of coarse aggregates is to bear the stresses due to wheels. Function of Coarse aggregates is also resisting wear due to abrasion. That portion of the mixture which is retained on 2.36 mm (No. 08) sieve according to the Asphalt Institute is termed as Coarse aggregates. Coarse aggregate used was Basalt rock.

Fig.1: Appearance of coarse aggregate

B. Fine Aggregate: Voids which remain in the coarse aggregates are filled by the fine aggregates. So, the function of fine aggregates in to fill the voids of coarse aggregates. Fine aggregates consist of crushed stone or natural sand. Aggregates that passed through 2.36 mm sieve and retained on 0.075 mm sieve were selected as fine aggregate. The source of fine aggregates used was River sand. Fine sand and stone dust mix, waste concrete dust and brick dust finer than 0.075 mm size sieve were used as filler in the bituminous mixes for comparison and economical point of view.

Fig.2: Appearance of fine aggregate

C. Filler: As the name indicates function of fillers is to fill up the voids. Fillers used may be brick dust, stone dust, concrete dust, limestone dust, fly ash or pond ash. Waste concrete dust and brick dust finer than 0.075 mm size sieve were used in the bituminous mixes for comparison and also for economy point of view.

(a)

(b)

(c)

Fig.3: (a)Appearance of fine sand and stone dust mix; (b) Appearance of waste concrete dust; (c) Appearance of brick dust [12]

D. Bitumen: Bitumen is used as a water repellent material. 80/100 grade of bitumen was used in this study. Same bitumen was used for all the mixes so the type and grade of binder was kept constant.

Fig.2: Appearance of Bitumen

II. RELATED WORK

Baodong Xinget.al. (2019) In this study, the conventional and rheological analysis methods are employed to evaluate the effects of filler particle size and filler/bitumen (F/B) ratio on the high and low temperature performance of asphalt mastics. It is found that the addition of mineral fillers can significantly improve the high temperature rutting resistance of asphalt mastics. Meanwhile, it is detrimental to thermal cracking behavior. As the increase of particle size, the percent recovery R, creep stiffness S and m-value increase, while non recoverable creep compliance J_{nr} decrease. In addition, scanning electron microscope (SEM) imaging analysis shows that the dispersion degree and the morphology of asphalt mastics with various particle sizes have the great differences. [11]

V. Ashok Varma et.al. (2018) This paper outlines the ongoing research on different mineral fillers used in bituminous mixes. Many studies regarding their effects on bituminous mixes were also analysed in combination with filler mastic. This paper summarizes the interaction of mineral filler with different properties like temperature, strength, and adhesion between aggregates, low-temperature cohesive strength of asphalt and the chemical composition of mineral filler. [12]

Dario Topini et.al. (2018) This paper reports the results of a laboratory investigation on the use of recycled fillers in bituminous mixtures for road pavements. The fillers were obtained by crushing and sieving (0.00–0.063 mm) Stabilized Bottom Ashes from municipal waste incinerators and Electric Arc Furnace Steel Slags. Moreover, a currently used calcareous filler was included in the research for comparative purposes. Two filler dosages were considered in the experiments.[13]

M.Pasettoet.al. (2017) the present paper illustrates the overall results of a wide research study aimed at verifying the utilization feasibility of steel slags in warm-modified asphalt concretes. This was accomplished by investigating in the laboratory the midrange and high-service temperature properties of warm bituminous binders, as well as mastics and mixtures containing steel slag aggregates. The warm modification was performed using a chemical tension active additive; steel slags were produced in a metallurgical plant by electric arc furnace (EAF) treatment. To evaluate the combined effect of manufactured EAF steel slags and warm chemical additive, a comparative analysis was carried out taking into account unmodified binders as well as mastics and mixtures prepared with only natural aggregates. The results showed that cleaner materials prepared combining chemical warm technology and EAF steel slag aggregates seem to assure equal or even enhanced performance than the corresponding traditional hot mixed materials, demonstrating promising field applicability. [14]

Rodrigo Miroet.al. (2017) This paper presents results from a strain sweep test applied to bituminous mastics prepared with different filler types and contents at several temperatures. The obtained stiffness modulus and failure strain results provide information to assess the fatigue behaviour of the analyzed mastics. [15]

Cesare Sangiorgi et.al. (2017) The aim of this laboratory research is to analyze the physical characteristics of three different recycled fillers and compare them with those of a traditional limestone filler. The alternative fillers presented in this paper are: a waste bleaching clay that comes from two consecutive stages in the industrial process for decolouring vegetable oils and producing biogas (Ud filler), a dried mud waste from a tungsten mine (MW filler) and a recycled glass powder (Gl filler). Results show significant differences between the fillers, and, in particular, Rigden Voids (RV) seem to have the largest potential influence on the rheology of Asphalt Concretes (ACs). [16]

M. K. Nivedya et.al. (2017) In this chapter, the factors affecting the foaming process are discussed. The characterization of BSM mixes carried out by the researchers is explained. The evaluation of sections which were constructed using CIPR technology in India is also discussed, and the needed research is highlighted. [17]

Cristina Bonicaet.al. (2016) The experimental investigation herein described is aimed at understanding the effects of cellulose-based fibers on the mechanical properties of bituminous mastics for paving applications. Three bitumen (two of which modified with SBS polymers), a calcareous filler and four different types of fiber with varying content were used to prepare the investigated mastics. The filler to bitumen ratio was maintained constant. The laboratory investigations were focused on empirical tests (Needle Penetration and Ring and Ball – R&B – Temperature) and dynamic-mechanical tests, the latter performed in a wide range of temperatures. Results suggest that fibers improve the behavior of mastics for hot mix asphalts, particularly with respect to the prevention of rutting phenomena at high service temperatures. [18]

Mohammad Altaf Bhat et.al. (2016) used as filler. The properties of bituminous mixes containing these fillers were studied and compared with each other. For the purpose of comparison Marshall Method of mix design was used. In this study various tests were also conducted on aggregates and bitumen and the results were compared with the specifications. The study revealed that use of concrete dust and brick dust as filler improves the physical characteristics of bitumen. Marshall Stability and flow value of bitumen mix also improved. [19]

Minakshi Singhal et.al. (2016) The present study aims for use of modified bitumen by using plastic waste for road construction. The paper includes details of literature and methodology of using modifiers in bitumen and aims to provide highway construction in an eco-friendly and economical way. The modified bitumen mix shows better binding property, stability, density and more resistant to water. [20]

V.Antuneset.al. (2016) In this study, the contribution of the chemical composition of the filler to the consistency and stripping resistance of filler–bitumen mixtures are analysed. The chemical composition and particle geometry of six fillers of different origins are related with the consistency of filler–bitumen mixtures, using four different binders. The fillers tested showed an excellent performance in the water susceptibility test, despite references of weak moisture resistance being made to asphalt with aggregates of the same petrology. [21]

Dipu Sutradhar et.al. (2015) In this study an attempt is made to find the effect of types of filler on the behavior of bituminous mixes. According the properties of bituminous mixes containing filler like waste concrete dust and brick dust is studied and compared with the mixes containing filler like fine sand and stone dust mixture generally used. The Marshall method of mix design was used for the comparison. The Marshall stabilities of mix types containing filler fine sand and stone dust mixture, waste concrete dust and brick dust were found 9.8 KN, 11.1 KN and 11.3 KN respectively which satisfy the limiting value of 5.33 KN according to Marshall Design criteria. The study indicates the possibility of using waste concrete dust and brick dust as filler in bituminous mix. [22]

R. Tomar et.a.l (2013) has studied the effect of fillers on bituminous paving mixes. Construction of highway involves huge outlay of investment. A good design of bituminous mix is expected to result in a mix which is adequately strong, durable & resistive to fatigue and permanent deformation & at the same time environment friendly & economical. A mix designer tries to achieve these requirements through a number of tests on the mix with varied proportions of material combinations & finalizes the best one. An attempt has been made in this investigation to assess the influence of non-conventional & cheap fillers such as brick dust & silica fume in bitumen paving mixes. It has been observed as a result of this project that bituminous mixes with these non-conventional fillers result in satisfactory Marshall Properties though requiring a bit higher bitumen content, thus substantiating the need for its use. The fillers used in this investigation are likely to partly solve the solid waste disposal of the environment. [23]

J. E. Edeh et.al. (2012) has reported a laboratory evaluation of the characteristics of rice hush ash (RHA) stabilized reclaimed asphalt pavements (RAP) subjected to British Standard light, BSL (Standard Proctor) compactive effort to determine the compaction characteristics and California bearing ratio (CBR) values is carried out. Test results show that the properties of RAP improved when treated with RHA, using up to 2% cement additive. The particle size grading improved from 100% coarse aggregates for 100% RAP to 10 – 90% coarse aggregate with 10 – 90% fines for the various RAP + RHA mixtures containing up to 2% cement. The CBR values also increased from 8 and 14% for the un-soaked and soaked conditions, respectively, for 100% RAP content to 73 and 79% (soaked condition) for 89.25% RAP in the RAP/RHA mix proportions with 1.5% cement/89% RAP content in the RAP/RHA mix proportions with 2% cement content, with corresponding un-soaked CBR values of 28 and 26%, respectively. Generally, soaked samples recorded higher CBR values than un-soaked samples. The RHA stabilized RAP mix proportions with 89.25% RAP/1.5% cement content, & 89% RAP/2% cement content with CBR values of 73 and 79% (soaked for 24 hours) can be used as sub base or sub grade materials in road construction.[24]

Anggraini Zulkati et.al. (2011) The role of filler on the mechanical performance of asphalt-concrete mixture was investigated. Three wearing course (W3B) mixtures incorporating granite, hydrated lime, and kaolin as filler fractions were evaluated by the Marshall mix design method to determine their optimum asphalt content. The use of hydrated lime or kaolin as a filler requires more asphalt because of their relatively higher specific surface area. The highest stiffness performance was found for W3B-hydrated lime, followed by W3B-granite, and W3B-kaolin mixtures. W3B-hydrated lime and W3B-kaolin mixtures exhibited higher deformation resistance than that of W3B-granite mixture. The results showed that the presence of filler in an asphalt-concrete mixture affects the mixture's performance in three ways: filler influences the amount of asphalt content, filler affects the workability during mixing and compaction, and the resultant properties of asphalt-filler mastic contribute to the mixture's performance. [25]

Problem Formulation

Municipal solid waste incineration (MSWI) bottom ash has the potential for utilization in construction, e.g. as a pavement. Such a utilization would decrease the amount of bottom ash to be land filled. However, leachates generated from bottom ash could be concentrated with respect to salts and metals. The emission of salts and metals from bottom ash roads could cause environmental problems. This thesis is about carbonation of MSWI bottom ash to decrease the leaching of inorganic pollutants during the utilization of the ash in construction. Field investigations and laboratory leaching experiments enabled the identification of inorganic pollutants whose leaching might be critical during such a utilization. Treatment methods by carbonation and water extraction were evaluated regarding the mobility of these critical pollutants. The stabilizing effect of carbonation to a moderate alkaline level (~pH 8.3) was evaluated and compared to the mobilizing effect of carbonation in excess (~pH 6.4). Numerous leaching experiments were performed including diffusion leaching, leaching at constant pH, availability test, compliance leaching test and column test. Multivariate data methods, viz. principal component analysis and partial least square analysis, were applied to evaluate the results. Carbonation to a moderate alkaline level demobilized four of seven critical components. The effect was most

III. THE PROPOSED METHOD

pronounced for Al, Cr, Cu and Sb, whose leaching decreased by 98.7% (Al), 96.5% (Cr), 62.9% (Cu) and 45.3% (Sb) over the course of a 64-day diffusion leaching. Washing to remove easily soluble salts was recommended in addition to moderate carbonation. The mobilizing effect of carbonation in excess was evaluated in connection with treatment by water extraction. Factors included were excessive carbonation of suspension, extraction pH, liquid-to-solid (L/S) ratio, treatment with ultrasonic waves, temperature and extraction time. Carbonation in excess had the highest mobilizing effect on Cr, Cu and Sb when interacted with other factors, mostly pH. Total mobilization was 356% for Sb, 110% for Cu and 92% for Cr. Carbonation in excess was therefore proven to be a key factor enhancing the effectiveness of MSWI bottom ash treatment by wet extraction. Considering the limitations, carbonation treatments might surpass natural weathering prior to the utilization and open the way to a wider application of MSWI residues in construction. Flue gas from MSWI is a promising source of CO2. However, due to the oxidizing character of flue gas its effect on contaminant mobility (e.g. Cr) needs to be investigated.

IV. PROPOSED METHODOLOGY

Step 1: Municipal solid waste ash is the most significant by product from Municipal solid waste incineration plant. It accounts 85-95% of the solid products resulting from Municipal solid waste incineration. In India, Municipal solid waste ash is mainly land filled, but utilization of residue is preferred for disposal in accordance with waste management policy of government.

Step2: In this study, some alternatives for utilization of Municipal solid waste ash and the wood ash and their impact were impact was investigated. Since Municipal solid waste ash is a fine and compactable material, it shows a high potential as a wood ash substitute in road construction applications. A typical road pavement consists of layers from the top drying surface wearing course, base course, sub-base course and sub grade course.

Step3: Each layer requires a material with very specific physical and geotechnical properties.

Step4: This study is aimed at determination of the proper use of the Municipal solid waste ash in road construction. The prime aim of this experimental work is to study the use of municipal solid waste ash and wood ash used some percentage in sub-base in road construction.

Step5: Following samples are used for experimental work using different percentage of municipal solid waste ash and wood ash. (0%,5%,10%,20%)

Step 6: The study was to determine the geotechnical properties of Municipal solid waste ash and wood ash. The following test were carried out soaked CBR test with Modified proctor test, Sieve test, Permeability tests, Specific gravity test

V. RESULT ANALYSIS

CBR Test (IS 2720(Part 16):1987)

Municipal solid waste ash shown in Table 1 shows the geotechnical properties value obtain during the test replacement of Municipal solid waste bottom ash and wood bottom ash in % like 0% (s-0), 5% (s-5), 10% (s-10),15%(s-15),20%(s-20). . From the replacement of 20% Municipal solid waste ash and wood ash cannot affect the soaked and un-soaked CBR values. The maximum CBR values achieved at 20 % replacement it can be increased 1% CBR value for soaked and unsoaked samples. It can be decreases with further increases in replacement % of Municipal solid waste ash. According to Ministry of Road Transport and Highway (MORTH) and Indian Road Congress. (IRC) 20 % replacement of Municipal solid waste bottom ash and wood bottom ash it is acceptable for sub-base material, sub grade material and filling materials.

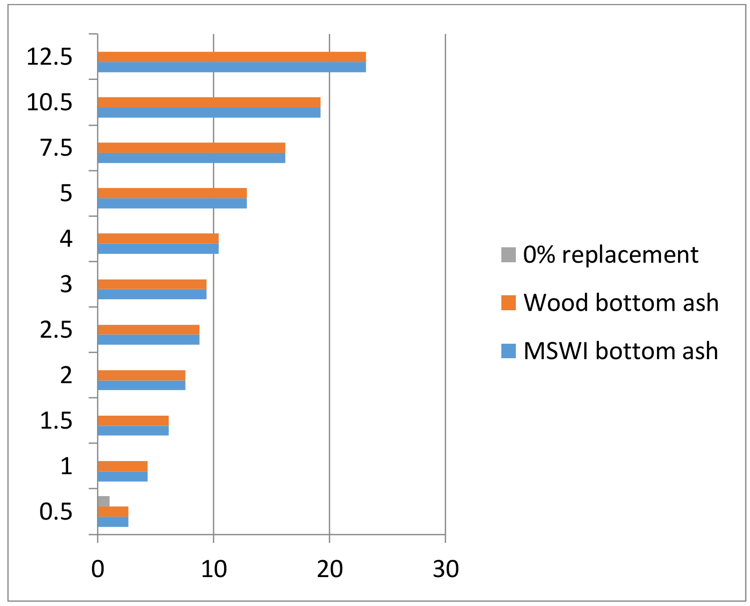

Fig.3: CBR Test 1 comparison on load intensity

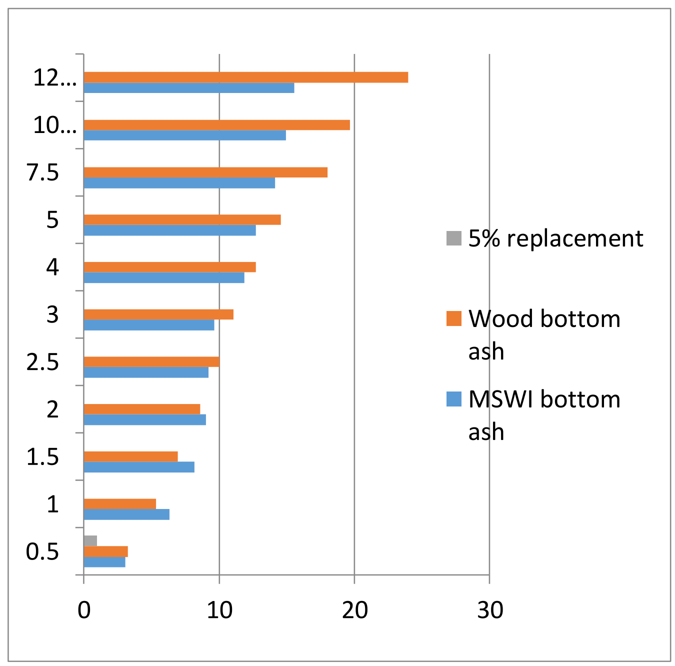

Fig.4: CBR Test 2 Comparison on load intensity

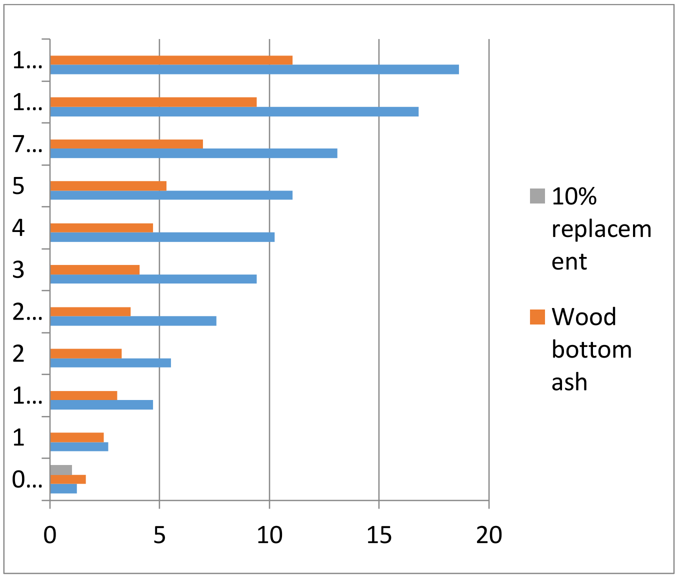

Fig.5: CBR Test 3 Comparison on load intensity

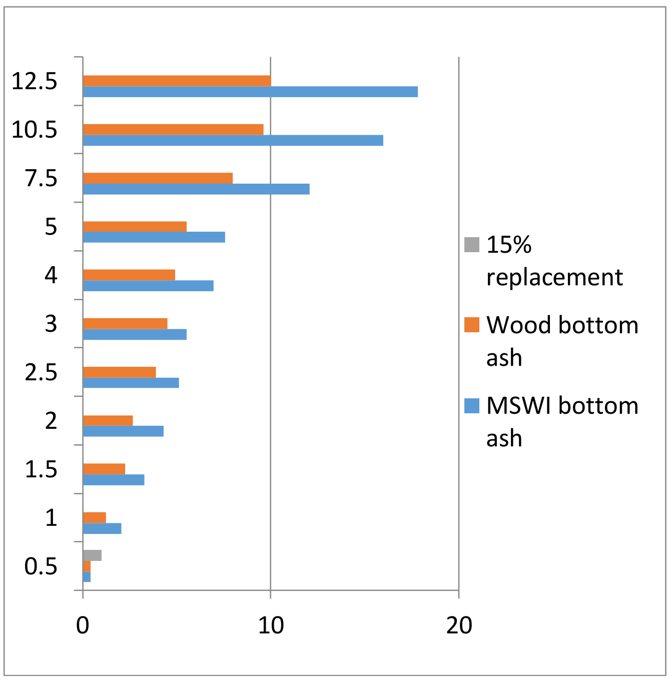

Fig.6: CBR Test 4 Comparison on load intensity

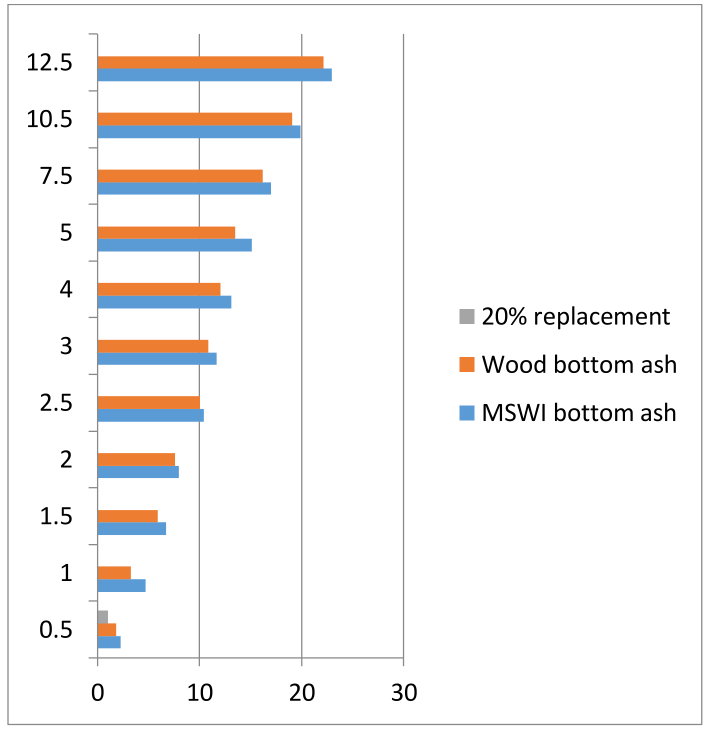

Fig.7: CBR Test 5 Comparison on load intensity

VI. CONCLUSION

- This article discussed the utilization potential of MSWI ashes in a variety of fields, various obstacles preventing utilization and various options for treatment procedures that could overcome these obstacles. The composition of ash depends on the input waste, type of incinerator and process parameters, and this varies spatially and temporally; it does not hinder its utilization in one of the various potential fields of application.
- The most suitable area of utilization for each type of ash produced in around 2200 waste to energy plants around the world needs to be identified and put into use locally. Moreover, the cement industry, which is identified as the most suitable agent for valorizing bottom ashes as raw meal additive and supplementary cementitious material, is equipped for dealing with variability in raw material composition and still produces a final product with the required quality control.
- One of the sources of variation is the process parameters of incineration plants, which are optimized currently for maximum energy generation. However, the process parameters can have an effect on the chemical properties

of final residues, which could in turn affect the technical quality of the final product after utilization.

- The process parameters of incineration plants need to be optimized for maximum utilization of residues. A comprehensive database of the effects of various characteristics of residues on the quality of final products after incineration needs to be developed after research.
- MWSI ash contains mostly heavy metals particles and the gradation of particles are uniform. The specific gravity ash is 2.09; which is lighter than conventional earth material.
- This is advantageous in constructing light weight embankments over soft compressible soil. The un-soaked CBR value of fly ash, compacted to its MDD at OMC is 13.8%. IRC: 37-2001 states
- That CBR value for sub base should be 20% up to 2 msa and should not be less than 30% after 2 msa. Hence, this fly ash is not suitable for sub bases in either of these conditions.
- The permeability of fly ash under dynamic compaction comes to be 4.2*10-4 cm/sec, which is very high and cannot be used as a direct material in pavement, earth dam etc.

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