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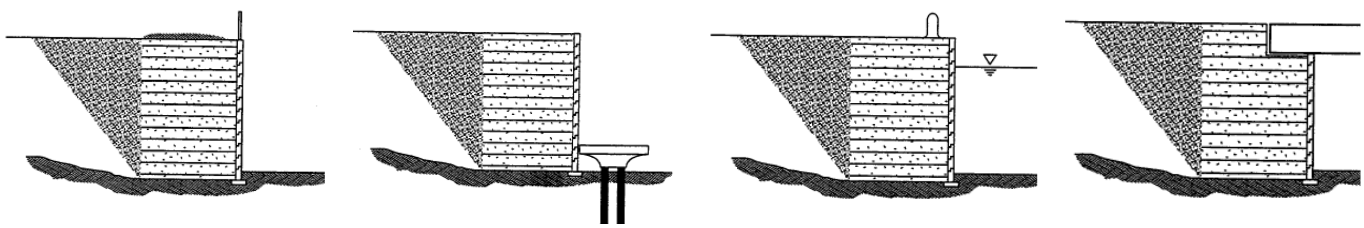
Industrial Waste Materials used as Backfill in MSE Wall Constructions in India: A Review

Naveen Pandey[1], Nupoor Dewangan[2]
[1, 2]*Civil Engineering Department, CSVTU, Bhilai, India*

Abstract: Continuous infrastructural development in the country consumes a massive amount of natural resource materials which could be replaced partially or fully in future by the wide variety of industrial waste materials available in the country. Such case is the construction of MSE walls for the smooth flow of traffic over the state highways and National highways which requires huge amount of non-plastic granular fine aggregates for backfilling. In this study, most of the potential industrial waste materials that can be used in place of standard structural fill materials and analyzed and compared. The tabular comparison helps in understanding the scope of using such waste materials in MSE walls at present time or in future. The material acceptability flow chart clearly describes the process of choosing a waste material for using as a backfill material in MSE walls.
Keywords: Industrial waste, MSE, Backfill, Reinforced soil, Recycled granular waste.

I. INTRODUCTION

Mechanically Stabilized Earth (MSE) walls are the earth retaining structures having a face angle in the range of 70° to 90° and mainly comprised of three major components: Precast facing panels, soil reinforcing elements (extensible or inextensible) and backfill materials (coarse size soil). These structures are widely constructed all over the country that have many advantages over the traditional type of retaining or gravity walls. Various applications in which these types of walls are used in the country are presented in Fig.1. These structures require granular materials with high durability for backfill materials as they have high hydraulic conductivity as well as possess structural reliability to the retaining structures [1]. The chosen backfill material are required to have several engineering properties for the adequate stability of the retaining structures. They must possess (i) adequate shear strength for better interfacial friction between soil and reinforcements, (ii) high hydraulic conductivity, (iii) minimal compressibility, (iv) minimal long term deformation, and (v) no harm to reinforcing elements through corrosion. For fulfilling these criteria, generally granular soils are used in construction of MSE walls. These criteria however increases the construction cost because of the inclusion of transportation cost of such selected backfill materials. Also, the rapid use of such natural resource materials cases the environment's sustainability.



(a) Retaining Wall (b) Access Ramp (c) Waterfront Structure (d) Bridge Abutement

Fig. 1 (a to d): Various MSE Wall Application (source: [2])

At the same time, various manufacturing and construction industries of India generates million metric tons of industrial wastes in the form of coal ash, steel slag, recycled asphalt pavement (RAP), foundry sand, etc. that creates the waste accumulation and environment pollution problem. Considering the bulk consumption of these waste materials, their proper utilization in MSE walls construction activities can minimize the disposal and environmental problems caused to the society and also open gateways for future sustainable developments. This could also save significant amounts of expenditure to the state transport departments which is done on extracting high quality natural occurring granular backfill materials. The appropriate utilization of industrial wastes is decided on the method of usage of these materials in an economical way compared to the presently used natural resources, considering the extraction and transportation cost [3]. Their reuse in MSE walls and reinforced soil slopes is one of the possible way of keeping the environment clean in sustainable.

Before concluding any possibility of usage of the industrial waste materials in MSE walls, they need to be tested for various physical, chemical and shear strength tests. The standard reinforced backfill materials can be partially or fully replaced by the alternative waste materials by performing some additional processing if needed, on the waste materials original state in which they are found and making their chemical and physical characteristics similar to that of conventional materials. In this manner a whole array of industrial wastes could be taken into reuse in MSE walls as backfill material. In this study we would be doing a comparison study of all the available industrial wastes in India which has high potential for their use in MSE walls and reinforced soil slopes. The tabular comparison of the quantity of their physical properties and processing or transportation cost could help in choosing an appropriate industrial waste materials from the sites nearby the MSE wall construction site.

II. INDUSTRIAL WASTES IN INDIA THAT HAS POTENTIAL OF BEING USED AS BACKFILL

Table 1 presents all the possible industrial wastes that have been studied for their suitability of being used as reinforced soil in MSE walls construction by many researchers. This tabulated comparison helps in understanding the variety of alternatives available in India and their useful properties for ultimate decision of using them in MSE wall construction.

Table 1 Comparative Analysis of Industrial waste materials used as backfill in MSE wall constructions in India

Industrial Waste	Generation Point in India	Physical properties	Remarks	References
Pond Ash	Ash Ponds of National Thermal Power Plants	G = 1.64-2.66 φ = 25-34° c = 0-56 kPa	Non-cohesive material having coarser particle size than Fly ash and rich in silica. Lightweight and available in huge quantities. High hydraulic conductivity. Due to significant variation in physical properties, generally mixed with high quality material like sand in some proportions while using as backfill.	[4], [5], [6]
Fly Ash	Boilers of National Thermal Power Plants (217.04 Million tons in 2018-19)	G = 1.66-2.55 φ = 20-41° c = 0 kPa	Finer Particles than Pond ash. High puzzolanic properties. Used as backfill by adding some amount of sand. It is already a successfully used waste material in cement and bricks manufacturing industries.	[4], [5], [6], [7], [8]
Steel Slag	Blast Furnace of Steel Industries (10 Million tons annually)	G ~ 2.9 7 to 8 % fines	Slag collected from quenching in water typically found in gravel size particle then again it is crushed to get the desired particle size. Behaves as long acting binder and higly skid resistant. Economical than standard filling materials in construction sites within 30 Km from steel industry.	[9], [10], [3]
Copper Slag	3 insutries in India (Sterlite, Birla and Hindustan Copper Ltd.) (~1.63 M metric tons present in country)	G ~ 3.6 φ = 35-49°	Non-Plastic, granular, black coloured and heavy material. The granular properties, physical properties and shear strength characteristics meets the standard specifications of conventional fill material. Higher pullout resistance than sand.	[11], [12]
Imperial Smelting Furnace (Zinc) Slag	During primary smelting of zinc ore in blast furnace of Zinc Industries (720,000 tons annually)	G ~ 3.6 φ = 33 - 52°	Non-Plastic, granular, black coloured and heavy material. The granular properties, physical properties, shear strength characteristics and pullout tests meets the standard specifications of conventional fill material.	[13]
Foundry Sand	Around 5000 Foundries (1.7 million tons annually)	G = 2.39-2.55	Have acceptable mechanical properties to be used in MSE walls. Great substitute for sand in concrete mixes.	[14], [15], [16]
Construction and Demolition Waste (i) Recycled Concrete Aggregate (RCA) (ii) Recycled Asphalt Pavement (RAP)	Renovation, Repair or demolition of existing structure	G = 2.6 (fine fraction), G=2.67(coarse fraction)	Non Hazardous waste. Contains RCA, RAP, recycled steel and crushed bricks. Easily available in loacal area. Used in MSE walls after processing in stone crushing plant. Poor draining material with hydraulic conductivity (order of 2×10^{-5}). RAP has comparatively low specific gravity and also it is widely used in producing new asphalt concrete.	[17]
Waste Tyre chips	Waste tyre shredding industries	-	Generally mixed with sand while using as backfill material. Increases the Fatigue life of Pavement over MSE walls. Special skills and equipments required to shredding into fine pieces. Reduces Earth pressure and Displacement by about 50-60 %.	[18], [10]

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III. MATERIAL ACCEPTEBILITY CRITERIA FOR USING IN MSE WALLS

The backfill of MSE walls are generally constructed with various compacted layers of granular non-plastic materials. There are number of standard tests performed on backfill materials and on the basis of those results and the characteristics, the feasibility of using that material is decided. These acceptability criteria ensures the high quality and long performance of the chosen material. Fig. 2 presents a flowchart to show the criteria which a waste material should go through before being used as backfill material in MSE walls.

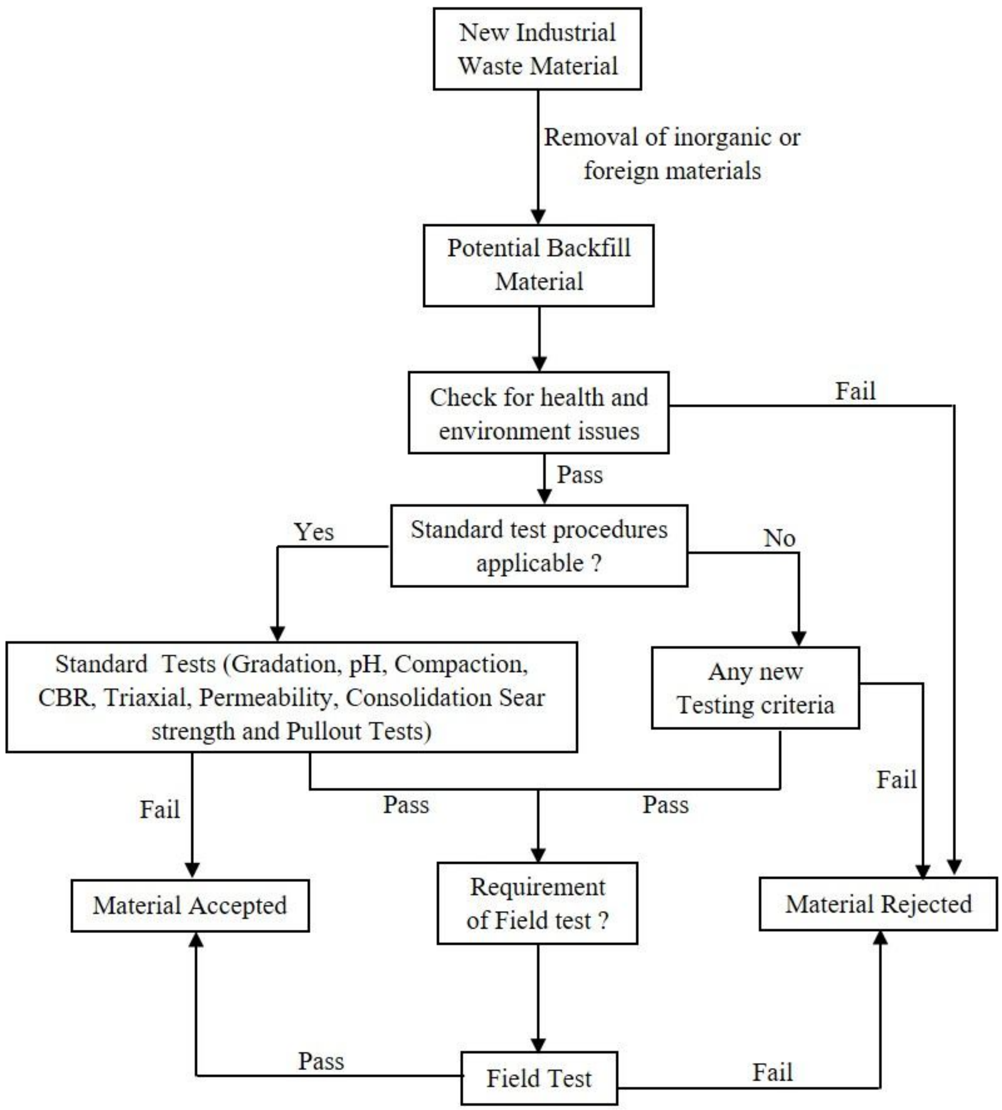

Fig. 2: Flow Chart showing acceptability criteria for a backfill material (Modified after [10])

The standard test procedures that are used for the assessment of conventional backfill materials might not be appropriate for the assessment of some other unusual materials like discarded waste materials from industries. The standard tests like grain size analysis, chemical composition, compaction characteristics, CBR values, water conductivity, etc. may be different for the non-conventional materials. Therefore, to analyze such industrial wastes, some new assessment methods may be innovated and new acceptable limits may be made. However, in starting, it is expected that both the conventional materials and industrial waste materials can be evaluated through same test procedures. The materials if passes through the standard laboratory tests, it is required further to perform as expected in the actual site condition and therefore it is also necessary to check waste materials performances though field tests. In some cases, the material may be assessed as the poor material in laboratory tests but can perform well in actual field condition. Thus the waste materials may be chosen as the backfill material through laboratory assessments or field performances.

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IV. CONCLUSION

The comparative study of all the industrial waste materials available in the country and studied by various researchers which has high potential to be used as backfill material in MSE walls and reinforced soil slopes helps in understanding the properties, performances, advantageous points and limitations of the materials. Some materials like fly ash, foundry sand and RAP have other usage also in the bricks manufacturing, cement making, road or building construction activities. But the other materials like pond ash, copper slag, tyre chips, zinc slag, RCA and steel slag are mainly used as filling materials in the road embankments or the pits and therefore, these materials have high potential to be used as backfill material in MSE walls. Any material prior to its application, must be assessed for its physical, chemical, shear strength and pullout behaviour through standard tests methods or any new developed method. The chosen material being a waste material in this case, would promote the sustainable development.

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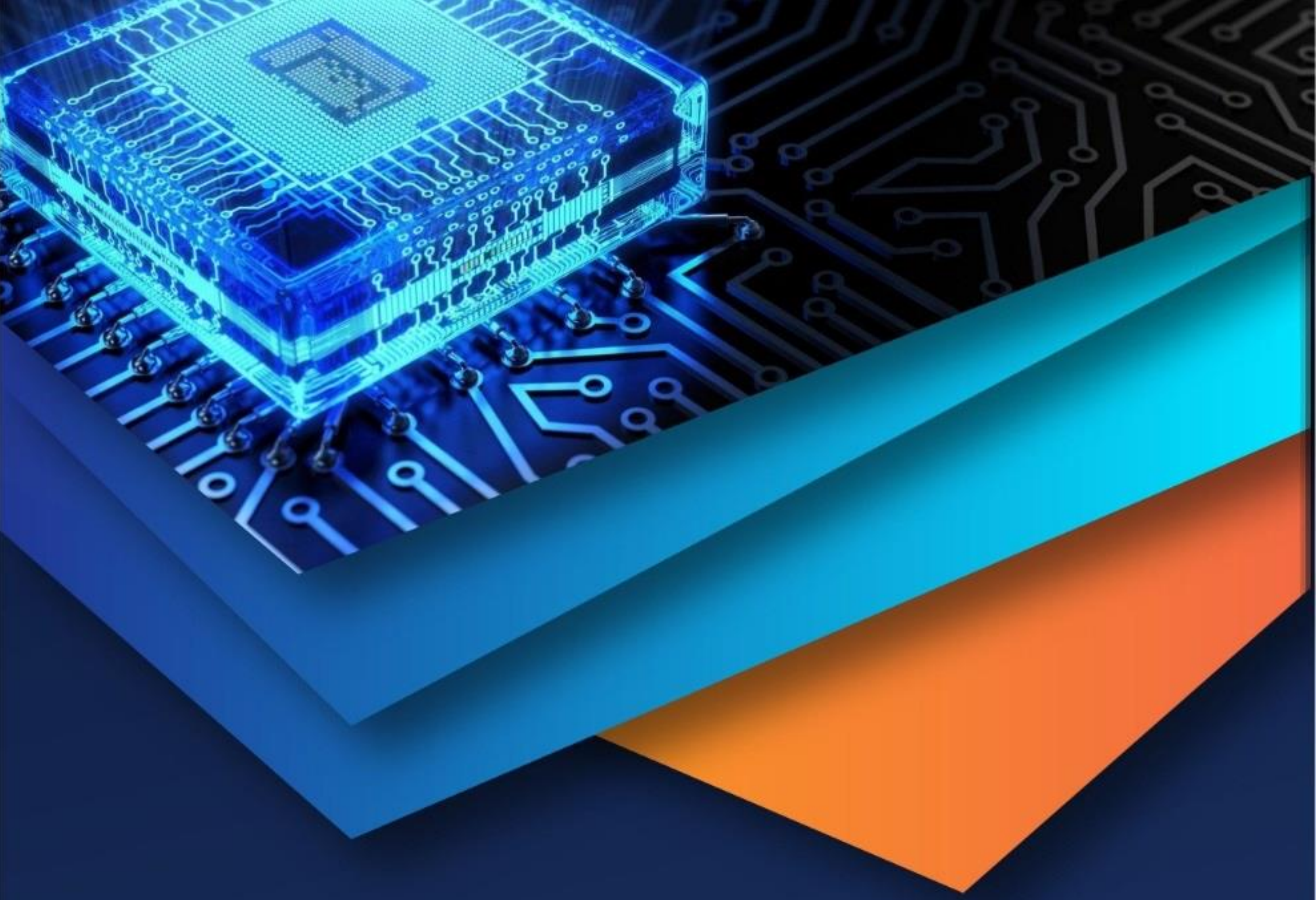

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