

# Feasibility Study of Using Pond Ash with some proportion of Sand as Backfill Material in MSE Walls

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**Abstract :** Continuous expansion in road networks of India and for smooth movement of traffic, it is obvious that the MSE walls would be constructed all over the country in upcoming years. These structures requires huge amount of inert, non-cohesive and granular materials like sand for backfilling, but in future, sand is not going to be available in such quantities. Therefore it becomes our responsibility to search for some locally available waste materials to be used in place of sand in MSE walls. In this study, one of the type of coal ash generated from the thermal power plants i.e. pond ash - a non-cohesive material, coarser in size and available in huge quantities, is analyzed to be used as partial replacement of conventional backfill materials. Badarpur sand was used to be mixed in different proportions with the pond ash to control the variation in physical properties of pond ash. Pullout tests performed with 20%, 25% and 30% incorporation of Badarpur sand with the pond ash shows an increases in the pullout resistance by 6.76%, 12.03%, and 18.04% respectively. The physical properties of Pond ash were found suitable to be used as backfill material in MSE walls and other retaining structures.

**IndexTerms - Pond Ash, Badarpur sand, Pullout test, Geograp, Backfill.**

## 1. INTRODUCTION

The vast road network of India covers more than 5.89 million Km and is continuously expanding. All these road expanding activities need to construct flyovers, wing walls, bridge abutments and sea walls for smooth traffic movement. Therefore it is very likely that many Mechanically Stabilized Earth (MSE) walls would be constructed over the National Highways and State Highways of India. MSE wall is a composite structure composed of compacted backfill layers and soil reinforcing elements, attached to the facing elements. Its stability is the function of the interaction between soil reinforcements and backfill materials. This type of construction method have almost replaced the conventional retaining structures all over the world due to its simplicity and rapid construction procedure [1]. MSE walls comprised of three main components: Facing (precast concrete blocks and panels), soil reinforcing elements and backfill material.

MSE wall construction requires massive amount of granular soil like sand or crushed stone for backfill materials, but seeing the worldwide massive consumption of sand, it is not going to be the source forever. Therefore it becomes necessary to use local available waste materials as the partial replacement of conventional backfill material. On the other hand, rapid increase in the coal ash generation in huge quantities can be seen in India. Based on a report of Ministry of Environment and Forest (MoEF), every year about 197 million metric tonnes of coal ash is generated in India and it is going to increase further [2]. For disposal of such a massive amount of coal ash, about 40,000 hectares of good cultivable lands is occupied in the country. Also, these coal ash particles are very tiny and airborne which is consist of toxic elements such as arsenic, nickel, cadmium, etc. that leads to serious health problems. Its disposal into the water bodies nearby the human settlement areas could seriously damage the community's health.

Fly ash, Bottom ash and Pond ash are the three types of coal ashes generated from the National Thermal Power Plants of India. Fly ash are the very fine particles separated out from the coal ash which shows puzzolanic properties and therefore, it is successfully being utilized in cement and brick manufacturing industries. Whereas, the bottom ash and fly ash mixture sluiced to the ash ponds through large amount of water is known as Pond ash and these are comparatively coarser in size which makes it feasible to be used in roads and highways construction as a backfill material. However, the samples of Pond ash when collected from ash ponds at different points, it possess large variation in granular and shear strength behaviour. This grain size variation of pond ash from designing stage to actual construction stage could lead to structural failures. Therefore in this study, several pullout tests were carried out to analyse the Pond ash alone and Pond ash-Badarpur sand mix to be used as backfill material. Pullout tests are the laboratory tests used by many researchers ([3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], etc.) to find out the pullout resistance factor between backfill material and reinforcements which is an important parameter while designing the MSE walls. On the basis of pullout test results, the conclusion on feasibility of using Pond ash as backfill material is then given.

## 2. LITERATURE REVIEW

Pond ash have coarser particles of coal ash generated from thermal power plants unlike fly ash. This property encourages its practical use as backfill material in various road, highway and MSE wall construction activities. Kumar, [1] stated that pond ash has a potential to be used as an alternative material for the backfill. According to [14], compacted pond ash could be taken into use as a granular sub-base material as it satisfies the gradation requirements and possess adequate bearing strength. Pant et al. [15] investigated the pullout characteristics of polyester geogrid embedded into Pond ash and then compared it with the behaviour of geogrid reinforced into the reference backfill material i.e. Yamuna sand. Laboratory pullout test at different normal stresses were used in their study whose results shows that however, pond ash is not having similar granular properties to that of sand but the pullout resistance values obtained between geogrid and pond ash found to be similar to that in sand. Kumar [1], presented a study of designing a flyover using locally available pond ash as the backfill material in place of conventional backfill such as sand considering the economic situations. They suggested the construction of these types of structures on soils with low bearing capacity and in earthquake prone areas. Sarkar & Dawson, [16] investigated pond ash as a sub-base material by using different proportions

of lime and fibers to increase its suitability as sub-base material. Satyanarayana et al., [17] used the mixture of pond ash and different proportions of recycled concrete aggregate as backfill material and studied the CBR values of these mixtures.

Most of the studies done on using Pond ash as backfill material in embankments and MSE walls consider it as non-cohesive granular material suitable for backfill material without considering its variation in granular properties and shear behaviour. Several studies [18], [19], [20], [21], [22] shows that the pond ash collected from different points (entry point, mid pond and exit point) of a same ash pond possess different granular and shear strength properties. This makes it highly unpredictable to design a MSE wall containing Pond ash as backfill material. Some attempts have been made to control this variation by using some proportions of recycled concrete aggregate, lime and fibers, sand, etc. in pond ash. Sharma, [23] used the pond ash-sand mixture and investigated its shear and frictional behaviour with a reinforced polymeric geograp. They concluded a satisfactory pullout resistance obtained between reinforcement and pond ash-sand mixture.

### 3. MATERIALS USED IN THE STUDY

#### 3.1 Backfill Materials

Pond ash (PA) samples taken for the present study (Fig. 1a) was collected from ash ponds of Badarpur thermal power station, Delhi. Badarpur Sand (BS) samples taken for the study (Fig. 1b) were carried from the quarries near Delhi where it is manufactured locally. Both the samples were sieved through a 2.36 mm sieve to remove any foreign or organic material present and then kept in a clean and dry place after taking out from oven drying at 105-110°C temperature.



Figure 1: Backfill materials used in the present study

#### 3.1 Reinforcing Material

The woven polymer strip reinforcement used in present study (Fig. 2) was taken from Maruti Rub Plast Pvt. Ltd., Noida. These strips were having an ultimate tensile strength of 30 kN and 87±3 mm wide. The thickness of the specimen was about 1.85-1.95 mm and the maximum elongation at design load was taken as 12±2 %. High density polymer strips (Geograp) are the type of extensible reinforcements used in MSE walls for soil reinforcement. Single layer of geograp was used in the middle of the tank for selected backfill materials to study the interfacial frictional behaviour through pullout tests.



Figure 2: Reinforcing material (Polymeric geograp) used in the present study

### 4. DETERMINATION OF ENGINEERING PROPERTIES OF BACKFILL MATERIALS USED

#### 4.1 Chemical Composition

Table 1 presents a typical chemical composition of backfill materials used in the present study. PA and BS both have silica as its major constituents but comparatively Badarpur sand is more silicious than Pond ash and also has very low amount of metal oxides of iron and aluminum. Absence of K<sub>2</sub>O, ZnO and MnO was observed in Pond ash.

Table 1: Chemical Composition of Backfill materials

Constituents (%)	PA	BS
SiO <sub>2</sub>	48.95	70.93
Al <sub>2</sub> O <sub>3</sub>	25.53	12.04
Fe <sub>2</sub> O <sub>3</sub>	9.78	2.95
CaO	5.06	2.57
K <sub>2</sub> O	-	6.04
ZnO	-	0.01
SO <sub>3</sub>	0.15	0.71
MgO	0.97	0.73
MnO	-	0.04
Ignition Loss	7.65	-
Others	1.91	3.98

#### 4.2 Grain size analysis

The particle size analysis of Pond ash and Badarpur sand were carried out by following [24] and their particle size distribution curves are shown in Fig 3. By observing the gradation curves, it is seen that Pond ash mainly contains silty-sand particles. Particle size of pond ash mainly depends on the pulverization process carried out in the thermal power plants and the temperature at which boiling units work.

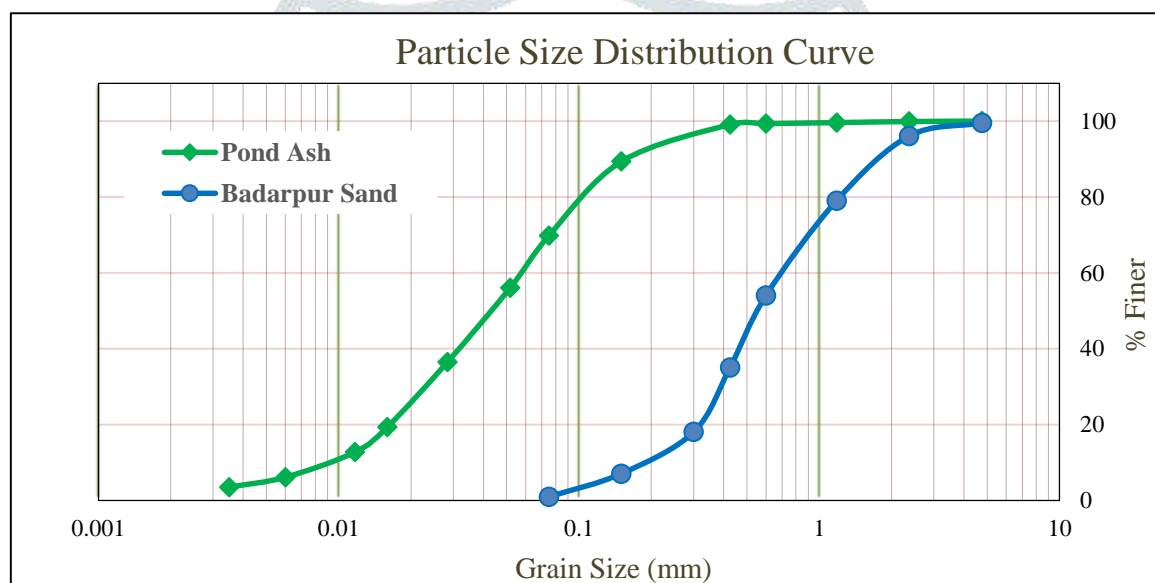


Figure 3: Grain Size Distribution of Backfill materials

The values of coefficient of uniformity ( $C_u$ ) and coefficient of curvature ( $C_c$ ) were determined by plotted particle size distribution curves and presented in Table 2. According to the Unified soil classification system, BS and PA were classified as SP (poorly graded sand) and SM (silty sand) respectively.

Table 2: Grain Properties of Pond ash and Badarpur sand

Grain properties	PA	BS
$C_u$	6.06	4.64
$C_c$	0.91	1.12

#### 4.3 Specific Gravity

By following [25], the specific gravity ( $G$ ) of PA and BS were found to be 2.06 and 2.60 respectively. The lower value of specific gravity observed for PA than BS due to cenospherical nature of pond ash particles. The specific gravity of Badarpur is similar to the conventional backfill materials i.e.  $G \sim 2.65$ .

#### 4.4 Atterberg Limits

The plastic limit and liquid limit (Atterberg Limits) of the BS and PA sample could not be obtained because of its non-cohesive, non-plastic and inert nature.

#### 4.5 Compaction Characteristics

The compaction characteristics of PA and BS were determined according to [26] in which 3 kg of oven dried sample was taken for both the material and then mixed with different percentages of water. The wet samples were then compacted in a proctor mould of 1000 cc in five layers using modified proctor rammer of 4.5 Kg. The imparted energy of 2674 kJ/m<sup>3</sup> was maintained through the adjusted number of blows in each layer. The moisture content of the tested samples were determined as per [27]. The compaction curves plotted for the PA and BS are presented in Fig.4. The compaction test results are given in Table 3.

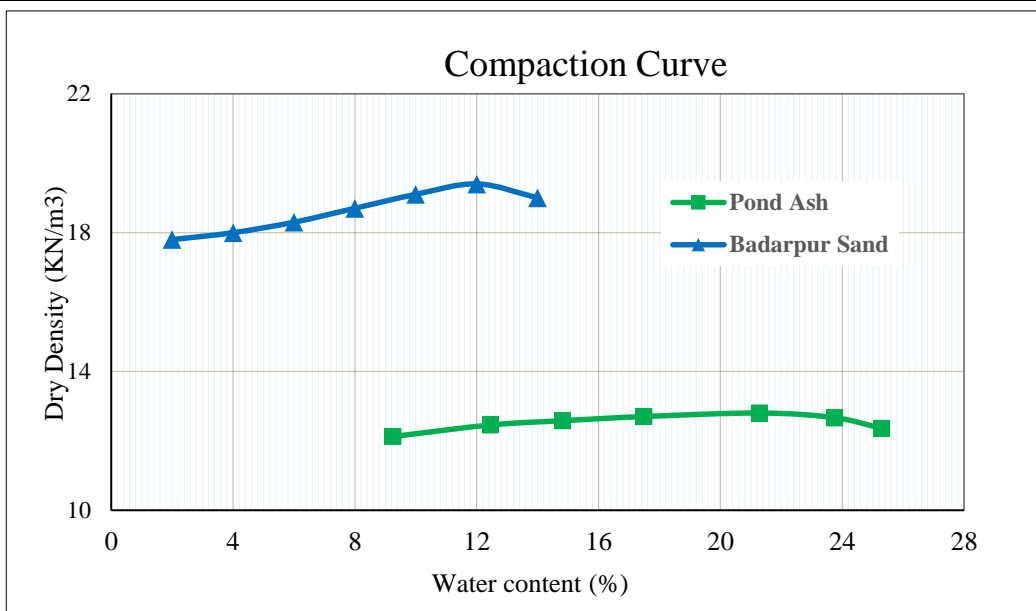


Figure 4: Compaction Curves of Backfill materials

Table 3: Compaction properties of backfill materials

	PA	BS
Maximum dry density (kN/m <sup>3</sup> )	12.56	19.43
Optimum moisture content (%)	22.25	11.92

### 5. PULLOUT TEST AND RESULTS

The pullout tests were conducted in a pulout test apparatus constructed according to ASTM D6706 [29] for studying the variation in the stress and strain behaviour of PA and PA+BS mixture under a constant confining normal stress (25kPa) at the reinforcement level of pullout box. Total of three pullout tests were carried out by filling the steel box with backfill materials as shown in Table 4 and using same 30 kN geostrap as reinforcing material in all three cases.

Table 4: Pullout test arrangements used in the study

Confining stress	Backfill material	Reinforcing Element
25 kPa	PA (100%)	Geostrap of 30 kN of Ultimate tensile strength
	PA (80%) + BS (20%)	
	PA (75%) + BS (25%)	
	PA (70%) + BS (30%)	

The pullout test of compacted pond ash and mixture of Pond ash and Badarpur sand were conducted at the maximum dry densities which were obtained during the compaction tests in laboratory. The samples were prepared in a steel box of dimension 1.5×1×1.0 m by compacting 5 layers of predetermined weight of the backfill materials according to their maximum dry densities. Geostraps were embedded in the middle of steel tank at 0.5m from below. The effective length (Leff) of the embedded geostrap was 1 m. Leff must be atleast 1 m for minimum anchorage length beyond failure point [28]. The constant confining stress (25 kPa) at the reinforcing level of the pullout box i.e. 0.5 from below, was applied through a double acting hydraulic loading system. The embedded reinforcing elements (geostraps) were pulled out through a clamping system at the strain rate of 1mm/min. The pullout load possessed by the geostraps were observed in a digital datalogger device which measures the load through a load cell attached in the pullout direction. The displacement of geostrap in the pullout direction were also observed in the datalogger device which measures the strain through two linear variable displacement transducers (LVDTs). A Schematic diagram of the pullout test carried out in the study is shown in Fig. 5.

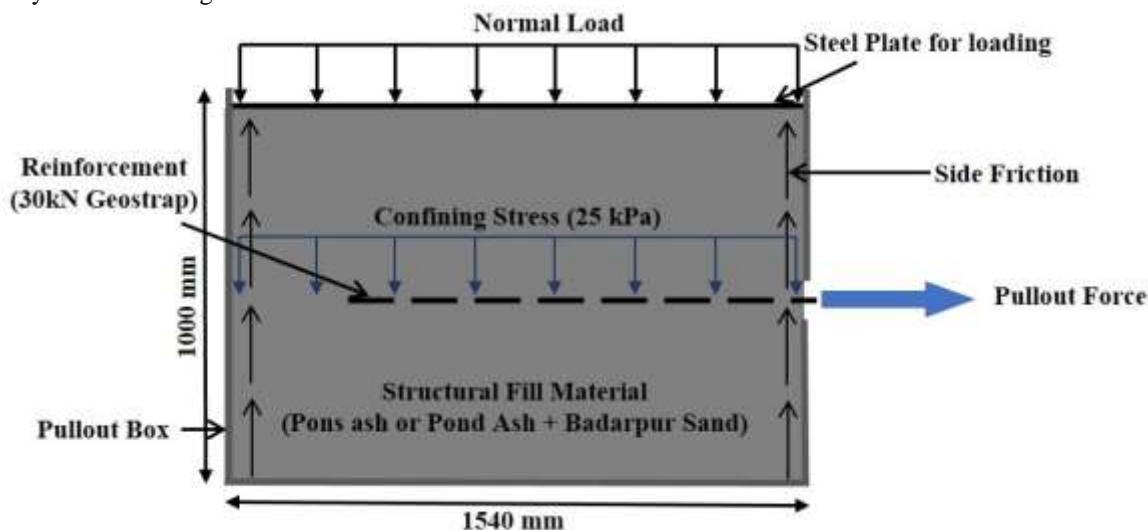


Figure 5: schematic diagram of Pull-out test apparatus used in the study

The pullout load (kN) versus geostrap displacement (mm) curves obtained through pullout tests performed under confining stress of 25 kPa for various selected backfill materials are presented in Fig.6. The peak pullout load value obtained from the curves is also known as pullout resistance (PR). The curves obtained here gives a better picture for comparison study of the pullout behaviour of the geostrap embedded in different combinations of backfill material. It can be clearly seen from the curves that in all the backfill-geostrap arrangements, the pullout load increases significantly in the early stages under constant confining stress and after some time decreases gradually and attains a constant behaviour. This indicates that the pullout resistance increases with increase in geostrap displacement for some time and once the peak pullout resistance value attained, the geostrap starts showing elastoplastic nature and possesses almost constant values. At elastoplastic stage, the pullout tests becomes more of a tensile test of geostrap.

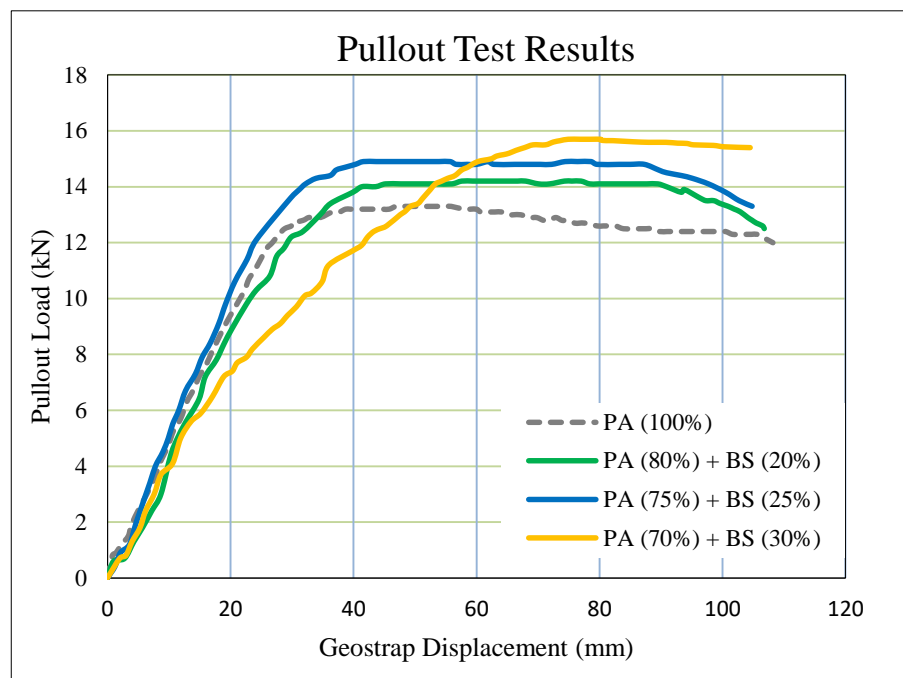


Figure 6: Pullout load Vs. Geostrap displacement curves for selected backfill materials

The peak pullout resistance values obtained through the pullout tests performed for different combinations of Pond ash-Badarpur sand mixtures are presented in Table 5. It can be clearly seen that with increase in percentage of Badarpur sand in the Pond ash-sand mixture, the peak pullout resistance values increases. The table also represents the percentage increase in the pullout resistance values by mixing different percentages of Badarpur sand in pond ash. A close observation in these values indicates that with every 5 percentage increase in the Badarpur sand content in the pond ash-sand mixture, the increase in PR values shows a linear behaviour.

Table 5: Pullout test results for different combinations of backfill materials used in the study

Backfill Material	(PR) (kN)	Percentage increase in PR (%)
PA (100%)	13.3	-
PA (80%) + BS (20%)	14.2	6.76
PA (75%) + BS (25%)	14.9	12.03
PA (70%) + BS (30%)	15.7	18.04

## 6. CONCLUSION

Based on the laboratory tests performed for analyzing the physical characteristics and pullout behaviour of backfill materials used in the study, it can be seen that by adding Badarpur sand in pond ash in various percentages increases the pullout resistance. 6.76% increase in the pullout resistance was observed on mixing 20% of Badarpur sand in the pond ash-Badarpur sand mix and after that a linear trend was seen in the increase in the percentage of pullout resistance for every 5% increase in the Badarpur sand content in the pond ash-Badarpur sand mix. The inert and non-cohesive nature of both the backfill materials makes it an effective backfill material.

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