FLY ASH AS BACKFILL MATERIAL FOR REINFORCED EARTH STRUCTURES

ABSTRACT:

The filling material performances and its interface friction properties with the geosynthetics would directly influence the application properties of the geosynthetics reinforced earth retaining walls. Road map to 2022, estimates Rs 3 lakh cr, targets 44 express highways (18,637 Km) across variable soil sub-grade over country. For Rs 20 cr per Km, approximately 2 cr will be spent for flyover/underpass involving Earth Structures (RE Wall etc). Thus there is a huge possibility of RE wall being constructed for every 2 Km of 6-4 lane road of NH, State Highway where there is a need of large fill/backfill quantity of sand. But in future sand is not likely to be a source forever, so there is a need for use of local waste/fill materials as backfill. and hence the present study. This paper includes review on fly-ash as backfill materials. The field instrumented observations for our structures to derive code of practice is recommended.

Key words: Fly-ash, Backfill Material, Reinforced earth retaining structures, Standard specification.

Introduction:

Because of the good engineering performances, a large number of reinforced earth retaining walls have been constructed throughout the world. Compared with the traditional gravity earth retaining walls, geosynthetics reinforced earth retaining walls have the better engineering characteristics of light deadweight, beautiful shape, construction convenience and etc. Especially on the soft ground, the better performances would be embodied in virtue of their light deadweight. Filling material's performances and interface friction properties with the geosynthetics directly influenced the application performances of the geosynthetics reinforced earth retaining walls. As the filling material of geosynthetics reinforced earth retaining walls, it should have the following engineering properties: good mechanical properties which include the

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strength and rigidity; better interface friction property with the geosynthetics; & the material had better be lightweight.

Road map to 2022, estimates Rs 3 lakh cr, targets 44 express highways (18,637 Km) across variable soil sub-grade over country. For Rs 20 cr per Km, approximately 2 cr will be spent for flyover/underpass involving Earth Structures (RE Wall etc) **[18]**. Thus there is a huge possibility of RE wall being constructed for every 2 Km of 6-4 lane road of NH, State Highway where there is a need of large fill/backfill quantity of sand. But in future sand is not likely to be a source forever, so there is a need for use of local waste/fill materials as backfill and hence the present study. The detail study is carried out on fly-ash as backfill materials. The field instrumented observations for our structures to derive code of practice is recommended.

The use of waste materials as fill for reinforced soil structures is desirable from an environmental as well as economic point of view. Coal based thermal power stations produce massive quantities of coal ash. There are mainly two types of ashes which are produced by burning the coal. The lighter one goes up the chimney and collected either by mechanical or by electrostatic precipitator, is known as Fly-Ash. The other fraction containing coarser materials are collected at the bottom of the furnace, is known as bottom ash. Fly ash is about 90 % of total coal ash and poses serious environmental problems. The use of stabilized fly ash as a light weight fill in construction is common. The material can also be used in reinforced soil structures. In vertically faced reinforced soil structures a better quality of fillis likely to be specified in contrast to embankment structures where the whole objective of there in forcing concept may be to improve the existing marginal fill.

Standard Specification of Backfill Materials:

Normal practice for the preliminary design of Reinforced Earth structures with **(Hausmann, M.R., 1990[10], BS: 8006-1995[2], Holtz, R. D et al., 1997[7], & Swami Saran, 2005[17])**: The percentage of fines (< 0.08mm) in the backfill is < 15%. Backfill compacted at a moisture content equal to or less than optimum (Soil fill should be compacted to 95 % of optimum dry density and - 2 % of OMC). Free-draining backfill & Soil reinforcement friction

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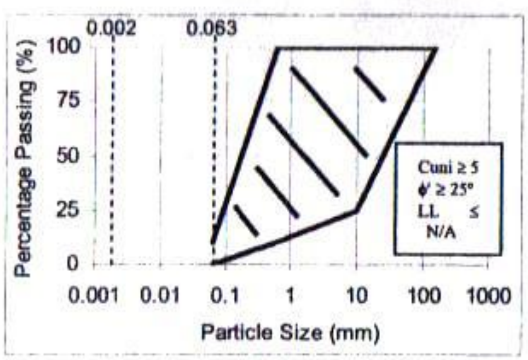
factor tan δ not < 0.3 (or Φ ≥ 30 □). The soils with appreciable fines (silt and clays) are not recommended for geosynthetic reinforced walls. The unit weight γ can be determined from the standard Proctor-test/Vibratory type relative density test. Shear strength parameters, C & Φ determine using direct shear or triaxial tests. For temporary walls, the only backfill chemical requirements specified are as follows: soil pH shall be between 3 and 11, and soil resistivity shall be >1,000 ohm-cm. For some soil environment posing potential concern when using geosynthetics. Soil with pH ≥ 12 or pH ≤ 3 should not be used in reinforced wall. A pH range ≥ 3 to ≤ 9 is recommended for sand. Specific supporting test data should be required if pH > 9.

BS 8006-1995 allows two principle types of fill to be used in the construction of reinforced soil retaining walls. The grading shown in Fig: 1(a) is suitable for use with all fill types and contains limited quantities of material passing a 63μm sieve. This is to ensure that fills for use with steel elements are free draining so as to avoid the corrosion concerns that would be present using water sensitive fill. The grading curve shown in Fig: 1(b), which allows a higher proportion of material passing a 63μm sieve, with specific controls on the Attrburg limits, is suitable for use with polymeric reinforcement only.

These constrains may be modified for a particular project, based on construction conditions, regional experience, depth of geotechnical investigation, and design provisions.



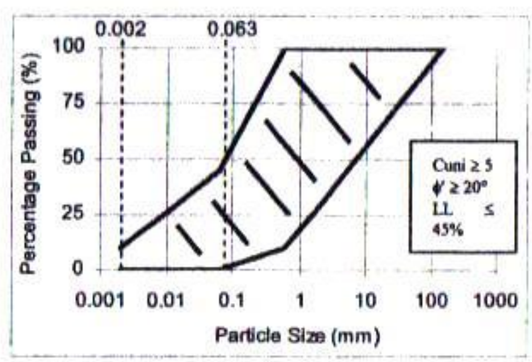


Fig: 1. Acceptable Fill Grading Curves for Use with (a). All Reinforcement Types and (b). Polymeric Reinforcement only (G.Venkatappa Rao. et al., 1995[5])

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Fly Ash as Backfill Material:

In order to evaluate and understand the present state of art in the field of back fill material usages, a through literature survey was carried out. A good numbers of research papers are published in the area of usage and specifications for back fill materials. Contributions towards both utilization of sand as wells as cohesive / composite fill material were reviewed thoroughly. As far as utilization of fly-ash as backfill material is considered, vast amount of literature is available as it has very well established codal provisions for usage.

The growing interest in utilizing waste materials in civil engineering applications has opened the possibility of constructing reinforced soil structures with unconventional backfills. Flay ash is a high-profile by product material for which several uses have been studied as backfill materials. The annual production of fly ash in India is more than 100 million tonnes per year posing serious problems of disposal and environmental hazard at many places. Hence, concentrated attempts are made to effectively use fly ash in an environmentally friendly way.

Chaney et al. (1982) [3] has added to the accumulating knowledge concerning the geotechnical properties of pulverized coal ash (fly ash). The writers would like to present some additional data for a fly ash material derived from the combustion of Eastern bituminous coals in a pulverized coal fired furnace equipped with electrostatic precipitators for removal of the fly ash from the flue gas stream. After removal from the precipitation hoppers, the fly ash was sluiced to a disposal pond. A detailed study of the static and dynamic properties of this material has been presented. The purpose of discussion is to present information on particle shape and cyclic properties.

McKittrict, 1978 Suggested the minimum specifications of a soil to be used in reinforced soil construction. These are given in Table: 1. Department of Transport (1978) recommended the use of cohesive frictional fill provided it corresponds to the grading and plasticity characteristics given in Table: 2.

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Table: 1. Minimum Specification for Select Fill

Sieve Size	Percent Passing
6"	100
3"	75-100
No.200	0-25
P.I. < 6	
OR If percent passing No.200 is greater than 25 percent, and percent finer than 15μ is less than 15 percent, material is acceptable if Φ = 30 □ and P.I. < 6	

Table: 2. Grading Limits of Cohesive Frictional Fill

B.S.S. Size	Grading Limits Percentage Passing by Weight	Remark
125 mm	100	The fill shall be finer than these grading limits
90 mm	85	
10 mm	25	
600 Micron	10	
63 Micron	10	
2 Micron	> 10	
Liquid Limit	> 45 %	
Plasticity Index	> 20 %	
Φ	< 20 □	

Study by **Peindl et al. (1992)** [14] was to evaluate the potential applications of a laboratory-developed flowable fly-ash backfill by comparing its structural support capabilities with those of normal compacted soil backfill in a full-scale controlled application. Tests were performed for buried pipe applications using a variety of pipe sizes and materials. Throughout the tests, the ashcrete backfill demonstrated superior capabilities by consistently reducing pipe strains compared with the soil backfill. Joint loads were found to be comparable for the two backfills. The ease of installation of this flowable fly-ash backfill makes it attractive from the stand point of reduced labor costs. The ashcrete backfill also experiences minimal settlement with heavy-vehicle traffic, thus reducing the necessity for subsequent regarding and maintenance. This was in contrast to the substantial continual maintenance required by the soil backfill subject to the same heavy-vehicle traffic. Although these tests demonstrate the structural advantages of this type of flowable fly-ash backfill, an overall comparison of material, labor, and maintenance costs associated with this alternative backfill versus standard backfills is left for

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further evaluation. In each case, for both static and dynamic loading conditions, the ashcrete backfill performed as well as, or better than the compacted soil backfill. In general, surface strains and joint loads increased with continued compaction for the soil backfill.

The strength of reinforced fly-ash is considerably more than unreinforced fly-ash **(Gupta, 1995[6])**. The concept can be used in the construction of roads, high-embankments, foundation etc. However, **(Bouddu, 2002[1] and Shankar, 2003[16])** it may be kept in mind that both fly-ash / reinforced fly-ash may lose their strength considerably on submergence.

Pandian et al. (2002) [13] shows that fly ash can be effectively used in bulk as a sub-base / fill material in combination with soils. The freely draining nature of fly ash is highly useful in this regards.

The geotechnical evaluation system often accepted for normal soils have revealed insufficiency of existing practice extended to ash fill. A large no of cone penetration tests conducted by **Trivedi et al. (2002)** [19] on various combinations of stress level and relative density indicated requirement of a new scheme for ash fills.

Pandian & Ahmed (2002) [12] shows that the addition of fly ash (about 80%) to black cotton (BC) Soil makes it non-swelling. The compacted density of soil fly ash mix is low compacted to BC soil alone which will be beneficial since a lower density will result in lower earth pressures leading to savings. The earlier studies have shown that fly ash has a high frictional value which will be beneficial in its use in geotechnical applications. Further, since it is a free draining material, it can be used in the construction of embankments / retaining wall etc. leading to its bulk utilization. When mixed with BC soil, the dust problems are solved and at the same time the engineering properties of BC soil get improved. Thus fly ash proves to be an effective admixture for improving the soil quality and at the same time affords means of utilizing the same without adversely affecting the environment.

Hazra & Nihar (2008) [15] studies the Experimental investigations on model counter fort retaining walls for lateral movement of the walls and the nature of the failure modes. Ennore sand, obtained from Madras India, and Fly ash, obtained from Panki Thermal Power Plant, India were used as backfill material. They conclude that the active earth pressure depends upon

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properties of backfill, type and amount of reinforcement used and wedge angle of failure surface, and the retaining wall with fly ash backfill is more stable than with sand backfill.

Through systematical experiments, the application performances of saponated residue and fly ash mixture were studied **by Ji-Shu Sun et al. (2009)[8].** The main conclusions obtained are summarized as: The mixture of saponated residue and fly ash has higher strength, rigidity, and good water stability. The strength of saponated residue and fly ash mixture would increase when saponated residue content, the curing age or degree of compaction, is increased. Both the direct shear coefficient and pull-out coefficient of the mixture of saponated residue and fly ash are relatively higher. These indicate the better interface friction between geogrids and the mixture of saponated residue and fly ash. The performance of saponated residue and fly ash mixture conform to the requirement of filling material of geogrids reinforced earth retaining walls. So it can be used as a good filling material of geogrids reinforced earth retaining walls.

Today, fly ash is being used as a structural fill material in highway and railway embankments, for ash pond bunds, levees, filling low-laying areas etc. Seepage induced failures in the form of piping can weaken and affect the performance of an embankment constructed with fly ash as a structural fill material. **Das et al. (2009) [4],** presents a study to examine the effect of randomly distributed geofibers on the piping behavior of fly ash. In this study, a number of experiments were carried out for determining the seepage velocity and piping resistance of fly ash, mixed randomly with flexible polyester fibers having various dosages and lengths. Seepage velocity of flow of water through fly ash is calculated for each case and compared with an unreinforced fly ash. It was observed that fibers reduced the seepage velocity, increased the piping resistance of fly ash and delays the attenuation of piping phenomena considerably. Finally the mechanism by which discrete and randomly distributed fibers restrain piping of fly ash is explained with the fly ash fiber interaction.

The potential fields of application of fly ash in large volumes are mainly construction of roads, embankments, and filling of low lands. Shear strength of fly ash is one of the important parameters required for the design of such projects. **Pal & Ghosh (2009)[11]** study the variation of shear strength parameters of fly ash with varying composition, unconsolidated undrained

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triaxial tests have been conducted on nine fly ash samples collected from different thermal power plants of the Eastern part of India. They presents shear strength parameters of all the nine fly ash samples, compacted at optimum moisture content and maximum dry density obtained from standard Proctor (AASHO) compaction tests. All the fly ash specimens were tested under three different confining pressures of 100, 200 and 300 kPa. Effects of confining pressure, MDD (12 ± 2 kN/m3) and OMC (28 ± 3 %) on shear strength parameters of fly ash samples are discussed. The values of the shear strength parameters i.e., angle of internal friction, Φ_{uu} and apparent cohesion, C_{uu} of all the fly ash samples vary within the range of 29.91°–36.93° and 14.31–59.59 kPa respectively. The angle of internal friction of the strength of fly ash samples is more significant than apparent cohesion, irrespective of type of fly ash. **Desai et al. (2005),** has conformed cohesion C, angle of internal friction Φ, modulus of elasticity of soil E, Permeability k, and compressibility characteristics for Ukai Fly Ash near Surat.

Experimental study is carried out by **K. Ramu (2009)** [9] to estimate effect of vertical flyash columns in the expansive clay bed on controlling the heave of the expansive soil bed. It is observed that the heave is considerably reduced (49.19 to 27.27 mm) with the vertical flyash columns in the expansive soil bed. Puzzolanic activity of the flyash is studied by replacing the flyash by sand in the vertical columns in the expansive clay bed. It is observed that the heave of the expansive clay bed increasing with the increasing sand content in the vertical flyash columns, since the flyash content decreases results in reduction in puzzolanic activity.

Observations & Conclusions:

Looking at the present scenario of rapid infrastructural development, availability and usage of purely cohesionless back fill is rarely possible at all site conditions. With the advancement of R & D methods over the decades study for use of composite materials on non availability of sand as backfill material is fast catching up, for at times it can also work out to be an economical and technically feasible option. Following are few conclusions derived on this regard:

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The sand backfill now which is an obligatory practice can be replaced by other materials, such as byproducts of industry, fly ash & wet expansive CH soil, cohesive heterogeneous fill materials [composite/blended soil mix], if they satisfy shear, compressibility, pull out resistance of reinforcing element, permissibility criteria's laid down by the code.

Lack of good quality control measures coupled with primitive construction practices and equipments have made usage of sand the most feasible and widely used obligatory fill material in the past for its excellent engineering properties and compaction characteristics. With the advancement, use of modern construction practices off late with high end mechanized equipments with good quality control checks and methods, use of materials other than sand as backfill is most sought after choice.

The material specification laid down in terms of grading is secondary for mixed and cohesive soils used as fills, with proper compaction at 2% < OMC.

Fly ash, a byproduct of industry available abundantly in major part of our country can be blended, compacted and/or stabilized with cohesive expansive soils. Fly ash can satisfy the requirements of fill material in reinforced walls, slopes with specified compaction, work as a filter material and bring about economy in construction practices.

The economy & feasibility in usage of property specified soil, byproducts of industry including fly ash as compacted fill material for backfill, other fill and fill of steep reinforced slopes, being still at a nascent stage, requires a through R & D and massive field trials of performance for better understanding and its optimum utilization for the massive infrastructural construction planning projects in India.

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