METHODOLOGY FOR THE ENVIRONMENTAL RISK ASSESSMENT OF FLY ASH USE IN HIGHWAY EMBANKMENTS

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Abstract: Fly ash can be used in highway embankments for larger and convenient consumption. Techno-economic considerations of fly ash use enforce the need to evaluate various models. The selected models also need to be evaluated from environmental considerations. So a flexible and suitable risk assessment methodology has been suggested in this paper by adopting different models. The environmental impact is based upon many factors and their relative weight-ages. Based upon subjective or specific judgment the values can be assigned to these factors. The quantitative analysis of these values can give sufficient indication in regard to the suitability of use of fly ash in embankment. The positive impact assessment values denote larger adverse environmental impact and the negative values denote the favourable environmental impact.
Key words: fly ash, environmental impact, risk assessment, models, highway embankment

Introduction

Fly ash is causing environmental pollution, creating health hazards and requires large areas of precious land for disposal. Due to increasing concern for environmental protection and growing awareness of the ill effects of pollution, disposal of ash generated at thermal power plants has become an urgent and challenging task. Also in developed urban and industrial areas, natural burrow sources are scarce, expensive or inaccessible. The environmental degradation caused due to the use of top soil for embankment construction may be un-measurable. Moreover, many power plants are located in urban areas, and therefore, fly ash can provide an environmentally better alternative to natural burrow soil.
The major environmental concerns with respect to the potential impact of fly ash usage in roadwork including embankment, are wind erosion, surface water erosion and leaching of toxic heavy metals into water bodies including under ground aquifers. During the construction of fly ash embankments, keeping the ash moist during compaction can minimize wind erosion.

Major portions of inorganic compounds in fly ash are present as alumino-silicate glass. Most of the other elements are present in very small quantities and are largely encapsulated in the glassy material. Typically less than 2% of the fly ash is water-soluble; calcium and silicate constitute the majority of soluble fraction (Lindon K.A.Sear, 2003). There are smaller amounts of sodium, potassium and magnesium. The pH is mainly determined by water-soluble calcium and sulphate producing an alkaline environment. When used in structural fill applications fly ash has very low permeability, which means that there is very little passage of water through it and very little potential leachate. Most trace elements are held in alumino silicate matrix and are not available to leach. A deposit of fly ash in embankment is further aids retention of metals. The highway embankment constructed using fly ash being a narrow stretch on land use has close to nil impact on water quality of the area. Fly ash embankment contains almost no biodegradable organic material and produces no gas as a product of such degradation. The radioactivity of fly ash embankment is similar to that of conventional construction materials. (Lindon K.A.Sear, 2003).

Despite the large volumes of ash produced, the total quantity of heavy metals is relatively small, and an even smaller amount of these elements can be released to the environment. However, it is important to note that despite these relatively low concentrations, if improperly managed, any waste can have a negative impact on the environment.

Adverse health effects from skin contact with coal ash appear to be extremely unlikely in highway embankment construction.

The physical location of the power plant often has a great impact on disposal and use of fly ash in highway embankments. Plants located in urban areas may have no space for on-site disposal necessitating transport to other locations for disposal. However, as these locations become completely filled, new land must be found for disposal. New sites may require environmental reviews and regulatory hurdles.

In some situations, the fly ash is not mixed with water, but instead loaded directly into covered trucks or pneumatic tank trucks for transport. If this material is disposed, then handling at the disposal site is normally more challenging due to potential dusting issues. The fly ash used in embankment construction must be kept suitably moistened as otherwise wind blowing may cause fly ash inhalation to workers and also its spread to adjoining areas.

The fly ash can be more easily spread and compacted than conventional soil, which may require lumps to be broken. Less compactive effort may save equipment-operating time thus having reduced impact on environment.

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In some situations fly ash with or without additives may improve the engineering properties of the subgrade thus necessitating reduced pavement thickness requirement in the case of flexible pavements. This may considerably save on cost, quarry operations, transportation and other factors, which adversely affect the environment.

Risk Assessment

All wastes or by-product materials should be evaluated prior to use to fully assess the inherent hazard potential of the material, if used in the proposed application. Simply because a waste legally may not be subject to hazardous waste regulation is not necessarily an indicator that it is not potentially chemically hazardous or contains constituents that could pose threats to human health or the environment

Historical Perspective (Gupta 2004)

Prior to 1970, there was little if any environmental regulatory oversight regarding the use of waste and by-product materials in pavement construction applications. In general, those materials that exhibited acceptable engineering properties and were both cost-effective and not considered to be “harmful” to workers or the environment were often used. During that period, however, there were no specific procedures or criteria available to quantify potential environmental concerns or “harmful” impacts.

Hazardous wastes may be identified as of two types. They may be referred to as listed wastes or characteristic wastes. A listed waste is a waste that is classified as hazardous due to its source and the way it is produced. A characteristic waste is a waste that must be tested to determine if it exhibits one of four properties: (1) ignitability, (2) corrosivity, (3) reactivity, or (4) toxicity.

General Requirements (Gupta 2004)

Due primarily to the increased pressure to recover and use waste and by-product materials, in recent years, most state environmental regulatory agencies (especially those in industrial areas) have begun the process of formalizing their regulatory procedure for approving the use of waste and by-product materials. At the present time, however, there are no universally accepted environmental approval and permitting procedures.

Regulatory requirements in general can take one or more of the following forms:

No approval is required — material is considered acceptable due to previous history of use.

Approval is required — material must not exhibit the characteristics of a hazardous waste.

Environmental or risk assessment is required — a field and/or desktop evaluation must be provided to demonstrate that the material will have no adverse impact on human health and the environment.

Although the first two requirements are rather straightforward, the latter requirement can necessitate a series of evaluations that could include the preparation of an environmental assessment, a human health risk assessment, or an ecosystem risk assessment.

Environmental assessments generally require a quantification of emissions or discharges from a proposed activity (e.g., construction of a pavement using a waste or by-product material) and a projection of the impact of this emission or discharge on the ambient environment. The magnitude of the impact is usually assessed by comparing the source discharge or the projected ambient impact to some source discharge standard (e.g., groundwater or surface water discharge limits) or some ambient air, water or soil quality standard (e.g., ambient air or water quality criteria). Projections of impacts to the ambient environment are normally estimated using environmental models (e.g., air and water quality models).

Human health assessments provide for a linking of discharges and emissions from specific sources to vulnerable human receptors in an attempt to quantify risks (using reference doses for carcinogenic and no carcinogenic effects) associated with a specific activity. They attempt to account for all potential contaminants and exposure routes (e.g., ingestion, inhalation, and dermal absorption) that might affect the identified receptor.

Ecosystem risk assessments are evaluations that focus on potential impacts to flora and fauna, usually in the immediate environment of the action. Like human health risk assessments, they tend to focus on specific transfer routes to identifiable flora and fauna and the impact on these organisms. They sometimes address long-term cumulative impacts that may result from the proposed action, such as bioaccumulation and potential food chain effects.

For environmental suitability of using waste and by-product materials in embankment construction applications, there are common elements to all environmental assessments that form the basis for determining the potential impacts associated with a proposed application. These common elements include the following:

Identification of potential hazards posed by the use of the material.

Identification of persons or media (air, water, soil) likely to be impacted by the identified hazard.

Identification of the magnitude of the potential impact.

Identification of Potential Hazards

Some waste and by-product materials may contain concentrations of trace metals or trace organics that are higher in concentration and/or more environmentally mobile than those found in conventional materials. Others may contain highly alkaline materials (e.g., free lime), high concentrations of soluble salts, very fine particles that may be susceptible to dusting and may also be respirable. Still others may contain volatile organic or inorganic material that could be released in high-temperature environments.

Impacted Persons or Media

The highway embankment construction process comprises numerous operations including material storage, handling, production, placement, excavation, and disposal or recycling operations. These operations are all part of the embankment construction, service life, and post service life activities. Potential dust or volatile emissions or liquid discharges from these operations could have an impact on ambient air, surface or groundwater, soils, or the worker environment.

The identification of each of these operations is important when identifying impacted persons or media.

Magnitude of Impact

Techniques for determining the magnitude of the impact will depend in great part on the type of evaluation that is required (i.e., traditional environmental assessment, human health risk assessment, or ecosystem risk assessment). In all cases the use of source emission, ambient air, surface water, and groundwater models will probably be required. An attempt has been made to have subjective environmental risk assessment by assuming different models (Fig 1 to 6) as given in the table-1 (Gupta 2004).

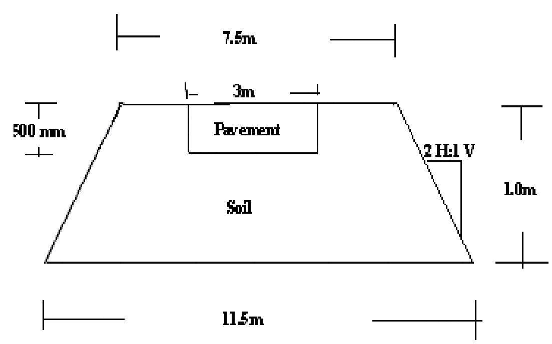
The Table 1 illustrates the environmental risk assessment model that can be used as a guide for evaluating the use of fly ash in highway embankments. The environmental impact is based upon many factors and their relative weightage. Based upon subjective or specific judgement the values can be assigned to these factors. The quantitative analysis of these values can give sufficient indication in regard to the suitability of use of fly ash in embankment. The below mentioned table has variation of cumulative weightage values between 3 and 78. Thus from 3 to 78 the value range can be divided into four broad categories if desired. **From 3 to 21 least impact, 22 to 40 moderate impact, 41 to 59 significant impact, and 60 to 78 large impact.** Thus for any specific site, the cumulative weighted environment impact value can be estimated and desirable inference drawn. The factors and their relative weightage can be reviewed from time to time as per past experience and best judgement (Gupta 2004).

As an example, six models (1 to 6) are subjectively assessed to have weighted environmental risk assessment value of 15,36,25,14,24 and 30 that are as per the earlier assumed classification. The model-4 denotes least impact to environment.

The various models (Gupta 2004) taken for study of highway embankment construction are:

- **Model-1:** Embankment constructed with the locally available soil of 2.3% CBR. Pavement crust thickness required is 500mm (sub base 350 mm + base 150 mm).

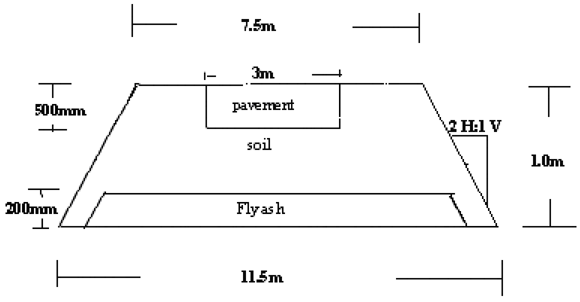
Fig. 1



Typical cross section of highway embankment with pavement (Model-1)

- **Model-2:** Embankment constructed with the fly ash and with 1m-earth cover on sides and top 0.3m of earth with 2.3% CBR to form sub grade. Pavement crust thickness required is 500mm (sub base 350mm + base 150 mm).

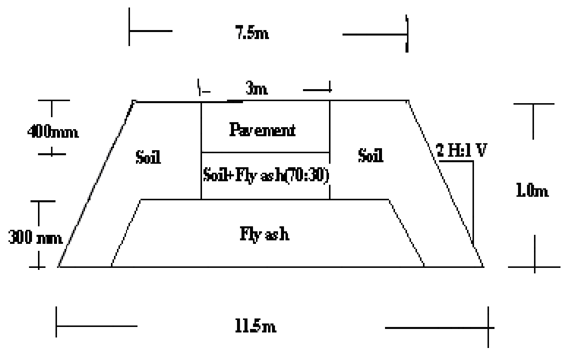
Fig. 2



Typical cross section of highway embankment with pavement(Model-2)

- **Model-3:** Embankment constructed with earth and with 1m-earth cover on sides and sub grade constructed with soil-fly ash mixture (70:30) of 3.3% CBR. Pavement crust thickness required is 400mm (sub base 250mm + base 150mm).

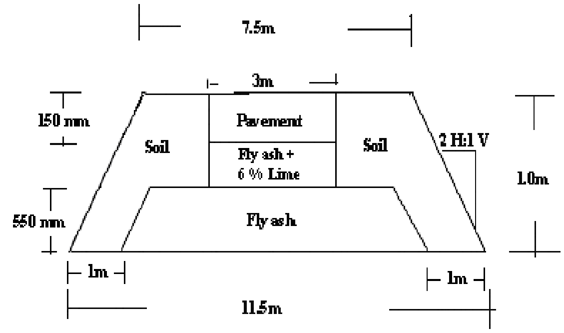
Fig.3



Typical cross section of embankment with pavement(Model-3)

- **Model-4:** Embankment constructed with the fly ash using suitable earth cover and sub grade constructed using stabilised layer (fly ash + 6% lime) of 18% CBR. Pavement crust thickness required is 150mm (base 150mm).

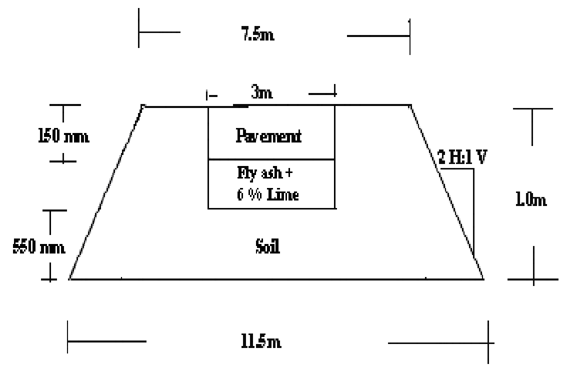
Fig 4



Typical cross section of embankment with pavement (Model-4)

- **Model-5:** Embankment constructed with earth and sub grade constructed using stabilised layer (fly ash + 6% lime) of 18% CBR. Pavement crust thickness required is 150mm (base 150mm).

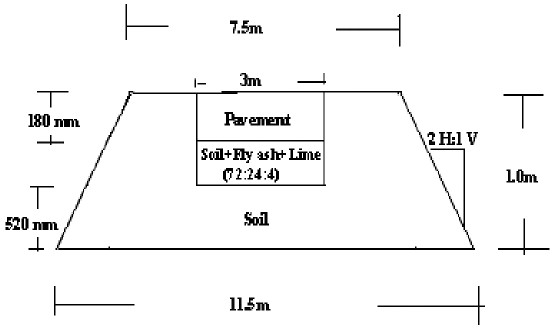
Fig. 5



Typical cross section of embankment with pavement (Model-5)

- **Model-6:** Embankment constructed with earth and sub grade constructed with soil-fly ash-lime mixture (72:24:4) of 15% CBR (sub base 30mm + base 150 mm).

Fig 6



Typical cross section of embankment with pavement (Model-6)

Only those cases have been considered where maximum use of fly ash could be achieved in comparison to the conventional soil. For comparison purpose the silty soil has been considered. These are only sample models and other models could also be prepared by using fly ash in stabilised sub base layer and in fly ash stabilised base layer.

The positive impact assessment values denote larger adverse environmental impact and the negative values denote the favourable environmental impact.

Conclusions

- Handling, transportation and storage of fly ash for fly ash based highway embankment does involve environmental impact. This impact may depend upon factors like carbon dioxide emissions, wind erosion, land degradation, health hazards, quantum utilisation, fly ash disposal procedure, technology of use, etc. All these factors have different qualitative and quantitative impact on environment.
- Environmental degradation being a broader term may not be assessable from all angles. However, for estimating the environmental impact of fly ash use in highway embankment and for getting a closer picture of impact, suitable weighted impact value may be assigned subjectively to each considered factor. A risk assessment model so prepared can give an appropriate overview of environmental impact of each project model so as to facilitate the decision making in regard to use of fly ash in embankment.
- The selected models may have global applications and the environmental risk assessment model so prepared can be applied, with or without modification, for monitoring the related impact of fly ash use in highway embankments.

References:

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• Lindon, K.A. Sear 2003. Paper No. 20. International Ash utilization symposium, Centre for Applied Energy Research, University of Kentucky,

Factor	Class	weightage	Class Weightage	Final Weightage	Max. Value	Min. Value	Model No.					
							1	2	3	4	5	6
Quantum of fly ash used in Embankment (% By weight)	(70-100) (30-70) (<30)	1	1 2 3	1 2 3	3	1	3	3	2	1	3	3
Green house gases	Savings in energy Extra energy required	1	-1 1	-1 1	1	-1	-1	1	1	1	1	1
Haul distance	<5 Km 5-50 Km 50-100 Km >100 Km	8	1 2 3 4	8 16 24 32	32	8	0	16	16	16	16	16
Mode of transportation	By trucks By train By pneumatic trailer By open trailer	2	2 3 1 4	4 6 2 8	8	2	0	4	4	4	4	4
Health	Manual Handling Mechanised Handling	3	2 1	6 3	6	3	0	3	3	3	3	3
Land contamination Through non use of fly ash in embankment	(70%-100%) (30%-70%) (<30%)	4	1 2 3	4 8 12	12	4	12	12	8	4	12	12
Water contamination	Disposed in pond Used in embankment	1 0	1 0	1 0	1	0	1	0	0	0	0	0
Change in sub grade CBR	Significant decrease Small decrease Significant increase Small increase	6	2 1 -2 -1	12 6 -12 -6	12	-12	0	0	-6	-12	-12	-6
Psychological barriers	Full motivation and awareness Less motivation and awareness	3	-1 1	-3 3	3	-3	0	-3	-3	-3	-3	-3
Total	-	-	-		78	3	15	36	25	14	24	30

Table 1. Environmental Risk Assessment Model for Fly ash use in highway Gupta 2004)