TECHNO-ECONOMIC EVALUATION OF FLY ASH BASED SUBGRADE

Dr Pardeep Kumar Gupta
Associate Professor, Civil Engineering Department,
PEC University of Technology, Chandigarh

ABSTRACT

The top 30 cm to 50 cm layer of the embankment acts as sub grade for pavement. In rural roads the top 30 cm of the cutting or embankment at the formation level shall be considered as sub grade. The embankment may be constructed with conventional locally available suitable soil, or with fly ash in the core with appropriate soil cover over top and sides, or with soil and fly ash blend material, or with one of the above and with modified sub grade so as to improve its CBR value.

Sub grade with Increased CBR value will require thinner flexible pavement for the similar other design parameters. It is possible that the cost of sub grade modification is lesser than the cost of extra pavement thickness required for unmodified sub grade**.**

Introduction

The ultimate purpose of all highway embankments is to support the pavements for carrying traffic. The top 30 cm to 50 cm layer of the embankment acts as sub grade for pavement. In rural roads the top 30 cm of the cutting or embankment at the formation level shall be considered as sub grade (IRC: SP:20-2002). For Expressways, National Highways and for Major District Roads, the top 50 cm portion of the roadway is considered as sub grade (IRC: 37-2001). The embankment may be constructed with conventional locally available suitable soil, or with fly ash in the core with appropriate soil cover over top and sides, or with soil and fly ash blend material, or with one of the above and with modified sub grade so as to improve its CBR value.

Sub grade with Increased CBR value will require thinner flexible pavement for the similar other design parameters. It is possible that the cost of sub grade modification is lesser than the cost of extra pavement thickness required for unmodified sub grade. It will also save the scarce natural materials for other construction purposes. If the CBR value of the unmodified sub grade

is low then the sub grade improvement has larger impact on pavement thickness.

As an example if the CBR value of the soil can be improved from 2 % to 6 %, the resulting saving in rural road pavement thickness for CBR curve C will be (595-325)=270 mm. For rural road considering pavement width of 3.75m, the total saving in paving material per kilometer will be more than (3.75 x 1000 x 0.27) = 1013 m^3. For Punjab if the sub base material is within 2 km, its cost per m^3 may be around Rs 80 and if the lead is 200 km, its cost may be around Rs 400 per m^3. Thus saving in cost of the pavement per km may be between Rs 81000 to Rs 405000. Net saving will depend upon the cost of soil sub grade improvement cost.

Depending upon the quality of soil and that of fly ash, the improvement can be in the form of soil + fly ash, soil + lime, fly ash + lime or fly ash + lime + soil. All these combinations will have different cost and proportions for the same amount of improvement. And at the same cost, all are likely to have different strength. Out of these the soil is generally available within 15m to 5 Km in rural area, and in urban area it may be available from outside the city limits. It is generally available free and has only handling and transportation costs. The lime is required in considerably less quantity compared to the other components of the sub grade and its purchase price is its main cost.

Thus for the use of fly ash in embankment construction and sub grade improvement, the viability and its mode of use will be site specific, and its usefulness will depend upon many factors like lead of sub grade materials, royalty, characteristics of each material to be used, their mix proportions, environmental regulations, lead of sub base materials, awareness of potential use of fly ash, and the willingness of the user agencies to adopt new and innovative technologies.

Laboratory Tests For Pond Ash use in Highway Embankments

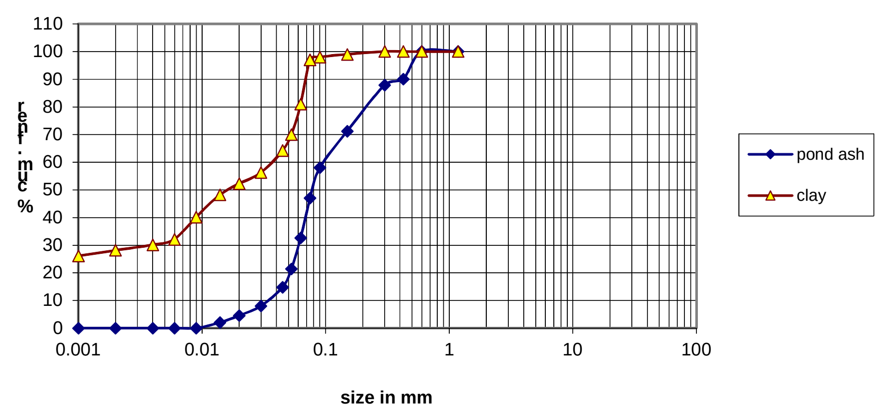
The highway embankments may consist of conventional material like soil, coal ash (fly ash, bottom ash, pond ash) in the core with sufficient soil cover on sides and on top. Similarly the sub grade material in the embankment may consist of only soil, only coal ash, soil + lime, coal ash + lime, soil + coal ash or soil + coal ash + lime.

Pond ash (a mixture of around 80% fly ash and 20% bottom ash) and which is the most easily available type of coal ash from thermal power plants, has been taken from the Guru Govind Singh Thermal Power Plant, gate No-9, Ropar and locally available soil samples have been used for testing. The properties such as grain size, OMC (optimum moisture content), maximum dry density, Atterberg's limits, CBR (California bearing ratio) values, shear strength parameters and permeability have been evaluated as follows:

Grain Size Analysis

Figure 1 shows the grain size analysis curve of the materials used. The tests have been carried out as per IS: 2720 (Part 4)-1985.

Fig.1. grain size analysis curve for different soils



Liquid Limit and Plastic limit

The liquid limit of clay was 32.5% and plastic limit was 21.92%. The tested sample of clay falls under CL group of BIS (Bureau of Indian Standards) soil classification system. The Table 1 shows liquid limit and plastic limit test results of the tested materials.

Table: 1
Liquid limit and plastic limit test results (IS: 2720 Part-5)

S. No.	Type of soil	Liquid limit (LL) %	Plastic Limit (PL) %	Plasticity Index (PI) %
1.	Pond ash	NP	NP	-
2.	Clay	32.5	21.92	10.58

Optimum Moisture Content

These tests have been carried out as per heavy compaction method (IS: 2720 Part- (8)-1983), in which the soil sample is compacted, using the same mould as used for light compaction test, in five layers each layer being given 25 blows.

Figure 2 shows the moisture density relationship curve for each type of embankment material. Table 2 shows the compaction test results for clayey soil and for pond ash. Table 3 shows the compaction test results for clayey soil mixed with different proportion of pond ash. Table 4 shows the compaction test results of each type of soil mixed with fixed quantity of lime and with varying proportion of pondash

Table: 2
Modified Proctor Compaction Test Results

Pond Ash					
Moisture content (w) %	15.38	17.86	23.08	27.14	31.08
Dry Density ((Y_d) gm/cc	1.14	1.18	1.216	1.17	1.12
Clay					
Moisture content (w) %	13.89	16.67	17.2	18.45	22.12
Dry Density ((Y_d) gm/cc	1.833	1.862	1.88	1.857	1.70

Fig 2 Compaction Curve for different materials

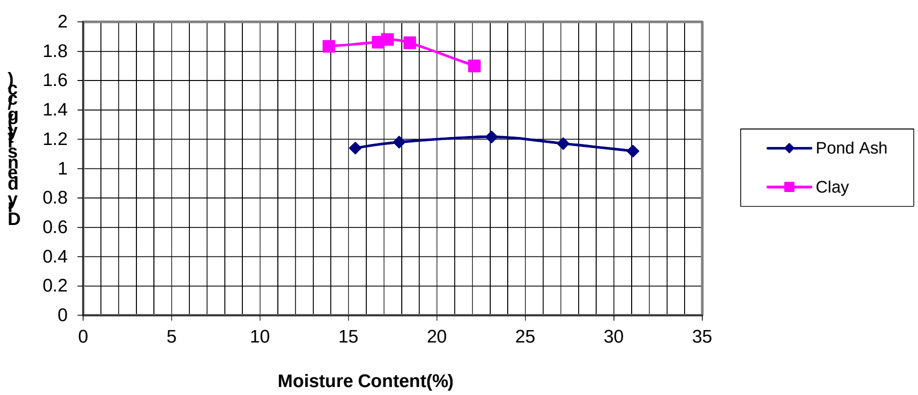


Table: 3
Compaction test results for different proportion of clay + Pond ash

S.No.	Type of soil	(Soil +pond ash) %	γ_d^{max} g/cc	OMC %
1.	Clay	80+20	1.74	18.37
2.		70+30	1.68	18.96
3.		60+40	1.61	19.55
4.		50+50	1.55	20.14

Table: 4
Compaction test results for different proportions of Lime+pond ash+clay

S.No.	Type of soil	(Soil+ pond ash +lime)%	γ_d gm/cc	OMC %
1.	Clay	80+15+5	1.68	17.22
2.		70+25+5	1.62	17.81
3.		60+35+5	1.55	18.39
4.		50+45+5	1.49	18.98

California Bearing Ratio Test (CBR)

In this study, the various embankment materials like clayey soil, fly ash (pond ash) have been tested for CBR, individually as well as with their different mixture proportions, with or without addition of lime .The CBR test was conducted as per IS: 2720-(Part-16). Static compaction method was employed to achieve the density as per heavy compaction method for the specimen sample remoulded at corresponding OMC. In case of different soils and pond ash mixed with varying percentage of lime, damp sand was placed in the space between the slotted weights, moulds were covered with wet gunny bags and samples were allowed to cure for 3 days (IRC: 51-1992). A small quantity of water was sprinkled everyday to keep the sand moist. After three days curing, samples were placed in a water tank and allowed to remain fully immersed in water for 4 days. Table 5 shows the consolidated CBR values of clayey soil with or without different admixture proportion of lime and pond ash.

Interpretation Of Various Test Results

a) From Table 3, it is clear that increasing addition of fly ash to clayey soil decreases the standard maximum dry density and increases the OMC. This may be due to lesser density of pond ash and due to greater surface area of pond ash.

As per Figure3, the addition of 2% lime has increased the CBR value of clay from 1.9% to 12%. The increase in clay may be mainly due to better compaction achieved due to decreased plasticity.

b) As per Figure 3, with the addition of 6% or more lime to clay the CBR value obtained was more than 20%. As per rural road manual of IRC (Indian Roads Congress) on such improved sub grade, there is no need to provide sub base especially in low volume roads. The reduction in pavement thickness required may be up to 425 mm depending upon the original soil CBR and traffic conditions. The approximate quantity of lime required per kilometre for improving 300 mm thick sub grade for 3m wide pavement section would be around 97 tones (=0.3 x 1000 x 3 x 1.8 x 6/100) costing around Rs 2,91,000 (=Rs 97 x 3000). This may translate into around 3 lakhs including lime-soil blending cost. The cost of compacted sub base material in Punjab may vary from Rs 270/cu.m. to Rs 540/cu.m depending upon its haulage distance. Thus the total reduction in sub base cost may vary up to, from Rs 3,44,250 (=270 x 3 x 1000 x 0.425) to Rs 6,88,500 (=540 x 3 x 1000 x 0.425). Thus

c) wherever fly ash is being used as fill
d) from thermal power stations, the top 30 cm of fly ash embankment below the pavement can be stabilised with suitable proportion (say 6%) of lime to offset the fly ash haulage cost through reduction in required pavement cost.
e) Figure 4 show that optimum percentage addition of pond ash, based upon CBR value improvement, to clay was 30%. Thus in fly ash embankment, the blending of local clay soil with optimum quantum of fly ash alone in sub grade layer only, may improve its strength. This may provide reduction in required pavement thickness without any significant increase in cost.
f) Figure 2 show a peculiar fall in plunger resistance of CBR test and its subsequent regain in clay-pond ash blend mixed with fixed, near optimum, percentage of lime. This may be due to material especially at longer distances breaking of cemented bonds in the said mixture. However the regain in strength is less than earlier strain resistance.

References

1.ASHTO Task Force Report 28 (1989). Guidelines and Specifications for Using Pozzolanic Stabilized Mixture (Base Course or Sub base) and Fly Ash for In-Place Sub grade Soil Modifications. Washington, DC.

2.ASCE (1993). Fly Ash for Soil Improvement. Geotechnical Special Publication No. 36. American Society of Civil Engineers. New York.

3. CSR (1987). Analysis of rates for common schedule of rates-1987, Government of Punjab, Volume-1, along with revision supplements 2004.

Appendix-A

Table: 5

Consolidated CBR test results for each specimen type (Unless specified the test results are under Relevant IRC standard soaked conditions)

S.No.	Type of test material	CBR (%)
7	C (Un)	9.2
8	C (S)	1.9
9	C + 2% L	12.0
10	C + 4%L	15.5
11	C + 6%L	22.4
12	C + 8%L	23.2
25	C (.8)+Pa (.2)	3.1
26	C (.7)+Pa (.3)	3.8
27	C (.6)+Pa. (.4)	1.4
28	C (.5)+Pa. (.5)	1
37	C (.8)+Pa(.15)+L(.05)	14
38	C (.7)+Pa(.25)+L(.05)	16
39	C (.6)+Pa(.35)+L (.05)	17
40	C (.5)+Pa(.45)+L (.05)	17

Fig 3 Variation in CBR for clayey soil with different proportion of lime

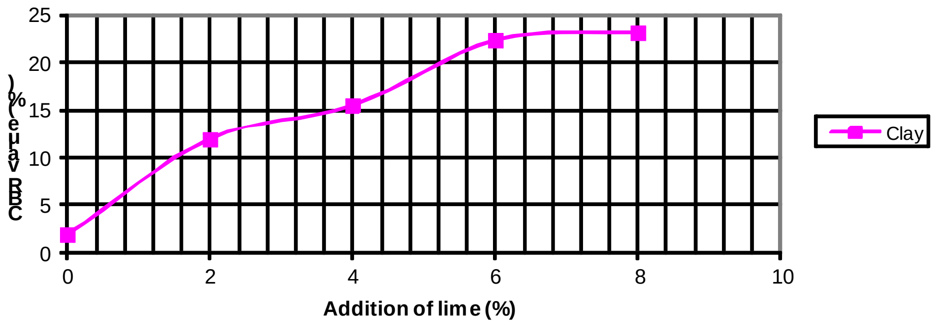


Fig.4 Variation in CBR value of clayey soil with different proportion of pond ash

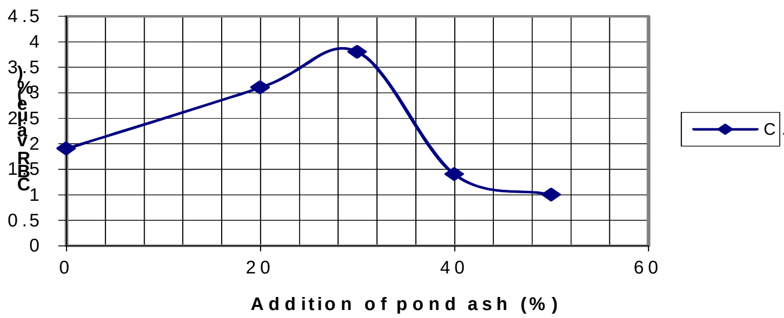


Fig.5 Variation In CBR value of clayey soil mixed with fixed percentage of lime against varying proportion of pond ash