Improving soils of low CBR with fly ash for road applications

Amélioration des sols à faible teneur en CBR et cendres volantes pour les applications routières

Udeni Nawagamuwa

Department of Civil Engineering, University of Moratuwa, Sri Lanka, udeni@uom.lk

DLS Prasad

Engineering Division, KDA Weerasinghe & Co;(PVT)LTD, Sri Lanka

ABSTRACT: Sri Lanka is now undergoing huge infrastructure changes to satisfy the current demands in the society and mostly with number of highways and related constructions. It has been observed that the requirement for good CBR soils for road constructions is increasing as most of the available soils near the construction sites do not satisfy the CBR requirement although they satisfy other conditions. There has been commendable research works carried out throughout the world to improve such soils using different additives. Due to insufficient capacity from hydropower, Sri Lanka now operates thermal power plants and fly ash is a waste piled at such locations. Use of fly ash in improving low CBR soils will solve two burning issues, i.e., dumping of fly ash and finding high CBR soils for road constructions. This study discusses the improvements in the properties of a poor CBR soil with fly ash in varying percentages. Laboratory tests such as particle size analysis, Atterberg limits, specific gravity, standard Proctor compaction and CBR tests were conducted on soil samples mixed with fly ash in various proportions and results are reported. It was observed that the optimum proportion of the fly ash to be added to the soil to achieve required properties is around 10% by its weight.

RÉSUMÉ : Sri Lanka subit actuellement des transformations considérables au niveau des infrastructures afin de satisfaire les exigences actuelles de la société et surtout avec le nombre d'autoroutes et de constructions relatives. Il a été observé que le besoin pour de bons sols en CBR nécessaires aux constructions des routes est en voie d'augmenter puisque la plupart des sols disponibles près des chantiers de construction ne satisfont pas aux exigences de CBR bien qu'ils satisfassent à d'autres conditions. Il y a des recherches remarquables qui ont été faites à travers du monde pour améliorer ces sols en utilisant de différents additifs. A cause de la capacité insuffisante d'énergie hydraulique, Sri Lanka exploite maintenant des centrales thermiques et les cendres volantes sont des déchets empilés à ces endroits. L'utilisation des cendres volantes pour optimiser des sols à faible teneur en CBR résoudra deux questions épineuses, à savoir, la décharge des cendres volantes et la recherche des sols à teneur élevé en CBR pour la construction des routes. Cette étude traite les améliorations dans les propriétés d'un sol à pauvre teneur en CBR avec des cendres volantes en pourcentages variables. Des essais en laboratoire tels que l'analyse de distribution granulométrique, l'essai de limite d'Atterberg, la gravité spécifique, le compactage standard et les essais CBR ont été effectués sur des échantillons de sol mélangés à des cendres volantes dans des proportions diverses et les résultats sont présentés. Il a été remarqué que la composition optimal des cendres volantes qui devraient être ajouté au sol afin de obtenir les propriétés requises est à peu près 10% par son poids.

KEYWORDS: CBR, fly ash, soil improvement.

1 INTRODUCTION.

Sri Lanka boasts more road density than any country in South Asia. However, there has been a considerable backlog in maintenance of these roads through years of neglect that is now being addressed. Rural roads are in a poor condition affecting people's lives resulting in poor economic growth in the rural population. It can be found that gravel surfaced, blotter, asphalt and Portland cement concreted road surfaces are available in the country (Sri Lanka Rural Roads Link Villages to Cities Improving Rural Economy, 2014). Gravel surfaced roads are generally constructed in rural areas such as Anuradhapura, Polonnaruwa, Thissa and Kataragama. However, suitable soils are not easily found in areas mentioned above as low strength soils are common.

Soil borrow pits are selected from nearby areas of the site considering the cost in the case of construction of rural roads. It is not that easy to find good quality soils in some rural areas to satisfy the specifications imposed by CIDA (formerly known as ICTAD) and those limits are presented in Table 1. It has been observed that the requirement for a CBR value of more than 30 is not satisfied although the other conditions are very much satisfactory. The reasons for the requirement of a good CBR soil could be due to the need of protecting soil road bases from surface water and/or light traffic could damage poor soil bases causing more maintenance in the long-run.

Mechnaical and other stabilizations with additives are widely used to improve such poor CBR soils. Chmical or lime/cement treated soils are used in the road sector although the use of fly ash in soil improvement in Sri Lanka has not been practiced.

Table 1: Specific limits (ICTAD, 1989)

Sieve Size	% Passing	Other criteria	
50	100	Criterion	Specification Limits
37.5	80-100	Liquid limit (LL)	<45
20	60-100		
5	30-100	Plasticity Index	< 15
1.18	17-75		
0.3	9-50	Maximum Dry Density (g/cm^3)	>1.750
0.075	5-25	CBR	> 30

Cokca (2001) recommended that both high and low calcium class C fly ashes could be used as effective stabilizing agents for improvement of expansive soils. Sharma and Kumar (2004) reported that with the increase of fly ash content, there is a reduction in optimum moisture content while increasing maximum dry density. Bhuvaneshwari et. al. (2005) concluded that when the fly ash percentage was 25%, workability had been the maximum for stabilization of expansive soils with fly ash. Mehta et. al. (2013) found that the plasticity index decreased with the increase of fly-ash content for stabilizing black cotton soil with fly ash.

All the above literature findings indicate that the use of fly ash would improve the properties required in road sector applications. Hence, this study aims at improving a rejected soil with fly ash in order to achieve the limits mentioned in Table 1.

2 STANDARDS MAINTAINED IN THE LABORAOTRY

Table 2 provides the standanrds and specifications maintained during laboraotry investigations.

Table 2. Standards manintained during the laboraotry tests

Test	Testing method
Particle size distribution	AASHTO T 88
Plastic limits (PL) (%)	AASHTO T 89
Liquid limits (LL) (%)	AASHTO T 90
Maximum Dry Density (kgm^{-3})	AASHTO T 180
Specific gravity	ASTM D 854-00
California Bearing Ratio (4 days soaked at 98% MDD) (%)	AASHTO T 193

3 PROPERTIES OF A REJECTED SOIL.

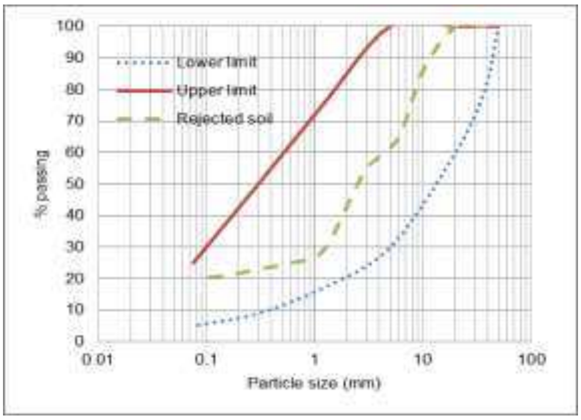

Figure1. Particle size distribution of the rejected soil

The rejected sample was collected from the road construction site in Thissa- Sithulpawwa road in the Southern Province of Sri Lanka. Figure 1 provides the particle size distribution of the rejected soil along with the ICTAD specifications (upper and lower limits) and it satisfies the required coinditions.

Further, it was observed that the liquid limit was 24.6 and the plasticity index was 9.6 and hence both the conditions related to Atterberg limits satisfied the specifications. Then it was continued with the standard Proctor compaction and the results were 1.93 g/cm^3 and 12.1% for maximum dry density and the optimum moisture content respectively. These two values are within the satisfactory limits.

However, when the California Bearing Ratio (CBR) test was done at 95% of maximum dry density, it revealed a very low vlaue of 6.6%. Eventually this soil was rejected due to low CBR value despite the satisfacory results from all other tests. Specific gravity of the rejected soil was determined using 500ml pyknometer as 2.63.

4 IMPROVEMENT OF REJECTED SOIL WITH FLY ASH

4.1 *Properties of fly ash*

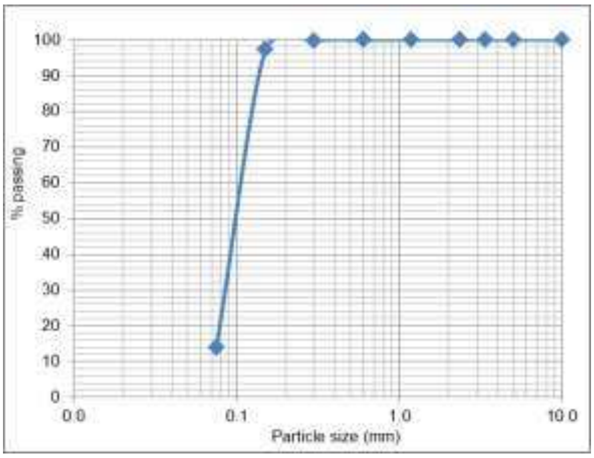

Figure2. Particle size distribution of fly ash

Fly ash is a fine, glass powder recovered from the gases of burning coal during the production of electricity at Norochchole, thermal power plant in Sri Lanka. Coals are delivered from Russia and Indonesia. These micron-sized earth elements consist primarily of silica, alumina and iron. These power plants grind coal to powder fineness before it is burned. Fly ash, the mineral residue produced by burning coal is captured from the power plant's exhaust gases and collected for use.

Figure 2 indicates that the particle size of fly ash is very uniform and varies around 0.1mm. liquid limit test was determined using cone prentration method and it was found to be 29. Due to non plastic nature, plastic limit and the plasticity index values were not determined. Specific gravity was determined as 2.20. Maximum dry density could not be determined and hence CBR test was not carried out on fly ash. However, gupta (2008) presented that Proctor density of fly ash is around 1.29 g/cm^3 and the specific gravity is between 1.95 and 2.2.

4.2 *Properties of improved soil with fly ash*

Dry soil samples from the rejected soil mentioned in Section 3 were mixed with fly ash on weight basis as follows.

- Soil
- Soil + 2% fly ash
- Soil + 5% fly ash
- Soil + 10% fly ash
- Soil + 15% fly ash
- Soil + 20% fly ash
- Soil + 30% fly ash

Figure 3 illustrates the particle size distribution of different mix proportions. All the mixed samples were well within the specification envelope.

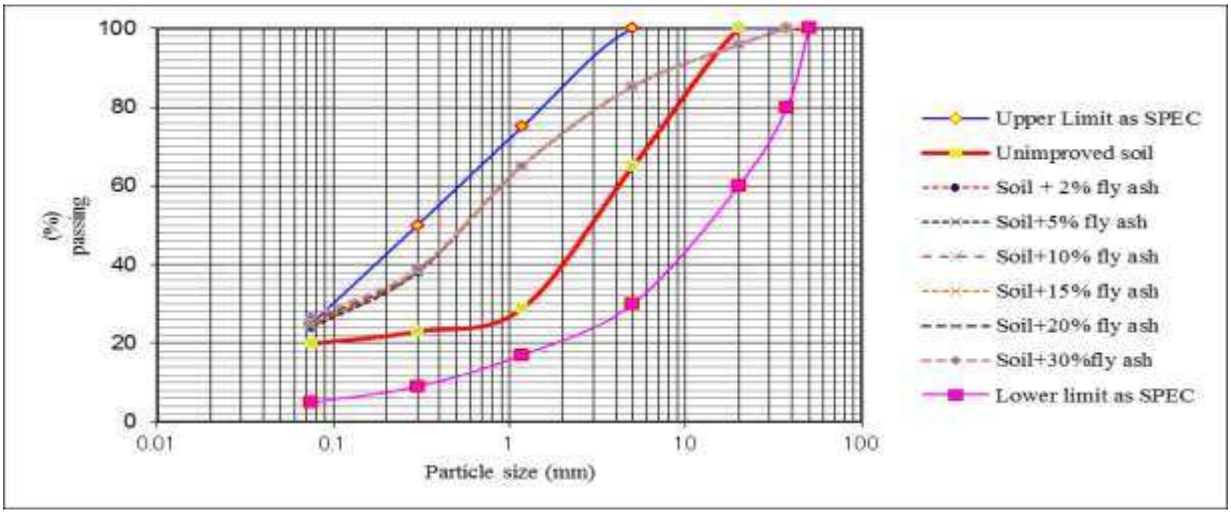

Figure 3. Particle size distribution of different mix proportions including the unimproved soil

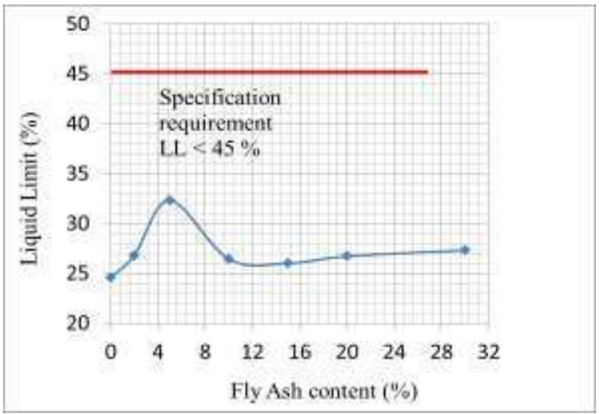

Figure 4. Liquid limit vlaues with different fly ash contents

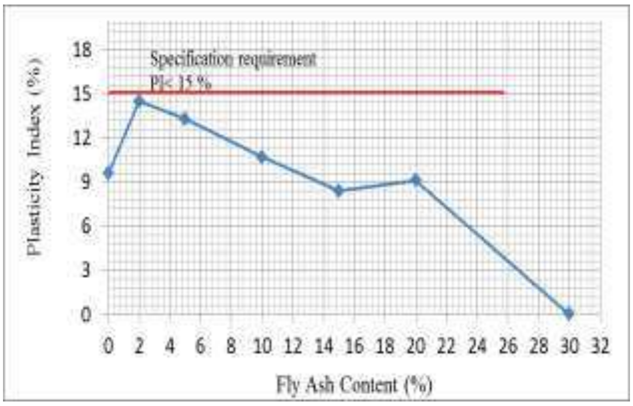

Figure 5. Plasticity index vlaues with different fly ash contents

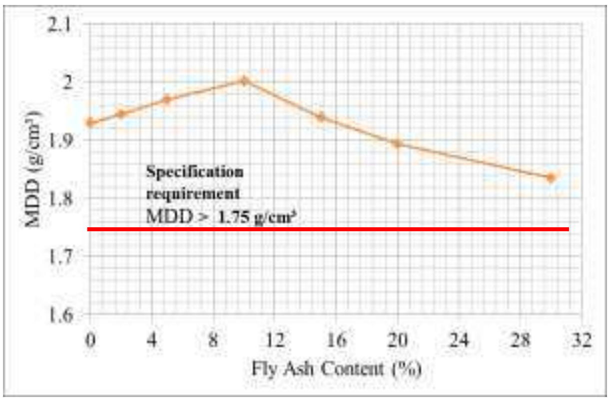

Figure 6. MDD with different fly ash contents

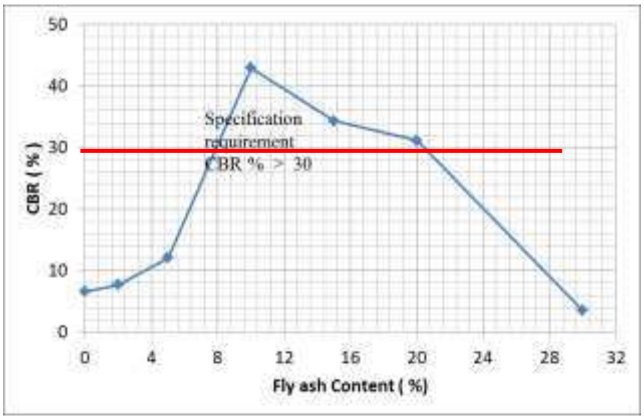

Figure 7. CBR with different fly ash contents

Figure 4 provdes the behaviour of liquid limit (LL) with fly ash content. At about 5% fly ash content, it shows a sudden increase in the LL and it could be due to a result of a material hetrogenity. However all the values of LL are less than the maximum limit of 45%. Plasticity Index (PI) trend is shown in Figure 5 and it also shows an incremental behaviour in the early stage , but chnages with more fly ash content. Maximum Dry Density (MDD) provides a clear peak value at 10% fly ash content and this is again validated in the California Bearing Ratio (CBR) test at 10% with a mximum CBR of more than 40. This finding clearly highlights that the soaked CBR could be increased with fly ash and 10% of fly ash could be treated as the optimum proportion on weight basis.

5 CONCLUSION

Low CBR soils are rejected in road sector eventhough they do have sufficient vlaues in other propoerties such as LL, PI and MDD. Fly ash is a huge waste in the thermal power plants in Sri Lanka and this attempt was made to make use them in a productive manner. This study concludes that the properties of low CBR soils could be enhanced with fly ash with an optimum vlaue at 10% and at that level the low CBR value could be increased by 6.5 times. In the field aspects, proper mix can be done with conveyor belt and a hopper system. However, the moisutre has to be maintained without loosing and hence should be covered once mixed and also the field work has to be completed without any delay as fly ash exhibits some pozzolonic action with time. The summary of the findings are presented in Table 3.

Table 3. Summary of findings

Paramter	Fly ash %						
	0	2	5	10	15	20	30
Liquid Limit (%)	24.4	26.8	32.3	26.4	26	26.7	27.3
Plastic Limit (%)	15.04	12.3	18.9	15.7	17.6	17.6	NA
Plasticity Index (%)	9.36	14.5	13.3	10.7	8.4	9.1	NA
Specific Gravity	2.63	2.68	2.60	2.55	2.52	2.45	2.40
MDD (g/mm³)	1.93	1.945	1.97	2.002	1.94	1.894	1.835
OMC (%)	12.1	8.4	8.1	7	9.1	9.1	9.6
CBR (%)	6.6	7.7	12.1	42.9	34.3	31.1	3.5

6 ACKNOWLEDGEMENTS

Authors would like to acknowledge the laboratory staff of University of Moratuwa, Road Development Authority and K.D.A. Weerasinghe Co (Pvt) Ltd for their invaluable guidance and help.

7 REFERENCES

American Association of State Highway Transportation Officials (AASHTO) standards (T 88/ T89 / T 90 / T 180 / T 193)

American Society of Testing & Materials standards (ASTM) – (ASTM D 854-00 and ASTM D 2487 - 06)

Bhuvaneshwari S., Robinson R.G. and Gandhi S.R.(2005):"Stabilization of expansive soil using fly" Indian institute of technology madras, chennai-36 fly ash utilization programmme (FAUP) , TIFAC, DST, new delhi-110016

Cokca.E, (2001)- Use of fly ashes for the stabilization journal of Geotechnical and Geo environmental Vol.127,July,pp.568-573

Gupta, R.D., (2008), effect on CBR value and other geotechnical properties of fly ash mixed with lime and non-woven geofibers, unimas.my/ojs/index.php/JCEST/article/view/73

Mehta, A, Parate, k., Ruprai, B.S., (2013), Stabilization of black cotton soil by fly ash. International Journal of application or innovation in engineering and management. Special issue for national conference on recent advances in technology and management for integrated growth 2013.

Sharma.R.S. and Kumar P.B.R., (2004) – Effect of fly ash on Engineering properties of soil – Journal of Geotechnical and geo environmental Engineering Vol. 130 no 07, July, pp.764-767

Report on "Sri Lanka Rural Roads Link Villages to Cities Improving Rural Economy" downloaded from http://www.worldbank.org/en/news/feature/2014/01/27/sri-lanka-rural-roads-link-villages-to-cities-improving-rural-economy.

ICTAD Technical specification 1989 volume III