USE OF FLY ASH TO IMPROVE SOILS FOR ROAD CONSTRUCTION PROJECTS IN SRI LANKA

D L S Prasad
Design Division, Central Engineering Consultancy Bureau, Sri Lanka.
dlsprasad@gmail,com

ABSTRACT*: Sri Lanka is ambitiously pursuing for the massive infrastructure developments to meet the social demand and to foster economic growth. Construction highways and railways is a key focus area of the development effort. A considerable quantity of suitable soil which would be a major requirement for implementing such projects. In most of the cases, soils found near to the construction sites are rejected due to low California bearing ratio (CBR); although, they satisfy other parameters. Hence, engineers have to transport the suitable soil by hauling long distances incurring additional transport cost. If, locally available material can be improved, it would be the most beneficial solution to infrastructure developments. This study discusses the improvement of such rejected soils with fly ash from several construction sites in Sri Lanka. Fly ash is an abundantly available byproduct of the Norechchole Thermal Power plant. The basic soil tests such as particle size analysis, Atterberg limits, Proctor compaction and CBR tests were conducted on unimproved and improved soils. The CBR values of improved soils in different locations could be identified as increased with various percentage of soil with fly ash on weight basis. Mixing is proposed with a traditional conveyor belt mechanism. Use fly ash for infrastructure developments is to be motivated with objective in protecting environment by utilization of new alternatives and reducing the excessive dumping of fly ash to the environment.*

Key words: CBR, fly ash, soil improvement

1. INTRODUCTION

Sri Lanka attends now at a rapid growth rate of infrastructure developments in across the country after the 30 years of civil war. Specially, road development projects and railway projects have been undergone by using mass quantity of soil. Soil is a primary engineering material for road construction and maintenance (Biggs and Mahony 2004). Constructing and maintaining a suitable transportation facility is a very resource intensive activity. Substantial amounts of materials and natural resources are required and it consumes proportionately large amounts of energy and fuel (Correia et al. 2016)

Traditional road construction consumes soil, bitumen, stone aggregates, sand, cement etc. and their further mining are declining gradually due to lack of natural resources. Also, the public pressure against mining of natural materials is immense while cost of extracting good quality natural material is increasing. Further, available soils in the proposed construction area sometimes do not possess the requirements imposed by the consultants to be used in road works. Hauling materials from faraway areas will create additional cost and environmental issues due to longer distance transportation. Considering these factors, engineers always look for alternative materials for road construction, and fly ash which have proven it's' capacity to replace some portion of the natural resources would be one of the best alternation. (Nawagamuwa et al. 2018).

Soil borrow pits are selected near to the site area; because, majorly cost is considering in case of road construction. Good quality soil in site area is not meet the specification imposed by CIDA (formerly known as ICTAD) and particular limits are presented in Table 1 & 2. It has been observed that soils with CBR values of less than 30 of soil is not satisfy in order to CIDA requirement although other conditions are satisfactory. Main reasons for high quality CBR soil could be the need of protecting soil road bases from surface water and/or to minimize damage to the soil base due to light traffic causing more maintenance in the long run.

Several methods are being used for improving soils with low CBR such as mechanical and other stabilizations with additives. Further, some road sector projects are used the chemical or lime/cement treated soils although the use of fly ash in soil improvement has not been practiced in Sri Lanka.

In recent years, use of industrial byproduct such as fly ash have been considered in road construction with great interest in many industrialized and developing countries. Use of these materials in road making is based on technical, economic, and ecological criteria (Nawagamuwa et al. 2018). Materials such as fly ash which are generated from thermal power plants and other coal fired industries, and many other solid wastes have already proven to be useful for road construction in many countries (Sen and Mishra 2010). Fly ash is an effective agent for chemical and/or mechanical stabilization of soils.

Therefore, the soil has become a main raw material which is needed for construction of rural roads, national highways and railways. However, soil types are varying with the location of the country based on the geological conditions, causing soils from some areas do not meet the specific limits imposed by ICTAD (2009) such as grading curves, Atterberg limits, maximum dry density and California bearing ratio (CBR). However, in the most of the cases, specification limits are not satisfied even though other relevant specific limits are being met. This study aims to identify soils with poor in different localities which have come across during major road and railway projects and to propose how to improve such soils by addition of fly ash. So, the concept is built for avoiding the environment pollution by fly ash dust and give sustainable solution for green environment in Sri Lanka.

2 METHODS

2.1 Site Description

Four localities have been selected across the country which are in close proximity of major construction projects including the Southern expressway extension (Thissamaharama) project, the Matara Beliatta railway project (Matara), the Central Expressway project (Pothuhara) and the Minnariya-Galoya road project (Minneriya) as shown in Figure 1. Soil samples were collected from borrow pits located at Thissamaharamaya, Matara, Pothuhara and Minneriya respectively from each project. According to Moormann and Panabokke (1961), Panabokke (1971) and Cooray (1984), Pothuhara consists of noncalcic brown soils with solodized solonetz, Minnariya with calcite red yellow latsols with solodized solonetz, Thissamaharama with reddish brown earth with solodized solonetz and Matara with reddish brown earth.

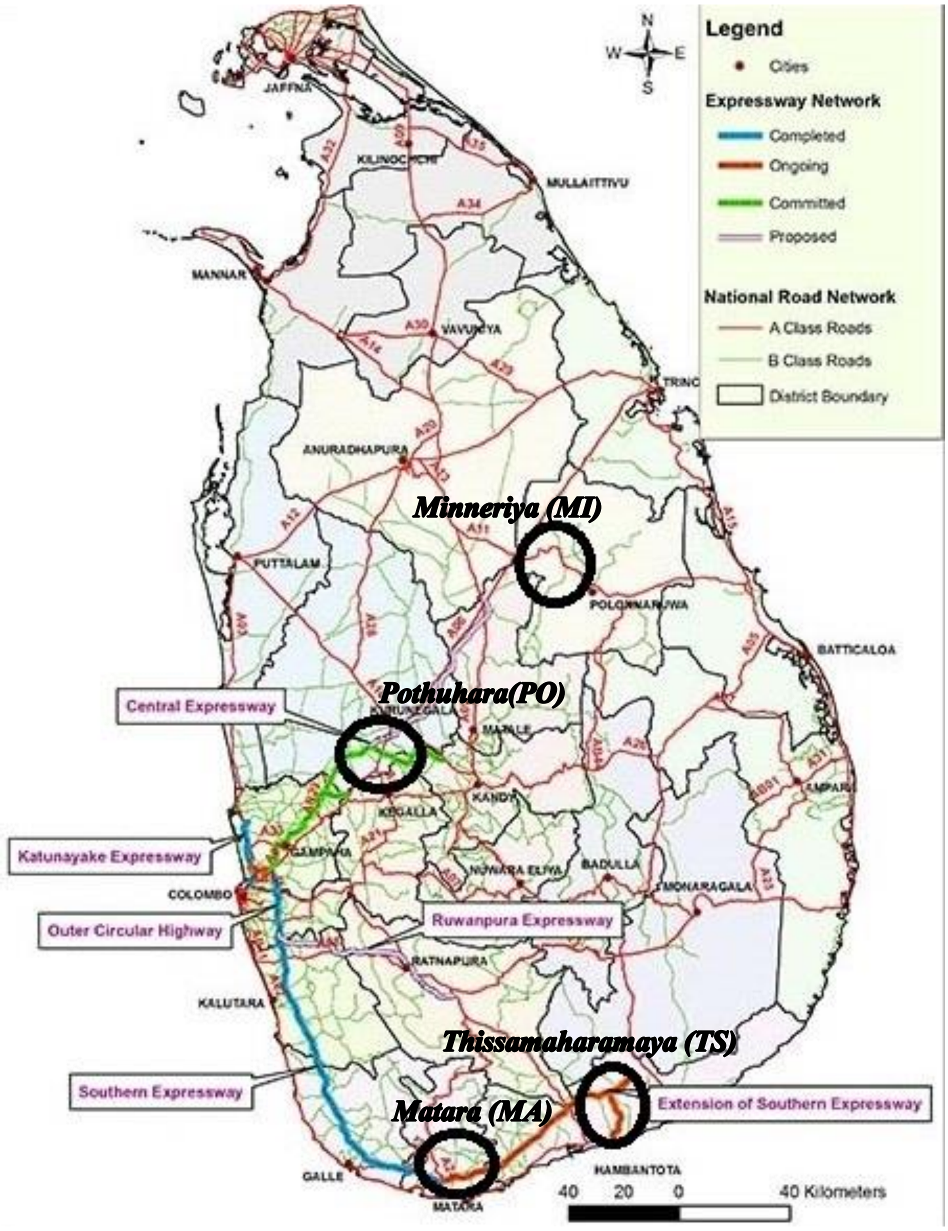

Figure 1. Four major selected sites in Sri Lanka (http//www.rda.gov.lk)

2.2 Standard maintained in the Laboratory

Standards and specifications are maintained during the laboratory investigations as provided in Table 1.

Table 1: Testing standards followed during the laboratory

Test	Testing method
Particle size distribution	ASTM D6913 – 04e 1
Liquid limit (LL) (%), Plastic limit (PL) (%)	ASTM D4318 – 10e 1
Specific gravity	ASTM D698 – 12e 2
Maximum Dry density (kgm^{-3})	ASTM D854 – 14
California Bearing ratio 4 days soaked at 98% MDD (%)	ASTM D1 – 883

2.3 Inclusion of fly ash to improve low CBR soil

Soil collected from four localities were mixed with fly ash as shown in Table 2 to find out the improvements in CBR value and added to respective soils gradually in steps. The optimum values which satisfies all the conditions stipulated in Table 4 and it was considered as the optimum percentage of fly ash to be mixed on weight basis to a given soil.

Table 2: Localities of soil collection

Project	*Sample collected location*		*Additive*
Extension of southern expressway	*Thissamaharamaya*	*TS*	*Fly ash*
Matara Beliatta railway	*Matara*	*MA*	*Fly ash*
Central Expressway	*Pothuhara*	*PO*	*Fly ash*
Minneriya Galoya road	*Minneriya*	*MN*	*Fly ash*

2.4 ICTAD Guideline for sub base soil

Standard specification for construction and maintenance of bridges (SSCB) is issued by Institute of Construction Training and Development (ICTAD 2009) and Road development authority that follows the criteria for preparing the highway scheduled rates. The stipulated conditions which are being used sub base soil in the road construction are given in the Table 3.

3 RESULTS AND DISCUSSION

3.1 Particle size distribution

Soils were mixed with fly ash with various mix proportions on weight basis by 0% to 30%. Optimum solution was selected as the point in which, provides satisfactory performances as per the stipulated conditions given in Table 3. Ultimately, selected solutions are mentioned in the Table 4. Different mix proportions on weight basis were carried out to separate locality to find optimum mix proportions of soil and fly ash.

Table 3: Stipulated conditions for sub base soil (RDA guidelines with adopting the ICTAD 2009)

Sieve size	*Passing (%)*
50	*100*
37.5	*80-100*
20	*60-100*
5	*30-100*
1.18	*17-75*
0.3	*9-50*
0.075	*5-25*

Maximum dry density (MDD)	$\geq$*1.650 kgm*$^{-3}$
California Bearing Ratio (at 98% MDD) (CBR)	$\geq$*20*
Liquid limit (LL)	$\leq$*40*

Plastic Index (PI)	*≤15*

Table 4: Notification of unimproved and improved soils with fly ash

Unim proved soil		*Improved soils*	*Optimum w/w percentage*
Extension of southern expressway	*TS*	*TSI*	*TS -90% FA-10%*
Matara Beliatta railway	*MA*	*MAI*	*MA -88% FA-12%*
Central Expressway	*PO*	*POI*	*PO -86% FA-14%*
Minneriya Galoya road	*MI*	*MII*	*MI - 84% FA-16%*

Grading requirements stipulated in ICTAD (2009) were checked with the four soil types as shown in Figures. 2 and 3 that shows the grading of elected proportions on soils improved with fly ash. Table 4 summarizes the optimum on weight basis percentages of soils improved with fly ash added in gradual steps.

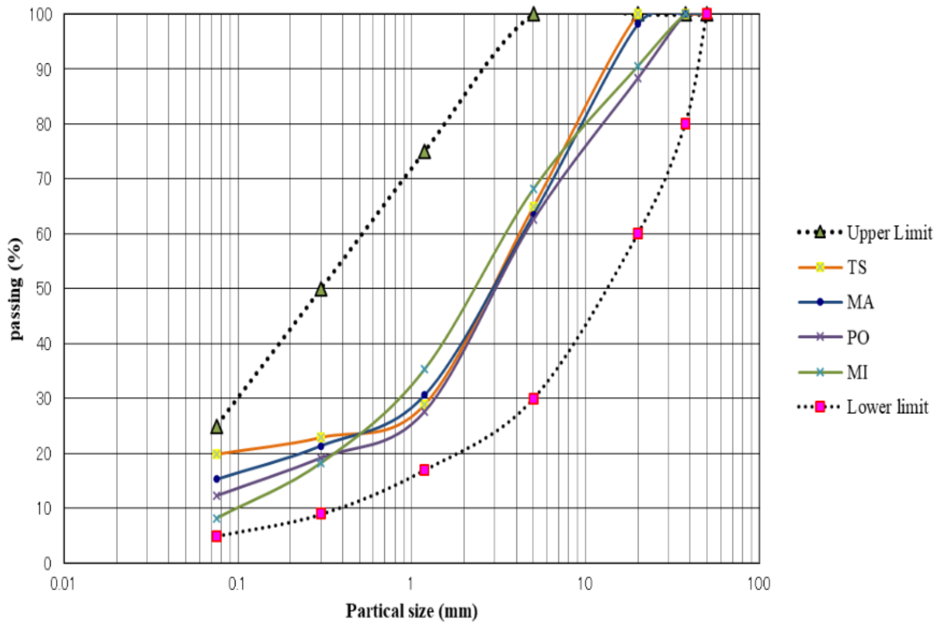

Figure 2: Grading curves of soils before improvements

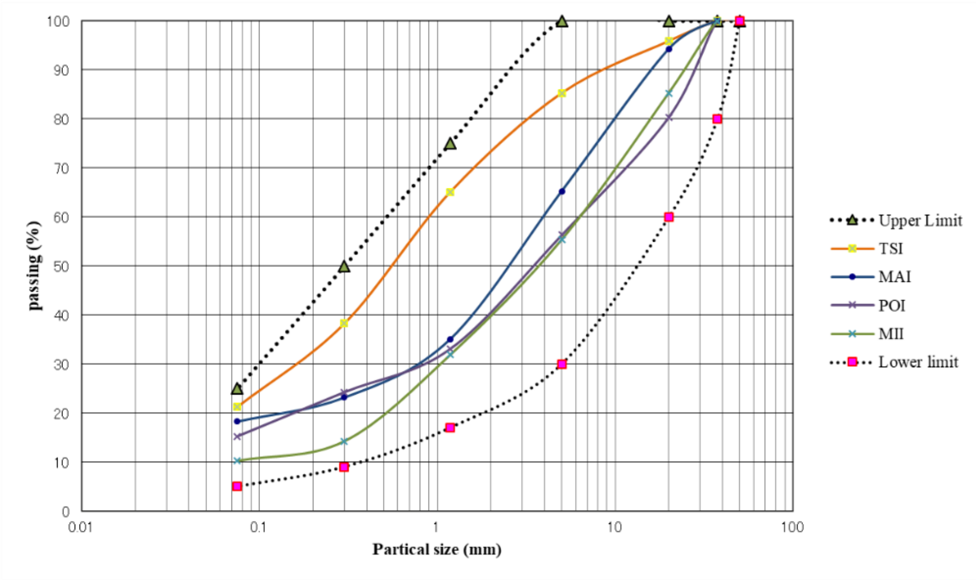

Figure 3: Grading curves of soils after improvements

According to the results, all the unimproved and improved soil specimens are within the specimic limits as relevant to the ICTAD 2009. The grading requirements are satisfy as give in Table 3.

3.2 Atterberg limit test

Plasticity behavior was compared before and after improvement of soils as given in the Figure. 4. All the unimproved and improved soils do satisfy the ICTAD (2009) requirements. As some soils Casagrande apparatus was not demonstrated for the workable limits for some soils, cone penetration test was used as proposed by Wasti (1987).

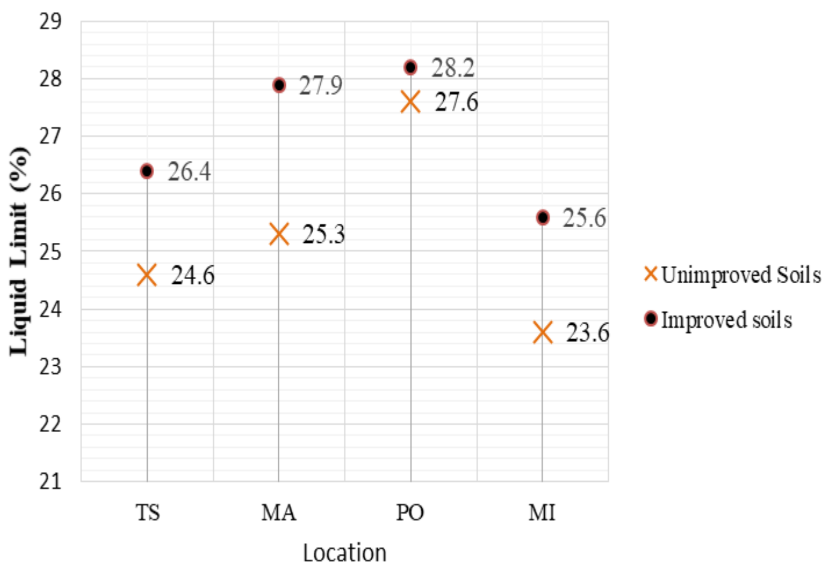

Figure 4: Atterberg limits of unimproved and improved soils

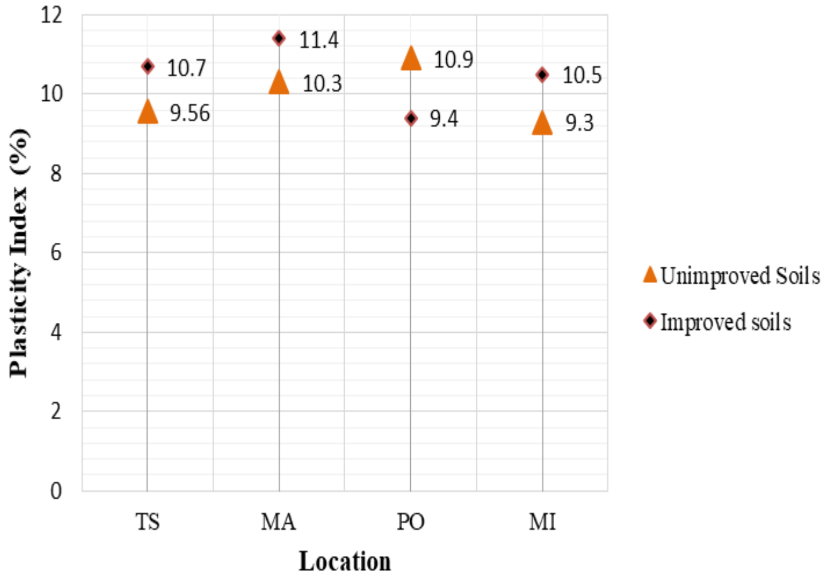

Figure 5: Atterberg limits of unimproved and improved soils

The liquid limit results of unimproved and improved soil specimens are satisfy as considered the figure 4 and 5. The maximum values of liquid limit and plasticity index in improved soils are represented by PO and MA respectively.

3.3 Compaction characteristics of soils before and after improvements

Standards proctor compaction test was carried out on soils collected from each localities before and after improvements with the guidelines of ICTAD 2009. The well satisfactory results were obtained and maximum was given in the MII and next MAI, mainly because, specific gravities are high around 3.6. The results of Maximum Dry Densities graphs are illustrated in Figure 6.

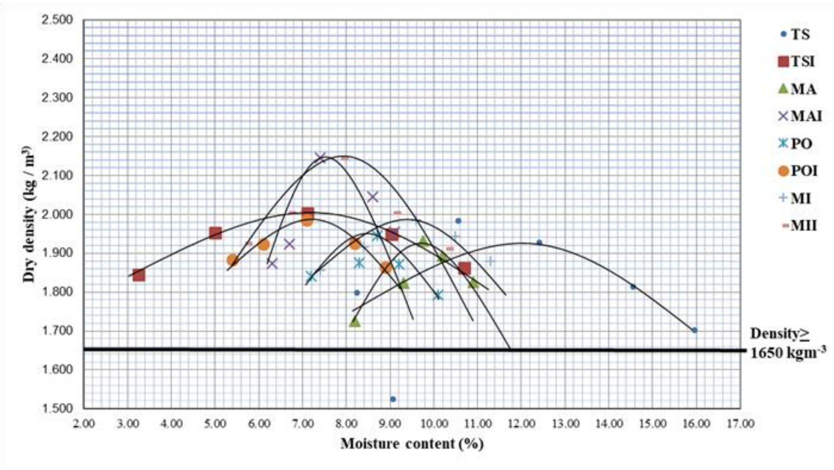

Figure 6: Compaction characteristics of unimproved and improved soils

The maximum MDD value of 2.15 is given by improved MII specimen and other all specimens are represented the relevant to the ICTAD 2009. Further, the improvement of MDD could be identified with adding the fly ash to unimproved soil specimens.

3.4 Improvements of CBR value

Summary of the improved CBR values are presented in Figure 7 with respect to the MDD obtained from Figure 6. MII is performed at the maximum value of MDD. It does not improved the CBR value considerably.

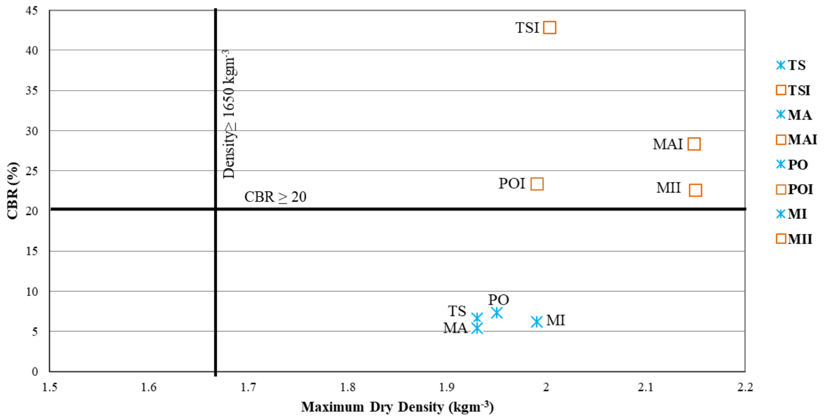

Figure 7: CBR values of unimproved and improved soils

In figure 7, the maximum improvement is given by TSI, it is about 7 times. Hence, MAI - 5 times, POI and MII – 3 times improvement could be identified with considering the all improved specimens and it is significant improvement of CBR value as considering unimproved specimen such value.

4 Conclusion

Due to new construction projects in Sri Lanka, especially in construction of roads, highways, railways and etc. Therefore, soil is a natural resources which is required in great quantities. However, due to regional geological issues, some soils do not provide high CBR values although they satisfy other conditions such as grading, plastic limits and compaction. Further, transportation of satisfied soils is not a solution with compare to the additional cost to the projects budgets. And, it is needed to investigate the advantage of industrial by products in improving the existing soil. Use of fly ash has been immensely practiced in ground improvement activities all over the world and especially it is an economical benefits for a developing country like Sri Lanka while it is saving natural resources instead of consuming virgin resources. This research study utilized four different soils improved with fly ash in four distinct areas of the country.

Laboratory tests indicated a high level of satisfactory agreement with the satisfied conditions given in ICTAD 2009. The developing countries like Sri Lanka will be greatly benefitted by such findings. These results with high CBR values of soils after improvement, motivate the engineers to apply this techniques with lot of monitoring. Further, Conveyor belts type mixing arrangement can be used in large scale mixing. This will enhance the income of the local residents in multiple ways.

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