



EXPERIMENTAL TREATMENT OPTIONS FOR EXPANSIVE SOILS ON UNPAVED ROADS IN ETHIOPIA

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Abstract

Many parts of Ethiopia are covered with expansive soils. The need arose to search for a suitable technology that can be used to stabilize these soils and use them for construction. The technology should minimise, as much as possible, the construction costs that would be incurred.

For this reason, a test section proposal entitled “Experimental Treatment Options for Expansive Soils on Unpaved Roads” has been prepared incorporating different trial options to be tested on site. The construction of the test sections has been carried along the Chancho-Ginchi road. In this research different types of soil stabilization techniques have been used such as mechanical, lime and chemical stabilization of the problematic soil.

The research has shown that construction in this kind of soil with various treatments for lower class rural access roads is possible. Further monitoring of the trials is necessary to determine the optimum treatment option.

1 INTRODUCTION

1.1 Background

The Universal Rural Road Access Program (URRAP) is aimed at connecting all kebeles to nearby higher-class road using all weather pavement solutions. Before implementing the program, it was necessary to develop different working guidelines and manuals to support the program. Consequently a “Technology Selection Guideline” and a “Design Manual for Low Volume Roads in Ethiopia” have been produced.

Gravel and all weather earth roads are selected as pavement types for this program. The technical aspects of adopting gravel or all-weather road options for low volume rural roads include the maximized and optimal use of low cost locally available materials and deployment of low cost, low capacity equipment both for construction and maintenance. Thus the requirements of materials and equipment for construction and maintenance can be accomplished within the locally available resource and skills in rural areas.

To realize this objective, the selected technology and design approach need to be demonstrated or tested before they are going to be implemented on a big scale. To this effect, a few research/demonstration areas were identified for research that directly and immediately supports the program.

As many parts of the country (Central, Western and South-Western regions) are covered with expansive soils, there was a need to validate passability in this soil. To address this problem, a need arises to search for a suitable technology that can be used to stabilize these soils and use it for construction so as to, as much as possible, minimize the costs that could be incurred, had another mechanism been used.

For this reason, a test section proposal entitled “Experimental Treatment Options for Expansive Soils on Unpaved Roads” has been prepared incorporating different trial options to be tested on site.

Hence, construction of test sections has been carried out on a road with expansive subgrade along the Chancho-Ginchi road. In this research different types of soil stabilization techniques have been used such as, mechanical, lime and chemical stabilization of the problematic soil.

1.2 Scope & Purpose

The main scope & purpose of this research is: -

- ✚ To verify the selected technologies in relation to the expected method of construction and equipment used.
- ✚ To fine tune the application and performance of the adopted design approaches from the geometry, pavement design and drainage point of view.
- ✚ To compare the performance of different remedial measures on expansive subgrade.

- ✚ To check the application of the selected technology related to the equipment and method of construction.
- ✚ To estimate the per kilometre cost of each test section and identify the most feasible option.

2 FIELD AND LABORATORY INVESTIGATION

2.1 Site Selection

- ✚ Selection of appropriate site(s) for this particular research project has been carried out in such a way that the sites should represent a wide spectrum of factors such as traffic, expansibility of the surrounding soil, construction materials, proximity to supervise & monitor at a logistically reasonable scale etc and hence appropriately fill the research matrix. Accordingly, the sites have been selected on 2+200-3+400 of Chanco-Ginchi road which is very close to the ERA, Chanco Training Centre.
- ✚ To have a feel of the actual situation in the field, field reconnaissance visits have been undertaken by the project team. This stage is vital for the final selection to avoid duplication and hence the project resources have been properly allocated vis-à-vis covering the breadth of data required for the project.

2.2 Sampling, Laboratory Testing and Determination of the Various Mix Ratios

Assessment of the Laboratory

In the construction of low-cost rural access, the routine testing and validation of the materials in going to be made in a lower class rural laboratory. To simulate this, advanced and complicated laboratory tests are not recommended and utilized.

- ✚ The skills of the Laboratory technicians & laboratory facility have been assessed
- ✚ the types & numbers of laboratory tests have been identified & compared with the available facility
- ✚ the appropriate material test standard has been selected
- ✚ Laboratory tests such as Grain size analysis, Atterberg Limits, Natural Moisture Content, California Bearing Ratio-CBR, Maximum Dry Density-MDD, Optimum moisture Content-OMC have been carried out
- ✚ Collection and Collation of relevant data has been carried out, the results of which is presented in Table 1.

It is recognized that the main purpose of the test-section construction is to find cost-effective remedial measures to problems related to the construction of roads on expansive sub grade. Thus it is imperative to see the effect of lime on the behaviour of expansive soils and determine the optimum application rate. Hence, laboratory tests including Atterberg Limits, CBR and Proctor Compaction have been carried out on both treated and untreated samples. From the test results, appropriate application rates for the treatment have been determined and replicated in the field during the construction of the experimental sections. The following sections present the laboratory results and analysis made on the results.

2.3 Plasticity and Strength Properties

The tests were performed on both treated and untreated samples of expansive soil and on non-plastic gravel materials that will be used for mechanical stabilization and as a wearing material. The application rates proposed for lime stabilization were 1.5%, 3%, 4%, 5% and 6% by weight of the expansive soil.

Atterberg Limit test results along with strength properties of the soils are shown in Table 1. Figure 1 & Figure 2 present a comparison of the plastic and strength properties of the expansive soil treated with different application rates of hydrated lime.

Table 1:- Laboratory Test Results at Different Applications of Hydrated Lime

Parameter	Mix Ratio					
	0%	1.5%	3%	4%	5%	6%
LL	97%	82%	66%	52%	50%	50%
PL	22%	24%	27%	30%	32%	33%
PI	75%	58%	39%	22%	18%	17%
CBR	2%	9%	21%		65%	
% Swell	5%	4%	1%		0.04%	

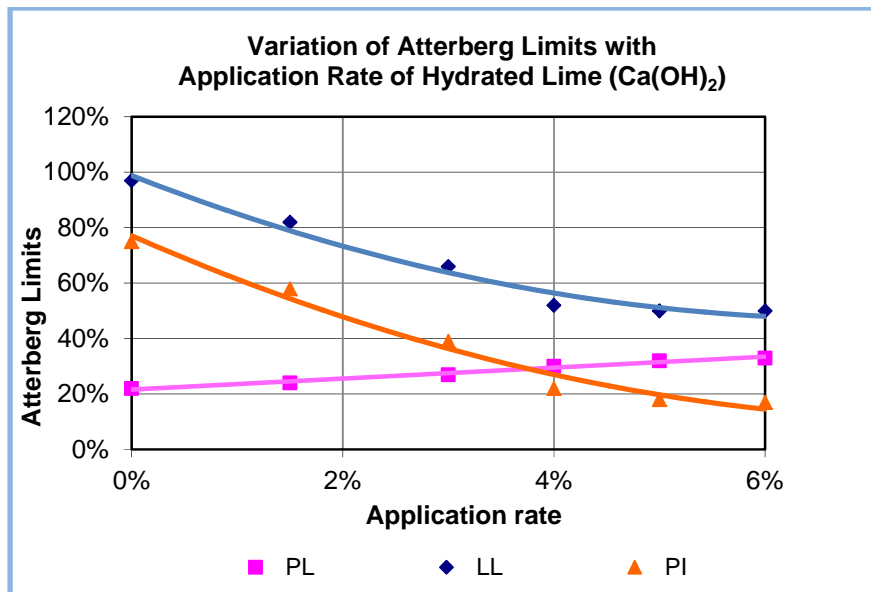


Fig 1:- The Variation of Atterberg Limit with Different Applications of Hydrated Lime

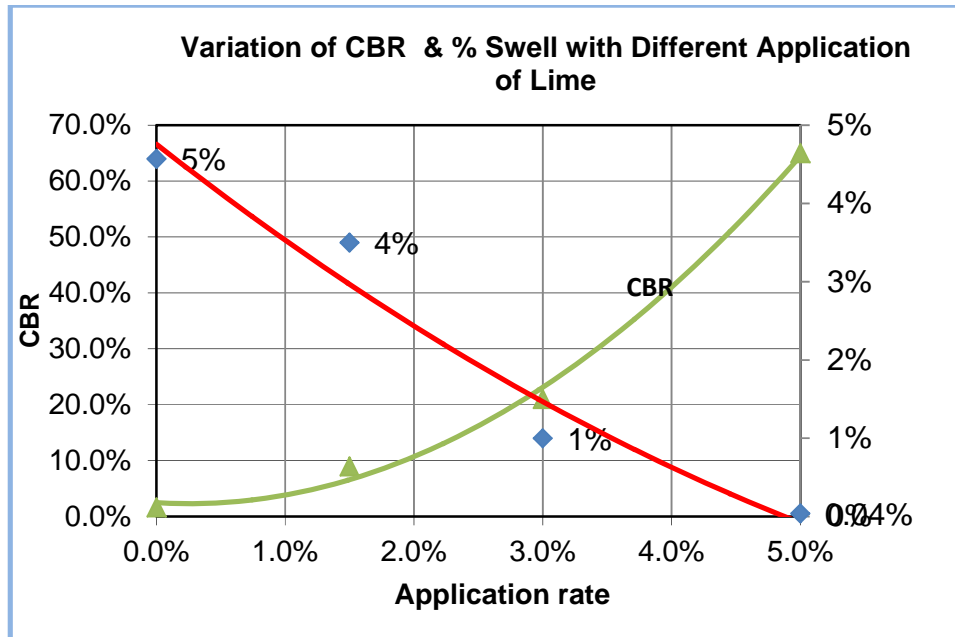


Fig 2:- The Variation of CBR values & Percent swell with Different Applications of Hydrated Lime

Hence, looking at the rate of decrease in plasticity index & increase in CBR, 5% application rate for a curing time of 5 to 7 days has been found to be the optimum value. Thus, construction of the trials has been performed on samples treated with 5% of hydrated Lime.

Similarly, 5% & 10% mix ratio (by weight) of semi-processed lime for a curing period of 5 to 7 days has been carried out and the variations of PI & CBR have been presented in Table 2 and the plot is shown in Fig 3.

Table 2- Laboratory Test Results at Different Applications of Semi-processed Lime

Parameter	Application Rate of Semi-Processed Lime		
	0%	5%	10%
CBR	2%	7%	23%
PI	75%	37%	21%

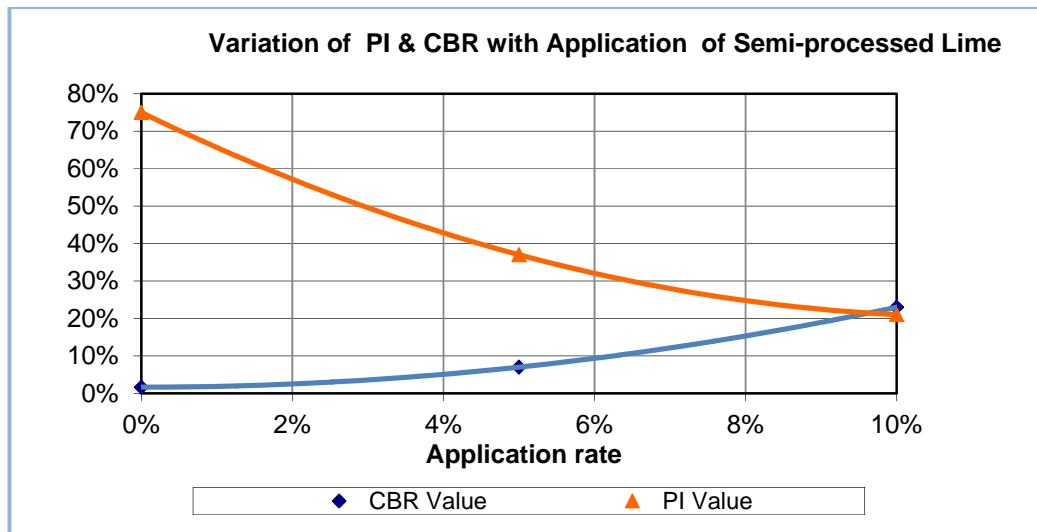


Fig 3:- The Variation of PI & CBR values with Different Applications of Semi-processed Lime

Hence, a mix ratio of 10% semi-processed lime (by weight) with a curing time of 5 to 7 days has been found to be the preferred option for the trial.

3 CONSTRUCTION OF THE TRIALS

Following the site set-up, construction of the test section with the different treatment options has been carried out. As the design of the different trial options differs widely, different construction methods and procedures have been followed. The description of each method and procedures, along with the typical cross sections of the different options, is presented in the forthcoming sections.

3.1 Construction

3.1.1 First Section (2+200 – 2+300)

Untreated Expansive Subgrade (Control Section)

- Following the scarification and removal of existing gravel wearing course, the expansive subgrade has been shaped with appropriate camber slope and compacted to the desired density with no application of treatment and/or additives thereof.

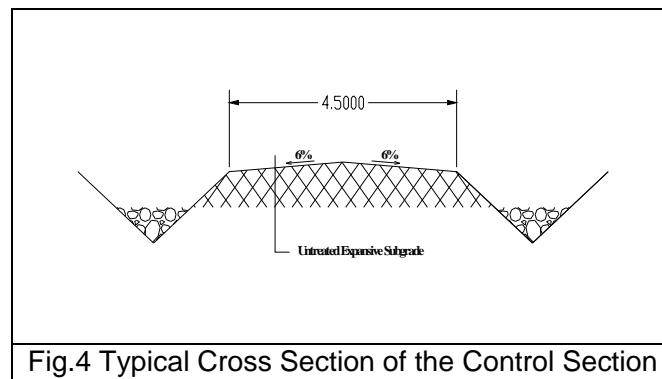


Fig.4 Typical Cross Section of the Control Section

3.1.2 Second Section (2+300 – 2+400)

Mechanically Stabilized Expansive Subgrade

- The expansive subgrade is mechanically stabilized by mixing it with a non-plastic gravel with a proportion of 50% by volume and compacted to the required density.

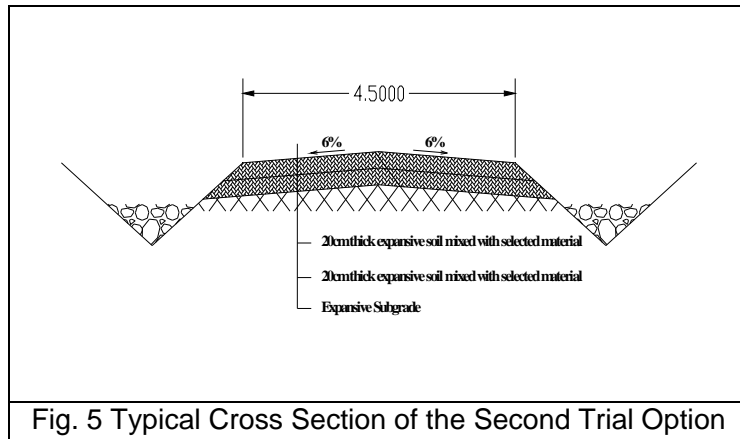


Fig. 5 Typical Cross Section of the Second Trial Option

3.1.3 Third Section (2+400 – 2+500)

Boulders on Expansive Subgrade with a Wearing Course on Top

- This option is constructed of two layers of different materials. The first layer is constructed by placing 15cm thick boulders on top of expansive subgrade as shown in the Fig 6. The second layer is a 15cm thick selected wearing course using plastic non-expansive soil compacted to the desired density.

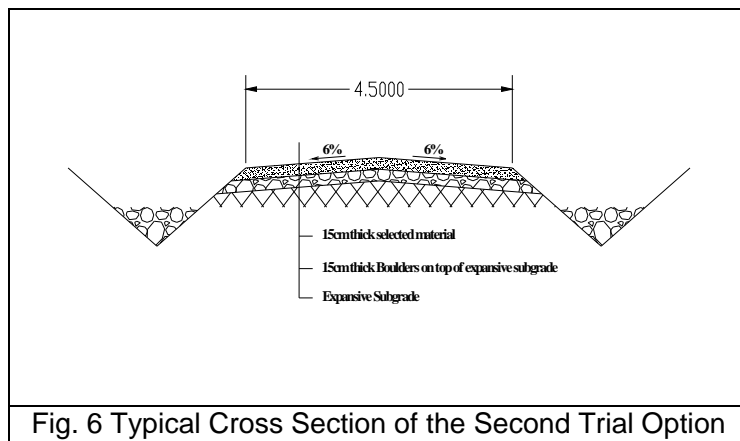
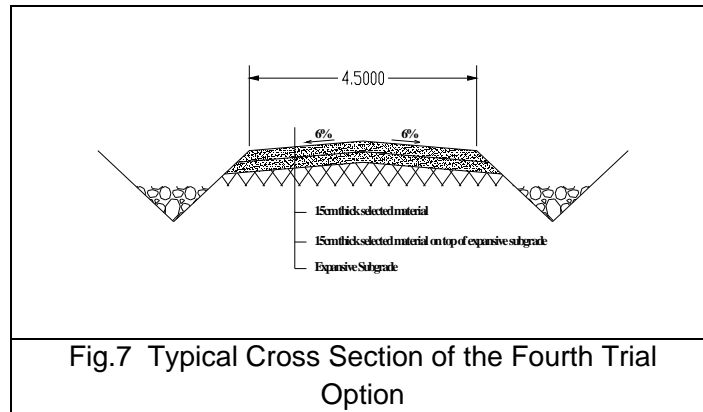


Fig. 6 Typical Cross Section of the Second Trial Option

3.1.4 Fourth Section (2+500 – 2+600)

Two layers of non-expansive plastic selected material on Expansive Subgrade with 30cm thickness

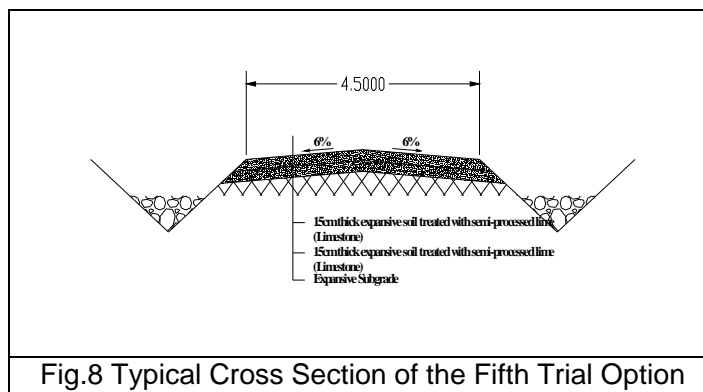
- Two layers of plastic non-expansive material each of which having 15cm thickness is constructed on top of expansive subgrade. The layers are compacted to desired density.



3.1.5 Fifth Section (2+600 – 2+700)

Stabilization of Expansive Subgrade using Semi-Processed Lime (10%)

- ✚ The expansive soil is treated with semi-processed lime with an application rate of 10% by weight, which was previously determined from laboratory tests.
- ✚ After proportioning and mixing of the semi-processed lime, it was allowed to cure for 5 days followed by spreading and compaction to the desired density.



3.1.6 Sixth Section (2+900 – 3+000)

Stabilization of Expansive Subgrade using Hydrated Lime (6%) and TerraZyme

- ✚ This segment is treated with a combination of Hydrated Lime and a chemical stabilizer called TerraZyme.
- ✚ The Hydrated Lime is mixed with 6% by weight application rate followed by the application of the chemical diluted in appropriate amount of water. The application of the chemical has been determined based on detailed procedures proposed by the supplier.
- ✚ There was no need for curing the mix for days, according to the instructions of the supplier. The mix was compacted to the desired density.

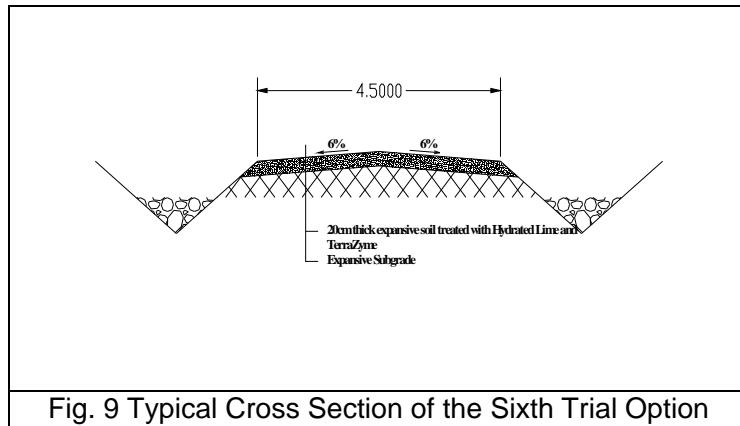


Fig. 9 Typical Cross Section of the Sixth Trial Option

3.1.7 Seventh Section (3+00 – 3+100)

Two layers of non-expansive plastic selected material on Expansive Subgrade with 20cm thickness

- ✚ The same as the trial option in section 2.2.4, but with a different layer thickness; this time being two layers having a thickness of 10cm each.

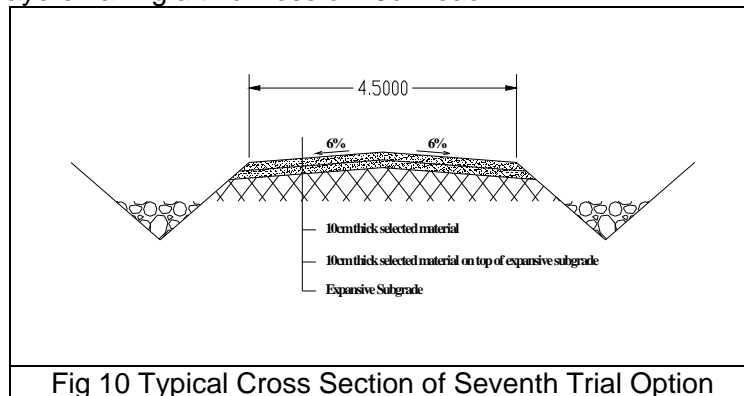
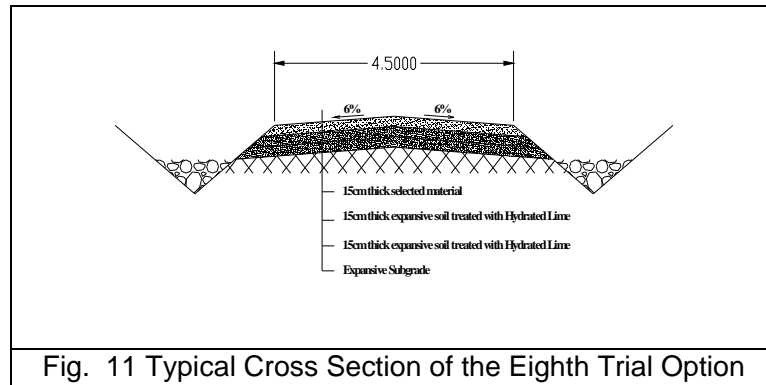


Fig 10 Typical Cross Section of Seventh Trial Option

3.1.8 Eighth Section (3+100 – 3+200)

Stabilization of Expansive Subgrade with Hydrated Lime (5%) with a Wearing Course on top

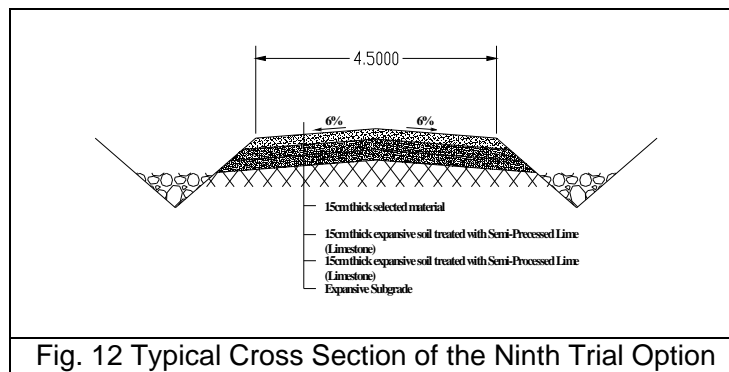
- ✚ The expansive soil is treated with Hydrated lime ($\text{Ca}(\text{OH})_2$) with an application rate of 5% by weight, which was previously determined from laboratory tests.
- ✚ After proportioning and mixing, it was allowed to cure for 5 days followed by spreading and compacting to the desired density. This was done for each layer of 15 cm thick.
- ✚ A wearing course of 15cm layer thickness was placed on top of the treated subgrade followed by appropriate compaction.



3.1.9 Ninth Section (3+200 – 3+300)

Stabilization of Expansive Subgrade with Semi-Processed Lime (10%) with a Wearing Course on Top

- ✚ In this segment, the expansive soil is treated with semi-processed lime with an application rate of 10% by weight, which was previously determined from laboratory tests and cost comparisons.
- ✚ After proportioning and mixing of the semi-processed lime, it was allowed to cure for 5 days followed by spreading and compaction to the desired density. This was done for each layer of 15 cm thick.
- ✚ A wearing course of 15cm layer thickness was placed on top of the treated subgrade followed by appropriate compaction.



3.2 Quality Control

Field density tests have been checked at three representative points of each test section. Fig. 5 shows the distribution of the average percent compaction along the test section on different layers.

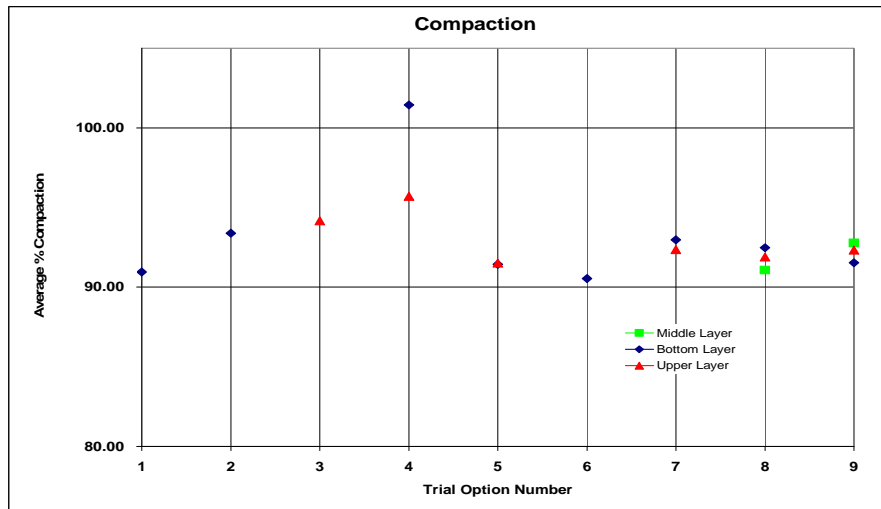


Fig 13:- Average Percent of Compaction

3.3 In-situ Characterization

Considering that all the construction is done by labour, there was a doubt about the replicability of the laboratory mix-ratio on the site. To ensure this, the construction has been carried out with intensive supervision and samples have been taken from the in-built, cured condition, and a series of Atterberg & strength tests have been conducted. The results are presented in Table 3. Despite intensive supervision, the results haven't shown significant discrepancies.

Table 3:- Laboratory test results of Samples taken from the road after built

Trial Name by Mix Type	Parameter			
	PI	PI, avg	Sdev	CBR
Soil + 5% Hydrated Lime	21	18	1.79	55
	19			
	16			
	17			
	18			
	17			
Soil + 10% semi-processed Lime	35	32	1.79	23
	30			
	31			
	33			

Trial Name by Mix Type	Parameter			
	PI	PI, avg	Sdev	CBR
	32			
	31			
Soil + 6% Hyd Lime + Terrazyme	17.12	17.12		
Soil + 50% NP Gravel	22.07	22.07		34

4 PERFORMANCE EVALUATION

Visual inspection and passability criteria were identified to be the preferred performance evaluation. Hence, it will be very essential to define passability at this juncture.

- ✚ The bearing capacity of the road material is reduced by moisture to such an extent that it becomes too low to support the vertical loads imposed on the road by a vehicle, resulting in shearing.
- ✚ The surface of the road becomes so slippery when wet that the wheels of the vehicles lose traction and the vehicle starts slipping to the extent that it becomes dangerous or impossible to make progress. This is a result of the lack of shear strength in the upper parts of the wearing course or inadequate friction between the vehicle tyre (often soil covered) and the wearing course material. Slipperiness can be a problem, even with soils with a high bearing capacity but with little friction-generating aggregate.

[Passability Criteria for Unpaved Roads, Department of Transport, Research Report RR 19/172]

To this end, the sections were subjected to small and medium truck traffic (of 40vpd) and the sections were classified and passability of each section has been categorized and marked as follows:-

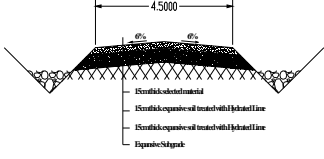
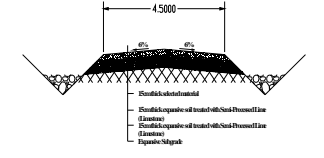
1. ---Vehicles get stuck
2. ---Slippery mainly but vehicles may also get stuck
3. ---Slippery
4. ---No problem

5 COMPARISON IN MATRIX FORM

Table 3: The Summarized Comparison in Tabular Form

Option No.	Template	Description	Comparative Options	Passability	Per Km Cost Estimate (ETB)

1		<p>Untreated Expansive Subgrade (Control Section)</p>	<p>Since this is a control section, it will act as the basis to compare the rest of the options against to it.</p>	<p>Vehicles get stuck (Impassable)</p>	<p>88,515</p>
2		<p>Mechanically Stabilized Expansive Subgrade</p>	<p>This Option will be compared against Option No. 1 in terms of performance and construction cost.</p>	<p>Slippery (Hardly Passable)</p>	<p>260,593</p>
3		<p>Boulders on Expansive Subgrade with a Wearing Course on Top</p>	<p>This Option will be compared against Option No. 1 in terms of performance and construction cost.</p>	<p>No problem (Passable)</p>	<p>182,859</p>
4		<p>Two layers of non-expansive plastic selected material on Expansive Subgrade with 30cm thickness</p>	<p>This Option will be compared against Option No. 1 in terms of performance and construction cost. Moreover, it will be used as a comparison for Option No.7</p>	<p>No problem (Passable)</p>	<p>153,653</p>
5		<p>Stabilization of Expansive Subgrade using Semi-Processed Lime (10%)</p>	<p>This Option will be compared against Option No. 1 in terms of performance and construction cost. Moreover, it will be used as a comparison for Option No 9.</p>	<p>Slippery mainly but vehicles may get stuck (Impassable)</p>	<p>194,917</p>
6		<p>Stabilization of Expansive Subgrade using Hydrated Lime and TerraZyme</p>	<p>This section will be compared to Option No. 10.</p>	<p>Slippery mainly but vehicles may get stuck (Impassable)</p>	<p>242,043</p>
7		<p>Two layers of non-expansive plastic selected material on Expansive Subgrade with 20cm thickness</p>	<p>This Option will be compared against Option No. 1 in terms of performance and construction cost. Moreover, it will be used as a comparison for Option No. 4.</p>	<p>No problem (Passable)</p>	<p>117,305</p>

8		Stabilization of Expansive Subgrade with Hydrated Lime (5%) with a Wearing Course on Top	This Option will be compared against Option No. 1 in terms of performance and construction cost. Moreover, it will be used as a comparison for Option No.10.	No problem (Passable)	275,107
9		Stabilization of Expansive Subgrade with Semi-Processed Lime (10%) with a Wearing Course on Top	This Option will be compared against Option No. 1 in terms of performance and construction cost.	No problem (Passable)	233,539

A comparison of all trials with respect to passability and construction cost have been presented in Fig 14.

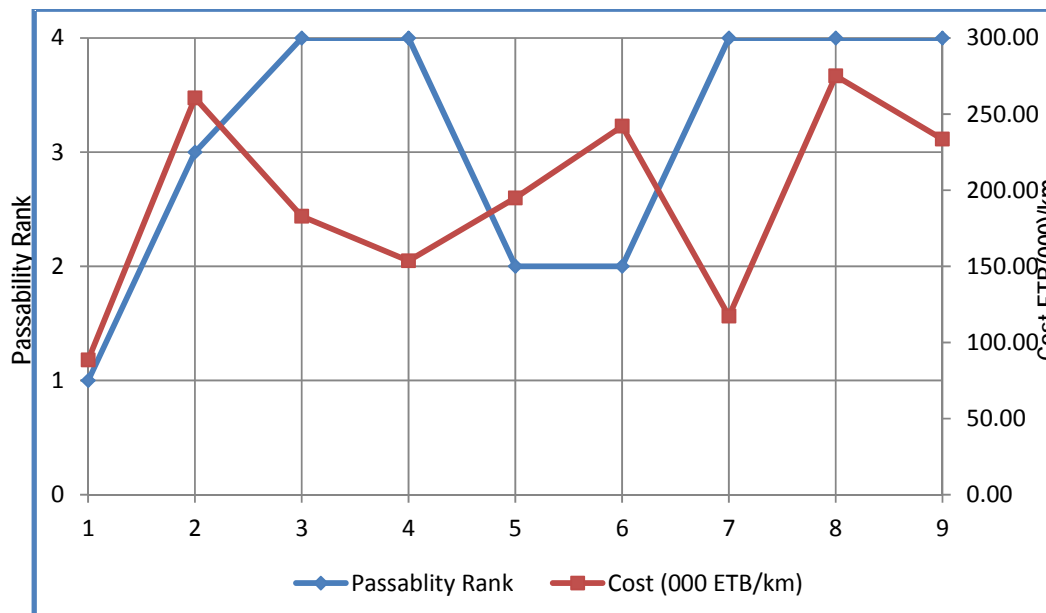


Fig 14 Graph Passability/Cost for the trials

6 CONCLUSION

- ✚ The possibility of construction in this kind of soil with various treatments using labour and compaction using a light weight roller (3 ton) at a desired quality standard for lower class rural access roads with up to 40 vpd has been proved. Hence, this will enhance the maximized & optimized use of low-cost locally available materials and deployment of low cost low capacity equipment for construction.
- ✚ Emphasis should be given to the importance in construction in this kind of soil of strictly applying engineered design of geometric, drainage, pavement thickness, material selection and proportioning
- ✚ From Fig 14, it can be concluded among the 9 (nine) options, 3, 4, 7, 8, and 9 show a good passability mark. Adding to this the per/km cost of construction, these options will further be

ranked in order of 7, 4, 3, 9 & 8. Nevertheless, the construction cost is always varying with respect to place and time. This may largely be due to the availability and accessibility of boulder material/select material, the price of lime etc. Hence, the rank ordered as (7, 4, 3, 9 & 8) may be changed in this regard.

7 INTERIM RECOMMENDATION

The performance of each section should be evaluated through time using appropriate monitoring schemes so as to establish sound conclusions. Hence, collection & collation of more monitoring data is heavily required.

The following monitoring activities should be carried out in order to come up with a sound and reliable result.

Exposure of the Test Section to Traffic

The test section should continuously be exposed to design traffic for a specific period of time so that the deterioration trend can be clearly observed. .

Monitoring

The following monitoring activities should be carried out:-

- ✚ Cross sectional surveys should be carried out timely in order to estimate the gravel and/or material loss of the section, which can easily be extrapolated to annual gravel loss of the road.
- ✚ Roughness measurement should be taken to have an idea of the roughness progression over the course of time.
- ✚ Dynamic Cone Penetrometer (DCP) tests should be carried out to know the insitu CBR (bearing capacity) of the section in various conditions (wet and dry).
- ✚ Visual condition survey should also be made to see other types of distresses on the road.

Analysis

Data collected from the monitoring phase should pass through a series of analyses analysis and rectifications to choose the viable option amongst others.

Further recommendations will be drawn from the results of the collation and analysis of data which will be collected later on.

Cost

- ✚ Costing progression from pilot project activities to national scale operation requires careful attention as conditions vary too much
- ✚ It is advisable to replicate this test section to selected Woredas in parallel with progress of the program

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