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Laboratory Investigations on the Causes of Road Failures Constructed Along Asendabo to Deneba Road Section

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***Abstract*: -Currently different construction activities are taking place, especially in road sector. It has been noticed that constructions on different types of soils face numerous problems and some attempts have been made to investigate the causes of the problems where some soils are prevalent. Most of the roads constructed in Ethiopia on some type of soils fail before their expected design life in some cases even after few months of completion. In this study an attempt was made to investigate the causes of the failure. The study focused on performing field tests, taking representative pavement material samples from different portions of the road and making the necessary laboratory tests on the collected samples. Additional natural sub grade samples were also taken for laboratory testing to identify the types of soil. From the field and laboratory test results, it was concluded that the materials used for the road construction were poor according to the design specification, on the other hand, the natural sub-grade soils type was expansive soil at which the road deteriorated as compared to the specification. The CBR values were also checked for extremely deteriorated area. The presence of Poor drainage conditions was also a case for failure had to be occurred. The poor drainage condition together with the material quality create the major causes of Asendabo to Deneba road segment failure.**

Keywords: CBR values, disturbance, design specification, natural sub grade, numerous problems, Poor drainage.

INTRODUCTION

1.1Current situation of Ethiopian roads

An appreciable part of Ethiopia is covered by different soil types. Currently different construction activities are taking place in the road and building sector on different soil types. It has been noticed that construction on some soils face numerous problems and the causes of the problems are not investigated in depth in Ethiopia. Most of the roads constructed in Ethiopia on expansive type of soils fail before their expected design life, in some cases even after few months of completion. Ethiopia's economic growth is highly dependent on the agricultural sector. Therefore, development efforts to change the existing socio-economic condition of the nation would also be dependent on the efficiency of this sector for the foreseeable future. However, a better performance of the agricultural sector, and the sustainable economic growth of the country at large would be achieved through an improvement of the basic infrastructure. Consequently, the road network has been identified as a serious bottleneck for the economic development of the country [1].

The major causes of road failure in asphalt pavement are fatigue cracking caused by excessive vertical compressive and horizontal tensile strain at the top subgrade and bottom of asphalt layer due to repeated traffic loading and rutting deformation, caused by densification and shear deformation of subgrade. Excess vertical surface deflections in flexible pavements have always been major concern and used as a criterion of pavement design [2].

The results of a series of parametric study to examine the effect of HMA modulus, effect of base modulus and effect of subgrade modulus on the performance of flexible pavement with special emphasis on the deflection and stress. The pavement structure is a combination of sub base, base course and surface course placed on a subgrade to support the traffic load and distribute it to the roadbed [3].

1.1 Statement of the Problems

Apart from the continuous cracking observed during the joint visual survey several further observations were also made. There appeared to be a serious deformation of the wearing course along the right-hand side (RHS), which manifested itself as clearly visible concave depression from the centerline to the edge of the asphalt. First impressions suggested this could be a very well-developed wheel track from shoulder of the new asphalt. This was easily seen after rainfall as a series of longitudinal puddles stretching. The same degree of surface deformation was not apparent on the left-hand side (LHS) and standing water was rarely observed.

Wherever cracking appeared on the right-hand side, standing water was observed at the toe of the embankment. This was observed through most of August and September. As the rains began to subside in October and rain was followed by several days of drier weather these locations were always the slowest to dry out. If rain recurred these locations once again became areas of standing water. Very little standing water was observed on the left-hand side. But, where cracks had been observed during earlier survey, standing water was always present (4).

From the observations made during the visual survey of the cracks, the height of the embankment did not appear to be linked to the zone of cracking. Cracks appeared indiscriminately in areas of low, medium, and high embankment.

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1.2 General Objective

The general objective of this research work was to undertake laboratory investigations on the construction materials to obtain the causes of road failures along Asendabo to Deneba section and try to give remedial measures for those which have already failed section.

1.3.1 Specific Objectives

i. To conduct some laboratory tests such as; Gradation test, Atterberg limits, (CBR) tests and proctor test (MDD and OMC).

ii. To compare test results with the design specification or standards.

iii. To check the thicknesses of each pavements as per the standard.

iv. To give or suggest remedial measures for the deteriorated road sections.

METHODOLOGY

2.1 Description of Study Area

The study was carried out from Asendabo to Deneba road segment found in the South-Western part of Ethiopia. Approximately, it is located 250 to 280 kilometers South-west of the capital Addis Ababa. The total length of the road is about 23 km asphalt pavement. Asendabo to Deneba road is at the center of the road network for South-west of Ethiopia. The first major road dates to the early 1930s, with a road that extended from the capital Addis Ababa to Jimma as a strategy for fostering economic growth in Ethiopia through generation of transportation to connect South-western part to Addis Ababa.

Figure 2.1 Map of study area

As shown in the figure 2.1, the samples were taken from four highly deteriorated area along the segment of the study area which covers the the tortal length of 23 km from Asendabo to Deneba.

2.2 Design of the study

The research was conducted by using both experimental and descriptive methods and it was designed in the way that important and exact information could be getting to understand the laboratory investigations on the causes of road failures constructed along Asendabo to Deneba section. It describes the input data, their source, and the methodology. The methodology of this work has the following components.

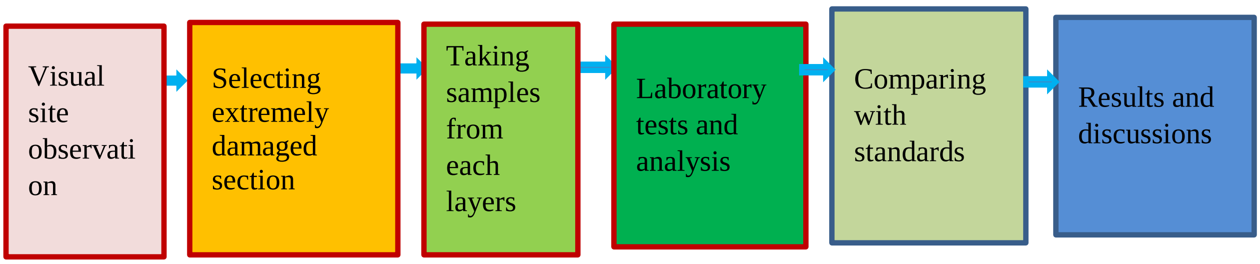

Figure 2. 1 The analysis methods of Input, Process, and results

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Figure 2.3 Sample pit hole at study area

From figure 2.3, tested materials were taken not only this but also depth of each pavement layers was taken from such test pit types.

2.3 Sample preparation for different laboratory tests

The California bearing is a comparative measure of the shearing resistance of a soil, which is restricted to pavement. It gives a precaution to allow for moisture content increase in the soil due to flooding or elevation of water table. The CBR value for a soil will depend upon its density, molding moisture and moisture content after soaking. It is done to provide the relative bearing values of each layers and swellness.

The objective was to determine strength of soil, subgrade, subbase and base course materials in terms of CBR and to know the bearing capacity of each layer. The strength of a sub grade, sub base and base course materials are expressed in terms of their CBR value. To observe the effect of rain on soil and percent of swell and to know the bulk and dry density, these tests were mandatory.

Figure 2.4 Sample preparation for gradation and CBR tests.

The CBR is a method of compressive measure of the strength resistance of a soil. It was done to provide the relative bearing values of each layers and their swelling potential. While this test was proceeding there were different checking parameters, like; penetration, soaking condition, swell test.

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Figure 2.5 Taking values and measuring soaked CBR with its machine**.**

Figure 2.6 Atterberg limit test process in the laboratory.

Atterberg limit tests are important classification criterions for soils' engineering properties. The Atterberg Limits, Linear Shrinkage, Volumetric Shrinkage and Plasticity Index values of the representative soil samples were done.

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RESULT AND DISCUSSIONS

The result of the particle size analysis indicates that the soil's clay content for all sub-base samples. According to the Federal Ministry of Works and Housing (1997) specification, the clay content for sub- base materials must not exceed 35%. The high clay content could be responsible for instability of road pavement in the area.so from test results for all sub-base materials are fulfilling the FMWH specification.

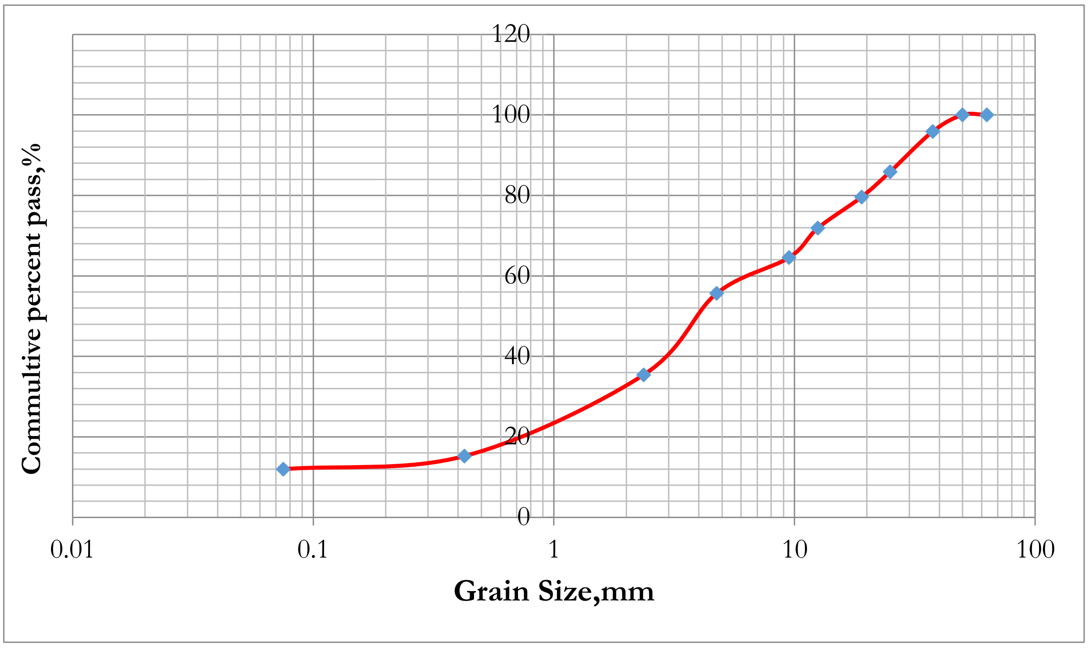

Figure 3.1 Average grain sizes for sub bases.

3.1 Average CBR Values for Pavement Layers

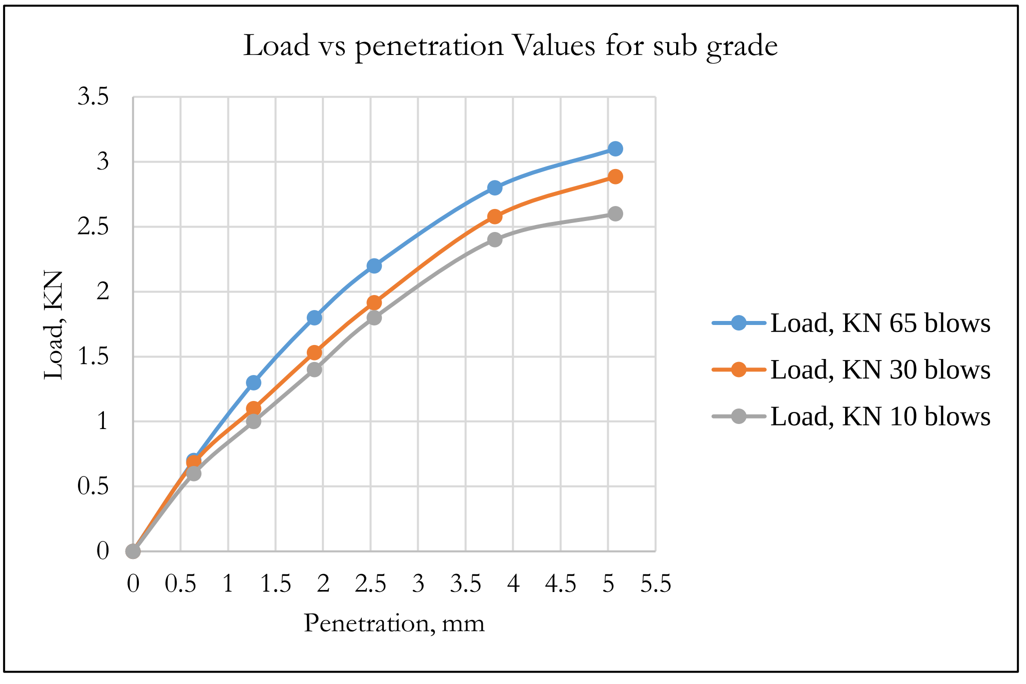

Figure 3.2 Applied load in newton vs penetration in mm.

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From the figure 3.2, the load versus penetration at each blow shows that as the applied piston load increased the penetration values were also increased.

Table 3.1 Sub base Material Specification for PI and CBR.

Soil Type	Natural Sub base Material			
Station	1	2	3	4
PI ≤ 30	18.05	17.81	9.29	10.44
	Fail	Fail	Fail	Fail
CBR ≥ 30 %	40.2	19.4	20.5	17.5
	Pass	Fail	Fail	Fail

According to Ethiopian Road Authority (ERA), Asendabo – Deneba road segment, material specification requirements had examined its sub-base material PI ≤ 20. All sub-base soil samples did not meet the required specification of materials.

Table 3.2 Natural Subgrade Material Specification for PI and CBR.

Soil Type	Natural Sub grade Material			
Station	1	2	3	4
PI ≤ 30	18.35	33.05	18.19	49.25
	Pass	Fail	Pass	Fail
CBR ≥ 5 %	7.78	3.3	2.1	3.0
	Pass	Fail	Fail	Fail

Therefore, the liquid limit is the moisture content for **25** numbers of blows, which is **58.6%** of moisture contents.

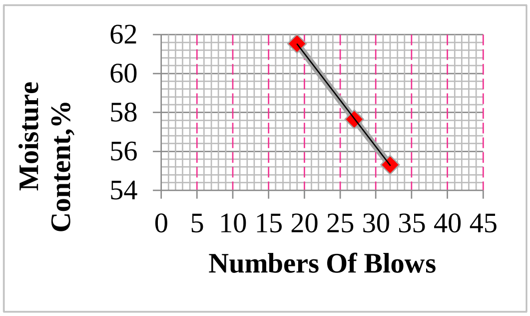

Figure 3.3 Average moisture contents vs number of blows for sub grades.

3.2 Compaction Tests for each Pavement Layers at three stations.

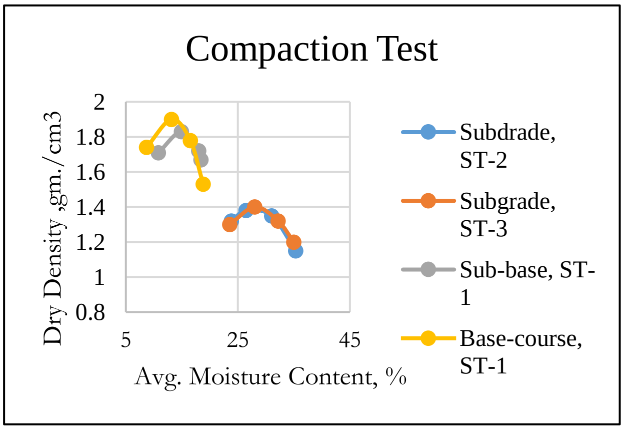

Figure 3.4 Compaction test result for each pavement layers.

Amount of water for CBR = (Omc / (Natural moisture content just before CBR test +100)) * amount of soil gm.

Table 3.3 Summary of Peak compaction values at each station.

Pavement layers	Stations	MDD (gm/cm3)	OMC (%)
Sub base	1	1.83	14.92
Base course	1	1.90	13.16
Sub grade	2	1.40	25.93
Sub grade	3	1.4	28.03
Sub grade	4	1.3	25.65

3.3 Comparison of Test results with standards

The base course used for the extremely damaged road section has the average OMC value of 13.16% and MDD of 1.90 gm/cc3 and on the other hand the field test results for moisture content are ranging from 10 gm/cc3 – 15 gm/cc3 and the maximum dry density was ranging from 1.40% to 1.90%. The percentage compaction for the base course was in between 74.30% and 78.30%, which is much lower than 95%.
The sub-base material for the same has an average OMC of 14.92 % and an average MDD of 1.83gm/cc. The field dry density results are ranging between 1.23gm/cc and1.41gm/cc and the moisture content is ranging from 18.86% to 29.41%. The percentage compaction is ranging between 71.92 % and 82.46%, which is the lowest of all.
From the test results the natural sub-grade has high swelling pressure and swelling potential.
The tests showed that the natural sub-grade has high PI and LL and the CBR values are very small when soaked for four days. Based on AASHTO T-258 the degree of expansion is high with PI values greater than 35 and LL greater than 60.

Table 3.4 Average Laboratory results of Pavement material properties with ERA standards.

Road properties	Layers thickness(cm)	Laboratory Test Result			ERA Standard Specification Result		
		CBR %	PI	Specific Gravity	CBR %	PI	Specific Gravity
surface course	3.5	-	-	-	-	-	-
Base course	10.3	83.2	6	2.71	≥80	≤ 6	≥ 2.63
Sub base	16.25	40.4	9.5	2.83	≥30	≤ 12	≥2.63
Subgrade	∞	7.78	18.5	2.9	3-15	≤ 20	≥ 2.9

Table 4. 4 Summary of Pavement layer thicknesses.

Stations	Types of Pavement Layers	Existing thickness(cm)	Standard thicknesses(cm)
1	Asphalt or surface course	3.5	5
	Base Course	10	12.5
	Sub base	15	20
2	Asphalt or surface course	3.5	5
	Base Course	10	12.5
	Sub base	15	20
3	Asphalt or surface course	3	5
	Base Course	11	12.5
	Sub base	17	20
4	Asphalt or surface course	3	5
	Base Course	10	12.5
	Sub base	18	20

As table 4.4 shows the actual pavement layer thicknesses of the existing pavements had constructed below the standard

3.4 Observations and proposed remedial measures

1) From the findings of the test results and field observations, all the problems are related with water from rain and material properties of pavement layers. Therefore, for the problems related to drainage, the Contractor, through the supervision of the Consultant, must provide drainage facilities farther from the toe of the shoulder to prevent the ingression of water in to the pavement. The materials properties should also need farther laboratory investigation especially for base course and sub base.

2) During the process of construction, the contractor must perform the activities immediately after excavating the original road not exposing the pavement materials and embankment expansive soils for longer wetness or dryness.

3) In areas of embankment fill where the fill materials are expansive soils, it is better to think about stabilizing it or replacing it with non-expansive material.

CONCLUSIONS AND RECOMMENDATION

From the findings of the field and laboratory test results the following conclusions are drawn:

4.1 Conclusion

1. The laboratory test results found during investigation proved that the pavement materials used for the construction of the road under investigation are not as per the specification and did not fulfill all the requirements.
2. The CBR values found related to the field dry density for base course and sub bases are less for extremely damaged road sections.
3. In areas of extremely damaged road sections the moisture specifications. This could lead the failures of the pavements.
content for subbase and sub grade are much higher than the standards.
4. The swelling potential and swelling pressure of the natural subgrade soils are high enough to create problems on the pavement when there is water at the toe of the road shoulder.
5. Unrecommendable thicknesses of each pavement layers was one of the reasons for the road deterioration along the study area.
6. During the field investigation, it is also found that expansive soils are used as embankment fill material in areas where expansive sub grade soil is prevalent. One of the main reasons for the causes of failure is this embankment expansive soil.

4.2 Recommendation

1) From Sendabo to Deneba road segment, moisture recording instruments are installed at different places of the newly constructed road sections to study the vertical as well as the horizontal moisture variation under the pavement at different seasons of the year. Future study can be made based on the results obtained from the instruments.

2) Evaluation on the effectiveness of different construction and design techniques which are currently in use for road construction on expansive soils can be area of further research.

3) Preparation of guide lines for design as well as construction of roads on expansive soils is essential.

4) Effectiveness of road rehabilitation on expansive soil areas of Ethiopia which includes expansion of existing roads is needing to be investigated in detail.

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