Research paper on Design & Performance of LVR under Traffic Environmental Conditions

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***Abstract*: A majority of roads in the India are low volume roads (LVRs). The ASTM has developed simplified methods for LVR pavement thickness selection. These guides allow users to obtain recommended asphalt surfacing and base course layer thickness based on the subgrade support and the average daily traffic (ADT) of the road. The main objective of this study is to relate the surface condition of LVRs to their ADT, layer thicknesses, foundation material properties, and maintenance. A secondary objective was to evaluate if the Dynamic Cone Penetrometer (DCP) is an acceptable tool in determining the subgrade support by using it to measure the penetration resistances of the foundation layers.**

A total of 18 different asphalt surfaced LVRs across SD were tested. The construction and maintenance histories of the road was obtained. The performance of the roads was evaluated based on the surface condition of the pavement. Field tests were performed to obtain the layer thicknesses, DCP Penetration Index, and samples were obtained for laboratory testing.

***Keywords*: Sub Base, Aggregates, Course, Liquid Limit, Plastic Limit, Sub Grade.**

Introduction

The sub grade is the in-place material beneath the pavement structure. very strong, durable, impermeable, manufactured strong, free-draining, manufactured moderate strength, free-draining, natural material The primary factors influencing road design include traffic volume, surface type, material properties, environmental factors, and geometry. These design parameters are significantly affected by the strength of the materials and the ADT. If these variables are not taken into account, the resulting roadway design could be either overly conservative or inadequate. In many cases the layer thicknesses ad materials used in LVRs may have been selected based on experience with materials and thicknesses used on previously constructed roads. However, these other roads may have different design variables than the roads being designed, resulting in a design that may not be appropriate **(Beckemeyer and McPeak, 1995).**

This is a major reason why low volume roads require different design guidelines than roads with higher volumes **(AASHTO, 2001).**

There are several different design methods for LVRs, including the AASHTO method, U.S. Army Corps of Engineers method, National Stone Association method, and the Asphalt Institute method. These methods require several inputs, such as 18-k/p Equivalent Single Axle Load (ESAL), roadbed soil resilient modulus, and layer California Bearing Ratio (CBR) values. However, local agencies may not always know these variables or have the resources, such as money and equipment, to obtain them.

The strength is affected by the gradation and plasticity of the material. These components of strength are significant factors in the design of the LVR. Therefore, the use of in-place density testing may not be an adequate indication of the support a sub grade and base provide for the pavement. The dynamic cone penetro-meter (DCP) is a device used to determine the in-situ support and stiffness of the soil and aggregate by correlating the results to the CBR value. Therefore, this device may be used for construction inspection. An increased interest in LVR design has evolved due to changes in agricultural and construction equipment over the past few decades. Equipment now is larger and heavier than it has ever been in order to increase efficiency of agricultural and construction operations. Increases in agricultural yields have also resulted in significantly higher crop output per acre of land. This increase in yield results in larger and heavier loads and more trips required by farmers to transport their crops. This can greatly affect the performance of LVR, especially since considerable agricultural, construction and commodity related traffic occurs on LVR.

1.2 Objectives and Scope

The objective of this study is to relate the surface condition of LVRs to their ADT, maintenance, layer thicknesses, and foundation material properties. Penetration resistance will be evaluated using the dynamic cone penetrometer to evaluate the support of the subgrade underneath the roads being studied. It is envisioned that this data will yield correlations between the primary factors influencing road design and their actual performance.

The main objectives of this study:

1. Review literature concerning the DCP, road foundation material selection, LVR design methods and guides, and asphalt surface performance.
2. Conduct field and laboratory evaluations of the foundation properties of asphalt surfaced LVRs.

3. Use the correlation between DCP Penetration Index and CBR value to determine subgrade support from the DCP test results. Determine if this DCP-CBR correlation is more suitable for estimating subgrade support than using the Liquid Limit or AASHTO soil classification.
4. Compare the layer thicknesses, material properties, ADT, and maintenance of the LVR roads to their surface performance to determine how these factors may influence the surface performance.

3.2 Testing Parameters

There were several parameters that were determined for each of the sample locations. Some of these parameters were obtained through research and the assistance of the county highway superintendents. This included ADT, ADTT, age of the road, and maintenance history. The other data was obtained through observation and measurements of the roads in the field and the results of laboratory tests. This data consisted of surface type, surface condition, surface and base thicknesses, base course gradation and plasticity index, base and subgrade moisture contents, and base and subgrade DCP penetration resistances.

3.3 Process of Comparing Road Performance Assessment to Recommended Design:

The field and laboratory testing provides the necessary information to determine the required road thickness using the methods presented in the Road Design, Maintenance, and Rehabilitation Guide and in the SD Local Road Manual. This first design method uses the subgrade support and the ADTT to determine the required layer thicknesses. The latter design method depends only on the ADT.

The following steps describe how the data was used to validate the effectiveness of the design methods by determining the recommended design thicknesses and relating the design to the road performance.

- Laboratory data was used to determine the material properties (gradation, PI, LL).
- Base course material properties were used to determine if the materials met the state specification.
- Subgrade material properties and DCP results were used to establish the subgrade support.
- Subgrade support and traffic data were applied to the design methods to determine the required layer thicknesses.
- Design layer thicknesses were compared to the in place layer thicknesses to determine the adequacy of the existing pavement layer thicknesses.
- Surface condition data was assessed to determine the road rating.
- Analysis was conducted to assess how layer thicknesses and material properties influence observed road performance.
- The effectiveness of the design methods were validated based on how the determination of design thickness and material properties influenced road performance.

The result of this process will subsequently be used to evaluate the effectiveness of the LVR design methods.

Test Methods and Protocols

This chapter outlines the test methods and protocols used for both the field testing and lab testing done in this study. The field testing consisted of the surface condition assessment, the DCP test, and obtaining base course and subgrade samples. The laboratory testing included sample reduction and testing for moisture content, particle size/gradation, Atterberg Limits, and soil classification. In addition to testing, information about the age, ADT, ADTT, original design, and maintenance history of each road was obtained, if it was available.

4.1 Field Testing

This section details the testing that was performed in the field at each of the testing sites. The surface condition of the asphalt pavement was assessed to determine the performance of the pavement. The DCP test was performed on the base course and sub-grade soil to obtain a penetration resistance of the soil. A boring was also done at each site so that the layer thicknesses could be measured and samples of the base and sub-grade could be obtained for laboratory testing.

Surface Condition Assessment

The different pavement conditions and distresses that were used to assess the pavement were weathering, oxidization, raveling, shoving, transverse cracks, longitudinal cracks, block cracks, alligator/fatigue cracks, rutting, patching, potholes, edge deterioration, and ride ability. The frequency and severity of these distresses determined the rating that the pavement surface received. The pavement ratings were determined according to Table 4.1: Flexible Pavement Rating and Evaluation Scheme from the Road Condition Survey Guide.

4.3 DCP Test

The Dynamic Cone Penetrometer (DCP) test was used to estimate the support of the base aggregates and the subgrade soils of the roads. The DCP test was performed at three locations for each test site: in the left lane outer wheel path, in the right lane outer wheel path, and on the centerline. For this test, the manual DCP apparatus was used. Before the DCP test was performed, a hole at least 2 inches in diameter was either axed or sawed into the pavement/surfacing to access the base aggregate. The DCP apparatus could be damaged if it was forced to penetrate the pavement.

The DCP test was then performed on the base and sub-grade. The cone was driven up to a depth of 2 ft or until refusal, whichever was shallower. Refusal occurs when the cone penetration is less than 0.1 inch (3 mm) per blow for ten consecutive blows (Dai and Kremer, 2006). The procedure for the DCP test is as follows:

- The DCP apparatus was assembled.
- The DCP was placed at the top of the base in the center of the hole in the pavement. The shafts were plumb and not touching the edge of the hole.
- One hand dropped the hammer from partial height until the entire cone surface was below the reference surface. The other hand held the top handle. This step is called seating the cone.
- The current shaft reading was recorded as the starting point for blow zero.
- The hammer was raised to its upper limit and then dropped so that it freely fell to the anvil.
- The reading on the shaft was recorded as the penetration for that blow. The shaft was read to the nearest millimeter.
- Steps 6-7 arrows were repeated up to a depth of 2 ft or until refusal.
- The DCP was removed from the hole and disassembled.
- The hole was filled, compacted, and patched. The DCP penetration depth was plotted against the number of blows for each of the tests performed.

Results & Analysis

Fourteen roads were tested during the summer of 2014, followed by another two roads in the summer of 2015. The field evaluations were conducted during the months of May through September. This chapter presents a summary of the data collected in both the field and laboratory testing.

5.1 Surface Condition

The surface condition assessment was performed as presented in Section 4.1.1 and Table 3.1, according to the Road Condition Survey Guide. Table 5.1 lists each road under the category that indicates its pavement condition. The detailed surface condition assessments for each of the roads are presented in Appendix E, Tables E.1 – E.16. Figures 5.1 – 5.3 are pictures from three different roads that demonstrate examples of the three different surface condition categories.

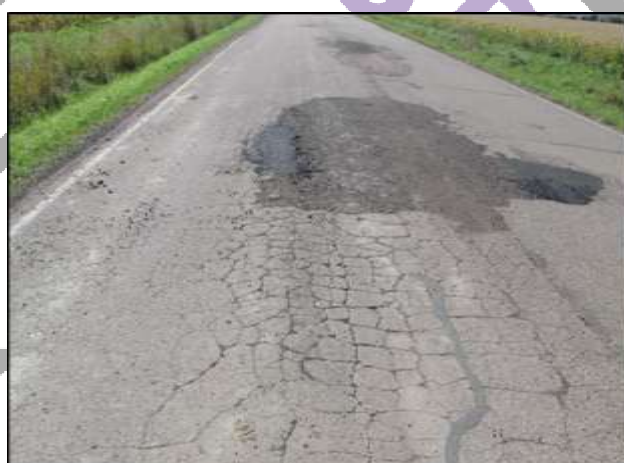

Fig. 5.1: Surface Condition Assessment Summary.

Figure 5.1 shows an example of Category 1 pavement condition on in Clay County. This pavement has severe fatigue cracking with disintegrating pavement in and around these cracks. This disintegration has resulted in some potholes. The multiple patches contain similar fatigue cracking and disintegration as the original pavement. There is also detrimental raveling and significant rutting present.

5.2 Base Course Quality

The gradations, LL, and PI for each base course sample determined during laboratory testing are shown Table 5.1, along with the requirements for the base course specification. The gradation, LL, and PI results for the samples were compared to the specification to determine if the base course satisfied this specification. Base course samples that had any one of the gradations, LL, or PI outside of the range for the specification by more than 2% passing or 2% moisture content were considered to not meet the specification.

Table 5.1: Laboratory Test Results

	Percentage passing								
Sieve size	1”	¾”	½”	No.4	No. 8	No. 40	No.200	LL	PL
Delhi to Ambala	100	100	93	70	56	44	25	30	16
Jalander to Jammu	100	95	89	59	53	35	22	27	11
Delhi to Agra	100	97	93	78	62	32	14	29	12
Chandigarh to Delhi	100	92	95	62	51	35	14	21	-
Chandigarh to jalander	100	92	79	66	52	25	8	22	-

5.4 Subgrade DCP

The results of the DCP tests for each road are shown in tables. Table 5.4 has the average PR for the subgrade layer of each test section determined from the raw DCP. The CBR for each section was then calculated. Then the CBR values for roads that had more than one section tested were averaged, as shown in Table 5.4. The resulting sub-grade support to be used in the Road Guide design method.

Table 5.2: Subgrade Gradation, LL, PI, and AASHTO Classification

	Percentage passing						
Sieve size	No.4	No.10	No. 8	No. 40	No.200	LL	PL
Delhi to Ambala	100	78	53	48	27	31	17
Jalander to Jammu	97	54	59	35	21	28	12
Delhi to Agra	92	78	63	36	15	31	12
Chandigarh to Delhi	86	56	52	30	14	22	14
Chandigarh to jalander	79	54	63	25	8	26	16

Table 5.10 Liquid Limit Test Result for base course

No. of blows	Mass cup	Mass cup+ wet soil	Mass cup + dry soil	Mass water	Mass soil	Moisture content	Liquid limit
33	3.56	11.25	9.72	1.61	6.16	26.1	21
29	3.55	12.36	10.52	1.82	6.58	26.1	
22	3.61	13.52	11.32	2.08	7.75	27	

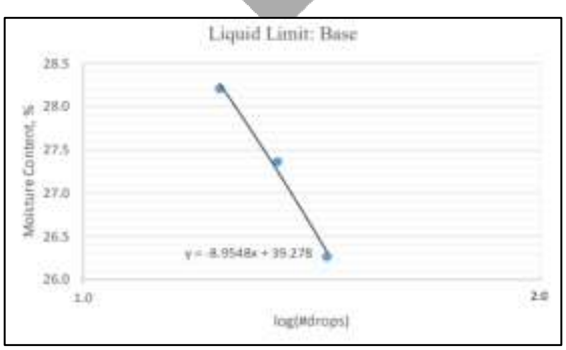

Fig. 5.7 Liquid limit test results for base course

The base course is an essential coponent of a roadway. The main purpose of a base course is to support the traffic load. Especially in asphalt surfaced roads, this layer distributes most of the traffic load to provide some structural support. A second purpose of the base course is to act as a drainage layer that permits water entering the pavement structure to drain

Table 5.8 Average Thicknesses

Surface Type	Blotter
Surface Thinkness	1.25 inchs
Base Thinkness	9 inchs
Subbase thinkness	N/A

6.2 Conclusions

The three design requirements of material quality, layer thicknesses, and maintenance schedule all contribute to the pavement performance of low volume, asphalt surfaced roads. When these three aspects satisfy the recommendations of the Road Design, Maintenance, and Rehabilitation Guide, they provide the support needed for the pavement to perform well. Therefore, this design guide provides adequate design recommendations for low volume, asphalt surfaced roads.

- If none of the design recommendations are satisfied, the road performance falls into Category 1.
- If only one of the design recommendations is satisfied, the pavement may have either Category 1 or Category 2 performance.
- If both the base course specification and regular maintenance are satisfied, the road performance will most likely be Category 2 but may also be Category 3.
- If both the required layer thicknesses and regular maintenance are satisfied, the pavement will have a performance of Category 3.
- If all three of the design recommendations are satisfied, the roads have Category 3 pavement performance.

The AASHTO soil classification is the most suitable method, compared to using the liquid limit or DCP results, for determining the sub-grade support used in the Road Design Guide. The age of the road does not strongly correlate to the pavement's performance.

Therefore, the way the road is built and the quality with which the road is built and maintained have a greater impact on the performance than the age of the road. The DCP may not be an adequate measure of the base course and sub-grade soil design support when tested throughout the summer, at lower moisture contents than the wet, spring design condition.

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