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Selection of Optimal Road Pavement Design Methods Based on the Quality of Road Construction Materials

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Abstract.

The main objectives of improving the reliability of roads and highways are to increase the durability of the road pavement structure, as well as its wear resistance. During design, it is important to determine the quality of the road construction materials used to ensure the required strength of the road pavement structure, which are resistant to plastic deformation and wear. In terms of operational reliability criteria, It is necessary to pay attention to the bearing capacity in relation to the impact of transport loads and the maintainability of road structures. Depending on the quality of road construction materials, it is recommended to use them selectively in the structural layers of the road pavement, so as to maximally take into account, on the one hand, the requirements of strength and reliability, and on the other hand, economic affordability.

Based on the above, the article presents the principles for selecting optimal road pavement design methods that provide the necessary operational characteristics and reliability over the service life under predetermined traffic volume conditions at a minimum cost.

Keywords: Road Pavement; Service Life; Structural layer; Structure.

Introduction

Pavement design is essentially an empirical science based on practical experience. The empirical-mechanical and engineering design system provides a unified pavement analysis procedure for evaluating existing pavements and predicting deterioration. The design procedure explained here is an empirical-mechanical one, combining elements of modeling with performance observations in determining the required pavement thickness for a set of design conditions. The empirical-mechanical and engineering design system is based on elementary physics and determines the stressed-deformed state of the pavement in terms of the normal and shear strength indicators under the impact of wheel loads. The empirical part of the design uses pavement operational reliability criteria to predict service life based on actual field performance observation. The layer thickness obtained from the above procedures should be considered as a minimum requirement and should not take into account construction tolerances. This is especially important in the case of layers of modified material.

Main Part

Design of Road Materials

For existing road pavements, test pits represent one of the common investigation methods to determine the thickness and type of the various pavement layers and to assess the condition of the sub-grade. Samples from each layer of the pavement and sub-grade can be taken for visual inspection and collected for subsequent laboratory testing. As a guideline, it is recommended to make two control pits every one KM, alternately on both sides of the roadway.

The Dynamic Cone Penetrometer (DCP) test is designed to provide the rapid in-situ measurement of the structural properties of existing road pavements and sub-grades. The DCP test results can be compared with laboratory test results. The DCP testing frequency is usually every 100 meters, but a testing interval of 200 meters can be sufficient.

Practitioners are encouraged to refer to the „TRL's Overseas Road Note 8, A User's Manual for A Program to Analyse Dynamic Cone Penetrometer Data", for a detailed discussion of DCP data analysis obtained from testing. Using data obtained from DCP and CBR tests, it is possible to determine the pavement thickness and quality of road construction materials. An example of dynamic cone penetrometer analysis is shown below in Figure 1.

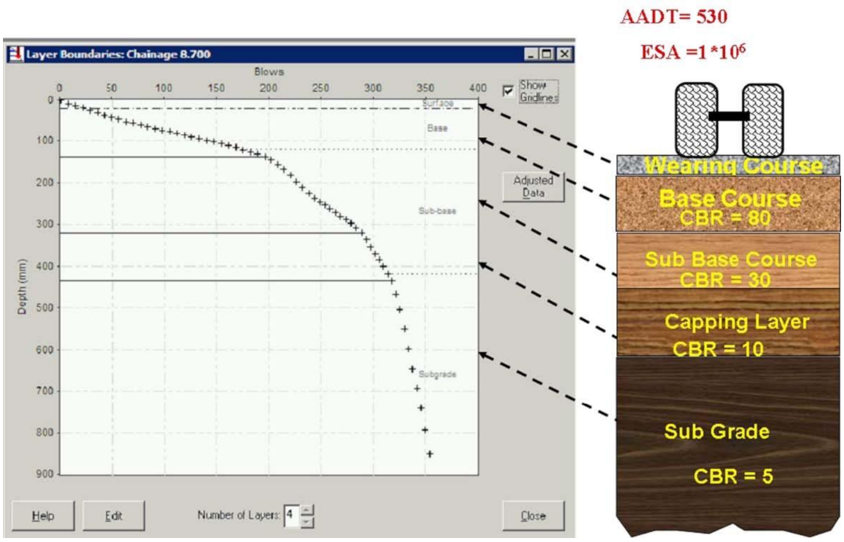

Fig. 1: Dynamic Cone Penetrometer Analysis Sample

In general, the use of improved sub-grade layers has the following advantages: provides additional protection during heavy axle loads; protects underlying earthworks; provides a running surface for traffic; promotes compaction of upper pavement layers; provides a homogenous sub-grade strength; acts as a drainage filter layer and is available for more economical use of materials.

Performance Characteristics of Road Pavement Layers

The thickness of unbonded base, sub-base, capping layer and sub-grade material specified in the design shall provide sufficient normal and shear strength, as shown in Figure 2, to support the expected load during the design service life of the pavement.

Surface design is based on providing a surfacing that is adequately durable to deformation under traffic loads, is resistant to atmospheric influences, has adequate skid resistance, is adequately smooth and is sufficiently wear-resistant during the design life of the pavement.

The optimal number of layers depends on the required stability, smoothness, and economy. Road pavements can come in a multitude of configurations and variations. For road design purposes, it is sufficient to consider some of the generally accepted solutions used to provide major all-weather access roads in the area. Roads can be categorized according to the main construction materials used in the pavement: earth; gravel or aggregate; bituminous mixes; concrete, and stone or brick.

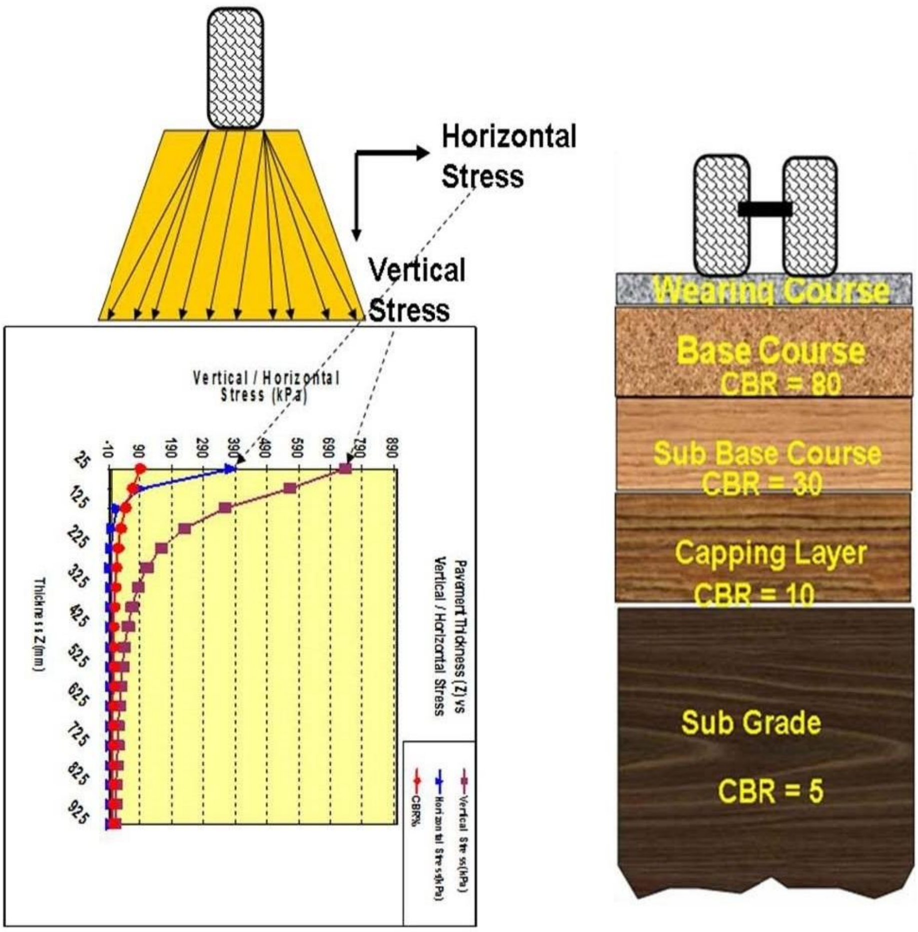

Fig. 2: Normal and shear strength characteristics of pavement layers

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The main steps to be followed in carrying out a design for a road pavement include:

- Estimating the volume of traffic and the cumulative number of standard axles that will use the road during the selected design life;
- Estimating the strength of the sub-grade soil over which the road is to be built;
- Selecting the most economical combination of pavement materials and layer thicknesses that will provide satisfactory service over the design life of the pavement.

Vehicle classification is an important aspect of traffic volume assessment (as well as equivalent axle load assessment). Vehicle types are typically defined according to the following breakdown (For reporting purposes, the breakdown can be further simplified and expressed in vehicle classes):

- Cars;
- (2) 4-Wheel Drive Vehicles;
- Small Buses;
- Medium and Large-size Buses;
- Small Trucks and Pickups;
- Medium Trucks; and
- Large, 2-Axle Truck.

Most often, traffic data will initially be available to the designer in terms of volumes, i.e., Average Annual Daily Traffic (AADT) for each vehicle class. It is noted that motorcycles and small cars do not contribute significantly to structural damage to roads. The AADT is defined as the total annual traffic summed in both directions and divided by 365. It is usually obtained by recording actual traffic volumes over a shorter period, from which the AADT is then estimated. Adjustments are usually required between the AADT based on recent traffic counts and the AADT during the first year of service. These adjustments can be made using growth factors. It is recommended that traffic counts to establish an average annual traffic figure for a particular site comply with the following practices:

The count is conducted over seven consecutive days. Some days are counted for a full 24 hours, preferably with at least one 24-hour count on a weekday and one on a weekend. A sixteen-hour count should be sufficient for the remaining days. Counting should be avoided during periods when the intensity of travel for short periods of time is abnormal due to wage payments, public holidays, etc. If possible, the seven-day count should be repeated several times throughout the year.

Future traffic volume is divided into the following three categories: traffic that would pass along an existing road or route even if no pavement improvements or rehabilitation works were provided; additional traffic caused by road improvements; Traffic that is changed from another route (or mode of transportation) due to improvements to the project road, but still travels between the same origin and destination.

The cumulative traffic for each class of vehicle is multiplied by the average number of equivalent standard axles of vehicles in that class to calculate the cumulative total number of equivalent standard axles over the life of the road. The Equivalence Factor (per axle) is defined as the pavement damaging effect of an axle in relation to the damage created by a standard axle which has a load of 10 tonnes. ESA (equivalent standard axle) is a standard axle load of 10 metric tons (or 100 kN). All axle loads are converted to equivalent standard axle loads (ESA) and pavement design is usually based on the total combined ESA value that the pavement will be expected to support over its design life.

The number of equivalent standard axles is related to the axle load as follows:

ESA = (P/10000)n (for loads in kg) or ESA = (P/100)n (for loads in kN) Where ESA = number of equivalent standard axles;

P=axle load (in kg or kN) and n = damage exponent.

The accumulated ESAs for each class for the design period are obtained by multiplying the cumulative traffic. The total cumulative standard axle load of all vehicle classes is obtained by adding the values for all classes.

Traffic on narrow roads is more channelized than on wide two-lane roads. In such cases, the effective traffic load is greater than for wide roads. Design traffic volume can also be a significant proportion of total traffic on roads, sometimes 20 to 40% of total traffic, and should be taken into account in the design of the wearing course. For high-volume roads detailed traffic analysis is warranted because environmental and traffic loading factors generally determine the performance of roads.

The main steps that must be taken when implementing a road pavement design include the following:

- estimating the amount of traffic and the cumulative number of standard axles that will use the road over the selected design life;
- assessing the strength of the sub-grade soil over which the road is to be built;
- selecting the most economical option of pavement materials and layer thicknesses that will provide satisfactory service over the design life of the pavement, taking into account local conditions of climate, traffic, available local materials and other environmental factors.

Based on the above, the main objective is to design an appropriate pavement structure with sufficient load-bearing capacity to accommodate the expected traffic during its design life at a given end-of-life service level.

Conclusion

The suitability of road pavement design methods can be assessed by taking into account the following factors:

The design traffic must be accurately determined to ensure the Equivalent Standard Axle (ESA) load range;

The design of the sub-grade should take advantage of a number of durable construction materials that are prevalent in large areas of the region;

Material classes should be represented in sufficient quantity to cover the full range and variety of properties of naturally occurring residual weathered rocks that occur extensively in the region;

Materials specifications should be based on proven field performance characteristics in relation to such factors as traffic volume, sub-grade design class, pavement design class and geo-climatic zone;

Depending on the quality of road construction materials, their selection should be made for optimal use in the structural layers of the road pavement, in order to maximally meet the requirements of durability and reliability, while remaining economically affordable.

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