CASE STUDY

Developing Pavement Thickness Design incorporating the Catalogue and Mechanistic Approach

New approaches are being taken to improve the design and durability of road pavement. Photo credit: ADB

A preliminary study in Sri Lanka provides important insights into mechanistic-empirical pavement thickness and overlay design for roadway networks.

Overview

During the last nine years, the Sri Lankan economy has grown rapidly. The government strives to, and encourages, continued growth. A prerequisite for this is an improved transport system and investments in the road network have been intensified.

For the last 9 years more than 10,000 km of roads were rehabilitated and around 150 km of new expressways were built. The government plans to build another 200 km length of expressways and to rehabilitate around 6,000 km of road within the next five years. The Road Development Authority of Sri Lanka is responsible for building, operating and managing national roads and expressways and provincial road agencies and local authorities are responsible for provincial and rural roads.

The current road pavement designs are based on empirical methods, based on Road Note 31, published by the Transport Research Laboratory about 30 years ago. The empirical methods restrict the material properties to specified limits and as a result, most of the soil and aggregates available in the country cannot be used for the road construction in an optimum way of usage. This situation has caused shortage of materials such as aggregates and as a solution the government expects to adopt the mechanistic-empirical approach for a road pavement thickness design.

Road networks in Sri Lanka are structurally designed according to Road Note 31, which restricts the indirect material property to a specified-limit of the California Bearing Ratio value. As a result, a large amount of in-situ soil and aggregates available in the country have not been used as roadway construction materials in the context of optimum quantity. This may also result in over-estimated or under-estimated catalogues of the current pavement design guide without any consideration of the structural capacity of a pavement system.

This situation has caused a shortage or overuse of materials. To solve this problem, the Sri Lankan government expects to adopt the mechanistic-empirical design system for new or overlay thickness design of pavements, especially for low-volume roads. Mechanistic-empirical design can provide flexibility in using a wide range of material properties because the pavement thickness design can be defined not by the indirect material property such as the California Bearing Ratio value but by mechanical responses, such as strain or stress in a critical location of a layered pavement system.

In January 2017, the Asian Development Bank and the Road Development Authority of Sri Lanka started a technical assistance project to develop the mechanistic-empirical design concept and procedure for a new road construction and the rehabilitation of existing pavements and to help the Road Development Authority prepare a comprehensive database system for pavement management and analysis in the near future.

Project snapshot

Dates	• **January 2017:** Approval Date • **August 2017:** Completion Date
Cost	• **US$ 138,000:** Cost
Institutions and Stakeholders	**Executing agency** • Korea Institute of Civil Engineering and Building Technology, South Korea **Financing** • Asian Development Bank • Road Development Authority, Sri Lanka

Challenges

The Road Note 31 is a catalogue pavement design guide, which is in the category of the first generation of the pavement design method, such as the empirical approach. The drawbacks in utilizing the empirical catalogue design method may be the lack of flexibility to introduce a new type of pavement system using in-situ materials in view of optimum amount and non-availability of mechanistic–empirical material property database.

Currently, the pavement design in Sri Lanka is carried out considering the traffic loading for a selected design period in terms of Equivalent Single Axle Load. While the asphalt surface is not treated as a structural layer especially for the double bituminous surface treatment (DBST), the structural capacities of unbound layers in base, subbase, and subgrade are generally characterized by California Bearing Ratio value with consideration of drainage capacity without and the calibration of seasonal variation.

A mechanistic analysis engine, including well-defined functions for material behavior, was needed to calculate the pavement responses. The pavement responses under the specified equivalent single axle load can be used as an independent variable to estimate the pavement performance life. The mechanistic-empirical design approach can provide flexibility in using a wide range of materials but is not optimum because the pavement thickness design can be defined not by the indirect material property of the California Bearing Ratio value but by the mechanistic responses such as strain or stress in a critical location of a layered pavement system.

Besides, an overlay design system was another challenge which is widely used in Sri Lanka but Road Note 31 doesn't cover anything about overlay design. Another challenge was to shift asphalt binder testing standards from Penetration grading to Superpave performance grading and a comprehensive rheological analysis for construction of Mastercurve for Sri Lankan asphalt binder.

For the successful implementation of aforementioned tools and lab tests, an overall roadmap explaining the time schedule and deliverables was proposed and roadmaps for individual systems were presented as a result of this project.

A Simplified Mechanistic-Empirical Design System

Mechanistic-empirical design requires short term and long term implementation plans. Short term and long term plans detail the time schedule for developing the mechanistic-empirical design engine for pavement response calculation, thickness design algorithm, and mechanistic-empirical design software for pre and post processes of the design and limited lab test and database preparation. The only difference between the two is that long term planning details are an additional feature of overlay design tools and database management systems.

The mechanistic-empirical design engine is supposed to calculate pavement responses due to axle loading. The engine can be developed by the layered elastic theory or continuum theory in the context of finite element approach. The concept of the design software is to verify the current catalogue of Road Note 31 based upon a mechanistic approach and have a function of a new structural pavement design also. A user can retrieve the graphical analysis results for all catalogues by a user query with respect to a location and traffic level. The design algorithm can be used for designing a new pavement structure in addition to the current catalogues.

Database System

The conceptual and logical database design can be done during the short-term plan. However, the physical database only includes a limited lab test, field test, and field survey data. The database should be interrelated with the mechanistic-empirical design tool, overlay design tool, and the pavement management system in the long run. A national specification for roadway construction can be effectively updated annually or else using the database system to decide a number of calibration factors after doing a multivariable regression analysis.

User requirement analysis, conceptual, logical, and physical database design can be done during the long-term plan. All the data will be interrelated by the entity-relation diagram and data flow diagram. A graphic user interface will be designed and implemented to manage all the data.

Overlay Design System

The mechanistic-empirical design of asphalt overlay pavements requires an iterative and trial and error approach. A designer must select a proposed trial overlay design and then analyze a design in detail to determine whether it meets applicable performance criteria (i.e., rutting and fatigue cracking) limited in a specification. If a particular trial overlay design does not meet the performance criteria, the design must be modified and reanalyzed until it meets the criteria. The design that meet the applicable performance criteria is then considered feasible from a structural and functional viewpoint and can be further considered for cost efficiency.

Asphalt Mastercurve

The mastercurve of an asphalt binder provides a relationship between the binder stiffness and reduced frequency over a range of temperatures and frequencies. For this purpose, complex modulus of asphalt