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Perpetual Pavements – An Enduring Flexible Pavement

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Abstract - Sustainability of road construction is one of the important factors disturbing the global environment, social development economy and in future. Several research projects are currently underway to study different construction methods, materials and designs that can improve the sustainability of roads. Although perpetual pavement is characterized by higher construction costs compared to conventional flexible pavement designs, they require less maintenance and less frequent rehabilitation over the 50 year lifecycle if designed and constructed properly. Pavement design can save on materials and energy used in maintenance over the pavement lifecycle and reduces the noise and emissions accompanied by maintenance activities. All these benefits lead to decrease in maintenance cost through the pavement lifetime and improve sustainability. Perpetual Pavements are a viable option for constructing structurally stable and long lasting roads with minimal maintenance and other overheads for Indian conditions
.Keywords— Perpetual Pavement (PP), Hot Mix Asphalt (HMA), Rich Bottom Mix (RBM), Stone Matrix Asphalt (SMA), Open Graded Friction Course (OGFC).

I. INTRODUCTION

Perpetual pavement in this study is defined as a bituminous pavement designed and built to last 50 years or more without requiring major structural rehabilitation or reconstruction. With perpetual pavements, the potential for traditional fatigue cracking is reduced, and pavement distress is typically confined to the upper layer of the structure. Thus, when surface distress reaches a critical level, an economical solution is to remove and replace the top layer. The perpetual pavement concept can be used for any pavement structure where it is desirable to minimize rehabilitation and reconstruction costs as well as minimize closures to traffic. These considerations are especially important on high traffic volume freeways where user delay costs may be prohibitive. In particular, in urban areas where new roads are being built, use of perpetual pavements may minimize future costs due to user delays and construction. Perpetual bituminous pavement is a very appealing alternative to concrete pavements, especially for large metropolitan areas.
Traditionally, bituminous pavements have been designed for a 20-year life, whereas perpetual pavements are expected to perform for 50 years or more. While there are some successes with perpetual pavements, there is a big gap in our understanding the design of this pavement. The main deficiency with the current perpetual pavement design method is that it does not ensure optimum structure and/or layers that have yet to satisfy 50 year design periods. However, through a sound pavement design methodology, it is possible to obtain optimal bituminous pavement structures that will last 50 years or more requiring only periodic top surface replacement. Such design methodology should include mechanistic pavement design, materials selection/innovation to improve durability and fatigue resistance, prediction of field performance, analysis of remaining service life and life-cycle cost. To this end, this study determines the combination of layer, stiffness, and thickness to produce optimal perpetual pavements. In particular, this study analyzes various alternatives of perpetual pavement structure through varying the thickness and stiffness of pavement layers. These analyses use the mechanistic-empirical design approach, and include an evaluation of the life cycle costs of the resulting alternatives.

II. THE PERPETUAL PAVEMENT CONCEPT

The PP concept was derived on a mechanistic principle that thickly designed HMA pavements with the appropriate material combinations, if properly constructed, will structurally outlive traditional design lives while simultaneously sustaining high traffic volumes/loads. The PP design philosophy is such that the pavement structure must:

- Have enough structural strength to resist structural distresses such as bottom-up fatigue cracking, permanent deformation, and/or rutting; and
- Be durable enough to resist damage due to traffic forces (abrasion) and environmental effects (e.g., moisture damage).

The PP mechanistic design principle thus consists of providing enough stiffness in the upper pavement layers to prevent rutting and enough total pavement thickness and flexibility in the lowest HMA layer to avoid bottom-up fatigue cracking.

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Like any other pavement structure, extended performance relies on a solid/stable foundation to provide long-term support to the pavement structure/traffic loading and to reduce seasonal support variation due to environmental effects (e.g., freeze-thaw and moisture changes).

A. Typical PP Structural Section

In general a PP structure consists of, but is not limited to, impermeable, durable, and wear resistant top layers; a stiff, thick rut-resistant intermediate layer for structural strength; and a flexible fatigue-resistant bottom layer resting on a permanent, stable foundation. The layer thicknesses are generally variable depending on the traffic loading, environmental location, and materials/mix-designs. However, the rut-resistant intermediate layers are often the thickest element, providing sufficient load carrying capability.

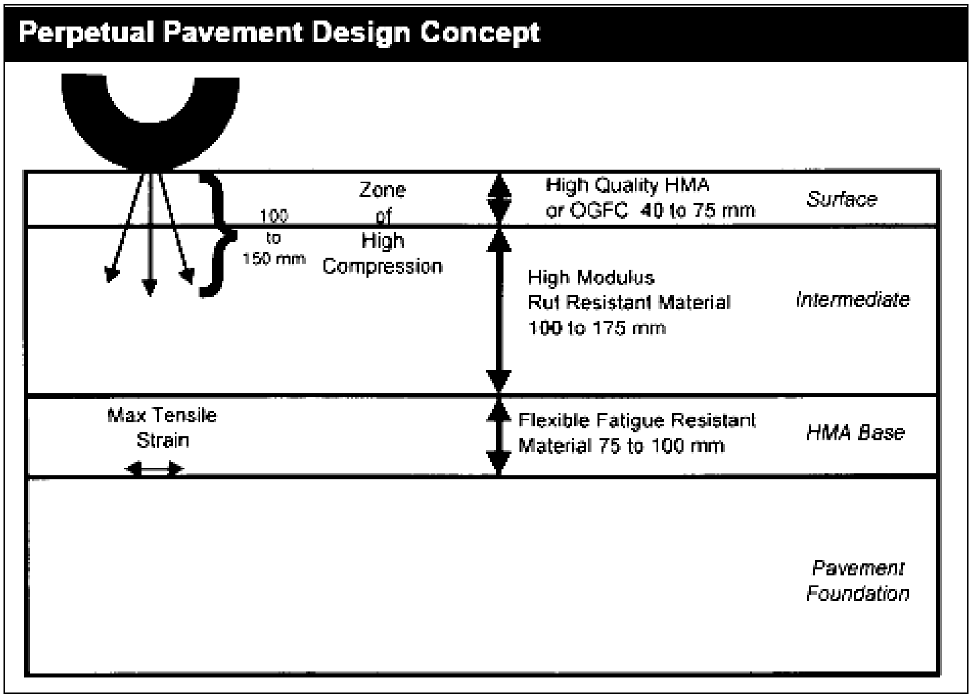

Fig 1. Typical Perpetual Pavement Section

III. PERPETUAL PAVEMENT DESIGN

A perpetual pavement structure should have unique mechanical and physical characteristics to accomplish long term performance. Washington State Department of Transportation defined several conditions that result in a pavement being considered a perpetual pavement design. The perpetual pavement sections should have a 40 to 50 year structural design life. The wearing course of a perpetual section should have a design to sustain a 20 year design life. The perpetual pavements layers are specifically designed so that all their distresses occur in the top surface course layer. Thus, a mill and patch rehabilitation is expected to be the primary maintenance activity throughout the pavement design life.

The perpetual pavement design theory limits the distresses to top-down cracking in the top bituminous lift which is designed as a high-quality, thin HMA layer. The pavement is maintained by milling and patching maintenance activity once pavement surface cracks are noticed on the road surface. These are repaired to limit the pavement roughness, to increase skid resistance, to increase tire-pavement interaction and to reduce noise. The lower HMA layers are designed to resist fatigue cracking, rutting, and permanent deformation. The perpetual pavement design structural performance is a function of the traffic loads, speed, climate, subgrade and pavement parameters, materials, construction, pavement compaction and maintenance quality.

The common theme for designing a perpetual pavement HMA section should consider designing every layer of the pavement cross section to fulfill the following conditions.

Construct the pavement section over a sound subgrade. Soil stabilization and treatment can be used to enhance the subgrade structural capacity.

Assemble a fatigue resistant HMA base layer to resist bottom-up fatigue cracking. This layer needs to be flexible to withstand freeze-thaw cycles without crack initiation taking place through it.

Install a rut resistant intermediate HMA layer. This layer is responsible for maintaining the rutting deterioration values within the accepted limits throughout the pavement lifetime.

A renewable surface course. This layer is designed to maintain skid resistance, reduce tire-pavement interaction noise and provide surface drainage through the road slopes.

The design of the fatigue resistant base layer can be implemented by using a softer binder and higher binder content. This increases the bituminous flexibility and eliminates crack development when subjected to traffic loading and freeze-thaw cycles. Rich Bottom Mix (RBM) layer incorporates an above optimum binder content. These layers showed superior performance and resistance to fatigue cracking. In addition, RBM layers reduce moisture susceptibility and enhance field compaction as it reduces in-place air voids in the field from7.0% to less than 6%. The intermediate layer is designed as a rut resistant layer. This can be achieved through designing a stable and durable layer with the new Superpave design methodology. The stability of bituminous mix is a result of stone-on-stone contact in the course aggregates. Thus, this layer is characterized by large nominal maximum size adding internal friction to the mix. An appropriate high temperature grade of bituminous binder is the factor which enhances the durability of the bituminous mix. The high temperature grade should be that of a surface grade to alleviate structural rutting.

The wearing surface layer is designed to withstand traffic and environmental conditions. It should be rut-resistant layer and eliminate surface cracking while providing a reliable surface drainage to prevent splash and spray. The surface course is usually designed as a dense-graded Superpave mix, Stone Matrix Asphalt (SMA) or Open Graded Friction Course (OGFC).While SMA and OGFC are expecting to result in better long-term performance results, the dense-graded Superpave mix is an acceptable option.

A. Mix Type Selection for PP

It is important to use the proper bituminous mixtures in the layers of a Perpetual Pavement keeping in mind that each layer serves specific functions. For instance, the lowest layer must provide excellent durability and the resistance to fatigue cracking. The intermediate layer provides both durability and rutting resistance, and the surface must be designed to withstand traffic and direct exposure to the environment. The use of reclaimed asphalt pavement (RAP) and recycled asphalt shingles (RAS) can help stiffen mixtures in providing rutting resistance, possibly without the addition of polymer modifiers. Simply increasing pavement thickness is not a guarantee that the pavement will have a long service life. Washington State's study of long-lasting pavements showed that in many cases pavements with shorter life-cycles in Washington were thicker than more fatigue resistant pavement structures. Other studies have shown that while increasing the thickness of a pavement will decrease the tensile strain at the bottom of the bituminous layer, the magnitude by which this reduction occurs is mix dependent. Thus, it is important to specify the right mixture for the right application in the pavement.

Table 2. Mix Type Selection Guide for Perpetual Pavements

Pavement Layer	Mix Type	NMAS, mm (in.)	Lift Thickness Range, mm (in.)[1]	Traffic Level, MESAL[2,3]		
				<0.3	0.3-10	>10
Base	Dense, Fine	37.5 (1-1/2)	110-150 (4.5-6)	√√	√√	√√
		25 (1)	75-100 (3-4)	√√	√√	√√
		19 (3/4)	60-75 (2.5-3)	√√	√√	√√
	Dense, Coarse	37.5 (1-1/2)	150-190 (6-7.5)	√√	√√	√√
		25 (1)	100-125 (4-5)	√√	√√	√√
		19 (3/4)	75-100 (3-4)	√√	√√	√√
	ATPB	37.5 (1-1/2)	75-100 (3-4)			√√
		25 (1)	50-100 (2-4)			√√
		19 (3/4)	40-75 (1.5-3)			√√
Intermediate	Dense, Fine	25 (1)	75-100 (3-4)	√√	√√	√√
		19 (3/4)	60-75 (2.5-3)	√√	√√	√√
	Dense, Coarse	25 (1)	100-125 (4-5)	√√	√√	√√
		19 (3/4)	75-100 (3-4)	√√	√√	√√
Surface	Dense, Fine	19 (3/4)	60-75 (2.5-3)	√√	√√	√
		12.5 (1/2)	40-60 (1.5-2.5)	√√	√√	√
		9.5 (3/8)	25-40 (1-1.5)	√√	√√	√
		4.75 (1/4)	15-20 (0.5-0.75)	√√	√√	√
	Dense, Coarse	19 (3/4)	75-100 (3-4)			√√
		12.5 (1/2)	50-60 (2-2.5)			√√
		9.5 (3/8)	40-50 (1.5-2)			√√
	SMA	19 (3/4)	50-60 (2-2.5)		√	√√
		12.5 (1/2)	40-50 (1.5-2)		√	√√
		9.5 (3/8)	25-40 (1-1.5)		√	√√
	OGFC	12.5 (1/2)	25-40 (1-1.5)			√√
		9.5 (3/8)	20-25(0.75-1)			√√

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B. Construction of PP

Construction of a Perpetual Pavement does not differ appreciably from conventional bituminous pavements, but it does require great attention to detail and a commitment to build it with quality from the bottom up. In the process of building the roadway or airfield, modern methods of testing should be employed to give continuous feedback on the quality of materials and construction.

The foundation must be able to support paving and compaction operations during construction. Materials for this layer may include sand or sandy-gravel subgrades, stabilized fine-grained subgrade, unstabilized or stabilized granular base materials, or rubblized concrete. Thus, this layer must be well-compacted, smooth and stiff enough to support construction traffic and provide resistance to compactors. It is recommended that in-situ testing of the foundation be used to ascertain both the quality and consistency.

When proper structural design and mix type selection processes are employed, good construction practices can ensure good performance. Issues that can surround the construction of the bituminous layers that can be detrimental to performance include lack of density, permeability to water, lack of interface bonding, and segregation

While construction procedures for Perpetual Pavements do not differ from normal best practices, it is important that close attention be given to all aspects of the production and placement of the material. To help ensure the longevity of the pavement structure, it is important that:

1) A strong and uniform foundation is prepared.
2) Optimum density in the bituminous mixtures is achieved.
3) The bituminous mix design, production, and placement lead to good uniformity.
4) Bonding between all pavement layers is achieved.
5) Normal quality control procedures are followed throughout the construction.

IV. ADVANTAGES OF PERPETUAL PAVEMENTS

Overall, some of the major benefits derived from perpetual pavements include the following:

High structural capacity for high traffic volume and heavy truck loads

Long life and low life-cycle costs with minimal or no major structural rehabilitation activities;

Decreased user costs due to rehab or maintenance delays; and competitive option to rigid pavements.

Because of the thicker and/or many HMA layers, the initial construction costs for PPs are often higher than that of conventional HMA pavements by more than 10 percent. However, the above benefits will generally outweigh this effect, particularly in the long-term, thus providing a sustainable solution to the ever growing traffic for the highway agencies. Another concern is the overall complexity, compelling the need for highly competent contractors. The multi-layered nature of these PP structures (often with multiple mix-designs and material types) means that quality control during construction is very critical and thus, the need for competent contractors

A. Need of Perpetual Pavements in India

As India is attaining greater modernization, the number of vehicles on the road is increasing significantly. This is imposing greater distress on the country's roads in the form of increased fatigue cracking and structural and surface rutting and directly increasing the maintenance cost and resource consumption. Pavements which are traditionally designed for 20 years need structural rehabilitation and reconstruction after their design life has been reached; this involves major traffic closures and rerouting adding to the rehabilitation cost. These considerations are especially important on high-traffic volume freeways where user delay costs may be prohibitive. Perpetual Pavements have been found to improve this situation as they are capable of maintaining the pavement performance for nearly 50 years without requiring major structural rehabilitation. They have gained a lot of importance in developed countries having been successfully constructed in USA, UK, and France. They are also being extensively studied in developing countries like China and recommended for India. The success of these Perpetual Pavements advocates their study and implementation in India while moving towards sustainable development.

The main feature of Perpetual Pavements is that they never need to be completely removed and replaced. In the world of pavements, this is the ultimate in economic and environmental sustainability. As only the surface is renewed and the base structure stays in place, there is considerable saving of construction materials. Also, the user-costs associated with construction delays are greatly reduced because routine maintenance can be done quickly in off-peak hours, unlike the remove and replace option which necessitates 24-hour road closures. In addition, significant fuel savings are achieved with pavements kept smooth by routine maintenance involving infrequent milling of the top layer for recycling, then placing a quiet, durable, safe new overlay. All these factors not only result in a more cost-effective design but also a reduction in the emission of greenhouse gases. By reducing greenhouse gas emissions, Perpetual Pavements can mitigate climate change, both now and for generations to come.

V. CONCLUSION

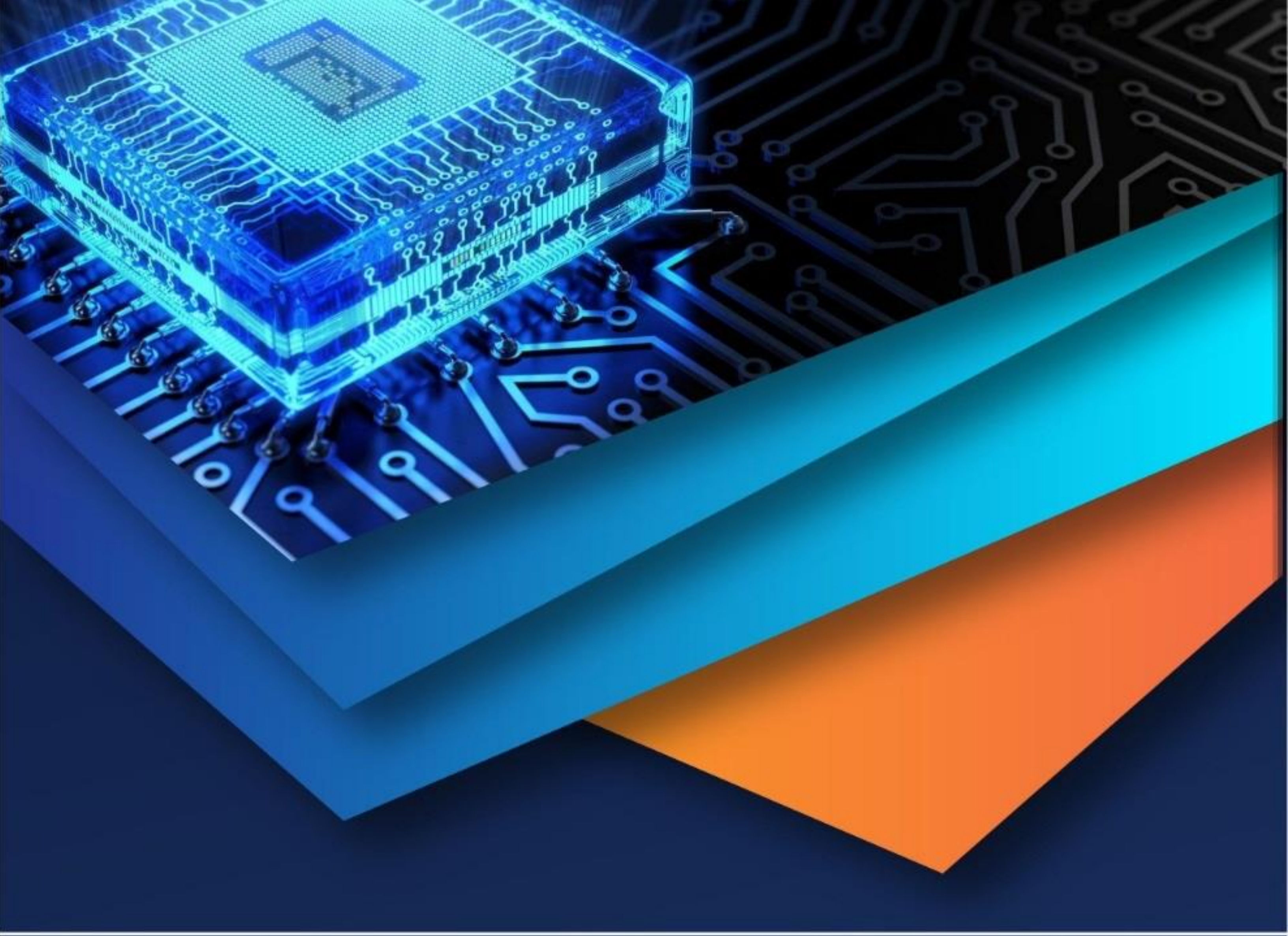
It can be concluded that Perpetual Pavements hold a lot of promise if implemented in India and require extensive study for suitable implementation on Indian roads. Though the pavement thicknesses proposed are not absolute, they provide a basis of comparing conventional bituminous pavements with Perpetual Pavements in order to prove the superiority of the latter.

Perpetual pavement designs are long life pavements with at least 50 year design life. Although the initial construction cost of perpetual pavements is higher than that of conventional pavement designs, the benefit of constructing the perpetual designs would be noticeable on the long term. Perpetual pavements are considered the most sustainable pavement designs for heavy traffic roads due to their superior structural performance thus limiting the maintenance and rehabilitation activities. The reduction of maintenance schedule would result in decrease in natural recourses consumption, energy saving and pollution reduction. The benefits resulting from perpetual design emphasizes that sustainable roads and perpetual designs are counterparts.

Currently, the constructed test section is being monitored and structurally evaluated through various data collected from embedded sensors and laboratory testing. The ongoing investigation will enable researchers to evaluate the benefits of constructing perpetual designs on heavy traffic road.

REFERENCES

[1] Lubinda F. Walubita& Tom Scullion, “Texas perpetual pavements – new design guidelines”, Performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration, December 2009.
[2] Transportation Research Circular, “Perpetual Bituminous Pavements”, TRB Committee on General Issues in Asphalt Technology (A2D05), Transportation Research Board National Research Center 2101 Constitution Avenue, NW, Washington, Number 503, ISSN 0097-8515, December 2001.
[3] David Newcomb, Richard Wills, David H. Timm, “Perpetual Asphalt Pavements-A Synthesis”, National center for Asphalt Technology, Washington, DC.
[4] “American Association of State Highway and Transportation Officials”(AASHTO). 2008.A Manual of Practice. Washington, DC.
[5] Rafiqul A. Tarefder, & Damien Bateman, “Future Design of Perpetual Pavements for New Mexico”, New Mexico Department of Transportation Research Bureau, Report No. NM08MSC-01, December 29, 2009.
[6] Mohab Y. El-Hakim & Susan L. Tighe, “Sustainability of Perpetual Pavement Designs: A Canadian ProspectiveN”, Department of Civil and Environmental Engineering, University of Waterloo, 200 University Avenue West,Waterloo, ON, Canada
[7] Deepthi Mary DILIP, Praveen RAVI, G.L. SIVAKUMAR BABU, “Life-Cycle Cost Analysis of Long Lasting Pavements”, Department of Civil Engineering and Centre for Infrastructure, Sustainable Transportation & Urban Planning (CiSTUP), Indian Institute of Science, Bangalore, India.
[8] IRC, “Guidelines for Design of Flexible Pavements” IRC:37-2012, Third Revision, The Indian Road Congress, July 2012.



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