PERPETUAL PAVEMENT: AN EMERGING CONCEPT

Roads play a vital role in modern economies by providing means for the movement of people, goods and other essential services. In case of developed countries, like USA in the early to mid 20th century, focus was on the construction of new pavements. In the latter part of the 20th century continuing into the 21st century, this focus has shifted mainly to the maintenance and rehabilitation of pavements. Highway engineers design pavements after carrying out all required investigations. However, pavements, particularly flexible pavements, even-though designed as per best specifications, usually do not serve for the design period efficiently, safely, comfortably, and economically due to early deterioration. Pavement deterioration is broadly a function of the original design, material types, construction quality, traffic volume, axle load characteristics, road geometry, environmental conditions and the maintenance policy pursued. It is in this context, the concept of "Perpetual Pavements" has emerged. This Perpetual Pavement concept was first launched by the Asphalt Pavement Alliance (APA) in a joint promotional effort with Asphalt Institute, National Asphalt Pavement Association, and the State Asphalt Pavement Associations of USA.

Perpetual Pavement is a term used to describe a long-lasting structural design, construction and maintenance concept. A perpetual pavement can last 50 years or more, if properly, maintained and rehabilitated. Research findings suggest that pavements with overall thickness of 370 mm or more should be able to withstand almost infinite number of axle loads without any significant structural deterioration due to either fatigue cracking or rutting. It is further observed that for flexible pavements with thickness of dense DBM layer of about 160 mm, normally exhibit only top down surface initiated cracking. Pavement life thus could be greatly increased, if surface initiated top down cracking and rutting can be suitably accounted for in design stage before they impact the structural integrity of the pavement. The long-lasting structural bases can be economically maintained by replacing just the wearing surface through recycling (milling) without any need for total removal and replacement of existing bases. It is, therefore, time to focus on Perpetual Pavement concept.

"Perpetual Pavement" utilizes a structural concept based on mechanistic design principles. The bituminous layer is broadly defined into three zones. The top zone is about 40 to 75 mm thick. This replaceable layer could be high quality bituminous mix (BC or HMA) or Open Graded Frictional Course (OGFC). In case of future strengthening or rehabilitation, this layer should be preferably scrapped before overlay. The second zone is high compression zone. This zone should be designed with high modulus Rut-resistant materials. The typical thickness could be between 125 to 200 mm. The third zone is maximum tensile strain zone and should be constructed with flexible fatigue resistant materials with the thickness between 75 to 100 mm. This third and bottom most zone of bituminous material rests on pavement foundation which are normally crust stone, like WMM and, therefore, the interface between the third zone and foundation should be free from any tensile strain.

Pavement life is inversely related to the magnitude of the traffic-induced pavement strains. These strains vary with the stiffness of various pavement layers. The stiffness of the asphalt varies with temperature. The performance of a pavement is directly related to the timing, type and quality of the maintenance it receives. Many climatic and environmental factors influence the surface temperature of the asphalt layer thereby influencing the performance of a pavement. Saturation of an unbound granular base course may lead to the premature failure of flexible pavements. Base course saturation results in increased flexural strains in the asphalt layers leading to cracking of the surface layer and increased rutting. Another most important contributing factor that greatly affects the pavement performance is roughness which is most evident to the traveling public. It greatly affects riding quality, safety, and vehicle operating costs. Flexible pavement roughness after a certain point of time generally shows a rapid increase.

Fatigue cracking originating at the bottom of an asphalt structure has long been acknowledged as the most costly form of distress to correct through rehabilitation. NCHRP observes that Bottom-up fatigue cracking occurs when repeated wheel loads impose tensile strains of sufficient magnitude to initiate cracking that eventually propagates up to the surface. Factors contributing to this form of distress include inadequate pavement structure, weak underlying materials, and HMA mixtures with inadequate material properties. For the purpose of designing and constructing a perpetual pavement all these concerns needs to be adequately addressed.

Perpetual Pavements limit the material strains to prevent damage accumulation. Understanding that fatigue cracking, which is the most devastating form of distress, affects the asphalt pavement's longevity and that fatigue cracking begins at the bottom and works its way to the top, a Perpetual Pavement is designed to resist the bottom-up fatigue cracking and structural rutting. Researchers have used this idea as well as pavement materials' research to develop a basic perpetual pavement structural concept. This concept uses a thick HMA pavement over a strong foundation designed with three layers, each one tailored to resist specific stresses as described above. Other specific distresses of concern would depend upon local experience. The wearing course is intended to be periodically cold-milled and overlaid with more HMA to restore condition. Proper construction techniques are essential to a Perpetual Pavement's performance.

Perpetual Pavement leads to increasing durability, as it is a product of mechanistic design modifying the age old long-standing empirical design. Most current pavement design procedures do not consider each pavement layer's characteristics relative to fatigue, rutting, and temperature cracking. So in recent years, engineers have increasingly developed what is called the mechanistic-empirical approach for use in analyzing the role of each layer in the pavement structure. In a mechanistically designed Perpetual Pavement, designers analyze how traffic stresses induce strain that will affect the pavement's performance, taking into account material qualities and thickness. So, by designing the pavement to keep strain below the critical level, fatigue failure is avoided and perpetual performance can be assured. New pavement design software Per Road 2.4, has been developed by National Center for Asphalt Technology at Auburn University, USA. This software is a perpetual or long-life, flexible-pavement design tool, to be used in conjunction with applicable design standards. This design tool is a mechanistic, not empirical, procedure for design of Perpetual Pavements. With this software, a design engineer can define the trial pavement structure, including the number of pavement layers, material types, material properties, variability and perpetual pavement thresholds. The program's deterministic mode may be used to estimate appropriate design thicknesses, and probabilistic mode may be used as the basis for final design. Finally, a cost analysis can be performed to estimate the cost per lane-kilometer based on the design thicknesses and materials in the pavement structure.

As per principle of Perpetual Pavement, pavement maintenance prolongs pavement life by slowing its deterioration rate. Preventive maintenance techniques are considered useful in extending the life of a pavement, if applied at the right time. Maintenance treatments include crack seals, fog seals, slurry seals, micro-surfacing, chip seals, thin asphalt concrete overlays, and other thin surface treatments. Ideally, scheduled preventive maintenance and periodic renewal of the sacrificial friction course would be the only work required on a Perpetual Pavement after initial construction. Such work could be done in a classic mill-and-fill operation at night, with reopening of the roadway in the morning, minimizing impact on the driving public. These maintenance activities on a section can also change the roughness of a section and repair of distressed areas can lead to a reduction of pavement roughness.

Maintaining a Perpetual Pavement can be compared to maintaining a house or any other structure. The owner may choose to paint it, put a new roof on it, or add to it. With Perpetual Pavement, Government organizations/contractors can maintain and even enhance an aging pavement, rather than breaking it up and hauling it away to a landfill, because the original structure is still sound and has great value. In addition, the process is environmentally friendly because the pavement material that is milled off is 100 per cent recyclable. Recent research in USA has shown that the asphalt pavement industry of USA is the nation's number one recycler. Also, easy acceptance criteria must be followed for achieving adequate thickness and adequate density of the placed and compacted materials. A procedure to measure the modulus of each pavement layer shortly after placement and after the completion of the project is carried out. Stress wave or seismic and GPR technologies have been used for this purpose. Simplified field and laboratory tests are suggested that can be rapidly and nondestructively performed and interpreted, so that any problems during the construction process can be adjusted. The field and laboratory methods are incorporated in a manner that their results can be readily reconciled without any scaling or simplifying assumptions. Therefore, the simplified laboratory tests can be used to develop the ranges of acceptable properties for a given material. Non-destructive field tests are performed to determine whether the contractor has achieved these levels.

NCHRP have also taken research study on Perpetual Pavements' Endurance Limit to Prevent Fatigue Cracking, so as to define an endurance limit for strain in the lower layers of HMA mixtures. This, in turn, would result in more efficient structural design of pavements for mixtures of different characteristics. Endurance Limit is a valid concept for HMA mixtures; its quantification could aid in the efficient design of long-life flexible pavements with a significantly reduced life cycle cost. Same efforts are required to be carried out in our research laboratories keeping an eye on our environment conditions alongwith economy in cost of construction. This can be accomplished through research, technology transfer, education and innovation etc.

It is time to shift towards good pavement management system, which could assist the decision makers in determining cost effective strategies for maintaining, upgrading and operating a network of pavements. Creating awareness about the Perpetual Pavements in respect of the fulfilling criteria like; nature of the original design; the overall quality of the pavement; the absence of structural failures; the condition of any long-lasting overlays; the existence of a history of low overall maintenance; the nature of the efforts that are made to minimize traffic disruptions during resurfacing is required, so as to develop long lasting road pavements. It is expected that different highway agencies of the country, like NHAI, MoSRT&H and State PWDs should sponsor some research schemes as part of their construction programmes to ensure that Indian pavements are long-lasting. We are a country with a road network second largest in the World at the same time, we are known for our poor roads. Constructing more roads without paying attention to their long-lasting characteristics is not desirable. Concepts like perpetual pavements must be given due encouragement by our highway agencies.

(V.K. Sinha)
Secretary General