PRESERVATION: A SUSTAINABLE PARADIGM FOR INDIA'S PAVEMENT INFRASTRUCTURE

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Abstract

India is in the midst of a tremendous expansion of both its airfield and roadway pavement infrastructure. Necessarily, the focus in this expansion is to deliver the facilities that will meet the needs of both the public and private sectors in an economical manner over the expected design life. Initially, the primary needs revolve around capacity, access, and safety. Over time, however, in addition to those needs it is important to consider reliability, maintainability, and sustainability, as these are keys to ensuring that India's growing infrastructure can serve its intended purpose in the long run. Many projects focus on design and construction, with little consideration given to the operation of the pavement. This can lead to a cycle in which pavements are constructed, put into service, allowed to deteriorate until they reach a highly distressed condition, and then are rehabilitated or even reconstructed, all at great cost. Not only is this economically unviable, it specifically fails to meet needs associated with safety, reliability, maintainability, and sustainability. Pavement preservation represents a recent paradigm shift in the approach being used to manage pavement networks. A key component of pavement preservation is preventive maintenance, which is briefly summarized as the practice of keeping good pavements in good condition without increasing their structural capacity. The overall practice of pavement preservation involves actively managing pavements early in their life cycle. This practice provides tangible benefits, including improved safety, rideability, reliability, lower operating costs, and less disruption to the traveling public. This paper identifies the key elements of a pavement preservation program, both for airfield and roadway pavements. It discusses the benefits of pavement preservation to the owner agency and pavement users. It also identifies the necessary components of a successful preservation program and the steps that should be taken to integrate pavement preservation into the operating agencies overall pavement management practices. These steps include the establishment of operating goals and performance measures for pavement networks, identification of the preservation strategies that will help to achieve those goals, development of guidelines for the use of those strategies, and the use of measurement and monitoring to track progress. It also identifies other best practices of agencies that have successfully initiated the paradigm shift toward pavement preservation. This paper is based on the authors' experience with preventive maintenance practices in state highway agencies in the United States, as well as observations of both roadway and pavement networks in India (such as at Bengaluru International Airport) and elsewhere.

Keywords: Pavement preservation, rideability, reliability

I. INTRODUCTION

The role that India's infrastructure plays in supporting its growth is well recognized, and after decades of stagnation the growth of India's transportation infrastructure is proceeding at a rapid pace. In the airport sector, in addition to the significant expansion projects well under way in Delhi and Mumbai and the recent completion of greenfield projects in Bangalore and Hyderabad, there are 35 to 48 airports targeted for upgrade and another 32 unused airports that the Indian Government wants to bring into operation [1]. Meanwhile, in the roadway sector "since 2004-05 26,883 kms of national highways have been completed, against 8,918 kms in the 5 years preceding this period" [2]. Plans for the future are no less ambitious: through the National Highways Development Project the Indian Government plans to add new roads, expand to four lanes certain National Highways, and upgrade other important National Highways, in all comprising 14,145 km and Rs 80,626 crore. This infrastructure growth is central to India's continuing economic development, facilitating commerce, the safe and efficient movement of goods, and the extension of services of all kinds to all regions of the country. This infrastructure growth is being accomplished through a variety of financing and contracting methods, including traditional public investments, design-build-maintain contracts, and public-private partnerships.

In the midst of this unprecedented growth it would be normal to expect that transportation network owner/operator agencies would emphasise capital development and downplay maintenance and preservation. In fact, following large investments in new or significantly upgraded pavement infrastructure, it is entirely reasonable to expect that this infrastructure would be in excellent condition for years to come. Most managers expect infrastructure in this condition to require minimal intervention; this in turn frees up funding to generate revenue, pay down debt, or develop even more infrastructure.

However, to avoid the misplaced priorities of many transportation agencies, it is precisely this new infrastructure that should receive attention, either now or in the very near future. What do we mean by this? Let us briefly consider the typical manner in which pavement infrastructure deteriorates. This is illustrated in Figure 1, which illustrates the change in network condition over time. At some time A, conditions have deteriorated to the point where major rehabilitation or reconstruction is needed. Performing that rehabilitation or reconstruction returns the pavement to a like-new condition and deterioration begins anew in a cyclical manner. This approach to managing a pavement network is often referred to as "worst first," in which actions are taken on those pavements in the network in worst condition first, then the next worst, and so on until there is no further funding available. On the surface, this approach makes sense both to owner agencies and to the traveling public: it extracts the most life out of the asset by delaying any action for as long as possible, and also maximises the time between large capital outlays. When works are carried out there is commonly little dissension about its actual need, as the poor conditions necessitating the work are plainly visible to all. The problem with this approach is at least twofold: it costs more to implement and it ensures that pavement conditions will become very poor before they are improved. Secondary problems include that the roadways may become unsafe before they are rehabilitated, and they will certainly become much rougher and more difficult to traverse.

The alternative is pavement preservation, which can be broadly defined as a network-level, long-term, cost-effective program that enhances the surface characteristics of pavements, extends pavement life, and improves safety [3]. A key component of preservation programs is preventive maintenance, formally defined as "a planned strategy of cost-effective treatments applied to an existing roadway system and its appurtenances that preserves the system, retards future deterioration, and maintains or improves the functional condition of the system (without increasing the structural capacity)" [4], and informally defined as "keeping good roads in good condition." In terms of pavement actions, preservation includes routine and corrective maintenance, preventive maintenance, and thin surface dressings (generally less than 40 mm thick). If the pavement is being strengthened or receiving other structural enhancements it is not considered preventive or pavement preservation. The remainder of this paper provides more background on pavement preservation in order to make the case for its role in the development of India's pavement infrastructure.

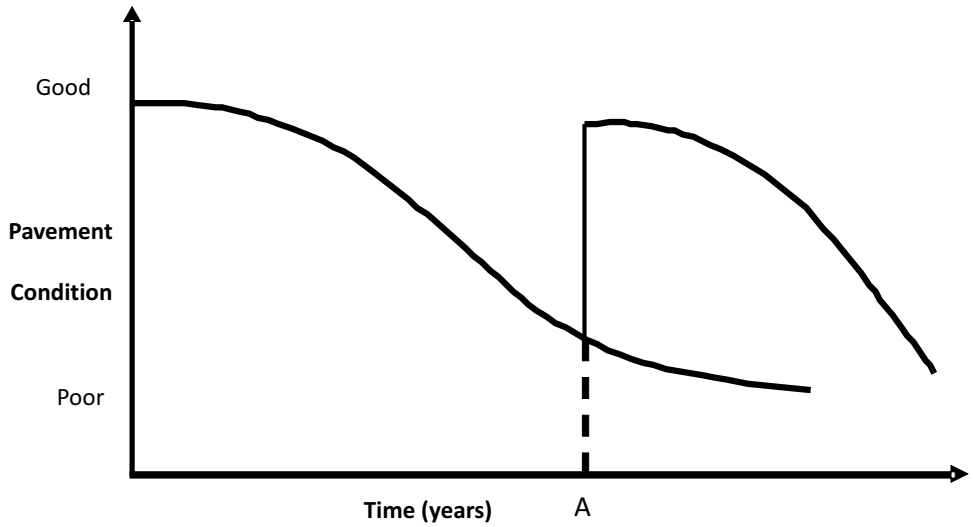

Fig. 1. Typical decrease in pavement condition over time with rehabilitation applied at Time A.

II. BENEFITS OF PAVEMENT PRESERVATION

It is proposed above that pavement preservation has distinct advantages over the "worst-first" alternative. Some of these advantages are briefly summarized here:

Improved pavement condition: several studies have compared pavement network performance under a worst-first and a preservation management philosophy and demonstrated that pavement preservation results in improved network health, as reflected in the percent of pavements in good, fair, and poor condition. Treating pavements earlier in their deterioration cycle increases the percent of pavements in good condition and decreases the percent in poor condition, especially in a long-term analysis. [5]

Lower operating costs: pavement preservation is performed earlier in the life of a pavement, while it is still in generally good condition. The types of treatments used in preservation have much lower initial costs than rehabilitation or reconstruction and are constructed with minimal disruption to traffic. When considering all of the different types of actions that can be taken on a pavement, from preventive maintenance and preservation to rehabilitation and reconstruction, as shown in Figure 2, it is noted that the treatments more closely associated with preventive maintenance that are applied early in the life of the pavement are likely to cost perhaps 10 percent of rehabilitation projects and 2 to 5 percent of reconstruction. From this it can be concluded that if preservation is appropriate it can be performed at a much lower cost than waiting until late in the life of the pavement.

It should be noted here that preservation does not eliminate the need for more expensive treatments; it merely postpones that need. In doing so, preservation is lowering the life-cycle costs of the pavement.

Increased safety: increased safety results in several ways. Many of the treatments used in pavement preservation improve surface texture, increasing pavement friction and wet weather friction in particular, and reducing splash and spray. Safety is also enhanced from operating on roads in better condition, as fewer crashes are associated with these improved conditions. Another safety benefit lies in the generally shorter work zones associated with preservation. Construction zones are inherently less safe than free flow conditions, and by shortening disruptions to normal traffic flow overall safety is improved.

Greater customer satisfaction: it has been common for maintenance and operations managers to focus on the technical needs of their networks. However, there is a growing recognition that a network of pavements ultimately exists to serve its users and their needs and interests must be considered. This connection is more obvious in tolled roadways, where the user pays to use the facility and expects a certain level of performance in exchange, but even in wholly public roadways it is reasonable to consider the public's needs and interests. Pavement preservation increases customer satisfaction in many of the ways previously

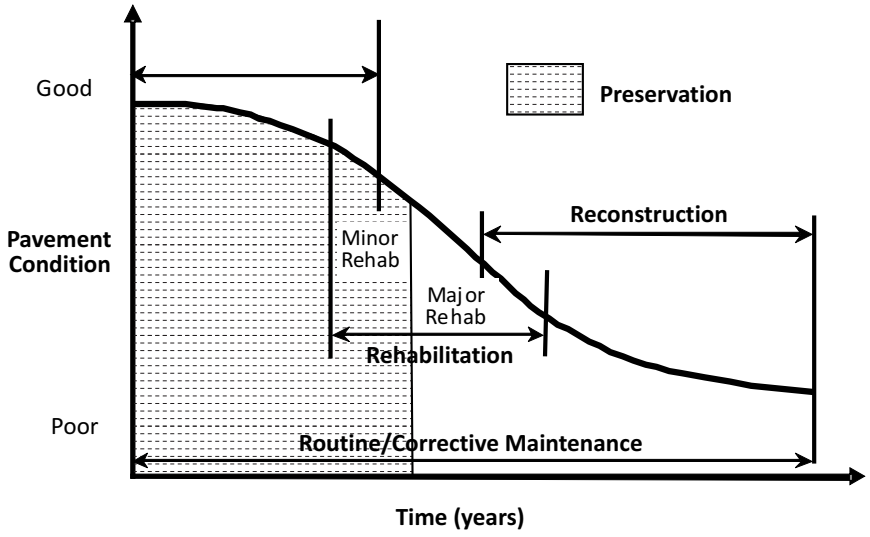

Fig. 2. Typical pavement performance over time showing the application of various categories of treatment.

discussed: roads are smoother and free of defects, improved surface characteristics lead to increased safety, and less frequent work zones insure minimal disruptions and delay.

III. KEY ELEMENTS OF A PAVEMENT PRESERVATION PROGRAM AND INTEGRATION WITH PAVEMENT MANAGEMENT

Formal pavement preservation programs are a fairly recent phenomenon. Tracing their history in the United States, in the late 1990s through 2004 perhaps 60 to 70 percent of state highway agencies stated they were practicing pavement preservation. [3]. Today that number is likely closer to 90 percent. From studying these programs, especially those recognised as being more successful, a number of common essential elements are identified. These are briefly described below.

Objectives

Objectives or goals define what an agency expects to accomplish in managing their pavements. These are not necessarily explicit regarding pavement preservation, but may be hard to accomplish without it. Objectives could address performance, safety, customer satisfaction, or some other goal or combination of goals. Examples include the following:

- In 5 years 90 percent of the primary road network and 75 percent of the secondary road network will have a condition rating of 85 or better (on a 100-point scale).
- By 2018 there will be a 25 percent reduction in pavement-condition related crashes.
- The average delay due to public works will not exceed 90 minutes.

These objectives can and should be specific to the pavement networks for which they are developed. What they will have in common are that they are important to that network, they are measurable, and they are achievable. This last is particularly important. If a network of pavements is in poor condition, a goal to improve overall conditions to a much higher level over a short time may not be feasible.

Inventory

Having an inventory of the pavement network helps in its management, whether it is through preservation, maintenance, or rehabilitation. The inventory contains data on the length and width of pavements, the pavement cross section, and the original construction date as well as the date of any subsequent treatments. A good inventory will also include a record of pavement performance at various times in the past. Today, network inventories are likely to be developed and maintained as part of a pavement management system or, increasingly, an asset management system.

Whereas a good inventory used to focus on original construction and major rehabilitation, today it must also include preservation. Many agencies can't demonstrate the effectiveness of their pavement preservation efforts because they are unable to locate where treatments are placed. As such, over time it is impossible to differentiate between the performance of treated and non-treated pavements. An explanation for this is that some preservation treatments are placed by in-house forces (rather than under contract) and the goal is to get the treatment placed rather than document its placement. However, if the location of a treatment can not be identified, especially in contrast to untreated locations, it is not possible to accurately attribute results to the presence (or absence) of the treatment.

Monitoring Program

Pavement performance is monitored through the conduct of regular pavement condition surveys. These surveys should be completed according to a well-defined, consistent and repeatable methodology in which parameters used in decision-making are measured and recorded. When condition surveys are completed as part of a regular schedule, they provide the information needed to report on overall conditions, to determine when treatments are needed, and to monitor the performance of those treatments. Surveys may be conducted via automated means or manually, but automated surveys are becoming increasingly common, especially for very large pavement networks or where manual surveys can not be safely carried out. In automated pavement condition surveys, specially equipped vans use imaging technology to capture data on pavement conditions and lasers to capture transverse profile (for rutting) and longitudinal profile (for roughness). To address the need for consistency and repeatability, methodologies such as ASTM D-5340-11 for airfield pavements [6] and ASTM D-6433-09 for roadway pavements [7] are used.

However, customized methodologies are also quite common, especially for roadway networks.

Again, monitoring is carried out as part of pavement management. Pavements should be evaluated so that conditions which would trigger the use of preservation treatments are recorded. Examples include cracking (fatigue and environmental), roughness, and surface texture. The pavement monitoring should also be linked to the agency's goals, so that no special efforts are needed to track progress toward those goals.

IV. PREVENTIVE MAINTENANCE TREATMENTS AND GUIDELINES FOR THEIR USE

A significant difference between pavement preservation and other approaches to managing pavements lies in the use of preventive maintenance treatments. These are treatments that are applied earlier in the life of a pavement, while it is still in good condition, to either prevent or slow down deterioration and improve surface conditions such as smoothness and texture. As noted previously, these treatments do not increase the load-carrying capability of the pavement. The treatments shown in Table 1 have all been used in preventive maintenance. Variations of these treatments, as well as other treatments, are also used. It is important to remember, however, that it is not the treatments themselves that define pavement preservation, but the combination of the treatment and the condition of the pavement at the time of their application. In other words, a chip seal placed on a pavement exhibiting severe fatigue cracking is not preventive maintenance. Using the same model performance curve shown in Figure 1, Figure 3 is a representation of the performance of a preventive maintenance treatment applied at approximately the correct time and the same treatment applied too late in the life of the pavement. The difference is that the treatment does not last very long and there is very little benefit realised from its application.

Table 1. Examples of preventive maintenance treatments for bituminous-surfaced and portland-cement concrete (PCC) surfaced pavements.

Bituminous surfaced pavement	PCC-surfaced pavement
Crack seal	Joint resealing
Fog seal	Diamond grinding
Sand seal	Load-transfer retrofit
Scrub seal	Slab stabilization
Chip seal	
Slurry surfacing	
Microsurfacing	
Thin hot-mix asphalt overlay	
Ultrathin bonded wearing course	
Cold in-place surface recycling	
Hot in-place surface recycling	

Guidelines for the use of preventive maintenance treatments strengthen pavement preservation programs. These guidelines reflect the types of pavements in an

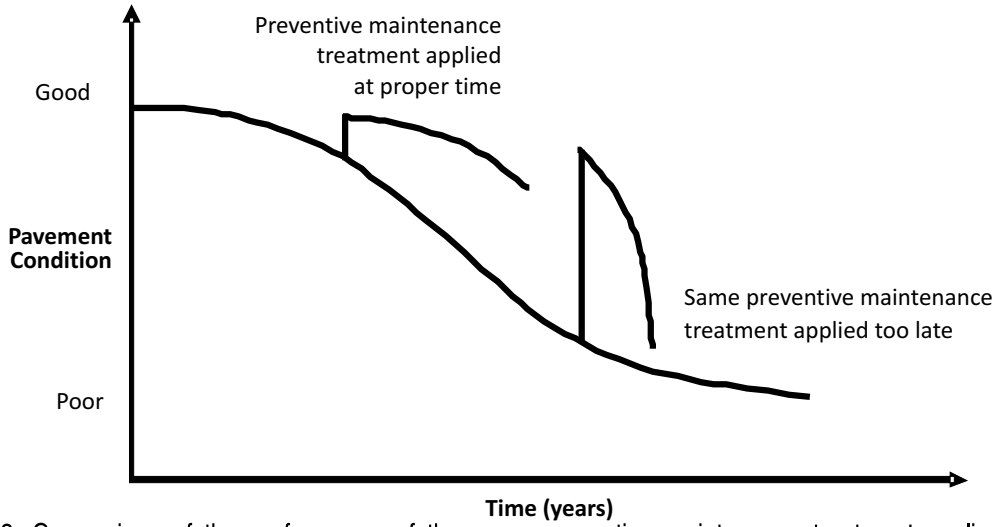

Fig. 3. Comparison of the performance of the same preventive maintenance treatment applied on time and too late.

Table 4. Feasibility matrix for final identification of candidate preservation treatments for HMA-surfaced pavements [8].

Preservation Treatment	Treatment Durability								Work Zone Duration Restrictions			Expected Performance on High Volume Facility, yrs	Relative Cost
	Rural Roads				Urban Roads				Overnight or Single-Shift	Weekend	Longer		
	High Traffic ADT > 5,000 vpd	Climatic Zone			High Traffic ADT > 10,000 vpd	Climatic Zone							
		Deep-Freeze	Moderate-Freeze	Non-Freeze		Deep-Freeze	Moderate-Freeze	Non-Freeze					
Crack Fill	●	●	●	●	●	●	●	●	●			2-3	$
Crack Seal	●	●	●	●	●	●	●	●	●			2-6	$
Slurry Seal (Type III)	○	×	◉	◉	○	×	◉	◉	●			3-5	$$
Microsurfacing-Single	◉	◉	●	◉	◉	◉	●	◉	●			3-5	$$
Microsurfacing-Double	◉	◉	●	◉	◉	◉	●	◉	●			4-6	$$/$$$
Chip Seal-Single Conventional Polymer-modified	◉	●	◉	◉	◉	◉	◉	◉	●			4-6	$$ $$$
Chip Seal-Double Conventional Polymer-modified	◉	●	◉	◉	◉	◉	◉	◉	●			6-8	$$/$$$ $$$
Ultra-Thin Bonded Wearing Course	◉	◉	●	◉	◉	◉	●	◉	●			5-8	$$$
Ultra-Thin HMAOL	○	○	◉	×	◉	◉	●	○	●			4-7	$$
Thin HMAOL	●	●	●	◉	●	●	●	◉	●			5-10	$$$
Cold Milling and Thin HMAOL	●	●	●	◉	●	●	●	●	●			6-11	$$$
Hot In-place Recycling Surf Recycle and HMAOL Remixing and HMAOL Repaving	○	○	○	×	○	○	◉	○	●			5-8 6-12 6-12	$$$ $$$ $$$
Cold In-place Recycling and HMAOL	◉	◉	◉	○	◉	◉	◉	◉	●			5-11	$$$
Profile Milling	◉	○	◉	◉	◉	○	●	◉	●			2-4	$
Ultra-Thin Whitetopping	○	○	○	○	○	○	◉	○	×	○	◉	NA	$$$$

● Highly Recommended ◉ Generally Recommended ○ Provisionally Recommended × Not Recommended

$ (lowest relative cost) ↔ $$$$ (highest relative cost)

agency's network, the expected performance of those pavement types, and the treatments that are available to address the expected performance. They are often presented either as a decision tree or in a matrix which relates treatments to performance measures. An example of what might be found in a decision matrix is provided in Table 4. It should be emphasised that the best guidelines are developed locally and reflect the local environment, traffic loadings, available materials, constructed pavement designs, construction quality, contractor capabilities, and available treatments. While there are many different guidelines available in the literature, it makes no sense to import them from elsewhere and expect them to be applicable.

While preservation offers valuable benefits to an agency and guidelines for realising those benefits are presented herein, the long-term sustainability of a pavement preservation program is unlikely

to be achieved if the program is not well integrated with the agency's overall practice of managing pavements. As such, the program elements described above (objectives, inventory, monitoring, treatments and guidelines) are essential to the long-term viability of successful agencies.

V. AGENCY BEST PRACTICES

Agencies that have established successful preservation programs share several common characteristics. Some of these are already noted, such as guidelines for treatment selection and timing. Others that have been identified [9] include the following:

- Dedicated funding, which enables planning so that treatments can be placed when the pavement conditions are such that they will still benefit from preservation. In India, this involves building funding for preservation into budgets as well as the reconstruction, recarpeting, and capacity improvements.
- Program integration, in which planning for preservation becomes an integral part of the management of a transportation network.
- Staffing, and especially staffing dedicated to preservation. This is especially important for mature organisations in which the traditional structures are oriented toward routine maintenance and reconstruction rather than preservation.
- Marketing, or the internal and external promotion of pavement preservation, has also helped successful programs. This can be necessary because there may be resistance to the idea of spending money on infrastructure that is in good condition rather than waiting until it is falling apart.

VI. OPPORTUNITIES IN INDIA TO PROMOTE THE CAUSE OF PAVEMENT PRESERVATION

As noted in the Introduction to this paper, the authors believe that implementing pavement preservation should be an essential part of the development and growth of India's infrastructure. Two examples are offered. The first is from the highway sector, in which a recent bid document for the six laning of Kishangarh-Udaipur-Ahmedabad section of NH-79A, NH 79, and NH-8 issued by the National Highways Authority of India under the National Highway Development Programme Phase V requires the development of a *Maintenance Manual* which will address both routine maintenance and reactive maintenance. The bid package also calls for the establishment of a Maintenance Programme that shall include a preventive maintenance schedule.

Unfortunately, there is no guidance on the components of preventive maintenance and many of the performance standards describe repairs made to defects (e.g., pothole repairs and limits on rut depth) rather than performance measures consistent with pavement preservation. Nonetheless, this is an opportunity for the winning concessionaire to use pavement preservation to maintain operations at a very high level while still making money. With the planned growth of the roadway network, this is a scheme that could be applied across the nation.

The second example relates to the recently completed airport at Bangalore. A greenfield project put into service in 2008, Bengaluru International Airport has implemented into its operations many cutting edge capabilities (see [10] and [11], for example). These relate to baggage handling, cargo, fueling infrastructure, and so on. While the traditional view might have been that the pavement infrastructure could be ignored for 5 to 10 years while other capabilities are built up, the Airport recognises that this is not possible. After 3 years of service the pavement facilities are being constantly evaluated both by visual condition surveys

and by automated means. While a preservation program is not yet in place, once a second runway is completed the Airport will have much greater access to implement preservation measures. When it does so, both the Operations team and the traveling public will be the beneficiaries.

VII. CONCLUSIONS

During the recent period of growth in India's airport and highway infrastructure, the focus of the responsible governing agencies has been on major works that add capacity. However, there exists an important opportunity to learn from practices around the world and also consider the preservation of this infrastructure. Whereas the typical practice among transportation agencies has been to postpone consideration of repairs until the system has deteriorated to the point where major rehabilitation or reconstruction is required, this is neither cost-effective nor beneficial for either the owner agency or the traveling public. Safety is also compromised with this approach.

This paper discusses benefits of preservation and describes some of the important components of preservation programs, including best practices. Examples of opportunities to apply the preservation concept to India's infrastructure are briefly mentioned and warrant closer investigation. Preventive maintenance and pavement preservation may not garner as much attention as adding capacity or upgrading old facilities, but these are the best means to proactively manage the existing infrastructure at high standards and in a cost effective manner.

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