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A General Characterization of Pavement System Failures, with Emphasis on a Method for Selecting a Repair Process

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This article provides an overview of pavement system failures; their potential causes and identifies a method for selecting a final repair process.

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Introduction

Regardless of the care exercised in planning, design, construction and maintenance of a pavement section, it will ultimately fail. It is when the failure occurs unexpectedly or prematurely that those involved in the planning, design, construction and maintenance of pavement sections are left to search for the causes and prevention of premature pavement failures and the resulting economic impact. Although the most common result of pavement failure is economic loss, a failure can result in a significant detriment to the lives and safety of passengers.

The primary purpose of a pavement section is to convey vehicles in a dependable manner for a designated period of time and provide both safety and comfort to the passenger. This simplistic task becomes a difficult problem to solve when factors of variable traffic frequency and load, variable pavement and subgrade materials, maintenance serviceability, the environment and economy are considered. It is these factors, which make the awareness of premature pavement failure, its causes, results and cures so important.

Definition

A pavement section may be generally defined as the structural material placed above a subgrade layer. In flexible pavement sections (asphaltic concrete) this is typically a multi-layer system composed of stabilization layer, base and surface layers each of which may be further subdivided. Subgrades are also considered as layers in pavement design with their thickness assumed to be infinite and their materials characteristics assumed to be unchanged or unmodified. Rigid pavement sections consist of portland cement concrete placed on a prepared base (usually called a subbase) or directly on the subgrade. Composite pavement sections consist of combinations of various sections of rigid and flexible pavements. Examples of this include asphaltic concrete overlays of rigid pavements and the use of rigid or semi-rigid base or subbase components such as soil-cement or cement treated materials in a flexible pavement section.

Failures

Although in a sense all pavement failures are functional failures, assigning failure categories makes the understanding of a failure somewhat easier. In a broad sense, failures may be categorized as structural, functional or materials failures. Certainly, these categories may overlap and the failure result from, or be contributed to, by one or more of the categories. Structural failure may be defined as the loss of load carrying capability of the pavement section resulting in the need for significant repair or replacement. A functional failure is a broader term, which may include the loss of any function of the pavement such as skid resistance, structural capacity, and serviceability or passenger comfort. A materials failure is the disintegration or loss of material characteristics of any of the component materials.

Early indications of pavement failure are not always available. Physical evidence of a failure is often too little, too late and significant, costly damage is already well on its way. Before the use of nondestructive testing became practical and economical, physical surveys were the primary means of failure discovery and failure prediction. Physical surveys supplemented by nondestructive examination and analyses are a common tool in the evaluation and characterization of a pavement system. Physical surveys that are most commonly used include those set up to provide the AASHTO Present Serviceability Index (PSI) for highway pavements and the Pavement Condition Index (PCI) for airfield pavements and highway pavements.

There is physical evidence available for each type of pavement failure. These manifestations of distress may be broadly classified as **cracking, distortion, disintegration and skid resistance**. In rigid or portland cement concrete pavements, cracking and disintegration are prominent forms of distress while in asphaltic concrete surfaces distortion (rutting, shoving), disintegration (raveling) and cracking (alligator, reflective) are relatively common.

Cracks in rigid pavements may be either traffic load induced, thermally induced, caused by chemical instability, caused by mix characteristics or by construction technique. These cracks vary in manifestation from slight crazing of the surface to full depth structural cracking causing loss of structural integrity. In assessing crack distress of concrete pavements it is important to recognize the relationships between the location and orientation of the cracking to its failure category. For example, crazing or map cracking is typically categorized as a materials or technique problem that, while affecting durability, has a little or no bearing on the structural integrity of the section, whereas large corner cracks in slab sections are significant structural problems.

Cracks in flexible pavement sections may be load induced fatigue, reflective (from cracks in the base), shrinkage or caused by a deficient mix design. Each type of crack shows up in a particular manner, for instance load induced cracks typically start as longitudinal cracks and progress to alligator cracking. Reflective cracks typically follow the shrinkage crack or joint pattern of the base material.

Distortion of pavement sections is defined as a change in the surface plane of the pavement resulting from post-construction compaction or consolidation, settlement, heave, shoving, or slab curl. Distortions seriously affect the riding quality of a pavement and are the items most often causing rider complaints.

Disintegration of the component materials can occur in rigid, flexible and composite pavement sections for a variety of reasons. Most disintegration problems are traceable to materials or mixture deficiencies.

Disintegration may include chemical reactions that can occur between cement and aggregates (alkali-silica or alkali-carbonate reactions), between the aggregate and groundwater (dissolving of carbonate aggregates in acidic groundwater), between the cement and groundwater (sulphate attack) and between or among other constituents. Chemical reactions range in severity from minor to major where entire pavement sections are required to be removed and replaced due to chemical instability of the components. Deficiencies in the mix proportions of both the asphaltic concrete and portland cement concrete can lead to severe disintegration in the form of raveling, scaling and spalling.

Loss of Skid Resistance is one of the most serious of pavement failures. This creates a significant detriment to the safety of the riding public. Loss of skid resistance may be caused by poor quality aggregate or aggregate that does not have adequate angularity, bleeding or flushing of an asphalt surface and the deposition of contaminants onto the surface.

A peripheral but equally important consideration in pavement failures is the drainage of the pavement system. Drainage can affect each category of pavement failure but typically affects the structural integrity and the skid resistance. Inadequate or improper drainage may cause materials characteristics of otherwise stable materials to become very unstable under load and thus create a variety of problems including potholes, depressions, and edge pumping and cracking. In the investigation of pavement failures, drainage must be considered.

Method for Selecting a Repair Process

Each type of pavement failure can be solved. The solutions may range from doing little or nothing and simply being aware that a potential problem exists to removal and replacement of an entire system. Both ends of the spectrum can prove to be quite costly. The key to solving pavement problems or failures is to follow a logical method for selecting an appropriate repair process.

Selecting an appropriate repair process or method will normally involve at least the following steps:

1. Identify/ classify anomalies, then thoroughly investigate and identify each failure aspect and analyze its cause
2. Identify system constraints such as traffic routing, funds, or other.
3. Perform literature/ information search.
4. Compare probable materials and techniques to system constraints.
5. Test the indicated materials.

6. Perform economic analysis.
7. Select and recommend appropriate materials and techniques to restore the pavement to serviceability.

It is imperative that each of the noted steps be compared to the issue at hand and applied in its appropriate context. As an example, if a pothole is a result of a petroleum spill on the surface of an asphaltic concrete pavement, then steps should be taken to mitigate petroleum spills, and only secondarily should consideration be given to changing the pavement design in an attempt to compensate for the probability of a future petroleum spill.

Materials, Techniques and Applications

Repair and rehabilitation are currently being performed all over the country to varying extents and with significantly variable success. Many techniques are being used and the list of materials employed is quite extensive. The unfortunate aspect of the existing technology is that there is little or no uniformity in materials, processes and technique and even fewer published guidelines for the initiation of such tasks. In short, procedural training and a concise application manual are greatly needed.

While many professional, technical or trade organizations provide specialized evaluation manuals, materials guides, and recommended techniques for a variety of pavement maladies, there has been a tendency of these groups to inadequately address the bridging of engineering evaluation to practical maintenance or rehabilitation strategy and application. The bridging process usually works well after a failure has occurred and there is a need for a full scale investigative, design, and specification effort; however, for the routine, daily interaction of the pavement system and its need for continuing attention and preventive maintenance, reliance is still placed on local individuals doing their best with local solutions, correctly or incorrectly applied.

Summary

In summary, the methods of detecting, classifying and repairing pavement system failures require using proper techniques, materials, and implementation of an economic feasibility study. The key to solving pavement system failures is the establishment and use of an ongoing method of repetitive repair processes integrated into a long-term maintenance and management strategy. Though the desired condition is to prevent being placed in the position of needing failure analysis by extensive front end planning and design, following good construction practices and controls, and developing and utilizing an active pavement management program, some failure is inevitable.

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