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Bituminous Pavement Failures

Surajo Abubakar Wada
M.Tech (Highway & Transportation Engineering),Department of Civil Engineering,Jodhpur National University, Rajasthan India

ABSTRACT
Pavement deterioration is a serious problem for road and traffic sector in almost every country, the most affecting causes of bituminous pavement failures have been studied in this paper. The paper describes the lessons learnt from pavement failures and problems experienced. Failures of bituminous pavements are caused due to many reasons or combination of reasons. Application of correction in the existing surface will enhance the life of maintenance works as well as that of strengthening layer. Along with the maintenance techniques there are various methods for pavement preservation which will help in enhancing the life of pavement and delaying of its failure.This paper discusses the possible causes of pavement failures, and recommendbetter ways to minimize and hopefully eliminate the causes of failures in bituminous pavements.
KEY WORDS:Deterioration, Bituminous pavements, Remedies, Causes of failure, Defects

I. PREAMBLE

The developing countries have lost precious infrastructures worth billions of dollars through deterioration of their roads. If their government do not do much to prevent their roads, they will lose billions more. Large road networks, built at great expense have been under maintained and more heavenly used and abused than expected. If this continues, the deterioration of roads will increase rapidly as the old pavements crumble and the new ones outlive the initial period during which the effects of neglect are barely noticeable (CSIR,1997). The cost of restoring these deteriorated roads is going to be much higher than expected for the timely effective maintenance.

Pavement deterioration on the other hand is very common in developing countries. Keeping roads in good condition is the most cost-effective way to save the pavements. (Okikbo,2012) refers to the road defects as the visible evidence of undesirable condition in the pavement affecting the service ability, structural condition or appearance. In his paper on road defects in Nigeria he indicates that the defects that most often cause injuries to people or damage vehicles include; inadequate road shoulders, uneven lanes, improperly marked signs, malfunctioning stop lights, construction negligence and municipal negligence. Legal framework and transportation management are the national aims in decreasing the road deterioration (Nordenegen and Oberholtzer,2006).

This seminar is aimed at identifying the factors that causes deterioration in bituminous pavement and their possible remedies.

II. GENERAL CONCEPT OF PAVEMENT:

The term pavement ordinarily means the surfacing layer only (Rangwala, 2013). But in highway design, it means the total thickness of pavement including surfacing, base and sub-base if any. It is a hard crust constructed over the natural soil for the purpose of providing stable and even surface for the vehicles. It is therefore a structure consisting of superimposed layers of materials above the natural soil subgrade, whose primary function is to distribute the applied vehicle loads to the subgrade. The pavement structure should be able to provide a surface of acceptable riding quality, adequate skid resistance and low noise pollution (Mathew and Rao, 2007).

Based on the structural behavior and for design purposes, the road pavements are generally ***classified*** into two categories namely;
(i) Flexible pavement, and
(ii) Rigid pavement

Other types of pavement structure include semi-rigid pavement or composite pavement and interlocking cement concrete block pavement (ICBP). However, these types of pavement are less common when compared to flexible and rigid pavement (Khanna, Justo and Veeraragavan, 2014).

III. SOME BASIC REQUIREMENTS OF A PAVEMENT

- It should be structurally sound enough to withstand the stresses imposed on it.
- It should be sufficiently thick to distribute the loads and stresses to a safe value on the subgrade soil.

- It should provide a reasonably hard wearing surface, so that the abrading action of wheels (Pneumatic and iron-tyred) does not damage the surface.
- It should be dust-proof so that traffic safety is not impaired by reducing the visibility.
- It should have a good riding quality and the surface should be impervious so that water does not get in to the lower layers of the pavement and the subgrade.
- The pavement should have long life and the cost of maintaining it annually should be low (Kadyali and Lal, 2012).

IV. INFLUENCING PARAMETERS ON PAVEMENT PERFORMANCE

The parameters/factors usually considered are as follows;

- Traffic Loads
- Subgrade Soil
- Climatic Factors
- Pavement Component Materials
- Drainage and Environmental Factors.

V. GENERAL CONCEPT OF PAVEMENT DETERIORATION:

Bituminous pavement deterioration generally takes place due to combined action of traffic, weather changes, drainage, environmental factors etc. Flexible pavements generally deteriorates at a very rapid rate when compared to rigid pavements due to the above factors, however, flexible pavements continue to deteriorate at a slow rate even without the traffic movement on the surface due to the climate and environmental factors (Khanna, Justo and Veeraragavan, 2014).

Rate of deterioration of bituminous pavement increases rapidly when water is retained in the void spaces of the bituminous pavement layers. Aging and oxidation of bituminous binder also lead to the deterioration of the bituminous surfacing.

VI. TYPES OF BITUMINOUS PAVEMENT DETERIORATION

The common types of distresses in bituminous pavement are classified in to the following four major groups; i.e

- surface deformation
- Cracking
- Disintegration, and
- Surface defects (Kadyali and Lal, 2012)

VII. SURFACE DEFORMATION

The surface deformation occurs usually due to failure or weakness in one of the layers of the pavement due to traffic movement after construction.The common types of surface deformation includes the following;

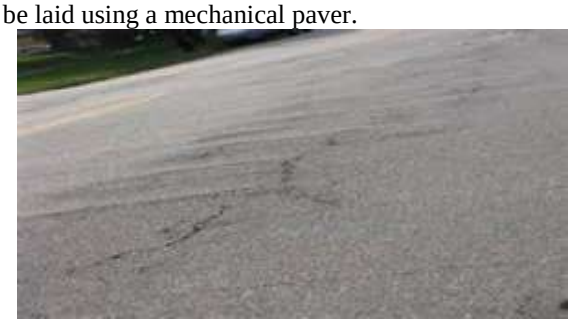
(a) Corrugations:

Corrugation is a form of bituminous pavement distress which usually occurs due to formation of regular and shallow undulations in the form of ripples or small corrugations of depth up to 25mm on the bituminous surface or across the road on some stretches.

The probable ***causes*** of corrugation include the following;

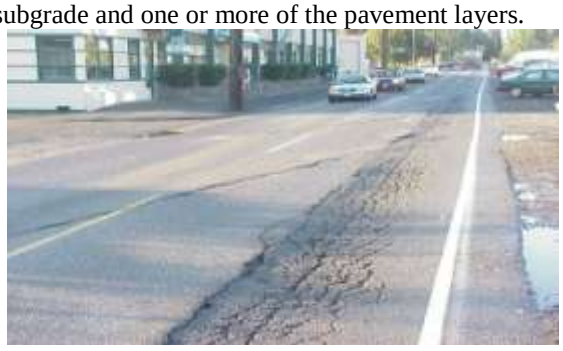
- Lack of stability in the bituminous mix
- Excess binder content in the bituminous mix
- Excess proportion of fines in the mix
- Use of binder of low viscosity with respect to the temperature of the region
- Faulty laying of surface course

The possible ***remedial measures*** for corrugation include scarifying the bituminous surfacing with corrugation and removing the surfacing along with top portion of the existing base course and re-compacting the material: After applying prime coat and tack coat another bituminous surface course may be laid using a mechanical paver.



(b) Rutting;

This is the longitudinal deformation or depression of the pavement surface along the wheel path of heavy vehicles formed due to repeated applications of heavy load along the same wheel path resulting in cumulative non-recoverable or pavement deformation of the pavement layers including subgrade and one or more of the pavement layers.



The various ***causes*** of rutting may be summed up as;

- Inadequate stability of the subgrade or sub-base or base course or surface course or few of these pavement layers.
- Inadequate compaction of the subgrade or any of the pavement layers
- Channelized movement of heavy wheel loads causing significant vertical stress on the subgrade
- Improper design and specification of bitumen mix
- Inadequate thickness of the pavement or weak pavement structure

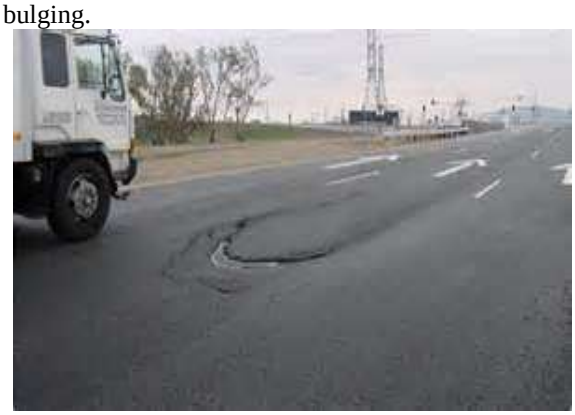
And the possible ***remedial measures*** for this type of distress include;

- Cleaning the affected surface
- Application of tack coat and covering the ruts
- Filling the ruts using either a dense graded bituminouss mix or open graded pre-mix followed by seal coat
- Compaction by rolling
- Providing a thin bituminous resurfacing course to achieve good riding quality.

The remedial measures may include either total reconstruction of the pavement starting from laying new subgrade or partial reconstruction of the affected portion along the pavement, starting from the subgrade depending upon the severity of the failure.

(c) Shoving;

Shoving is a form of plastic movement resulting in a localized bulging of the pavement surface. Shoving can take a number of different forms such as upheaval, "wash boarding" or ripples across the pavement surface, or even a crescent –shaped bulging.



The ***causes*** of shoving include the following;

- Lack of stability in the bituminous mix
- Too much binder content in the hot mix
- Use of rounded and smooth textured aggregate particles in the mix
- Excess proportion of fines in the mix

The ***remedial measure*** for shoving is the removal of the materials to firm base and relaying a stable mix.

(d) Shallow depressions:

Shallow depression are small localized bowl-shaped area that may include cracking. Depressions usually causes the roughness on the bituminous pavement surface and are hazardous to automobiles, and they also allow collection of water on the pavement surface.

The probable ***causes*** of depressions are the presence of inadequate compacted pocket or rather a localized consolidation or movement of the supporting layers beneath the surface course due to instability.

Remedial measures include filling with pre-mix materials, excavating and rebuilding the localized depressions, and reconstruction is required for extensive depressions.

(e) Settlement and Upheaval:

Settlement and upheaval occurs due to large deformation of the pavement surface caused by expansion of the supporting layers beneath the surface course or the subgrade

The ***causes*** due to this kind of distress include; poor compaction of fills, poor drainage, inadequate pavement or frost heave.

The ***remedies*** to this include carrying out one of the following;

Where the fill is weak, the defective fill should be excavated and re-done. And where inadequate pavement is the cause, the pavement should be strengthened.

VIII. CRACKING

The presence of surface cracks significantly reduces the life of bituminous pavements. This is because the surface cracks are one of the main contributors to the development of other different types of cracks in bituminous layers. They accelerate the development of cracking which would ultimately lead to early failure of the pavement (Halim et al., 1993).

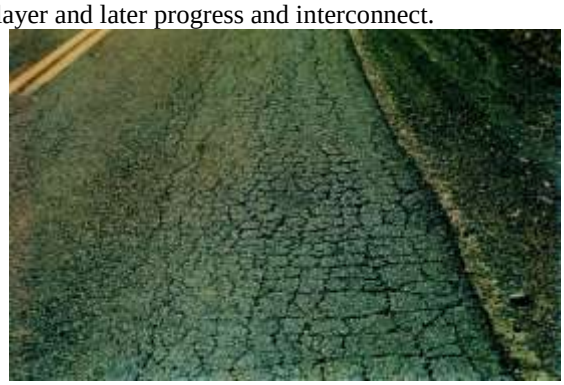
The common types of cracks include the following;

(a) Fatigue cracking (b) Transverse cracking (c) Longitudinal cracking (d) Edge cracking and (e) Reflective cracking

(a) Fatigue Cracking:

Fatigue cracks are a series of longitudinal and interconnected cracks caused by the repeated application of wheel loads. This type of cracking generally starts as short longitudinal cracks in the wheel path and progress to an alligator cracking pattern (Interconnected cracks) as shown below.It happens due to repeated bending action of the hot mix asphalt HMA (surface layer) when the load is applied, this generates tensile stress that eventually

creates cracks at the bottom of the asphalt layer. Cracks gradually propagates to the top of the asphalt layer and later progress and interconnect.



The possible ***causes*** include inadequate structural support which can be caused by a number of things. A few of the more common ones are listed here;

- Decrease in pavement load support characteristics.
- Loss of base, sub-base or sub-grade support (e.g poor drainage orspring thaw resulting in less stiff base).
- Stripping on the bottom of the HMA (surface layer) (the stripped portion contributes little to the pavement strength, so effective HMA thickness decreases).
- Increase in loading (more than design load)
- Poor construction (e.g Inadequate compaction)

The ***remedial measures*** for a fatigue cracks generally includes;

- Removal of the cracked pavement area then digging out and replacing the area of poor sub-grade and improving the drainage of that area if necessary.
- Patch over the repaired sub-grade.
- Alternatively, place the HMA overlay over the entire pavement surface. This overlay must be strong enough structurally to carry the anticipated loading because the underlying fatigue cracked pavement most likely contribute little or no strength (Roberts et.al., 1996)

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(b) Transverse Cracking:

These are cracks perpendicular to the pavement centerline or lay down direction, they usually begin as hairline and widen with age. If not properly sealed and maintained, multiple cracks develop parallel to the initial crack.

Possible ***causes*** to this type of cracking include;

- Shrinkage of the HMA surface due to low temperature or asphalt binder hardening.
- Reflective crack caused by cracks beneath the surface layer

The ***remedial strategies*** depend upon the severity and extent of cracking.

Low severity cracks (<1/2-inch-wide and infrequent cracks);

Seal the cracks to prevent:

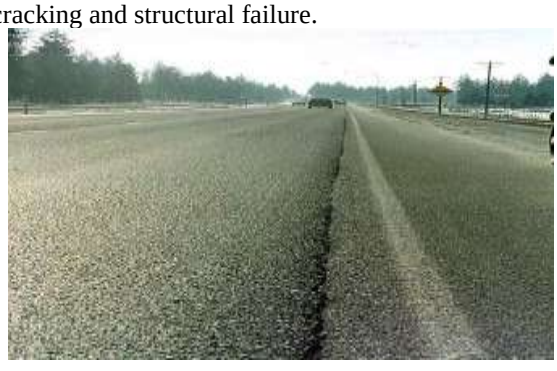
- Entry of moisture in to the sub-grade through the cracks.
- Further raveling of the cracked edges.

HMA can however provide years of satisfactory service after developing small cracks if they are kept sealed (Roberts et.al., 1996)

High Severity Cracks (>1/2 inch wide and numerous cracks); Remove and replace the cracked pavement layer with an overlay.

(c) Longitudinal Cracking:

These are cracks parallel to the pavement centerline or lay down direction, which may eventually lead to moisture infiltration, roughness, and may indicate the possible onset of alligator cracking and structural failure.



The possible ***causes*** include poor drainage, shoulder settlement, weak joints between adjoining spread of pavement layers or differential frost heave.

The possible ***treatment***depends on whether the pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with low viscosity binder or slurry seal or fog seal depending on the width of the cracks. Unsound cracked pavements would need strengthening or rehabilitation treatment.

(d) Edge Cracking:

Edge cracks typically starts as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. They may occur in a curbed section when subsurface water causes weakness in the pavement

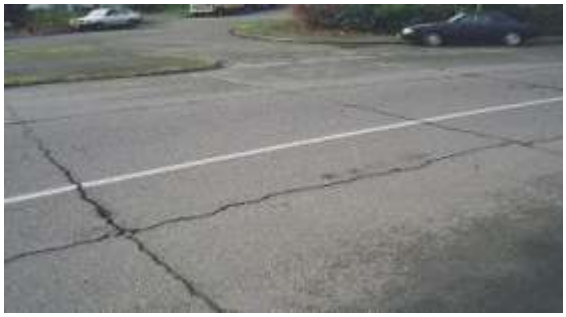
This type of cracking ***result*** from lack of support of shoulders due to weak materials or excess moisture. Frost heave and inadequate pavement width also contributes towards formation of this type of distress.

The ***remedial measures*** include filling the cracks at low severity. As the severity increases, patches and replacement of distress areas may be needed. In all the cases, the excessive moisture should be eliminated and the shoulders rebuild with good materials.

(e) Reflective Cracking:

Reflective cracking has been traditionally thought to initiate at the bottom of the lower pavement layers and then propagate to the surface (Abd El Halim ,1987)

Reflective cracks generally develop in bituminous resurfacing or an overlay constructed over an existing cracked bituminous surface without resorting to appropriate measures.



The most common ***causative*** agents of this type of cracking are due to joints and cracks in the pavement layer underneath.

The possible ***treatment*** depends on whether the pavement is structurally sound or unsound. Where the pavement is structurally sound, the cracks should be filled with low viscosity binder or slurry seal or fog seal, depending the width of the cracks. Unsound cracked pavements will need strengthening or rehabilitation treatment.

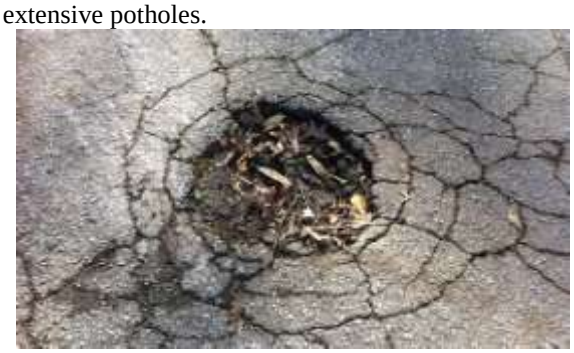
IX. DISINTEGRATION

The progressive breaking up of the pavement into small, loose pieces is called disintegration. The two most common types of disintegration are:
(a) Potholes and (b) Patches

(a) Potholes

Potholes are small, bowl-shaped depressions in the pavement surface that penetrate all the way through the hot mix asphalt (HMA) layer down to the base course. They generally have a sharp edges and vertical sides near the top of the hole.

Causes:Generally, potholes are the end result of fatigue cracking. As fatigue cracking becomes severe, the interconnected cracks creates small chunks of pavement which can be dislodged as vehicles pass over them. The remaining hole after the pavement chunk is dislodged is called a pothole.***Repair*** by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes.



(b) Patches:

An area of pavement that has been replaced with new materials to repair the existing pavement. A patch is considered a defect no matter how well they

perform because it never completely meshes with the existing pavement nor is it structurally bound to it.

The ***causes*** include the previous localized pavement deterioration that has been removed and patched, and also the utility cuts along the pavement.
Repairs: Patches are themselves a repair action, but the only way they can be removed from the pavement surface is by either a structural or non-structural overlay.

X. SURFACE DEFECTS

Surface defects are related to problems in the surface layer. The most common types of surface distress are:
(a) Raveling (b) Bleeding (c) Polishing

(a) Raveling

Raveling is the loss of material from the pavement surface as a result of insufficient adhesion between the asphalt, cement and the aggregate. Raveling typically tends to occur on an older pavement that have already oxidized. Raveling can be accelerated by traffic and other environmental conditions. A raveled pavement can be repaired with a wearing course or an overlay.

(b) Bleeding:

Bleeding occurs when the bituminous mix contains too much asphalt cement relative to the aggregates. In this case, the asphalt cement tends to bleed through the surface, hence, reducing the skid-resistance of a pavement thereby making the pavement very slippery when wet, creating hazard to the road users. This problem is generally ***caused*** by the presence of excessive binder content in the mix and also using the binder with too low viscosity (too flowable) or an improperly applied seal coat. Bleeding occurs more often in hot weather when the bituminous binder is less viscous (more flowable) and the traffic forces the asphalt to the surface.

The ***repairs***include eitherthe application of a chip seal using absorbent aggregates or to mill off the top the top layer of the asphalt and apply a new course of hot mix asphalt (HMA) that contains a lower asphalt cement content.

(c) Polishing:

Polishing is a failure mode of the pavement surface consisting of rough exposed aggregates which is ***caused*** by excess repeated traffic on an aging pavement system. It can result in a dangerous low friction surface with a decreased skid-resistance. ***Repair*** the surface by applying a skid-resistant slurry seal or a non-structural overlay.

XI. CONCLUSION AND RECOMMENDATIONS

Road deterioration is a critical situation for road sector because of the high cost for construction of new roads and maintenance of existing roads and routes.Restoring serviceability of bituminous pavements has significant economic and societal benefits as the pavements plays an important role in our daily life thereby providing safe and a convenient means of transportation which is one of the major aspect of our life. However, insufficient funding often limits the timely repairs and rehabilitation of the pavements.Therefore, better funding and management should be provided in order to keep the pavements in good condition and from getting damaged due to the aforementioned distresses. Global warming on the other hand has also taken deep impact in many countries nowadays, and this phenomenon also influences the performance of the pavement in different ways. Therefore, instead of inclining solely towards global warming issues, designing of pavements should also be upgraded for better climate resistance.

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