ANALYSIS OF BITUMINOUS ROAD FAILURES CAUSES AND PREVENTION

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ABSTRACT

The daily traffic volume has increased considerably. It has increased by more than 100% as per the traffic study done during the study in the year 2015. This increase in the traffic took place in a very short span of time. As a result of growth in heavy traffic loads and their tyre contact pressure with adverse climatic conditions, fatigue and rutting performance has resulted in an interest towards the use of bituminous materials. Bitumen is used in road construction due to various properties and advantages it has over other pavement construction materials.

Pavement deterioration is a serious problem for road and traffic sector in almost every country. The most affecting causes of bituminous road failures have been studied. Failures of bituminous pavements are caused due to many reasons or combination of reasons. Application of bitumen in the existing surface will enhance the life of the pavement and delaying of its failure. In this project we have discussed the possible causes of pavement failures and recommend better ways to minimize and hopefully eliminate the causes of failures in bituminous pavements. By applying the recommended preventions to the failures of the bituminous roads the workability, efficiency, durability of the road can be increased. For every cause of the road failure, preventions are recommended and by considering these steps, the various failures of the bituminous roads can be eliminated and smooth flow of vehicles on the roads can be achieved. Various modifiers are added while using the bitumen in the construction of roads by using these modifiers.

INTRODUCTION

Bitumen also known as Asphalt is a sticky, black and highly viscous liquid or semi-solid form of petroleum. It may be found in natural deposits or may be a refined product; it is a substance classed as a pitch. Until the 20th century, the term asphaltum was also used.

Bitumen gains certain unique properties that are inbuilt in it during its manufacture. The bitumen as a raw material in flexible road construction and bitumen as a mix (composing other materials i.e. aggregates/ pozzolans) serves certain advantages, that prompt to use bitumen widely in road construction. Bitumen is a by-product of crude oil distillation process. Crude oil itself is a composition of hydrocarbons. The crude oil is pumped from storage tanks, where it is kept at about 60°C, through a heat exchanger system where its temperature is increased to typically 200°C by exchanging heat gained from the cooling of newly produced products in the refining process. The crude is then further heated in a furnace to typically 300°C where it is partly vaporized into an Atmospheric Distillation Column. Here the physical separation of the components occurs. The lighter components rise to the top and the heaviest components (the atmospheric residue) fall to the bottom of the column and pass through a second heat exchanger prior to treatment in a vacuum distillation column. Finally, Bitumen is obtained by vacuum distillation or vacuum flashing of atmospheric residue from the vacuum distillation column. This is "straight run bitumen". This process is called bitumen production by straight run vacuum distillation.

Bitumen is a civil engineering material used for construction of highways in terms of flexible pavements. One of the advantages of bitumen as an engineering construction material is its great versatility. Bitumen is a strong binding material that has very high adhesive property and highly waterproof and durable, making it useful in road Constructions. It is also highly resistive to the actions of most acids, alkalis, and salts.

The primary use (70%) of asphalt/bitumen is in road construction, where it is used as the glue or binder mixed with aggregate particles to create asphalt concrete. Its other main uses are for bituminous waterproofing products, including production of roofing felt and for sealing flat roofs.

Certain additives or blend of additives called as bitumen modifiers can improve properties of Bitumen and
bituminous mixes. Bitumen treated with these modifiers is known as modified bitumen. Polymer modified bitumen (PMB)/ crumb rubber modified bitumen (CRMB) should be used only in wearing course depending upon the requirements of extreme climatic variations. The detailed specifications for modified bitumen have been issued by IRC: SP: 53-1999. It must be noted that the performance of PMB and CRMB is dependent on strict control on temperature during construction. The advantages of using modified bitumen are as follows

- Lower susceptibility to daily and seasonal temperature variations
- Higher resistance to deformation at high pavement temperature
- Better age resistance properties
- Higher fatigue life for mixes
- Better adhesion between aggregates and binder
- Prevention of cracking and reflective cracking

Since a bituminous mix prepared with modified bitumen has higher stiffness modules, enhance fatigue life, better resistance to creep and higher indirect tensile strength, it is suitable as a wearing course, a binder course and overlay material on surface which are cracked and subjected to heavy traffic. Modified binders are also used for application like Stress Absorbing Membrane (SAM) for sealing cracks, Stress Absorbing Membrane Interlayer (SAMI) for delaying reflection cracking, porous Asphalt and Stone Matrix Asphalt (SMA).

Modified bitumen performs better than conventional bitumen in situation, where the aggregates are prone to stripping. Due to their better creep resistance properties, they can also be used at busy intersection, bridges decks and roundabouts for increased life of the surfacing.

**Literature review**

The aim of this study is not only to analyze the failures and causes of bituminous roads, but also to provide good quality preventions and to study various bituminous tests through an experimental investigation.

Bituminous materials or asphalts are extensively used for roadway construction, primarily because of their excellent binding characteristics and water proofing properties and relatively low cost. Bituminous materials consists of bitumen which is a black or dark coloured solid or viscous cementations substances consists chiefly high molecular weight hydrocarbons derived from distillation of petroleum or natural asphalt, has adhesive properties, and is soluble in carbon disulphide. Tars are residues from the destructive distillation of organic substances such as coal, wood, or petroleum and are temperature sensitive than bitumen. Bitumen will be dissolved in petroleum oils where unlike tar.

Bitumen is an essential component of any pavement and is used widely throughout the world. It can be termed as the building block of the pavements without which all the pavement materials would behave independently and thus will be deemed useless. Almost ninety percent of bitumen is used in road construction. It is usually available in dark colours ranging from brown to black. The main purpose of bitumen in flexible pavements is to strongly bind and hold the other pavement components together and provide a smooth and levelled surface for the moving vehicles. Bitumen is a naturally occurring material and is found in large quantities in the solid or semi solid forms of petroleum. It is also manufactured artificially in vast amounts globally.

Bitumen mixed with some other materials has always been used as a sealant and adhesive material over the ages. It was also widely used in the water proofing of boats and ships as it is insoluble in water. Highest applications of bitumen are found in the construction filed for the construction of roads, airports etc, in the hydraulic field for the construction of water tanks, dams, bridges etc, is also used in battery making, tyre making and for the thermal and acoustic insulation purposes.

**Tests On Bitumen**

There are a number of tests to assess the properties of bituminous materials. The following tests are usually conducted to evaluate different properties of bituminous materials.

1. Penetration test
2. Ductility test
3. Softening point test
4. Specific gravity test
5. Viscosity test
6. Flash and Fire point test
7. Float test
8. Water content test
9. Loss on heating test

**Penetration test**

It measures the hardness or softness of bitumen by measuring the depth in tenths of a millimeter to which a standard loaded needle will penetrate vertically in 5 seconds. BIS had standardized the equipment and test procedure. The penetrometer consists of a needle assembly with a total weight of 100g and a device for releasing and
locking in any position. The bitumen is softened to a pouring consistency, stirred thoroughly and poured into containers at a depth at least 15 mm in excess of the expected penetration. The test should be conducted at a specified temperature of 25°C. It may be noted that penetration value is largely influenced by any inaccuracy with regards to pouring temperature, size of the needle, weight placed on the needle and the test temperature. A grade of 40/50 bitumen means the penetration value is in the range 40 to 50 at standard test conditions. In hot climates, a lower penetration grade is preferred.

Ductility test

Ductility is the property of bitumen that permits it to undergo great deformation or elongation. Ductility is defined as the distance in cm, to which a standard sample or briquette of the material will be elongated without breaking. Dimension of the briquette thus formed is exactly 1 cm square. The bitumen sample is heated and poured in the mould assembly placed on a plate. These samples with moulds are cooled in the air and then in water bath at 27°C temperature. The excess bitumen is cut and the surface is leveled using a hot knife. Then the mould with assembly containing sample is kept in water bath of the ductility machine for about 90 minutes. The sides of the moulds are removed, the clips are hooked on the machine and the machine is operated. The distance up to the point of breaking of thread is the ductility value which is reported in cm. The ductility value gets affected by factors such as pouring temperature, test temperature, rate of pulling etc. A minimum ductility value of 75 cm has been specified by the BIS. Figure 4.2 shows ductility moulds to be filled with bitumen.

Specific gravity test

In paving jobs, to classify a binder, density property is of great use. In most cases bitumen is weighed, but when used with aggregates, the bitumen is converted to volume using density values. The density of bitumen is greatly influenced by its chemical composition. Increase in aromatic type mineral impurities cause an increase in specific gravity.

The specific gravity of bitumen is defined as the ratio of mass of given volume of bitumen of known content to the mass of equal volume of water at 27°C. The specific gravity can be measured using either pycnometer or preparing a cube specimen of bitumen in semi solid or solid state. The specific gravity of bitumen varies from 0.97 to 1.02.
Viscosity test

Viscosity denotes the fluid property of bituminous material and it is a measure of resistance to flow. At the application temperature, this characteristic greatly influences the strength of resulting paving mixes. Low or high viscosity during compaction or mixing has been observed to result in lower stability values. At high viscosity, it resists the compactive effort and thereby resulting mix is heterogeneous, hence low stability values. At low viscosity instead of providing a uniform film over aggregates, it will lubricate the aggregate particles. Orifice type viscometers are used to indirectly find the viscosity of liquid binders like cutbacks and emulsions. The viscosity expressed in seconds is the time taken by the 50 ml bitumen material to pass through the orifice of a cup, under standard test conditions and specified temperature. Viscosity of a cutback can be measured with either 4.0 mm orifice at 25°C or 10 mm orifice at 25 or 40°C.

Figure 4: Viscosity Test

Pavement Deterioration and Its Types:
Pavement deterioration is the process by which distress (defects) develop in the pavement under the combined effects of traffic loading and environmental conditions. Types of Pavement Deterioration. The four major categories of common asphalt pavement surface distresses are:

- Cracking
- Surface deformation
- Disintegration (potholes, etc.)
- Surface defects (bleeding, etc.)

Cracking:
The most common types of cracking are:

- Fatigue cracking
- Longitudinal cracking
- Transverse cracking
- Block cracking
- Slippage cracking
- Reflective cracking
- Edge cracking

Fatigue Cracking (Alligator Cracking):
Fatigue cracking is commonly called alligator cracking. This is a series of interconnected cracks creating small, irregular shaped pieces of pavement. It is caused by failure of the surface layer or base due to repeated traffic loading (fatigue). Eventually the cracks lead to disintegration of the surface, as shown in Figure. The final result is potholes. Alligator cracking is usually associated with base or drainage problems. Small areas may be fixed with a patch or area repair. Larger areas require reclamation or reconstruction. Drainage must be carefully examined in all cases.

- Longitudinal cracking:
Longitudinal cracks are long cracks that run parallel to the centre line of the roadway. These may be caused by frost heaving or joint failures or they may be load induced. Understanding the cause is critical to selecting the proper repair. Multiple parallel cracks may eventually form the initial crack. This phenomenon, known as deterioration, is usually a sign that crack repairs are not the proper solution.

- Transverse cracking:
Transverse cracks form at approximately right angles to the centerline of the roadway. They are regularly spaced and
have some of the same causes as longitudinal cracks. Transverse cracks will initially be widely spaced (over 20 feet apart). They usually begin as hairline or very narrow cracks and widen with age. If not properly sealed and maintained, secondary or multiple cracks develop, parallel to the initial crack. The reasons for transverse cracking, and the repairs, are similar to those for longitudinal cracking.

In addition, thermal issues can lead to low-temperature cracking if the asphalt cement is too hard. Figure shows a low-severity transverse crack.

- **Block cracking:**
  Block cracking is an interconnected series of cracks that divides the pavement into irregular pieces. This is sometimes the result of transverse and longitudinal cracks intersecting. They can also be due to lack of compaction during construction. Low severity block cracking may be repaired by a thin wearing course. As the cracking gets more severe, overlays and recycling may be needed. If base problems are found, reclamation or reconstruction may be needed.

- **Slippage cracking:**
  Slippage cracks are half-moon shaped cracks with both ends pointed towards the oncoming vehicles. They are created by the horizontal forces from traffic. They are usually a result of poor bonding between the asphalt surface layer and the layer below. The lack of a tack coat is a prime factor in many cases. Repair requires removal of the slipped area and repaving. Be sure to use a tack coat in the new pavement.

- **Reflective cracking:**
  Reflective cracking occurs when a pavement is overlaid with hot mix asphalt concrete and cracks reflect up through the new surface. It is called reflective cracking because it reflects the crack pattern of the pavement structure below. As expected from the name, reflective cracks are actually covered over cracks reappearing in the surface. They can be repaired in similar techniques to the other cracking noted above. Before placing any overlays or wearing courses, cracks should be properly repaired.

- **Edge Cracking:**
  Edge cracks typically start as crescent shapes at the edge of the pavement. They will expand from the edge until they begin to resemble alligator cracking. This type of cracking results from lack of support of the shoulder due to weak material or excess moisture. They may occur in a curbed section when subsurface water causes a weakness in the pavement. At low severity the cracks may be filled. As the severity increases, patches and replacement of distressed areas may be needed. In all cases, excess moisture should be eliminated, and the shoulders rebuilt with good materials.

Surface Deformation:
Pavement deformation is the result of weakness in one or more layers of the pavement that has experienced movement after construction. The deformation may be accompanied by cracking.

Surface distortions can be a traffic hazard.

The basic types of surface deformation are:

- Rutting
- Corrugations
- Shoving
- Depressions
- Swell

- **Rutting:**
  Rutting is the displacement of pavement material that creates channels in the wheel path. Very severe rutting will actually hold water in the rut. Rutting is usually a failure in one or more layers in the pavement. The width of the rut is a sign of which layer has failed. A very narrow rut is usually a surface failure, while a wide one is indicative of a sub grade failure. Inadequate compaction can lead to rutting. Figure shows an example of rutting due to sub grade Failure. Minor surface rutting can be filled with micro paving or paver-placed surface treatments. Deeper ruts may be shimmmed with a truing and levelling course, with an overlay placed over the shim. If the surface asphalt is unstable, recycling of the surface may be the best option. If the problem is in the sub grade layer, reclamation or reconstruction may be needed.

- **Corrugation:**
  Corrugation is referred to as wash boarding because the pavement surface has become distorted like a washboard. The instability of the asphalt concrete surface course may be caused by too much asphalt cement, too much fine
aggregate, or rounded or smooth textured course aggregate. Corrugations usually occur at places where vehicles accelerate or decelerate. Minor corrugations can be repaired with an overlay or surface milling. Severe corrugations require a deeper milling before resurfacing.

- Shoving:
  Shoving is also a form of plastic movement in the asphalt concrete surface layer that creates a localized bulging of the pavement. Locations and causes of shoving are similar to those for corrugations. Figure shows an example of shoving. Repair minor shoving by removing and replacing. For large areas, milling the surface may be required, followed by an overlay.

- Depressions:
  Depressions are small, localized bowl-shaped areas that may include cracking. Depressions cause roughness, are a hazard to motorists, and allow water to collect. Depressions are typically caused by localized consolidation or movement of the supporting layers beneath the surface course due to instability. Repair by excavating and rebuilding the localized depressions. Reconstruction is required for extensive depressions.

- Swell:
  A swell is a localized upward bulge on the pavement surface. Swells are caused by an expansion of the supporting layers beneath the surface course or the sub grade. The expansion is typically caused by frost heaving or by moisture. Sub grades with highly plastic clays can swell in a manner similar to frost heaves (but usually in warmer months). Repair swells by excavating the inferior sub grade material and rebuilding the removed area. Reconstruction may be required for extensive swelling.

- Disintegration:
  The progressive breaking up of the pavement into small, loose pieces is called disintegration. The disintegration is not repaired in its early stages, complete reconstruction of the pavement may be needed.
  The two most common types of disintegration are:
  - Potholes
  - Patches

- Potholes:
  Potholes are bowl-shaped holes similar to depressions. They are a progressive failure. First, small fragments of the top layer are dislodged. Over time, the distress will progress downward into the lower layers of the pavement. Potholes are often located in areas of poor drainage, as seen in Figure. Potholes are formed when the pavement disintegrates under traffic loading, due to inadequate strength in one or more layers of the pavement, usually accompanied by the presence of water. Most potholes would not occur if the root cause was repaired before development of the pothole. Repair by excavating and rebuilding. Area repairs or reconstruction may be required for extensive potholes. Potholes caused by poor drainage.

- Patches:
  A patch is defined as a portion of the pavement that has been removed and replaced. Patches are usually used to repair defects in a pavement or to cover a utility trench. Patch failure can lead to a more widespread failure of the surrounding pavement. Some people do not consider patches as a pavement defect. While this should be true for high quality patches as is done in a semi permanent patch, the throw and roll patch is just a cover. The underlying cause is still under the pothole. To repair a patch, a semi-permanent patch should be placed. Extensive potholes may lead to area repairs or reclamation. Reconstruction is only needed if base problems are the root source of the potholes.

- Surface Defects:
  Surface defects are related to problems in the surface layer. The most common types of surface distress are:
  - Raveling
  - Bleeding
  - Polishing
  - Delamination

- Raveling:
  Raveling is the loss of material from the pavement surface. It is a result of insufficient adhesion between the asphalt cement and the aggregate. Initially, fine aggregate breaks loose and leave small, rough patches in the surface of the pavement. As the disintegration continues, larger aggregate breaks loose, leaving rougher surfaces. Raveling can be accelerated by traffic and freezing weather. Some ravelling in chip seals is due to improper construction technique. This can also lead to bleeding. Repair the problem with a wearing course or an overlay.

- Bleeding:
  Bleeding is defined as the presence of excess asphalt on the road surface which creates patches of asphalt cement. Excessive asphalt cement reduces the skid-resistance of a pavement, and it can become very slippery when wet, creating a safety hazard. This is caused by an excessively high asphalt cement content in the mix, using an asphalt cement with too low a viscosity (too flow able), too heavy a prime or tack coat, or an improperly applied seal coat. Bleeding occurs more often in hot weather when the asphalt cement is less viscous (more flow able) and the traffic forces the asphalt to the surface. Figure 13 shows an example of bleeding during hot weather.

- Polishing:
Polishing is the wearing of aggregate on the pavement surface due to traffic. It can result in a dangerous low friction surface. A thin wearing course will repair the surface.

Causes of Pavement Deterioration:
Sudden increase in traffic loading especially on new roads where the design is Based on lesser traffic is a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road. This accelerates the fatigue failure (Alligator Cracking). Temperature variation ranging from 50º C to below zero conditions in the plain
- Areas of North and Central India leads to bleeding and cracking. Provision of poor shoulders leads to edge failures.
- Provision of poor clayey sub grade results in corrugation at the surface and increase in unevenness.
- Poor drainage conditions especially during rainy seasons, force the water to enter.
- The pavement from the sides as well as from the top surface. In case of open graded bituminous layer, this phenomenon becomes more dangerous and the top layer gets detached from the lower layers. If the temperature of bitumen/bituminous mixes is not maintained properly, then it also leads to pavement failure.
- Over heating of bitumen reduces the binding property of bitumen. If the temperature of bituminous mix has been lowered down then the compaction will not be proper leading to longitudinal corrugations.

Conclusion
By conducting the above tests and other various experiments in this project we have concluded that in the construction of road pavements, the selected bitumen sample must pass all the above tests mentioned then that sample can be used for construction and if the preventions that are mentioned above are followed, road failures can be avoided for a long period of time.
- To prevent longitudinal cracking we found that we need to improve drainage by removing the source that traps the water
- Periodic and preventive maintenance is the key.
- Budget money for crack filling on a yearly basis
- If deteriorated pavement is caused by poor sub-base conditions, periodic patching maybe required to keep those areas from spreading.

References