Failures in Flexible Pavements and Remedial Measures

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Abstract

The Purpose of this project is to improve the pavement of Highway in order to provide a satisfactory surface over which vehicles can operate effectively and safely. This project presents the classification on failures and its patterns. Firstly, failure patterns are classified between every five miles in existing pavement by visual inspection. Secondly, Visual maintenance and structural maintenance are studied. For structural maintenance, stress and deflection of Highway are determined by using the method of Soil Mechanic of Three Layered System. The required overlay thickness is evaluated in accordance with Indian Road Congress formula. According to this evaluation, it is found that resurfacing or routine maintenance is needed in almost portions. Within the study area, it is needed to be overlaid in the four portions. The maximum bituminous overlay thickness is 6 in and minimum is 4.5 in. Moreover, the maximum granular overlay thickness is 12 in and the minimum is 9. In India, flexible pavements with bituminous surfaces are widely used. Due to increased traffic intensity of roads, overloading of commercial vehicles and temperature variation of pavements due to climatic changes leads to formation of various distresses like rutting, shoving, bleeding, cracking the pavement.

Keyword: Modified Bitumen Marshall Stability Test. SBS PMB

1. INTRODUCTION

For the development of the economical of a country transportation system takes a special role. By means of good transportation system safe, rapid, comfortable, convenient, communication for people becomes possible and which is essential for distribution of various goods in the country that is the basic important for economical, industrial and environmental. For developing country good highway system is very important to gain the way of modern society. For good highway system various factors of deterioration of the road should be considered. Maintenance of the highway is very important for the whole traffic management. With weak maintenance system of the road various defects in the roads are main causes of accident. So, to be a successful engineer, a person should not only able to design the road, but also skill-full to maintain the road.

RELATED WORK

Causes of flexible pavement

Failures Flexible pavement fails due to any one of the following three failures. They are sub-grade failure, sub-base or base course failure and wearing course failure. The pavement deterioration usually is not only the result of poor design and construction but also it is caused by the inevitable wear and tear that occurs over years, variation in climate.

Friendly Technology Cold asphalt mix is produced by mixing unheated mineral aggregate with either emulsified bitumen or
foamed bitumen. Unlike hot mix asphalt (HMA), cold asphalt mix does not require any heating of aggregate which makes it economical and relatively pollution-free (no objectionable fumes or odours). Production of cold asphalt mix does not require high investment in equipment, which makes it economical. It is also suitable for use in remote areas. Cold asphalt mixes can be used both for initial construction (100% virgin mixes) and for recycling of asphalt pavements. Cold asphalt mixes do have some limitations. These mixes should not be used when ambient temperatures under 10°C are expected during construction. Cold asphalt mixes are typically suitable for light to medium trafficked roads when used in base and surface.

**Virgin Cold Asphalt Mixes**

Unlike recycled cold asphalt mixes, virgin cold asphalt mixes use 100% virgin aggregates and bitumen.

**Mix Types**

Primarily two types of virgin cold asphalt mixes are used: Dense graded and Open graded. Dense graded mixes are continuously graded from the maximum aggregate size down to material passing 0.075 mm sieve size. Open graded mixes usually lack material passing 2.67 mm sieve and have high air voids. Slurry seal and micro surfacing can also be considered cold mixes although used as surface treatment. The slurry seal consists of a mixture of mineral aggregate (mostly fine aggregate), slow setting cationic bitumen emulsion, water and additives (if needed) proportioned, mixed and uniformly spread over a prepared surface. The mixture is free flowing like freshly made cement concrete and is applied with a self-propelled slurry seal machine. Micro surfacing is like slurry seal, the primary difference being the former uses a modified (polymer or rubber latex) bitumen emulsion. Untitled photographs in this article show application of micro surfacing.

**Both Slurry Seal And Micro surfacing Have The Following Application Limitations:**

- Should be used on existing bituminous surfaces,
- Existing pavement should be structurally sound and should have good riding quality,
- Existing bituminous surface should not have any severe distress except hairline cracks, oxidized (aged) road surface or polished surface, and
- It should be applied to roads carrying low to medium traffic only. On heavy traffic roads both wear off prematurely especially in the wheel tracks.
- Both slurry seal and micro surfacing are good preventive maintenance tools and are especially suited for surface renewal of city streets because they do not significantly.
- The failure patterns such as alligator cracking, longitudinal cracking, transverse cracking, block cracking, edge cracking, ravelling corrugation and shoving, patching, potholes, polished aggregate, bleeding, and depression, are classified by visual investigation along the road portion.
- Formation of ruts falls in this type of failure. A rut is a depression or groove worn into a road by the travel of wheels. This type of failure is caused due to following reasons.

**2. IMPLEMENTATION**

Bitumen: Bitumen is a black, highly viscous and very sticky liquid or semi-solid, found in some natural deposits. It is also the by-product of fractional distillation of crude petroleum. Basically, Bitumen is composed of highly condensed polycyclic aromatic hydrocarbons, containing 95% carbon and hydrogen (± 87% carbon and ± 8% hydrogen), up to 5% sulphur, 1% nitrogen, 1% oxygen and 2000 ppm
metals. Also bitumen is a mixture of about 400 - 2000 chemical components, with an average of around 600 - 800. It is the heaviest fraction of crude oil, the one with the highest boiling point (525°C). Bitumen acts as a binding agent for aggregates in bituminous mixes. Generally in India, bitumen used in road construction of flexible pavements is of grades 60/70 or 80/100 penetration grade.

**Types of Bituminous Materials**

Depending upon the temperature and other factors various types of bitumen are found and used throughout the world.

**Cutback Bitumen**

Cut-back bitumen's are those which are prepared with the addition of a volatile to reduce the thickness of the binder.

**Fluxed Bitumen**

Fluxed bitumen's are those bitumen which are prepared by the addition of relatively non-volatile oils to reduce the viscosity of the binder.

**Construction aggregate**, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geo-synthetic aggregates. Aggregates are the most mined materials in the world. Modified bitumens generally use a traditional waterproofing medium -- asphalt -- modified with atactic polypropylene (APP), styrene butadiene styrene (SBS), synthetic rubber or other agents that create a uniform matrix that enhances the physical properties of the asphalt. SBS and APP are the most common bitumen modifiers.

**Bitumen**

Bitumen is a mixture of Organic Liquids that are highly Viscous, Black, Sticky, Entirely Soluble in Carbon Disulfide, and composed primarily of highly condensed Polycyclic Aromatic Hydrocarbons. Naturally occurring or crude bitumen is a sticky, tar-like form of petroleum which is so thick and heavy that it must be heated or diluted before it will flow. At room temperature, it is much like cold molasses. Refined Bitumen is the residual (bottom) fraction obtained by fractional distillation of crude oil. It is the heaviest fraction and the one with the highest boiling point, boiling at 525 °C (977 °F). In British English, the word 'Asphalt' refers to a mixture of mineral aggregate and bitumen (or tarmac in common parlance). The word 'Tar' refers to the black viscous material obtained from the destructive distillation of coal and is chemically distinct from bitumen. In American English, Bitumen is referred to as 'Asphalt' or 'Asphalt cement' in engineering jargon. In Australian English, Bitumen is sometimes used as the generic term for road surfaces. In Canadian English, the word bitumen is used to refer to the vast Canadian deposits of extremely heavy crude oil, while asphalt is used for the oil refinery product used to pave roads and manufacture roof shingles. Diluted Bitumen (diluted with Naphtha to make it flow in pipelines) is known as dilbit in the Canadian Petroleum industry, while bitumen upgraded to synthetic crude oil is known as syn crude and syn crude blended with bitumen as syn bit. Most bitumen contain sulfur and several heavy metals such as Nickel, Vanadium, Lead, Chromium, Mercury and also Arsenic, Selenium, and other Toxic Elements. Bitumen can provide good preservation of plants and animal fossils.

**Uses of Bitumens**

Bitumen is primarily used for paving roads. Its other uses are for Bituminous Waterproofing Products, including the use of bitumen in the production of roofing felt and for sealing flat roofs. Naturally occurring crude bitumen is the prime feed stock for petroleum production from tar sands currently under development in Alberta, Canada. Canada has most of the world's supply of Natural Bitumen, covering 140,000 square kilometers (an area larger than...
England), giving it the second largest proven oil reserves in the world. The Athabasca oil sands is the largest bitumen deposit in Canada and the only one accessible to surface mining, although recent technological breakthroughs have resulted in deeper deposits becoming producible by in-situ methods. Because of oil price increases since 2003, upgrading bitumen to synthetic crude oil has become highly profitable. As of 2006 Canadian crude bitumen production averaged about 1.1 million barrels (170,000 m$^3$) per day and was projected to rise to 4.4 million barrels (700,000 m$^3$) per day by 2020. The total amount of crude bitumen in Alberta which could be extracted is estimated to be about 310 billion barrels (50×10$^9$ m$^3$), which at a rate of 4.4 million barrels per day would last about 200 years. In the past, bitumen was used to Waterproof Boats, and even as a coating for buildings with some additives. The Greek historian Herodotus said hot bitumen was used as mortar in the walls of Babylon. It is also possible that the city of Carthage was easily burnt due to extensive use of bitumen in construction. Vessels for the heating of bitumen or bituminous compounds are usually subject to specific conditions in public liability insurance policies, similar to those required for blow torches, welders, and flame-cutting equipment. Bitumen was also used in early photographic technology. It was most notably used by French scientist Joseph Nicéphore Niépce in the first picture ever taken. The bitumen used in his experiments were smeared on pewter plates and then exposed to light, thus making a black and white image. Thin bitumen plates are sometimes used by computer enthusiasts for silencing computer cases or noisy computer parts such as the hard drive. Bitumen layers are baked onto the outside of high end dishwashers to provide sound insulation.

**Bitumen alternatives**

The world has become increasingly concerned over the global climate change thought to be caused by greenhouse gases, chief among them anthropogenic carbon dioxide which is released into the atmosphere from burning carbon fuels. This has led to the introduction of bitumen alternatives that are more environmentally friendly and non-toxic. Bitumen can now be made from non-petroleum based renewable resources such as sugar, molasses and rice, corn and potato starches. Bitumen can also be made from waste material by fractional distillation of used motor oils, which is sometimes disposed by burning or dumping into landfills. Non-petroleum based bitumen binders can be made light-coloured. Roads made with lighter-coloured pitch absorb less heat from solar radiation, and become less hot than darker surfaces, reducing their contribution to the urban heat island effect.

**Geologic origin**

Naturally occurring deposits of bitumen are formed from the remains of ancient, microscopic algae and other once-living things. These organisms died and their remains were deposited in the mud on the bottom of the ocean or lake where they lived. Under the heat and pressure of burial deep in the earth, the remains were transformed into materials such as bitumen, kerogen, or petroleum. As bitumens are also found in meteorites and Archean rocks it is possible that some bitumens are primordial material formed during accretion of the Earth and reworked by bacteria that consume hydrocarbons. Bitumens are associated with lead-zinc mineralizations in Mississippi Valley type deposits.

**Characteristic properties of bitumen**

Bitumen is defined as “A viscous liquid, or a solid, consisting essentially of hydrocarbons and their derivatives, which is soluble in trichloro-ethyelene and is substantially...
nonvolatile and softens gradually when heated”. It is black or brown in color & possesses waterproofing and adhesive properties. It is obtained by refinery processes from petroleum, and is also found as a natural deposit or as a component of naturally occurring asphalt, in which it is associated with mineral.

**Bitumen adheres**

Bitumen has excellent adhesive qualities provided the conditions are favorable. However in presence of water the adhesion does create some problems. Most of the aggregates used in road construction possess a weak negative charge on the surface. The bitumen aggregate bond is because of a weak dispersion force. Water is highly polar and hence it gets strongly attached to the aggregate displacing the bituminous coating.

**Bitumen is elastic**

When one takes a thread of bitumen from a sample and stretches or elongates it, it has the ability to return to a length close to its original length eventually. For some bitumens this process may take longer than others. This property is referred to as the elastic character of bitumen.

**Bitumen is plastic**

When temperatures are raised, as well as when a load is applied to bitumen, the bitumen will flow, but will not return to its original position when load is removed. This condition is referred to as plastic behavior. Applying a load means that you put a weight on the bitumen in order to subject it to stress. This could be in a lab or in the bitumen final position in the road and it is done to assess the bitumen’s reaction to the load.

**Bitumen is viscoelastic**

Bitumen has a Visco elastic character. Its behavior may be either viscous or elastic depending on the temperature or the load it is carrying. At higher temperatures there is more flow or plastic behavior, while at lower temperatures and short duration loading, the bitumen tends to be stiff and elastic. At intermediate temperatures it tends to be a combination of the two.

**Bitumen ages**

Aging refers to changes in the properties of bitumen over time, which is caused by external condition. These changes are visible as cracks or crumbling areas. When bitumen is exposed to atmospheric conditions, the bitumen molecules react with oxygen, which results in a change of the structure and composition of the bitumen. This process of combining with oxygen, called oxidation, causes the bitumen to become brittle and hard and to change color from dark brown or black to grey. This change is usually referred to as oxidative hardening or age hardening. This form of ageing occurs more frequently in warmer climatic or during warm seasons, causing older pavements to crack more easily. The condition can also occur where the surface films of bitumen are thin, or if there has been inadequate compaction during construction.

**Bitumen hardens**

Exposure to ultraviolet (UV) rays and the evaporation of volatile compounds can cause bitumen to harden. A volatile material is a material that can change into a gas very quickly. There are two kinds of hardening:

- Physical hardening:
- Exudative hardening:
- Modifiers:
- Physical hardening occurs when waxy crystals form in the bitumen structures, or when asphaltenes agglomerates clump together. This condition can be reversed if the temperature is raised.

Exudative hardening is caused by the absorption of oily components in the bitumen. Modifiers in bitumen: The modified binder are more stable under heavy loads, braking and accelerating forces and shows increased
resistance to permanent deformation in hot weather. It resists fatigue loads and having better adhesion between aggregates and binders.

3. RESULTS CALCULATIONS

Impact Test Value

<table>
<thead>
<tr>
<th>Sl no.</th>
<th>Details of sample</th>
<th>Trail-1</th>
<th>Trail-2</th>
<th>Trail-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total weight of aggregate sample</td>
<td>635</td>
<td>613</td>
<td>624</td>
</tr>
<tr>
<td>2</td>
<td>Weight of aggregate passing 2.36mm sieve after the test</td>
<td>551</td>
<td>519</td>
<td>535</td>
</tr>
<tr>
<td>3</td>
<td>Aggregate impact value= w1/w2*100</td>
<td>86.77%</td>
<td>84.68%</td>
<td>58.73%</td>
</tr>
</tbody>
</table>

Trail-1:
W2/W1*100
=551/635*100
=86.77%

Trail-2:
W2/W1*100
519/63*100
=84.66%

Trail-3:
W2/W1*100
=535/624*100
=85.73

Los Angle Abrasion Test

<table>
<thead>
<tr>
<th>Sl.no</th>
<th>Details of sample</th>
<th>Trail-1</th>
<th>Trail-2</th>
<th>Trail-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wt. Of samples=W1</td>
<td>5000 g</td>
<td>5000 g</td>
<td>5000 g</td>
</tr>
</tbody>
</table>

Wt of sample after abrasion test coarier than 1.70mm Is sieve=W2

4950 4945 4937.

Trail-1=(w1-w2/w1)*100
=5000-4945/5000*100
=1%

Trail-2=5000-4945/5000*100
=1.5%

Trail-3=1.25

The average value of los angle abrasion test is 1.25%

The percentage of a wear should not be more than 16% for concrete aggregates

For Road the abrasion value is not more than 10% if it is more than, then it is not suitable for road construction. It cannot bear the load.

Penetration Test On Bitumen

<table>
<thead>
<tr>
<th>Reading</th>
<th>Trails</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrometer dial</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>initial reading</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Penetrometer dial</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>final reading</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Penetration Value</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The average penetration value of a given bitumen samples is 23.9 and the grade of bitumen is

By using modifier along with bitumen it decrease the penetration value up to 10%. The penetration values of various types of bitumen used in pavement construction in this country range bitumen between 20 and 225,30/40 and
80/100 grade bitumen are more commonly used, depending on construction type and climatic conditions. In hot climates in lower penetration grade bitumen like 30/40 bitumen is preferred.

**Results Of Ductility Test:**

<table>
<thead>
<tr>
<th>Test Property</th>
<th>Trails</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ductility value</td>
<td>1 2 3</td>
<td>74+77/3 =75</td>
</tr>
</tbody>
</table>

The ductility value of the given bitumen sample is **75 cm**

The ductility values of bitumen vary from 5 to over 100 for different bitumen grades. A minimum Ductility value of 75 cm has been specified by the ISI for bitumen of grades 45 and above. Obtained from sources other than ASSAM petroleum (i.e., S45 and above), the sources. However, the bitumen produced from Assam petroleum and India have bitumen grades 652 used in certain regions.

**4. CALCULATION AND RESULTS**

**Softening Point Of Bitumin**

<table>
<thead>
<tr>
<th>Test property</th>
<th>Trials</th>
<th>Mean value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (c) at which 1 ball touch the bottom plate</td>
<td>1 2 3</td>
<td>40+35+48/3 =41</td>
</tr>
</tbody>
</table>

The softening point value of given bitumen sample is **41°C** and grades of bitumen is VG 40.

The softening point of various bitumen grades used in paving jobs vary between 35°C to 70°C.

**Flash and Fire Test On Bitumen**

<table>
<thead>
<tr>
<th>Test</th>
<th>Trails</th>
<th>Mean Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point</td>
<td>115 120 117</td>
<td>117.33</td>
</tr>
</tbody>
</table>

The temperature at which the flame application that cause a bright flash 117°C (flash point).

**5. CONCLUSION**

The daily traffic volume has increased considerably on the study road. It has increased by more than 100% as per the traffic study done during the study in the year 2012. This increase in the traffic took place in a very short span of time. The increment in the design traffic is phenomenal in terms of commercial vehicles per day. Prior to the design of the road, the average traffic volume was around 270 commercial vehicles per day in the year 2003 which got increased to around 543 commercial vehicles per day. The road was not at all able to bear such a heavy traffic load which caused the failure of the study road.

There were some other reasons identified for the failure of the study road: The CBR values of the sub grade, determined in the laboratory were below the designed CBR value of 7%. Low CBR values cause uneven settlement of the different pavement layers causes rutting and undulations on the top surface of the pavement. The width of the carriageway was kept 3.75 m in the study road with unpaved shoulders on both sides of the carriageway. The crossing of heavy vehicles became a big problem which further damage and scarify the sides of the bituminous layer the soil below the sub grade was found to be the Black Cotton soil, which exhibits the characteristics of the
excessive swelling in presence of moisture and shrinkage in the absence of moisture. The soil also exerted heavy selling pressure on the sub grade and made it vulnerable and susceptible to failure. The shoulders were found not properly compacted due to which rain water started accumulating in the ruts created on the Use of the innovative technology not only strengthened the road construction but only also increased the road life. Plastic road would be a boon for India’s hot and extremely humid climate where durable and eco-friendly roads which will relive the earth from all type of plastic waste Roads laid with plastic waste mix are found to be better than the conventional ones. Rain water will not sleep through because of the plastic in the tar. So, this technology will result in lesser road repairs. Use of the innovative technology not only strengthened the road construction but also increased the road life.

REFERENCE


