FAILURES IN FLEXIBLE PAVEMENTS & ITS ECONOMICAL TREATMENT

ABSTRACT

Approximately 80 per cent of Haryana falls in National Capital Region, National Highways, State Highways, Major District Roads and some District Roads serve as feeder roads to National Capital for quarry materials, bricks and other heavy axle loads which result in damage to road crust. Inadequate thickness of road crust, poor subgrade and heavy axle loads on the road contribute damage to road in geometric proportions. The roads as damaged were investigated and treated subsequently with the economical specifications by excavating upto subgrade at damaged spots and filling with GSB and adjoining pavement material. Same treatment as has been done has stood the scrutiny of time. These investigation also reveal new problems of interest both to the maintenance engineers and research workers.

1. INTRODUCTION

In this Paper, locations in Haryana have been selected where highways have failed due to failure of subgrade, poor quality of filler material in WBM WMM, imperious bitumen layer due to inadequate density and heavy axle loads. The highways as have been studied are as under:-

(a) Kaithal bypass (Part of NH-65)
(b) Jhajjar Badli road upto Dhansa border of Jhajjar-Delhi (Major District Road No.123).
(c) Diversion road at Jhajjar (Part of NH-71)
(d) Narwana Jind road (Part of NH-71)

The roads as have failed were investigated and remedial measures taken in an economical way and thereafter roads gave its performance in a satisfactory way.

2. BRIEF BACKGROUND OF FAILURES

Deformation of pavement layer materials has been the key factor governing design as well as performance of flexible pavement. Excessive surface settlement of flexible pavements resulted in uneven pavement surface, thereby, affecting serviceability of the pavement. Ruts affect riding comfort, increase in wear and tear of the vehicles and reduce life of the pavement. The excessive rutting along wheel tracks causes longitudinal cracking and wasiness of pavement surface over clay subgrades of high compressibility. Most of the pavement failures and rut observed in flexible pavement are caused by high compressible clay as subgrade, due to high plasticity and due to penetration of sub base material into softened subgrade.

Water enters the pavement structure in many ways, such as through cracks, joints and by infiltration. Effect of this water on pavement results into the reduction in strength of soil subgrade, the reduction in strength of unbound granular material and differential heaving over swelling soils.

The main emphasis in pavement design is on density and stability rather than on draining out the water from the pavement structure, but permeability of various materials being used in construction of pavement requires attention. The high permeability can be achieved by controlling the aggregates grading. Water is undesirable in the pavement because the effective stress is reduced.

\[ \sigma = \sigma' - \mathcal{P} \]

where,

\( \sigma \) = Effective Stress,
\( \sigma' \) = Total stress,
\( \mathcal{P} \) = Pore water pressure.
Since, soil sub grade is a frictional material, its strength depends upon the normal stress also.

\[ \tau = \sigma^1 \tan \theta \]
\[ \tau = \text{Shear stress} \]
\[ \sigma^1 = \text{Normal/Effective stress} \]
\[ \theta = \text{angle of friction} \]

The effective resilient modulus of sub grade material (strength in terms of stiffness) reduces when moisture and plasticity increases and complete saturation due to bad drainage leads to failure of soil subgrade in the form of cumulative permanent distress or inadequate stability. The emphasis is needed to exclude water from pavement and to provide for rapid drainage or by using sub soil intrusion barriers for controlling ruts. GSB resulted in satisfactory performance as intrusion barriers for soil sub grade. Gradation of Granular Sub Base (GSB) has been covered in Clause 401, three gradings are for close graded granular sub base material and three are for coarse graded granular sub base materials and same have been provided in Table 400-1 & 400-2, MORT&H respectively.

The main issues to be considered for selection of GSB shall be governed by following parameters:

a) The water absorption value of coarse aggregates shall not be greater than 2 per cent, if greater than 2 per cent, then soundness test shall be carried out as per IS.383.

b) Fraction passing the 75 mm should not exceed 60 per cent of the fraction passing 600 mm sieve.

c) The material passing 425 micron sieve for all three grading, when tested according to IS.2720 shall have liquid limit and plasticity index not more than 25 per cent and 6 per cent respectively.

d) By providing a layer of GSB, beyond the full width of carriage way and by keeping its end faces open for breathing is required to be adopted.

3. DETAIL OF HIGHWAYS TAKEN FOR STUDY

a) Kaithal Bye-Pass (Part of NH-65) i.e. Ambala-Kaithal-Hisar

Ambala-Kaithal-Hissar road was declared as NH-65 vide Govt. of India notification dated 9 February 1998.Kaithal Bye-Pass having length of 6.70 km & carriageway width of 6.71 m was constructed about 20 years back by using clay as soil subgrade. Moreo, as per traffic census of year 2002, 5829 CVD were plying. Clayey soil subgrade and method of pavement construction of Kaithal Bye-Pass had resulted in poor drainage of sub base course as water held by capillary forces in soils could not be drained. It had been observed that water got accumulated in borrow pits along the sides of embankment of this stretch during rainy season and saturated the soil subgrade by capillary action, resulting failure and rut observed in flexible pavements due to high plasticity of clayey subgrade and penetration of WBM material into softened soil subgrade. By the end of year 2002, condition of Kaithal Bye-Pass was very bad due to development of rut and surface deformation in the form of differential heaving over swelling soils, as flexible pavement was constructed over clay sub grade and idea of reconstruction of whole byepass was being thought of.

Earth for Bye-Pass was procured from site of work from two different locations. The engineering properties have been determined from Laboratory as per table below:

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Engineering Properties</th>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Grain size analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Sand (%)</td>
<td>9.3</td>
<td>22.85</td>
</tr>
<tr>
<td>b)</td>
<td>Silt and Clay (%)</td>
<td>90.7</td>
<td>77.15</td>
</tr>
<tr>
<td>2</td>
<td>Plasticity characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Liquid Limit (%)</td>
<td>30</td>
<td>55.55</td>
</tr>
<tr>
<td>b)</td>
<td>Plastic Limit (%)</td>
<td>23.5</td>
<td>18.85</td>
</tr>
<tr>
<td>c)</td>
<td>Plasticity Index (%)</td>
<td>6.5</td>
<td>16.50</td>
</tr>
<tr>
<td>3</td>
<td>Compaction characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>Optimum Moisture contents (%)</td>
<td>-</td>
<td>14.70</td>
</tr>
<tr>
<td>b)</td>
<td>Max. in dry density (t/m³)</td>
<td>-</td>
<td>1.85</td>
</tr>
</tbody>
</table>

Kaithal Bye-Pass was repaired in the year 2000 by providing 50 mm thick BM and 20 mm thick MSS but due to the presence of excess water combined with increased traffic volume and axle loads led to
premature pavement distress. It was inspected in January 2003 and Bankleman Beam test was conducted at site and thickness requirement of overlay was 20 cm with Bituminous Macadam (BM). MORT&H sanctioned provisions of 50 mm thick BM and 25 mm thick SDBC for repair of this damaged stretch. Before carrying out this work, the Kaithal Bye-Pass was again inspected in August, 2003 by the author of this Paper.

On the basis of site studies and observing that the soil subgrade was clayey having liquid limit greater than 25 and plasticity index greater than 6, it was decided to increase drainage by providing emphasis to exclude water from the pavement and provide drainage otherwise pavement whatever may be its thickness may go to “Pieces”. Accordingly, an estimate amounting to Rs. 4 Lacs for the repair of damaged reaches of Kaithal Bye-Pass was got approved. As per this estimate, a provision of treatment of 461.20 sqm area having ruts/undulations/differential heaving, out of Kaithal Bye-Pass were repaired by digging out damaged crust including plastic soil subgrade and substituted with provisions consisting of earth work in embankment, providing and laying 250 mm thick GSB as per MORT&H specifications, providing and laying 150 mm thick WBM in 2 layers G-1 and G-2, 75 mm thick each, providing & laying 75 mm thick BUSG and finally sealing by providing & laying 20 mm thick MSS type-B.

After giving the above treatment, ruts in flexible pavement of Kaithal Bye-Pass had been reduced by 98 percent by investing only a small amount. Granular subbase has satisfied the requirement of structural strength as well as drainage aspect of pavement.

This stretch has been tested for five years as of now and have stood the scrutiny of time and thereby, have given an improved performance.

b) Jhajjar Badli road upto Dhansa Border in Jhajjar/Delhi District (Major District Road No. 123)

The Jhajjar-Badli road from km 0.00 to 18.250 Jhajjar District was initially constructed about 45 years back, to connect the Jhajjar with National Capital Delhi via village Badli and Dhansa. The original width of road was 12 feet and constructed at adjoining field level with Brick Soling/Kankar, which was covered by laying a layer of Stone Metal and Premix Carpet during 1971. At that time, no design data was in practice to be followed. After that, the road was widened from 3.66 to 5.50 m during the year 1990-1991 by providing two layers of Stone Metal & Premix Carpet on both sides in widened portions only.

With the development of Dwarka Residential Area in Delhi, which is Asia’s largest residential colony and Cyber City Gurgaon about 300 Bricks kilns had been set up in this area. The feeding of raw materials like brick, stone aggregate, coarse sand, bajri and other construction materials for Delhi & Gurgaon are being carted through this route. Hence in 2005, the Govt. of Haryana decided to widen & strengthen this road upto Delhi Border from 5.50 to 10.00 m wide under C.R.F Scheme, as per design given by N.I.T., Kurukshetra.

A) Widening of portion of 2.25 m each side was done with GSB = 150 mm thick, Stone Metal (G-II) = 75 mm thick and Stone Metal (G-III) = 75 mm thick.

B) Strengthening portion of 10.00 m carriageway was done with LBM = 100 mm thick. BM = 100 mm thick. DBM = 60 mm thick and SDBC = 25 mm thick.

The improvement work of this road was completed in October 2006. Within one year of widening / strengthening of the road, the left hand side lane leading to Delhi from Jhajjar started getting damaged by way of waviness and ruts. A team of two Chief Engineers was sent to site to study and report. They concluded to refer the same to some engineering institute for study and suggesting remedial measures. As is in government departments, same gathered dust in government files. After site studies, it was decided by the author that it was not wise to reconstruct the damaged reaches of such a big length by scarifying the entire length because of huge expenditure to the state exchequer.
The reasons after due inspection were established as under:

a) Originally, the soil characteristic of this road is not good and is having high percentage of clay contents.

b) Higher water table in the area.

c) The strengthening with a layer of WBM materials in some kilometers was done on the black top i.e. without scarifying the bituminous black top layer due to which seepage water trapped between the layers of road and created damage of improved carriageway, later on.

d) Because of heavy traffic volume and over loaded multi axle trucks/trailors leading to Delhi/Gurgaon.

It was decided to repair the road with the following treatment on experimental basis. (Photo 1).

(ii) WBM material with the thickness about 300 to 350 mm.

(iii) Finished with 100 mm thick BUSG + 20 mm thick Premix Carpet.

By following above procedure, about 150 nos pit were dug, i.e. on the points where the road was damaged and refilled (i.e 20 to 25 pits per km). The approximate cost for repair came to Rs. one lac per km.

After rectification of road from July 2007 to August 2007, it was found that no further damage of road occurred in the kms where this treatment had been done and the road is giving a proper performance. Again during monsoons from April-2008 to July-2008, few more distresses developed in other kms and similar rehabilitation measures were adopted. The performance of rehabilitation measures is being closely watched.

(c) Jhajjar Diversion Road (Part of NH-71)

Another failure was diversion road of Jhajjar town. This road was constructed on embankment of drain. It was observed after inspecting the entire length of the by pass, that the by pass has failed miserably and it has settled on left side while moving from Jhajjar to Rewari. It was noted that this by pass was constructed on Ring Bundh of Irrigation Department. The land also belongs to Irrigation Department. Basically, the Bund from right side was trimmed and the earth was dumped on left side while moving from Jhajjar to Rewari side. The earth work done on left side settled by more than 6 inches.

Additional earth work wherever required was done by taking the earth from lead. The density of the earth work was checked to be 1.70 gm/cubic cm even after running of traffic for about 1 ½ years. It has also been observed from the record that CRRI had also done quality check of the work and the density observed by them at site varied from 1.58 to 1.77 against the requirement of about 1.97, which means that achievement of density as observed by CRRI is about 87 per cent and by taking the same proctor density, the result achieved was about 86 per cent of the required density.
While checking the records, it was observed that there was a provision of Granular Sub Base (GSB) in the rough cost estimate which was however deleted during the approval of bidding documents as an economical measure. Subsequently, however, after the receipt of the design, the 60 mm thick DBM was additionally provided even after the provision of DBM as the crust was very much deficient as per the design requirement. During the inspection it was observed that there was very high traffic intensity on this road and the crust provided at site was highly insufficient.

It was also observed that the irrigation drain running parallel to the diversion road through which water continuously seeps in the sub grade was partially responsible for damaging the road crust. (Photo 2 & 3).

From the perusal of the above findings, the main reasons observed for failure of the bye pass were as under:

a) Insufficient compaction of earth work in embankment and sub grade.
b) Non provision of granular sub base over the sub grade.
c) Insufficient thickness of crust. The crust thickness was to be provided about 71.5 cm thick (for 5 years life) whereas only 48.5 cm crust was provided. It has also been observed at site that even the crust of 71.5 cm is insufficient keeping in view the heavy density of over loaded vehicles having high axle loads.
d) Running of Irrigation drain parallel to the diversion road.
e) Deficient quality control exercised by the field staff during execution of work.
f) Opening of traffic just after laying of BM.

Road crust was being dug at hundreds of places of failure upto a depth of 1.00 m (approx.) and was replaced with GSB material and covered with pavement material on top. Further the irrigation drain which is running parallel to the road would have to be lined to protect against seepage of water. The top wearing course subsequently would have to be treated either with fog seal or additional layer of SDBC to make it impervious. The performance of treatment as have been given is being watched.

(d) Narwana Jind Road (Part of NH-71)

Within few months of execution of work in year 2007, the finished surface showed signs of distress, slippages and formation of ruts. On investigations, it was found that the density of SDBC was not as per the requirement. Substandard execution of SDBC item led to deterioration and premature distresses in the pavement. The grading of GSB material had excessive finer material to the tune of 8 per cent in comparison to the limits prescribed in the specifications. The bond between SDBC and BM was found impaired. The material of BM had lost cohesion which showed
structural dis-integrity of the pavement due to penetration of water from surface. Cracks had developed in the pavement. The lumps of clay/silt were found formed below BUSG in WMM layer at the locations checked, where cracks/distress in pavement had occurred. The performance of said stretch is being watched after due remedial measures.

4. OBSERVATIONS

a) From drainage view point, the GSB provided in the widened portion serves partial purpose, as drainage is not provided throughout the crust.

b) There are inadequacies in the design.

c) The lower compaction achieved results into lower CBR values.

d) The CBR values are much lower than that assumed in design.

e) There is no provision of adequate drainage layer.

f) The strength of the pavement in the widened and strengthened portion differs.

g) The CBR values of GSB will be much less than that of the WBM which has been well compacted by traffic. Thus the overall composition of widened and original crust does not match.

h) Appropriate borrow areas of earth were not finalized for the raising portion.

i) Appropriate densities were not achieved in subgrade.

j) Appropriate densities were not achieved in bituminous layers at the top which resulted into permeability of water during the rains.

k) GSB material was not appropriately tested for its gradation and inherent properties.

l) Adulteration of WBM/WMM material with local earth accelerates the damage to the pavement.

All the above had severely distressed the pavement in alligator cracking and shoving of the pavement towards the shoulder as well as rutting.

5. CONCLUSIONS

The rehabilitation measures as adopted had to be measured in terms of internal rate of return so generated because of control of vehicle damage factor and traffic inconvenience minimized. The treatment so done has increased the life of pavement, improved subgrade and reduced the damage due to deficiencies in process of execution. The treatment acted as a filter for surrounding earth and thereby improving the performance of road crust in an economical way. Last but not the least, these are not the permanent solutions. We, the civil engineers have to be cautious enough while framing the specifications and thereafter ensuring strict quality control and quality assurance during the process of execution.

REFERENCES


