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EVALUATION STUDY FOR DETERMINING PREMATURE PAVEMENT CRACKING OF A SECTION OF JHANG SHORKOT ROAD

BY
Zubair Emran Khawaja

EVALUATION STUDY FOR DETERMINING PREMATURE PAVEMENT CRACKING OF A SECTION OF JHANG SHORKOT ROAD (KM 22+000 TO KM 55+500)

By

Engr. Zubair Emran Khawaja[1]

- *Paper tables the probable causes for the present condition of Jhang Shorkot Road. In severely cracked reaches early crocodile cracks spread was between 10 to 15 %. In moderately cracked reaches multiple longitudinal and transverse cracks spread was between 5 to 10%. In normally cracked reaches single longitudinal cracks with occasional transverse cracks spread was up to 5 %. However, there was substantial reach where to-date cracks had not appeared. Longitudinal and transverse cracks normally were at top of the surface but occasionally they had penetrated through full depth of wearing course. Latest research report published by Transport Research Laboratory London (TRL) describes these cracks as top down fatigue cracks.*

- *Deflection and component analysis results revealed that the cracking had not impaired the structural integrity of the asphalt. Apart from few reaches where deteriorated asphalt should be replaced by sound new asphalt, Jhang Shorkot Road was not in a critical condition. It was concluded that in the presence state of distress it could still carry over 6 to 21 million ESA. However, that would require 50 mm overlay in the reaches where the deflection values are 0.38 mm i.e. from Km 25+500 to 28+500 and Km 36+000 to Km 39+000 (6 Km), which should enhance its life to 17 million ESA. For the remaining length one coat of surface chipping will help in enhancing the fatigue life of the bituminous wearing course.*

Key words; bituminous, fatigue, age hardening; equivalent axle, (ESA) longitudinal cracks; transverse cracks; top down cracks; rutting; shearing force; excess voids.

1- INTRODUCTION

Jhang Shorkot Road is an important inter district Link, which provides the shortest route between Jhang and Khanewal and then onwards to Multan and further south. The road originally was constructed at touch grade and had 20 cms thick and three meters wide pavement. In the year 1974 it was widened to 6.1 meters.

Punjab province in the year 1992 experienced exceptionally heavy monsoon floods. which resulted in wide spread destruction. The section of the road between km 2 I and 42 was badly damaged in floods. A section of the road from km 22+000 to 55+50() (33.5 Kms) later was taken up as one of the sub projects in EC funded Post Flood Rehabilitation and Protection Project (Project No. AL.A/94/04). M/s M±R International – NDC-EGC were responsible for the design and detailed construction supervision,

[1] *Director, PR&MTI, & PSPIC, Communication and Works Department, Punjab*

whereas M/s Khalid Rauf and Co. were the builders. Project Commenced in August 1996 and was completed on August 15, I 998.

2- SCOPE OF WORK

Embankment in the entire length on the existing alignment had been widened from 9.7 to 13.3 meters (top width). Despite intensive water logging along the entire route, raising or improvement of sub grade, except near bridges and few other locations where entire embankment was rebuilt was not provided in the approved scope. In general the old black top was scarified and dressed, however, there was no provision for compaction of exposed base course layer. About 34 culverts had been replaced all along the road. Most of culverts were 0.6 meter wide and one meter in height. Apart from this, about 8 bridges had been re-decked.

3- TRAFFIC ANALYSIS AND PAVEMENT DESIGN.

The Consultant M+R International had used traffic data published by P&D of Punjab Highway Department (PHD) for the years 1981 and 1993, which was projected to base year 1998 and then to year 2008 (10 years design life) by adopting *3.5%* constant growth rate. Traffic data of the year 1981 and I993 used for calculating design ESA has been tabulated in **Table- I**

AVERAGE DAILY TRAFFIC

Type	Conversion Factor	1981		1993	
		ADT	ESA	ADT	ESA
Buses	0.635	253	163.83	462	293.370
Trucks 2 axle	4.956	1185	5872.86	948	4698.288
Trucks3 axles	7.627	--	--	225	1716.075
Agriculture Tractors *	0.0 10	--	--	35	0.350
Tractor Trolleys 3 axle	1.104	90	99.36	38	41.952
TractorTrolleys4 axle	3.664	--	--	5	18.320
N.L.C.Unit4axle	18.066	--	--	132	2384.712
N.L.C. Unit 5 axle	6.946	21	146.866		34.730
		Total: -	6281.916		9187.797

Table: I * Sugar cane tractor trolleys were not included in traffic count.

The total ESA, based on the assumption that the mid strip of the pavement in actual practice would carry both ways traffic provided for the project were 48.0x 10^6. As per Road Note 29, the following pavement design was adopted.

- 20 cms thick sub base in widened portion whereas for the old road the existing pavement (average 20 cms) was taken as sub base. Sub base had been laid in 8-meter width.
- New road base 35 cms thick and 7.3 meter wide consisting of graded crushed rock.
- New bituminous base course in 6 cms thickness and 7.3 meter width.
- New bituminous wearing course in 4 cms thickness and 7.3 meter width.

4- INVESTIGATION STRATEGY

A committee comprising representatives of RR&MTI. Highway Division .Ihang and Consultants inspected the project on August *30,* 2000. More or less based on criteria adopted by TRL Road Note 18, it was decided to sample the material from severely cracked, moderately cracked, nominally cracked and un cracked areas of the most affected left lane. The test results and different observation have been made part of the paper.

5- OBSERVATIONS, INVESTIGATIONS AND DISCUSSION OF RESULTS

The pavement evaluation study was conducted to establish the nature, severity and extent of the road deterioration, the causes of the deterioration and the strength of the existing road pavement. The following sequence was followed:

- Collected and interrelated the design, construction and maintenance data.
- Carried out surface condition survey and traffic analysis.
- Carried out structural and material testing.
- Established the cause of pavement failure.
- Selected appropriate method of maintenance and rehabilitation.

5.1 General

The inspection and testing was made during the maximum moisture condition for the embankment. The stagnant water near the toe of the embankment and general water logging condition in vicinity of the road suggested that embankment height was too low. Change in the moisture regime could easily cause reduction in sub grade strength. From km 29 to km 42 a canal runs parallel to road. The full supply level all along was above the finished grade elevation of the project road. The hydraulic gradient itself is a threat to sub-grade. In the widened portion sand cushion has not been provided for free draining of sub soil moisture.

Following pavement distresses were studied: -

- Edge failure
- Cracking
- Patching and potholes
- Rutting

However, no bleeding, fatting up, major fretting and stripping were noted. As per TRL rating surface texture was observed to be medium.

5.2 Edge Failure

Two Sugar Mills are located at the too ends of the under study road project. Most of 'the sugar cane supply for Kashmir Sugar Mill on Shorkot side used left lane of the road. Similarly the aggregates trucks from Sargodha quarries used left lane for supply of material to Khanewal, Multan and further down to south. It therefore, was observed that the heavy axle loads had pronouncedly affected the wheel paths of the left lane. Non-plastic A-4 soil had adversely contributed towards the erosion of embankment. Sugarcane trolleys and overtaking traffic had badly damaged the surface treated shoulders. It was observed that edge of the asphalt pavement was eroding at a very fast rate. If this trend is not arrested in time then there is likely hood that the width of asphalt will further reduce by the end of next sugarcane crushing season. The pavement on the average was measured as 7.25 m against design width of 7.30 m.

5.3 Cracking

It was important that initial form of deterioration and its cause(s) was identified because that could determine the type of most appropriate maintenance. After further trafficking the initial causes of deterioration could be influenced by subsequent deterioration. The type, intensity position, width and extent of cracks were studied by coring the asphalt from the affected areas. In all 16 cores were sampled for crack study.

The reach between km 39+000 to 55+500 was almost free of cracks. Other form of surface irregularities such as rutting and settlements were noticed. The appearance of asphalt here was quite lively.

In nominally cracked reach between Km 30+000 to 39+000 only scattered single longitudinal cracks (in wheel paths and not in wheel paths) with occasional transverse cracks were noticed. Their spread was observed to be random in nature; however majority of them had appeared in the wheel path of left lane. The crack width here was less than 1 mm. Examination of extracted cores further revealed that they were confined to top of wearing course. Asphalt concrete generally was intact and was in good condition.

In moderately cracked reach from km 27+000 to km 30+000 more than one inter connected longitudinal as well as transverse cracks were observed. Comparatively their spread too was more than nominally cracked reach. Both visual and core observations revealed that asphalt in the cracked areas still was intact. No difficulty in coring was faced. Cracks at times had traveled up to half depth of wearing course and their average width here too was 1mm. Cracks tip to 2.0m length were noticed, however most of them varied from few cms to 50 cms.

In severely cracked reach, from km 22+000 to 27+000 most of the times asphalt core crumbled during extraction, Cracks up to 2-mm width were measured and these at time had traveled through the full wearing course depth and even beyond. In this reach besides longitudinal and transverse cracks, early crocodile cracks were also noticed. There were clear signs of ingress of water and earth through these cracks. Mix too, had a hungry the look with excessive voids within the body of the asphalt. The integrity of asphalt, where early crocodile cracks had appeared. was found doubtful. Most of the cracks reportedly were progressive in nature and they were estimated to be propagating @ 0.5% to 1% per month.

5.4- Potholes and Development

At least at two locations minor local depressions and potholes were noticed. This sort of local damage to pavement was not unusual and could easily be attributed to construction defects. It was further observed that contractor during the maintenance had patch repaired the surface defects, (rutting/cracks) which might have appeared on the verge side-wheel path of left lane. A thin sheen of asphalt was also observed predominantly in left lane in the first 10 kms of' road length. It might have contributed in arresting rate of' spread of' crack

5.5- Rutting

Using 4-meter straight edge rutting was measured at 26 locations. It generally ranged from 0 to 6 mm without shoving. In severely cracked reach between km 22+000 and Km 27+000, maximum rut depth except for two locations, did not exceed 12 mm which was less than the critical rated value of' I5 mm. Cracking generally was not coincident with higher value of rutting. Mostly in areas of' lesser crack intensity there was no rutting. It suggested that the cracking preceded the rutting. The thickness of cores taken from rutted area was slightly less than the minimum specified value.

5.6- Benkelman Beam Deflection Survey

The strength of a road pavement is inversely related to its maximum vertical deflection under a known dynamic load. Maximum deflection under a slowly moving wheel load thus is good indicator of the overall strength of a pavement and has shown to correlate well with long-term performance of pavements under traffic. TRL LR 834 & LR 835 method was adopted to determine the deflections at different asphalt temperatures. The left-hand lane was severely affected by heavy axle loads. Based on extent severity of' cracking, Benkelman beam tests were run every 160 meters from km 22 +000 to km 39+000 and km 45+000 to 50+000 (in all 22 kms) on left lane and 25+000 to 28+000 on right lane respectively. The results were then plotted. The temperature corrections were applied and statistical analysis was also run. Observing the temperature trends the road was divided into different sections. Mean standard deflection of' each section was determined. Design figures, recommended by LR. report 833 were used to predict the future structural performance of the pavement.

The corrected deflection except for Km 22 +000 to Km 22+800 varied between 0.23 mm to 0.38 mm only. Deflection results revealed that structural integrity of' the pavement has not been seriously impaired. However it was rated in critical condition. Further the uniformity of deflection results in cracked and un-cracked stretches of the road indicate that despite surface cracking, pavement strength in general was quite sound. For a road on which in initial 2.5 years of' design life approximately 7.08 million equivalent axle loads had passed the remaining designed life for 0.38 mm deflections was estimated as 6 million ESA only.

6- COMPONENT ANALYSIS

Dictated by the state of distress entire road length was divided into four representative sections. Pavement layers in each group were tested to establish their conformance to the specifications. In this connection joint team of' RR&MTI and project consultants conducted following studies/tests:

i) Study of sub grade moisture up to 3' depth tinder the pavement.
ii) Field Density/compaction of sub grade, sub base and aggregate base course.
iii) Sampling for classification, laboratory density and CBR.
iv) Sampling of sub base & aggregate base course samples for suitability tests.
v) Testing of' asphalt concrete Base and Wearing Course.

6.1- Moisture Movement

The field moisture content up to 3 ft at 1 ft interval in the embankment was studied at Km 23+000 and 44+900. The results indicated that at km 23 +000 I/s in the widening portion varied from 7,1% to 13.2% and at km 44+900 it varied from 8% to 17%. Higher value of moisture content indicated change in moisture, however, the field moisture content at two locations checked was below plastic limit of the soil.

6.2- Sub-Grade

6.2.1- Compaction and Classification

Compaction of sub grade was checked at one location. Field density when compared with modified AASHTO density was found 88.8 %. It conformed the test results reported by PHD in the year 1 994.

6.2.2 C.B.R Value

Design of pavement was based on sub grade strength S3 and traffic category T8 (Road Note 29) CBR value ranging between 5% to 8% and traffic more than 30 msa. One representative sample of soil collected from site at Km 23+000 was tested for soaked CBR (three points) modified AASHTO test. *5.6 %* CBR value was obtained at 89% compaction. The sub grade CBR was found within assumed limits of design (i.e. 5% to 7%).

6.3- Sub Base Course

6.3.1 Quality and Compaction

Sub base was tested at four locations, selected on the old pavement. The gradation of material broadly was within required limits of clause 20l.2 except at one location i.e. Km 23+000 IS where it was 3% finer on 2" sieve. Plasticity Index of material ranged from3% to 6% against specified non-plastic material. The coarser material had 26% Los Angeles Abrasion value against maximum specified value of 40%. Compaction of sub base varied from 93.8% to 96.4% compared to 98% minimum specified. The compaction of exposed surface upon scarification should have been included in the contract. The material properties suggested that even at 94% compaction, CBR value would be in the vicinity of 45%. which was more than the minimum required by Road Note 29. Quality of sub base material except plastic index met the requirement of specifications.

6.4- Quality Of Aggregate Base Course

Aggregate Base course was also tested at four locations to assess its quality as well as its %age compaction. The test results indicated that the sample at 35+000 L-Section was coarser on sieves, 2" & 1" by 2.0% & 4.0% respectively. Similarly it was coarser on sieves No. l" by 8%, sieve 3/8" by 6.0% sieve No.10 by 7.0% and No.40 by 5.0% at km 44+900(t/s) when compared with clause 202.2 of Technical Provisions of project. The plasticity Index of fines in base course varied from 5% to 8% against non-plastic specified material. Perhaps traffic was allowed to pass over the different layers of base course which could have contributed in foreign soil deposition over the base course leading to increase in Pl value. Contractor was allowed to skin patch, the trafficked surface of base course. which too had contributed in increasing the Pl of base course material. Los Angeles value of stone metal was 25.6% against 30% Max allowed in specification. The compaction of Aggregate base course varied from 96.2% to 100.3% against 100% minimum specified the quality of the material except high Pl value met the requirement of' specifications.

6.5 Asphalt Cement Base (A.C Base)

Four samples of' asphalt Base Course were collected to assess the quality of the AC Base. Two of these samples represented the area affected by cracking whereas the other two represented area, which was crack free. The samples were tested for their gradation, percentage bitumen content, compaction and thickness.

6.5.1 Gradation

The material sampled at Km 23+000 L-Section was finer at 3/4" sieve by 4.5% and coarser at # 8 sieve by 4.8%. The material sampled at Km 29+030 was coarser at sieve #8 by 7.2%. The material sampled at kill 35+000 L/s was coarser at sieve #8 by 7.8%. 'The material sampled at km 44+900 was finer at ^{3}/4"sieve by 9.4% and 14.4% at sieve # *1/2"* and 3.3% on # 8 sieve. The coarser material not only contributed to excessive voids hut also such mixes due to low workability are difficult to handle and compact.

6.5.2- Bitumen Content

Bitumen content in all case on the lower limit of specification, which suggested that the voids in mix were near the upper limit of specifications.

6.5.3- Thickness

The thickness of' A.C base was checked at 40 locations. It ranged from 3.464 to 7.672 cms. Thus the average measured thickness was 5.85 cms against specified requirement 6.0 cms.

6.5.4- Compaction

The compaction of A.C Base checked at 38 locations varied from 91 .5% to 100% against minimum requirement of 97%. Marshal from the mm design instead of the daily work reference density was used to calculate the %age compaction. (It could give error of 2 to 3%).

6.6- Asphalt Concrete Wearing Course

Four samples of AWC were collected to assess the quality of AC wearing course. The JMF recommended 4.8% (± 0.3%) optimum asphalt content, whereas site contract record showed 5.0% optimum asphalt content. Consultant could not give any justification for change in asphalt content without issuing' revised mix design. Mix used for wearing course in three out of' four locations was finer at sieve #3/8". It was coarser at sieves # 8, #. 30.

6.6.1 Bitumen Content

Bitumen content of all the four samples was deficient by 0.2%, *0.3%.* the cores had hungry look.

6.6.2 Thickness

The thickness of the asphalt-wearing course was measured at 40 locations, which ranged from 2.733 cms to 4.955 cms, thus the average of the all locations was 3.761 cms against specified thickness of 4.0 cms. The results though were within tolerable limits yet average thickness should have been 4 cms.

6.6.3 Compaction

The compaction of AC Wearing was checked at 38 locations and it varied from 91 % to 100 % against 97% minimum required by (he specification. In the absence of daily Marshall density JMF density had been used for calculation of compaction. Some of the cores had excessive voids.

7- AXLE LOAD STUDY

The road under investigation during construction and after opening had been subjected to proven southbound extraordinary heavy trucks carrying aggregates from Sargodha quarries. In addition to this there were two Sugar Mills, namely Kashmir Sugar Mill and Shakar Ganj Sugar Mill on Shorkot Cantt side and .Jhang side respectively. The reported total daily consumption of Kashmir Sugar Mill was 450 sugarcane trailer trolleys. out of which approximately 250 trailer trolleys (150 single axle and 100 double axle) used left lane of Jhang Shorkot Road. Similarly reported consumption of Shiakar Ganj Mill was 250 sugarcane trailers trolleys per day, out of which approximately 150-tractor trailer (100 single axle and 50 double axle) used the right lane of the-cited project. Sugar cane traffic uses this road from November to April (150 days in a year). These trolleys perhaps were over looked in traffic counts at design stage level. In summer again there is wheat movement on it. Wheat trailers too are heavily loaded

In the most recent times premature cracking of Ihang Chiniot Road. built under Asian Development Bank (ADB) aided Provincial Road improvement Programme was attributed to heavy sugar cane traffic (axle load as high as 20 tons). In addition to this southbound aggregate trucks from Sargodha quarries (axle load as high as 15 tons) adversely contributed to the problem. The aggregate trucks, which originate from Sargodha travel on Chiniot Jhang Road and then use Jhang Shorkot Road for delivery of construction material to further south of the province. The calculated damaging factor for Sugarcane trolleys was as high as 56.

According to Boussinesq's theory for a uniformly distributed circular load the magnitude of vertical pressure at any depth below the pavement is a function of stress and load at the point of its application. For a surface pressure of 14 kg/cm^2 increase of load from 18 ton to 36 ton will increases the vertical stress from almost 0 to 5 kg/cm^2 at 50 cms depth. Drivers of the commercial vehicles habitually over inflate tyres to allow them to overload their trucks. This not only results into an increased pressure on the pavement surface but also higher vertical stress at different layers of the road pavement. The over stressing of different pavement layers could lead to premature fatigue cracks

8- COMMON TYPES OF FAILURES ATTRIBUTED TO HEAVY AXLE LOADS

In Pakistan in last decade or so many asphalted roads have faced pre-mature failures either due to rutting or cracking. These failures generally had been attributed to heavy axle load without looking into overall construction and mix design properties. Using coarser mixes with air voids in the range of 5% to 8% and low asphalt contents are tricky and difficult to compact. They though help in controlling the phenomenon of rutting yet if such mixes are not compacted to 99% to 100% marshal densities, tend to leave very high voids within the mass of asphalt concrete. Particularly in non-trafficked portion of the pavement. High voids tend to reduce the fatigue life and are responsible for 'top down cracking' in asphalt-surfaced pavements.

9- REPORTED RESEARCH FINDINGS OF AUSTROADS

Air voids within a compacted dense graded asphalt mix have a major influence on service properties. In -situ air voids are partly a function of' design and manufacture but more particularly are an outcome of compaction achieved during placing.

Water permeability through an asphalt mix can cause damage to underlying layers as well as damage to the asphalt mix itself'. At around 6-7% air voids. the void spaces are largely unconnected and the rate of moisture entry is low and unlikely to cause harm. Above about 1 3% air voids, the asphalt is free draining.. Between 7 and 13% there is a risk that the asphalt mix can become saturated. Heavy traffic, which causes pore pressure within the saturated mix, can then lead to separation or stripping of the binder from the aggregate surface.

9.1- Assessing Field Density

Field density may be either expressed relative to the bulk density of a laboratory compacted mix or the maximum density (void-free density). In the first case estimation of' insitu air voids must make allowance for the air voids in the laboratory compacted mix. In the latter case, relative density is a direct measure of air voids as shown in **Table-2** below:-

Table-2

Insitu Air Voids (%)	DENSITY RATIO (RELATIVE COMPACTION	
	Relative to Maximum Density	Relative to Laboratory Density of 5% Voids
4	96	101
5	95	100
6	94	99
10	90	95
14	86	91

9.2- In-situ Air Voids and Density Ratios

Design air voids are selected on the basis of the expected level of' traffic and the risks associated with rutting and texture loss of wearing course mixes subjected to heavy traffic. Table 3 gives an outline of laboratory compaction levels and air voids for typical dense graded mixes.

Table-3

MIX TYPE		Laboratory Compaction Level (Cycles)	Design Air Voids (%)
Traffic Group	Application		
Light	Wearing and base	50	4.0
Medium	Wearing and base	80	4.0
	High fatigue base	80	3.0
Heavy	Wearing and base	120	4.0
	High fatigue base	120	3.0
Very Heavy	Wearing and base	120	5.0

9.3- Typical Design Air Voids

Dense graded asphalt mixes are designed to achieve the lowest practicable air voids consistent with the risks of' rutting and instability under heavy traffic. Service properties will however, be seriously affected if mixes are not compacted close to the laboratory design level.

10- CONCLUSIONS

10.1 High air voids in the asphalt mix, particularly in asphalt wearing course, asphlat content on the lower side of permissible limits and at places less than specified compaction had substantially reduced the fatigue life of top asphalt pavement layer (estimated at more than 50%). Air ingress had also caused gradual hardening of asphalt. Viscosity perhaps had approached the critical level. Brittle asphalt thus was very conducive to different types of' cracking. Apparently while making asphalt mix design attempt had not been made to ensure that traditional fatigue failure of the surfacing did not occur within design life i.e. $48x10^6$,ESA or 10 years life. The characteristic of overlays, which did not crack to date, had shown how mixes could be designed for long life but the tolerance are likely to be too strict for normal production method.

10.2 There was nothing to show that either project or other roads of similar construction in the region are cracking/ rutting because of deficiency in overall strength of pavement. This phenomena was confirmed by standard deflection values. Mean standard deflection values irrespective of cracked surface varied between $30x\ 10^{-2}$ mm to $38x\ 10^{-2}$ mm suggesting that structural integrity of pavement layer was intact. Thin layer of sealant had already arrested further spread of cracks.

10.3 In tropical and sub tropical climates bitumen in the top few millimeters of high voids bituminous asphalt-wearing courses oxidizes rapidly. This causes the material to become brittle and results in cracking being initiated at the top of surfacing rather than at the bottom despite strains being lower. The type and severity of' this form of cracking is complex function of material properties and both environmental and traffic stresses. Its development has yet to be successfully described by means of practical analytical model. Longitudinal 'top down cracks', which has been reported by TRL Overseas Road Note 18 (1999) as fatigue cracks, often develop long before other types of' cracks and thus performance of asphalt-surfaced roads rarely agrees with analytical models.

104- None of the sections had reached a failure criteria of an average rut depth of 15 mm, $120x10^{-2}$ mm deflection and crack width 0.25 mm or more in 2 ½ years of trafficking

105- Water permeability due to fatigue cracks had not only damaged the underlying layers but also asphalt. This particularly was true for areas where skin patching of aggregate base course was allowed. It had weakened the bond between asphalt surfacing and the aggregate base course. Surfacing thus could effectively bounce under traffic. It quickly resulted in crocodile cracking in wheel paths and was characterized by blocks of less than 200 mm square.

10.6- Extraordinary high axle loads of sugarcane trolleys in winter and large number of south bound aggregate trucks in summer had not only caused very high deflections leading to further cracking of weakened bituminous wearing course but also high shear forces across the fatigue cracks had contributed to the propagation of cracks to full asphalt depth or even beyond.

10.7- Train of' Sugarcane trolleys plying in winter on this road had played havoc with the treated shoulders and pavement edges. This required continuous maintenance. Perhaps it was ignored during the maintenance period.

11- RECOMMENDATIONS

11.1 Benkelman beam survey results, component analysis and visual inspection of' the distress road suggested that fatigue and other sympathetic cracks were progressive in nature, therefore, following measures were suggested.

- Two local potholes should be repaired by removing pavement layers including aggregate base course. It should be replaced with lean concrete followed by Bituminous Wearing Course (BWC).
- BWC from Km 22+00 to Km 22+800 (800 mts) had failed beyond repair. It should immediately be removed and replaced with properly designed fresh asphalt.
- The reach from Km 25+500 to Km 28+500 and Km 36+000 to Km 39-1000 (6 Km) where corrected standard deflection was 0.38 mm, a 50 mm overlay (after' replacing the badly cracked asphalt and sealing the cracks) should be considered to enhance the remaining life of the road from 6 million standard axle (msa) to 17 msa.
- For the balance length of the road (26.70 Kms) a single surface treatment coat (12 mm chipping) is recommended to reduce the risk of premature 'top down cracking' associated with bitumen age hardening.
- Badly eroded shoulders, which were causing progressive edge failure, must be repaired before the next sugarcane crushing seasons.

The estimated cost of the above stated remedial measures, based on prevailing market rates of July 2000 worked out to Rs. 34 Million.

11.2. Heavy axle loads particularly of sugarcane trolleys based and aggregate trucks (measured up to 24 tons) are a great menace for our network. Premature failures of asphalted roads in the last decade or so had costed billions of rupees to fragile national economy. It is recommended until nation wide axle load restrictions are imposed weighbridges be installed on newly constructed costly asphalt roads. Normal toll tax for the maintenance and upkeep of the road may also be levied.

11.3 Unfortunately hardly any indigenous research work regarding the affect of heavy axle loads on the pavement behavior are available. There is immediate need to make these studies in local environment. Traffic and axle loads studies should be made part of all future Provincial Road Improvement Programmes.

11.4 Different types of asphalt mix designs have been introduced by foreign and local consultants, most of which are not time tested. When roads built with densely graded asphalt mixes failed in rutting, high void bituminous mixes were introduced. They in tropical and sub-tropical climatic condition markedly reduce the fatigue life of the pavements. RR&MTI in the past has successfully designed asphalt mixes for these conditions, therefore, in case of foreign aided projects; local experience must be blended with foreign expertise to offer the best suitable solutions.

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