NATIONAL TRANSPORT RESEARCH CENTRE

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DISTRESS ANALYSIS
OF
KASHMIR HIGHWAY

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EXECUTIVE SUMMARY

Highway pavements are designed to resist traffic loadings and climate changes during their life time but, unfortunately in Pakistan, highways generally fail prematurely. Kashmir Highway in Islamabad is a case in point. The section between Peshawar More and N-5 was reconstructed in 1989-90 and dualized in 1997 but signs of distress in terms of cracking, rutting & raveling have already started appearing on the pavement.

NTRC evaluated functional & structural characteristics of the road to determine the possible causes of distress/failure. The salient features of the analysis are as follows:-

PART A : VISUAL CHARACTERISTICS

1) The outer lane of the old carriageway has been extensively milled and patched since its re-construction in 1989-90, and has failed.

2) The inner lane of the old carriageway, which was previously used as out-bound lane, has a satisfactory riding quality, but it too has been milled and patched.

3) Riding quality of the new carriageway is poor.

4) Signs of high severity alligator/fatigue cracking, an indicator of structural weakness of pavement, were observed on several sections, in the outer lanes on both sides of the highway.

5) Bleeding/flushing of asphalt in shape of spots on small sections of new carriageway were also noticed while large sections of the old highway were found severely effected.

6) Corrugation/Shoving was found at three small portions of new highway, while the old highway is riddled with such distress type.

7) Three large embankment sections of the new highway have settled, while the old highway had five such sections.

8) Low-medium severity longitudinal and transverse cracking were found at many locations on the new carriageway.

9) Old carriageway had many potholes having diameters as large as 20 cms.

10) The outer lane of the new carriageway has developed ruts of low, medium and high severity on atleast 23 sections. Six sections had high severity ruts.

11) Drains were found silted and chocked, with soil and vegetation.

PART B : LABORATORY ANALYSIS

12) The laboratory analysis of extracted cores revealed that the distressed sections have either worn out due to high severity stripping/raveling or due to rutting of asphalt concrete.

13) Measurements of cores extracted from the unfailed sections of the new carriageway showed that the pavement thickness was 5-16 mm less than the specified.

14) The gradation curves show that the average pass percentage of aggregates of distressed sections was significantly higher than that of control sections. While no significant difference for the old highway was recorded.

15) The bitumen content in the distressed sections of old carriageway was higher then unfailed sections.

CONCLUSIONS

The rapid deterioration of the new carriageway of Kashmir Highway with a variety of distress types indicates that:-

i) Pavement was designed with insufficient structural strength and inappropriate estimation of heavy traffic loads.

ii) Cracking,corrugation, rutting, longitudinal and transverse cracking, bleeding are most probably caused by varied/poor quality of bituminous mix as well as poor construction quality.

iii) Poor control of the surface levels of pavement layers have effected the riding quality as well as the uniformity of the thickness.

iv) Settlements are caused by lack of slope protection and/or inadequate compaction.

v) Quality of aggregates used in the new highway was poor.

vi) Poor surface drainage, improper quality of bitumen along with usage of dirty aggregates caused stripping/ raveling.

The foregoing conclusions indicate that the major cause of poor performance of the new carriageway is inaccurate and incomplete quality control during various phases of highway construction.

RECOMMENDATIONS

- Accurate and complete quality control must be exercised at each stage of pavement construction.
- Since many forms of distress are closely interconnected and at later stages it becomes difficult to identify the primary cause, therefore, pavement monitoring survey (PSI/CPI) should be regularly carried out in order to apply timely remedial measures.
- Cracks and potholes must be sealed immediately.
- Drains must be kept clear.

1 : Introduction

Kashmir highway has been upgraded in November, 1997 to a two lane divided highway facility (from Zero-point to Motorway and N-5) to provide efficient and smooth passage to Pakistan Motorway (M-2) section as well as to GT Road (N-5). Signs of distress became very noticeable in the newly dualized section of Kashmir Highway since its opening (November 1997) which is being used as out-bound two lane highway facility.

Nearly Highway pavements are designed and constructed to last a certain period having several physical, structural, and functional properties. These properties (pavement performance) are assessed to determine that how well the pavement served the user overtime. The engineers often associate pavement properties with an arbitrary, but quantifiable value relating to pavement roughness, pavement distress or pavement strength. Performance is than measured as a change in properties over time.

all the prominent distress signs like alligator/fatigue cracks, rut and stripping were quite visible. The old section which was a two lane undivided facility catering both in-coming and out-going traffic was re-constructed in 1989-90. The left lane which was used as incoming lane had been milled extensively and at several locations patch work was visible which had been done from time to time. While the right lane which was used as out-bound lane before dualisation is in better condition then the left lane but not free of distress signs.

A team of NTRC engineers carried out the pavement condition survey to determine the types, severity, and extent of distress and their causes. The team made several visits and thoroughly inspected the road pavement and road environment, and made various qualitative assessment and quantitative measurements as well as took photographs to augment the report. The information was duly recorded on the specifically designed performa, as shown in Fig 7. Extraction of cores from the distressed and controlled sections was carried out to evaluate the mix properties in NTRC's laboratories.

2 : Objectives

The NTRC Engineers were assigned the following objectives :-

i) To assess the surface distresses and estimate the riding quality.

ii) To compare the bitumen content of cores drilled out from distressed section and that from the control section (unfailed section).

iii) To inspect drainage and shoulder conditions.

3 : Methodology

The team visited the Peshawar More - G.T.Road Interchange section of Kashmir Highway several times. The methodology of the study covered the following steps :

(a) Riding quality assessment based on AASHTO criteria of Pavement Serviceability Rating (PSR)

(b) Inspection of the section for:

1) Distortions (depressions, ruts, corrugation, etc)
2) Cracking (fracture in pavement)
3) Disintegration (raveling, stripping potholing, etc)

(c) Photographing.
(d) Core extraction.
(e) Laboratory analysis/testing of drilled cores for:

1) Determination of bitumen content
2) Density of cores
3) Size and gradation of aggregates

(f) Analysis and discussion on results and report writing.

4 : Distress/Failure in Asphaltic Concrete Pavements

The basic measurement of pavement condition is existing distresses which are as follows:-

4.1 : Distress, class types, identification and measurement criteria:

There are two classes and several types of distress that are associated with each type of pavement. In general, two classes of pavement distress and/or failure are **structural and functional**. The structural distress is associated with the ability of the pavement to carry the design load. The functional distress deals mainly with ride quality and safety issues. Pavements that exhibit structural distress and/or failure (e.g., severe alligator cracking) will also exhibit functional distress (e.g. uncomfortable ride, low skid resistance) and/or failure. Inversely, functionally distressed and/or failed pavements (very rough) may be structurally sound. Each class of distress (functional or structural) contains several types of distress and/or failure.

These types are broadly classified into

(a) Distortion (depressions, ruts, corrugation)

(b) Cracking (fracture)

(c) Disintegration

These distress types are further defined into 17 distinct types. These are listed below in alphabetical order:

1. Alligator or fatigue cracking
2. Bleeding
3. Block cracking
4. Corrugation
5. Depression
6. Joint Reflective cracking from PCC slab
7. Lane/shoulder drop off or heave
8. Lane/shoulder separation
9. Longitudinal and transverse cracking (non-PCC slab joint reflective)

10. Patch deterioration
11. Polished aggregate
12. Potholes
13. Pumping and watering bleeding
14. Raveling and weathering/stripping
15. Rutting
16. Slippage cracking
17. Swell

During pavement evaluation, each distress should be identified using, a minimum of three factors: type, severity, and amount. Further, each type of distress is the result of one or more variables. When these variables are known, they provide great insight into the causes of pavement deterioration/failure.

1. Type: distress type can be determined primarily by similar mechanisms of occurrence and similar visual appearance.

2. Severity: Most distress types can take on a variety of severity conditions. These are divided into three levels: low, medium, and high. These levels are somewhat subjective but, in general they describe distinct categories of the progression for the distress type that relate well to rehabilitation needs. Photographs of the various levels of severity are an indispensable part of the identification process.

3. Amount: The quantity of each type and severity level that measured and expressed in convenient units provides a valuable data.

5 : Components of Flexible Pavement

The fundamental components of a flexible pavement are given below and are shown in Figure 5.

(a) Subgrade

(b) Subbase

(c) Asphaltic Concrete layer

(a) Subgrade: Subgrade is the supporting structure on which the layers of the pavement rest. In cut sections, its the original soil while in fill sections it is the imported soil. The causes of failure in a subgrade are:

(i) Elastic deformations

When the elastic deformations in subgrade are small, they do not cause the failure of pavement. But with highly resilient soils these small deflections become critical and under repeated heavy wheel loads can cause fatigue failures in asphaltic course.

(ii) Secondary compaction/consolidation

Consolidation or secondary compaction due to large wheel loads fills the voids and removes water from the pavement. Although such deformation are small but they are permanent. Excessive consolidation causes rutting.

(iii) Subsidence

Subsidence or settlements are typical subgrade failures. These are large depression in the pavement, occurring due to lack of lateral support to the embankment or due to inadequate compaction of the imported material. Subsidence is also effected by the moisture changes in the underlying soils.

(b) Base Course

A base course is an intermediate layer, supporting the upper asphaltic layer and distributing the load on subgrade. Base course have a higher quality material then the subgrade.

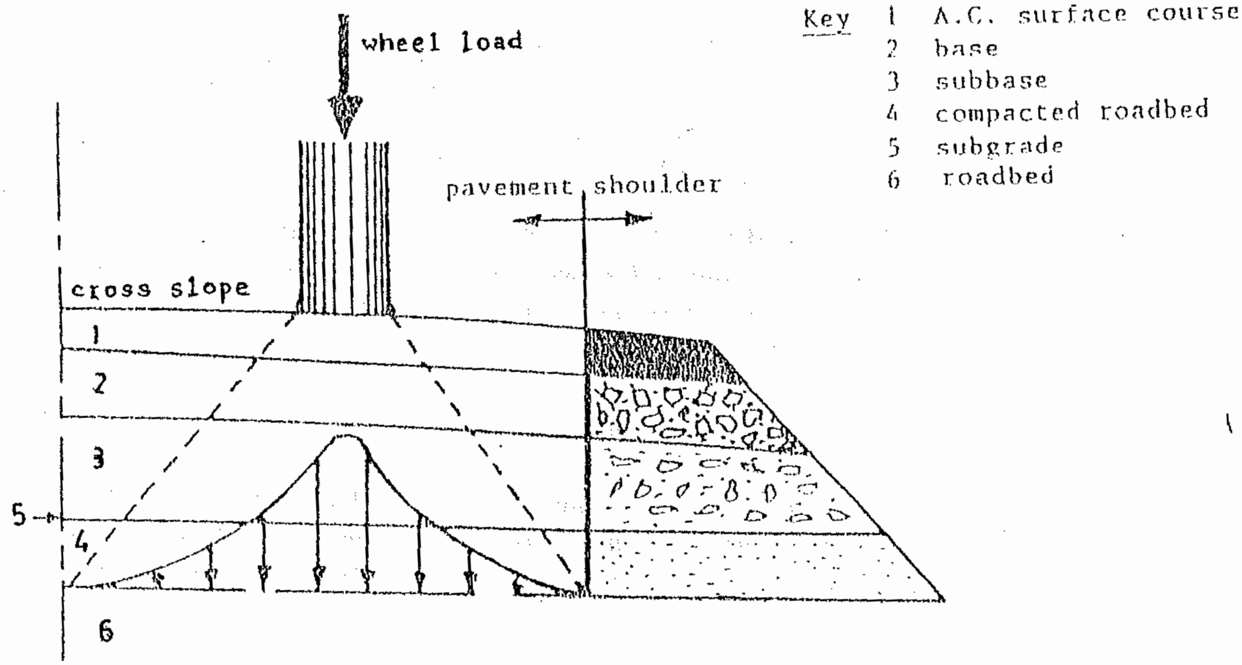


Fig. 5 : Components of a typical flexible pavement

The causes of failure in base course are more or less the same as in subgrade.

(c) Asphalt Concrete Layer

Asphalt concrete layer is the pavement's most sensitive layer to imposed loads and environmental conditions. The aspects of material, design and placement of this layer are important and need due consideration to avoid inadequacy/failure of the asphaltic concrete. This layer should have the following properties:-

(a)	Stability	(b)	Flexibility
(c)	Durability	(d)	Skid Resistance

(i) Aggregate

The aggregates in mix shall be chemical inert. They in addition to being the component which provide strength to the layer to support the load, also determine the texture of the surface through its shape and gradation. Texture of the finished surface is important for every road as utilization of low quality aggregates causes failure. The required qualities of aggregates are enumerated below:

a) Chemically inert
b) Gradation and its control
c) Affinity to bitumen and resistance to stripping
d) Shape and size
e) Water absorption
f) Utilization of clean and sound materials

(ii) Gradation

Gradation plays important role in the stability and performance of asphalt concrete layer both directly and indirectly.

(iii) Particle Shape

The use of flaky or elongated particles should be avoided, as presence of such particles results in mixture which are difficult to compact, likely to segregate and lose mechanical stability. Further the use of elongated particles require increase in bitumen content because of their increased surface area.

(iv) Surface Texture and Resistance to Skidding

Surface texture cannot be over emphasized for high quality highways. For the safety of drivers, sufficient bond between wheel and road surface is needed to prevent vehicle from sliding particularly during adverse weather condition. Experience has shown that the mixture having coarse aggregate with rough surface texture are more stable than those mixture which contain smooth crushed aggregate.

(v) Affinity of bitumen and stripping

Water has great tendency to displace the film of bitumen which coats aggregate of asphalt concrete, thus weakening the bond. This is generally known as stripping. It has been experienced that this phenomenon of wetting of aggregate surface varies in degree from one types of rock to other. The rocks more sensitive to stripping are known as Hydrophilic.

(vi) Bitumen

Bitumen which act as binder is one of the most important constituent of asphalt concrete. Its excess as well as its deficiency is harmful for the stability of mixture. The behavior of asphalt is very much related to local environmental conditions. Therefore, asphalt content and grade (penetration) should be carefully selected for asphalt concrete layer to be laid under severe loading and moderate climate condition.

Specifications for asphalt concrete layer shall take into consideration the following in particular in addition to general specifications:

a) Grade of asphalt
b) Bitumen content
c) Laying of asphalt concrete

(vii) Grade of Bitumen

The behavior of asphalt and penetration varies with temperature. Asphalt of low penetration grade is desirable for hot climate whereas high penetration grade is recommended for cold climate.

(viii) Bitumen Content

Bitumen content for asphalt concrete mix should be such that it provides a proper balance of stability and durability. In the case, where severe loading and moderate climate conditions with heavy rainfall prevail, it is more important to have bitumen in proper amount. The porosity and void in mineral aggregate is important for proper functioning of asphalt pavement. Lower porosity will result in trapping of water vapors in asphaltic course in hot weather. This will result in considerable vapor pressure from below the asphalt course, causing bleeding. Whereas high porosity will result in free circulation of air in mat. This is undesirable because of oxidation of bitumen making it hard and brittle. It is recommended to consider environmental condition while preparing mix designs during construction.

(ix) Laying of asphalt concrete

Consideration of weather limitations is most important in laying of asphalt concrete. In normal climate, the penetration of asphalt at the time of laying is close to that determined in laboratory. If penetration of asphalt determined in laboratory is changed from that of design mix, it will result in unexpected behavior under loads.

(x) Coordination of Mix Design Testing:

Mix design testing for asphalt paving construction must be thoroughly coordinated. Normally, mix design testing will have five important steps:

1) Preliminary Design
2) Source acceptance
3) Job-mix control
4) Routine construction testing.
5) Post construction testing

6 : Kashmir Highway

Kashmir Highway provides a vital link to Islamabad. It joins Murree Road on one side and Motorway (M-2) and GT Road (N-5) on the other side. It caters to a great deal of out-going and in-coming traffic. The layout plan of Kashmir Highway is shown in figure 6(a). The new out-bound carriageway of the Kashmir Highway was built in 1997 at a very rapid pace in order to provide access to the newly constructed Lahore-Islamabad Motorway. The new carriageway is a 7.65 meter (25 ft) wide two lane highway which is separated from the old highway by a 6.26 (20.5 ft) wide median. It has a 2m (6 ft) wide treated shoulder.

As regards the old in-bound carriageway, it was built by Pakistan Public Works Department, way back in 1963-64 and later on reconstructed by Capital Development Authority in 1988-89.

The old carriageway was a two lane undivided highway facility and catered for both incoming and outgoing traffic. The old carriageway is 7.3 m (24 ft) wide, having 2 m (6 ft) wide kacha shoulder. The shoulder is now being repaired and treated.

6.1 Cross Section of New and Old Carriageway

The following pavement cross sections have been adopted for the new carriageway section and the old carriageway section of the Kashmir Highway, as shown in fig 6.1(a) & 6.1(b).

Section A: Peshawar More to GT Road Intersection (New Section)

Asphalt Wearing Course 65 mm

Asphalt Base Course 100 mm

Aggregate Base Course 350 mm

Sub-base (Drainage layer) 250 mm (depending on topography)

LAYOUT PLAN OF KASHMIR HIGHWAY

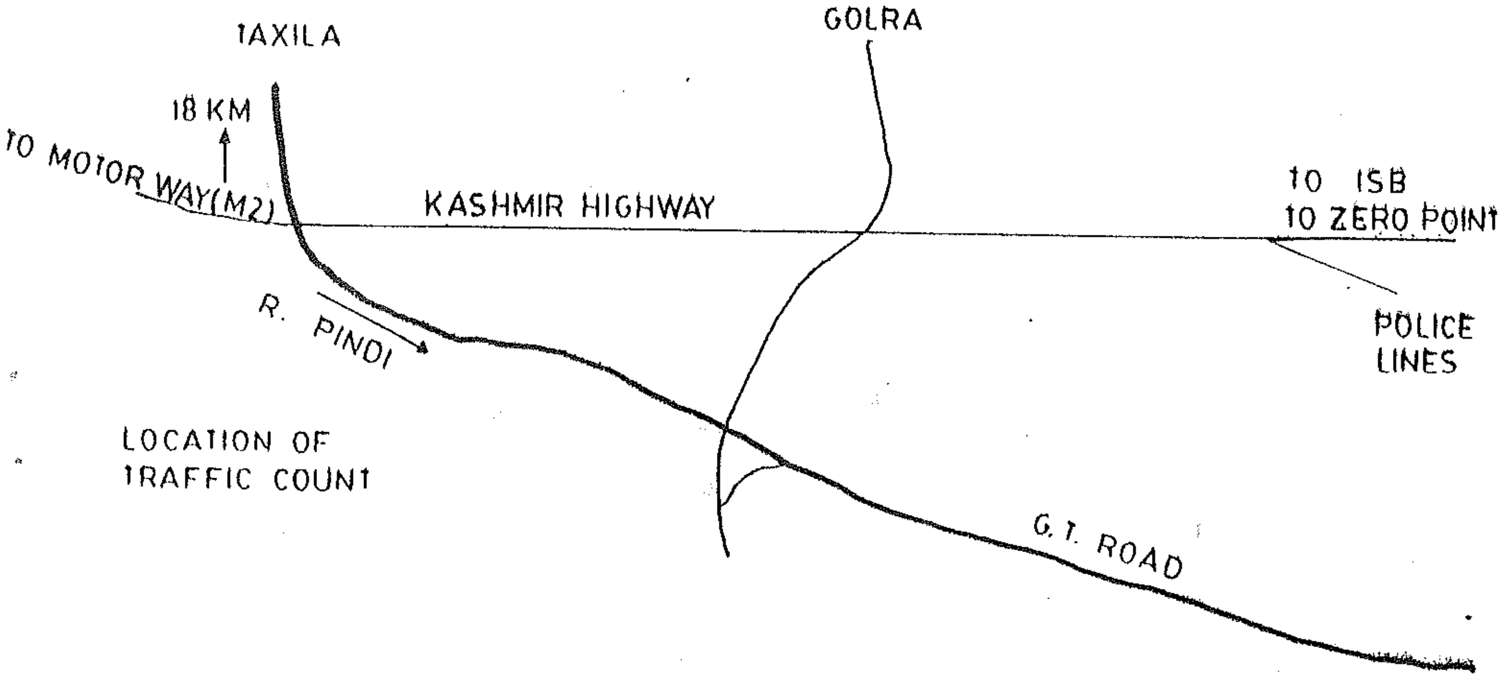


Fig. 6(a)

PROPOSED SECTIONS OF ROAD

(New carriageway)

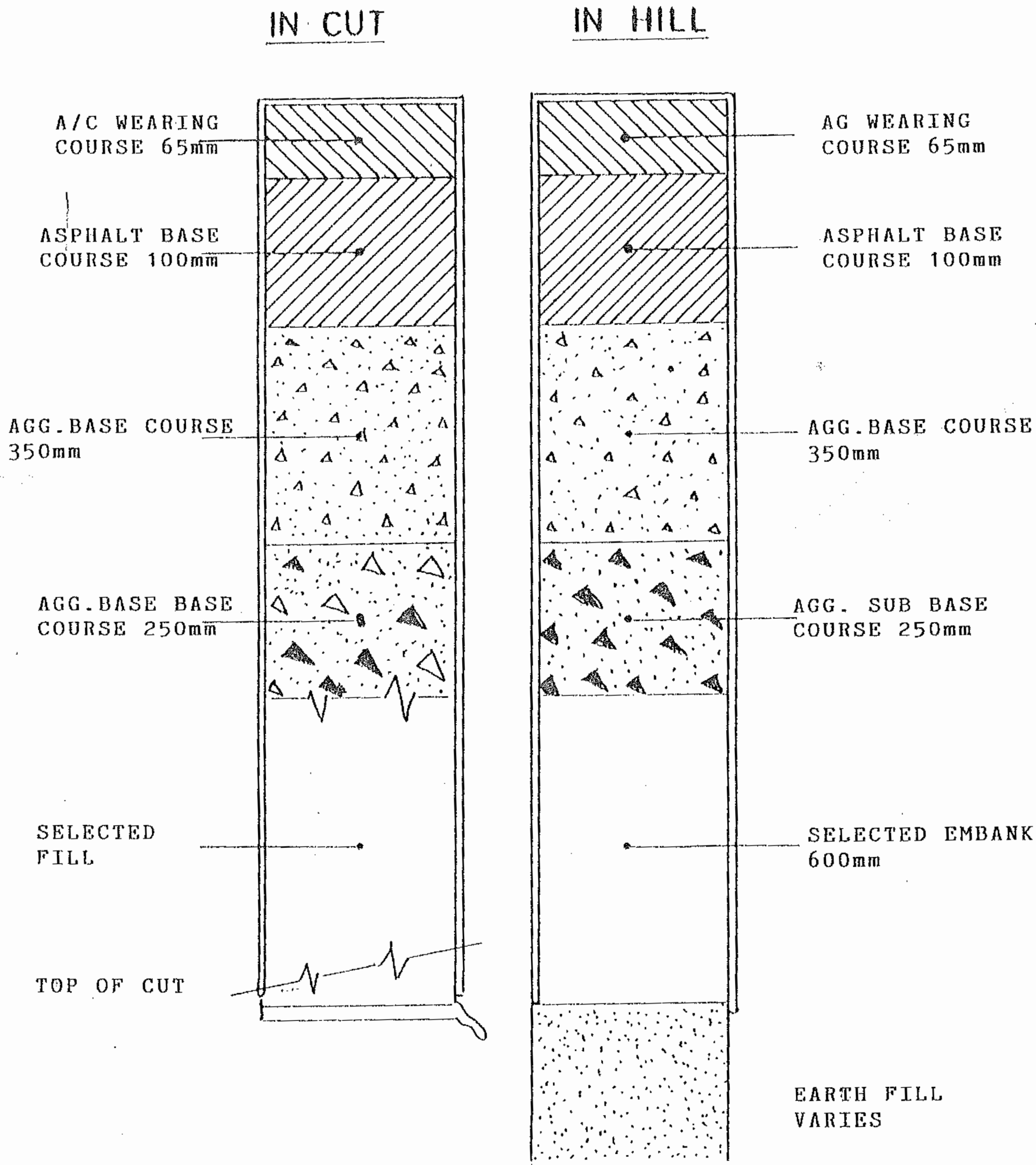
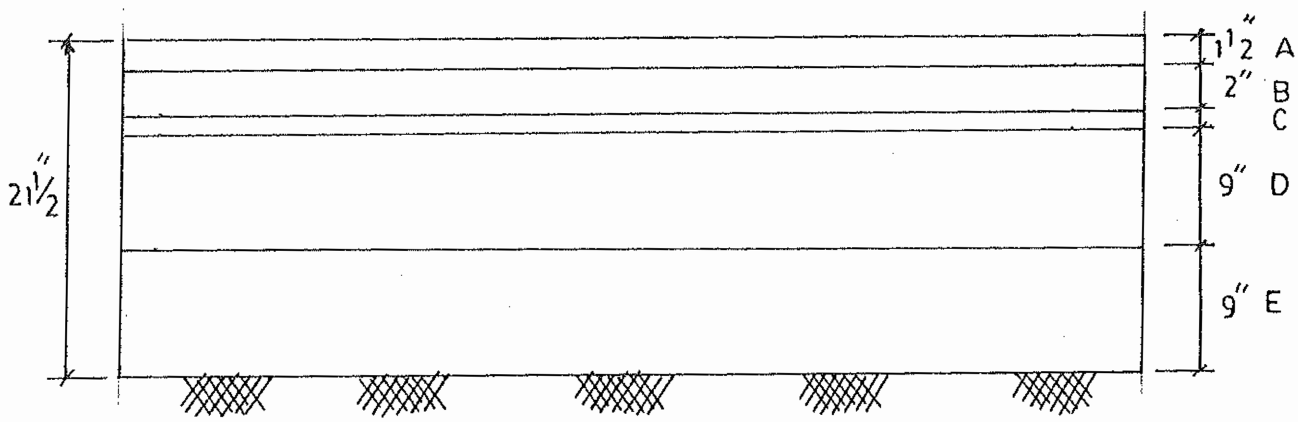


Fig. 6.1(a) Thickness of Various Layers

Old Kashmir Highway's X-Section



CDA Overly 1988-1989	A =	1.5" Av Thick Wearing Course of Asphaltic Concrete (40 MM)
	B =	2" Av Thick Binder Course of Asphaltic Concrete (50 MM)

First Time Const. by PWD 1963	C =	Old Triple Surface Treatment (TST)
	D =	9" Base Course of 2" Down Crushed Stone
	E =	9" Sub-base 1.5" Down Crushed Stone

Figure 6.1 (b)

Section B: GT Road Intersection - Peshawar More (Old Section)

CDA overlay 1988-89

Asphalt Wearing Course: 40 mm

Asphalt Base Course: 50 mm.

First time construction by PWD 1963

Sub-base (Old triple surface treatment (TST)

Aggregate Base Course: 230 mm

Drainage layer) 230 mm

7 : Visual Inspection/Surface Characteristics

The objective of visual inspection was to assess and locate the visible signs of distress, like, surface irregularities, type and extent of cracking, rut depth in wheel tracks, stripping, lane or shoulder drop off etc. These important indicators allow pavement engineers to depict the functional condition of highway facility. To check and locate the above mentioned distress signs in the pavement, close visual inspections were made along the whole length of the pavement, and measurements were taken at every 100 meter or 200 meters depending on the severity of distress, using the chart shown in figure 7. In all around 100 observations were made.

The results of the survey are summarized below:

7.1 General Surface Condition(Roughness):

Roughness is pavement surface's irregularities that adversely affect ride quality, safety and vehicle maintenance costs.

The general surface condition of the newly constructed out-bound section is not to the standard of a world class highway. The pavement surface was observed to be uneven, and a six foot straight edge revealed difference of 3-6 mm, between parallel planes of the lanes on the highway causing vibrations during traveling.

The left lane of the incoming section, which is the old Kashmir highway has failed and had been milled and patched extensively on a number of locations, while the second lane is considerably in better condition than the left lane. The AASHO pavement serviceability rating (PSR), a subjective criteria of ride quality, was used to determine the riding quality of the pavement.

Table 7.1 **AASHTO PSR Criteria**

RATING	NO
Excellent	5
Very Good	4
Good	3
Poor	2
Very Poor	1
Failure	0

Road Section ______________________ Date ________________

Direction ________________ Lane _______ Starting Chainage ________

Asphalt Pavement Distress Survey Data

S. No	Types of Distress	Causes of Distress					Classes of distress		Severity
		Load	Moi	Tem	Mat	Comb	Structural	Functional	L/M/S
1.	Alligator cracking								
2.	Block cracking								
3.	Slippage cracking								
4.	Longitudinal cracking								
5.	Transverse cracking								
6.	Diagonal cracking								
7.	Corrugation								
8.	Depression								
9.	Rutting								
10	Heave								
11	Swell								
12	Patholes								
13	Ravelling & weathering/stripping								
14	Pumping								
15	Patch deterioration								
16	Bleeding								
17	Lane/shoulder separation								
18	Lane/shoulder dropoff								

Load = Load related Moi = Moisture Related
Temp = Temperature related C = Any combination of
Mat = Material Related (Surface,base,subbase, subgrade, or Comb.)
n = No y = Yes p = Possible
L = Low M = Medium S = Sever

Fig. 7

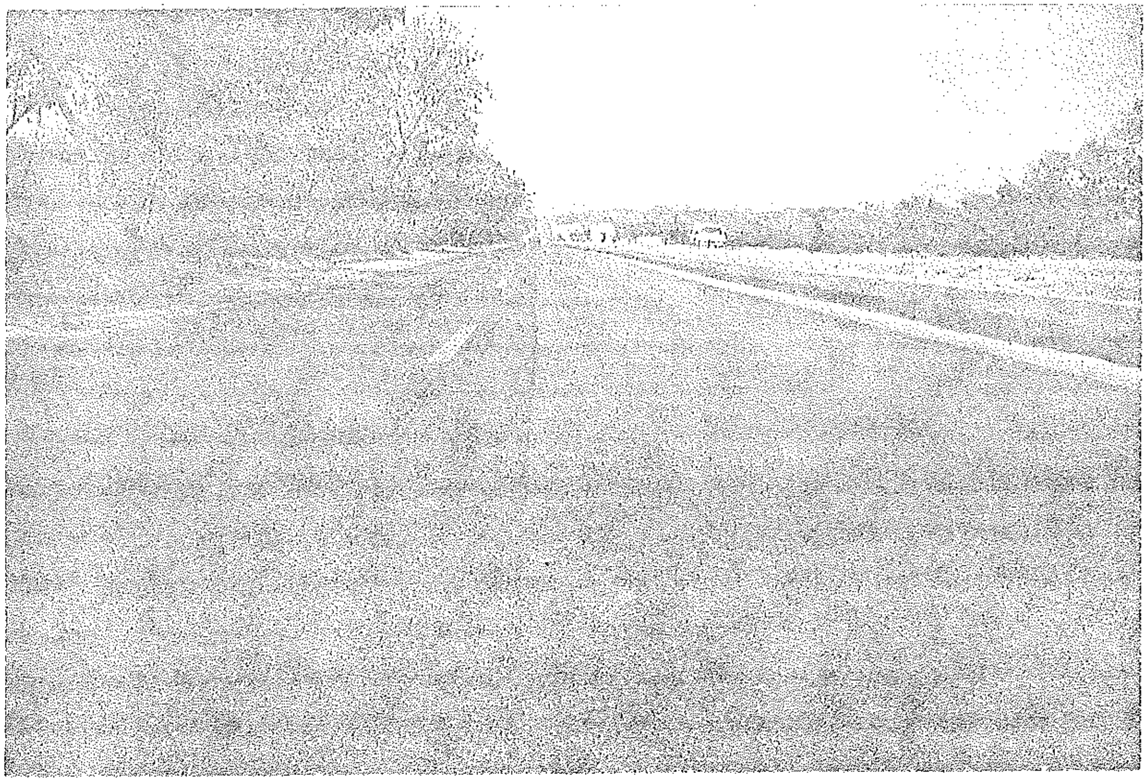


Plate 7.1(a) Completely milled outer lane of the old highway, exposing the texture to weathering. Polished surface of 2nd lane is also detectable.

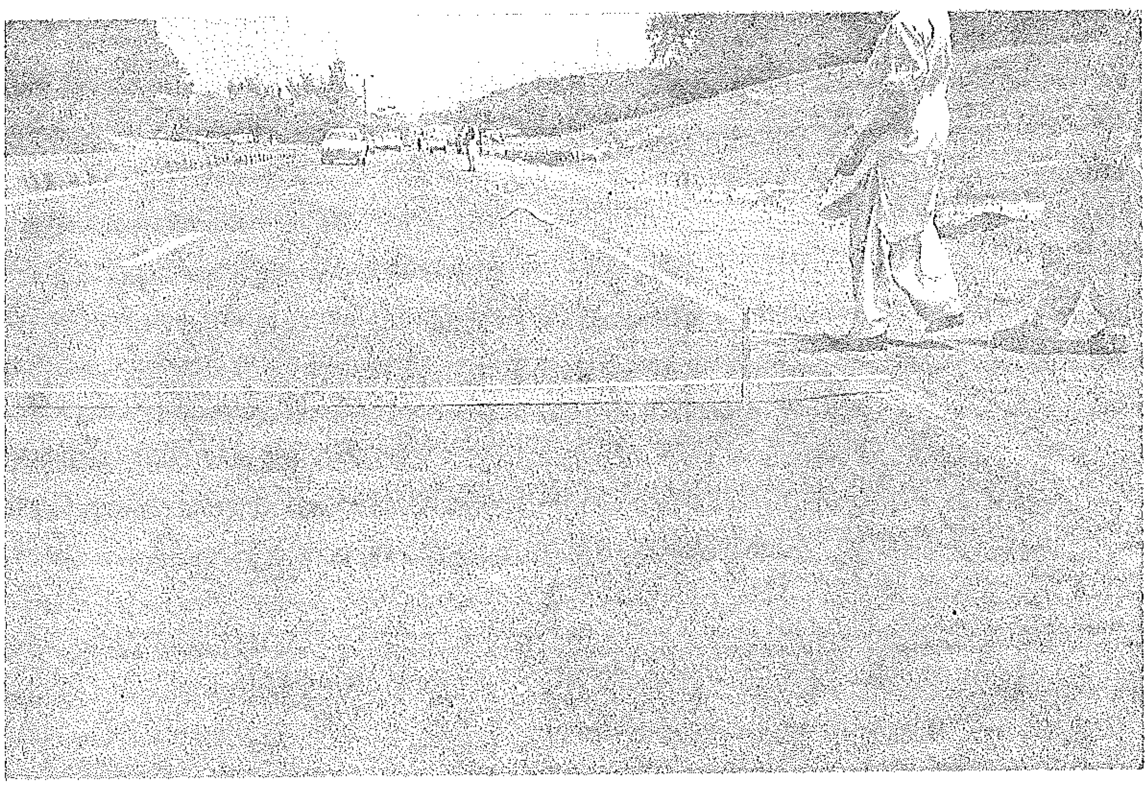


Plate 7.1(b) Partially milled outer lane of New Carriageway

A panel of two engineers rode the pavement in question and independently rated the riding quality of the out-bound and in-bound carriageways as tabulated below.

Table No 7.2 Riding Quality of Kashmir Highway

PESHAWAR MORE-G.T.ROAD INTERSECTION
(BASED ON AASHO CRITERIA)

Sl No	Highway Section	Riding Scale	Remarks
1.	Newly Constructed (out-bound)		
	a) Left-lane (Truck-lane)	2.0	Poor
	b) Right-Lane	3.0	Good
	Old Construction		
	Overall	2.5	Fair
2.	a) Left-lane (old incoming)	0	Failed
	b) Right-lane (old out going)	2.0	Poor
	Overall	1.0	Very poor

It is pertinent to point out that the riding quality of the Zero-point - Peshawar More section is good, because of the fact that no trucks ply on this section.

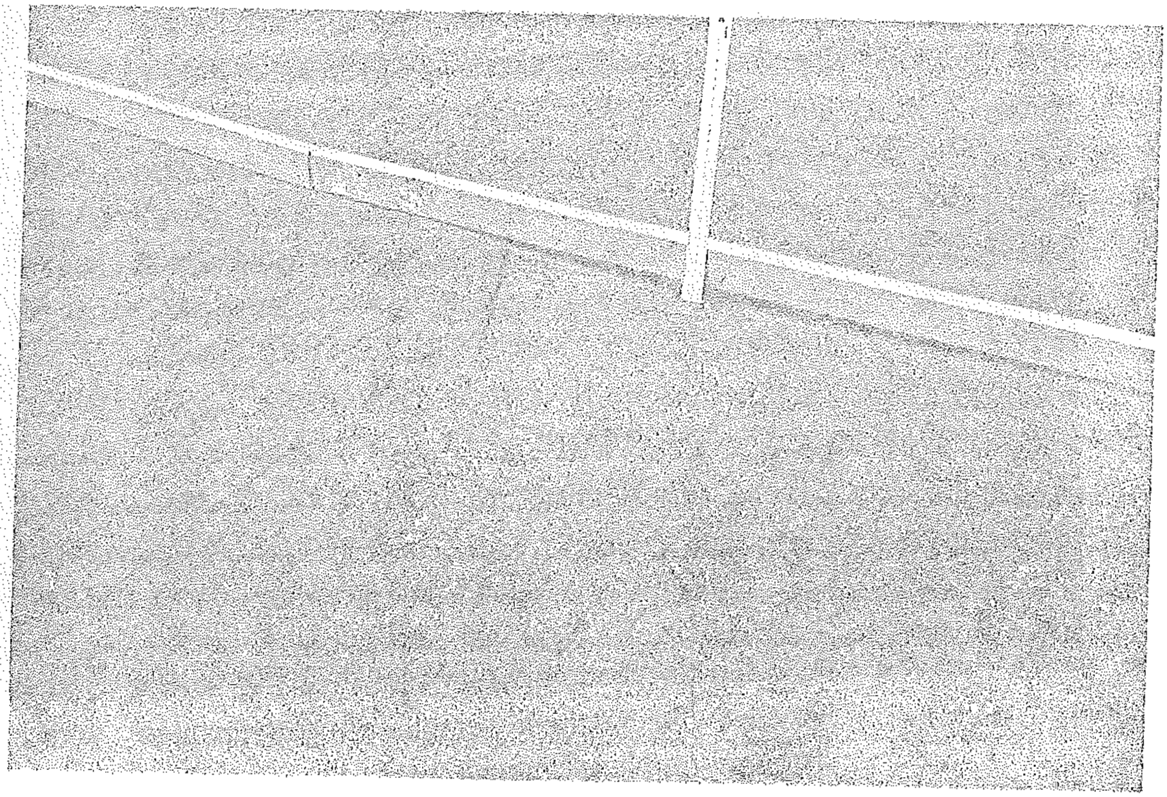
7.3 Alligator/Fatigue Cracking:

Signs of alligator and fatigue cracking, a series of interconnecting cracks caused by asphalt concrete failure, were observed on eight locations of the new highway. The cracks were of low severity at two locations and were of high severity at six sites and were spread over a large area of 15 meter to 30 meter in length. These cracks were located in the truck lane. While on the old highway, six locations were found to be severely cracked. Nearly a quarter of the outer lane of the old highway had been patched and half had been milled. This patching is spread over a number of sections of 25 meters to 200 meters long as shown in photographs 7.3-1 and 7.3-2.

These cracks have most probably developed because of:

i) Passage of heavy axle loads caused excessive defections/deformations of subbase and subgrade. Big part of these deflections/deformations were recovered after the removal of load as a 350 mm sub-base and 250

Plate 7.3-1 Severe wheel track cracking, longitudinal and interconnection (alligator).



(New Carriageway)

(Old Carriageway)

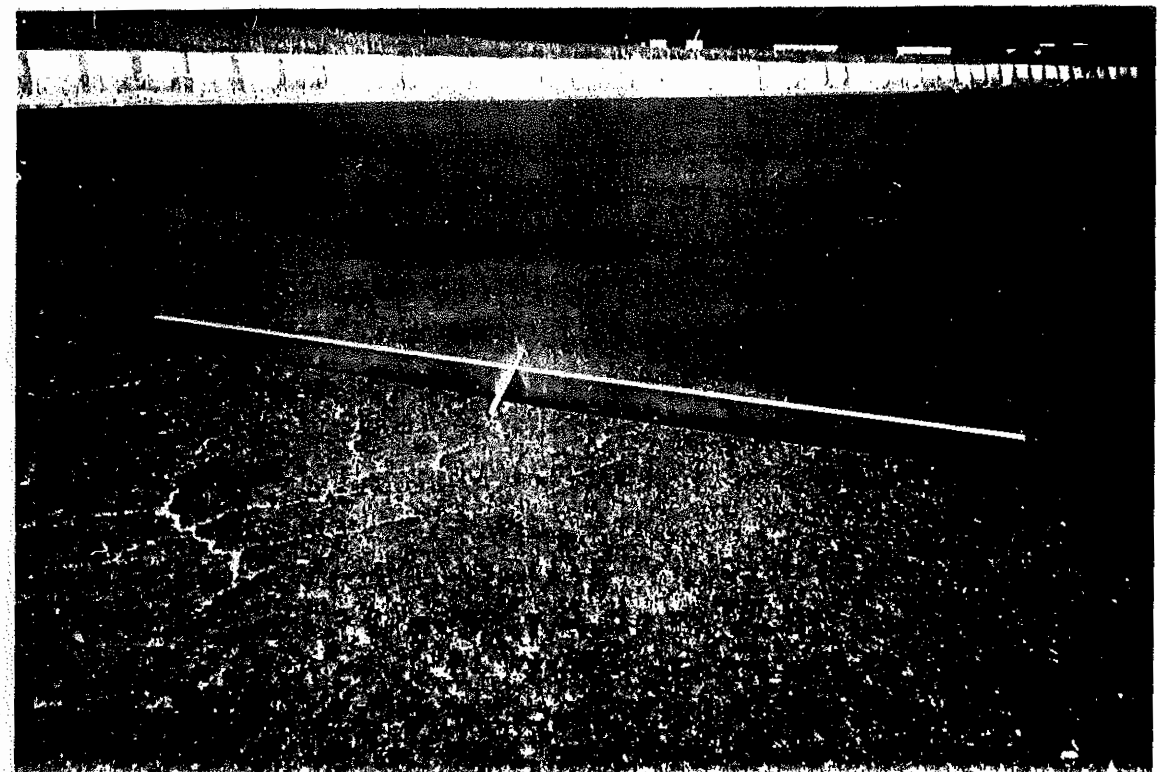


Plate 7.3-2(a) Severe wheel track cracking accompanied with severe stripping on New Carriageway.

Plate 7.3-2(b) Severe wheel track cracking and development of potholes on Old Carriageway.

mm subgrade is quite resilient enough to bounce back. This fact is substantiated by high values of DCP results. But the bituminous pavement was not flexible enough due to low tensile strength to follow these deformations and hence alligator cracks have appeared.

ii) Passage of heavy axle loads with high intensity of traffic at slow rates kept the pavement under stress for long periods. In such cases a major part of stress was relieved while a small part kept accumulating causing the pavement to crack (fatigue).

Apart from the above two distinct probabilities, age hardening of bituminous material due to oxidation and slow rates of loading decreased flexibility of asphalt and facilitated cracking.

Other factors which can cause alligator/fatigue cracks were related to design and construction such as inadequate thickness of pavement layers, construction lapses etc.

7.4 Edge Cracks

Signs of edge cracking were not observed in the new highway while the old highway had many. The probable cause was no lateral support and moisture difference between shoulder and pavements, as shown in photograph 7.10.

7.5 Bleeding or Flushing

Bleeding or flushing, i.e. a film of bituminous material on the pavement surface was observed to have started at several locations of the new highway, while the old highway had many. Bleeding of asphalt over pavement surface has created a shiny, viscous glass like reflecting spots at the moment on the new highway. It appears that bleeding has been caused by secondary compaction of asphalt concrete by heavy commercial vehicles in hot weather, as the asphalt content in the plant mix was found well within the design range. The additional densification filled the voids and then flushed the bitumen to surface as shown in pictures. Bleeding may have also been caused by too heavy seal/tack coat. Bleeding is a great safety hazard and considerably reduces skid resistance of the pavement surface. This phenomenon is shown in photograph 7.5-1 & 2.

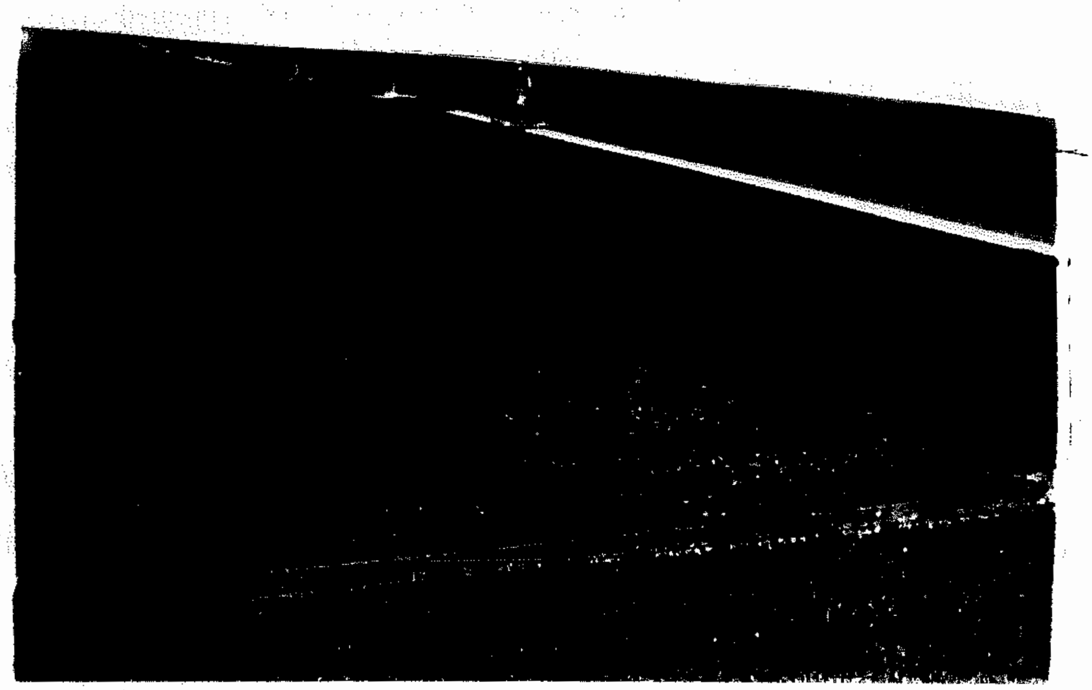


Plate 7.5-1 Bleeding in shape of spots on New Carriageway.

Plate 7.5-2 The rich surface texture provides ample evidence of bleeding on Old Carriageway.

7.6 Block Cracking/Shrinkage Cracking

No signs of block or shrinkage cracking, which are easily identifiable because of large block size and sharp edge corners (right angles) were observed.

7.7 Corrugations

Corrugation is a form of plastic movement of the asphalt surface typed by ripples across the asphaltic pavement surface, particularly in the proximity of the wheel path.

As corrugation usually occurs at a point where vehicles accelerate or decelerate, therefore, it was observed where trucks had to climb up the hill, take a sharp turn and had to stop. The severity was medium on the new carriageway while the old highway was severely effected at many places even at minor rises or decents, as shown in photograph 7.7-1 & 2.

7.8 Grade Depressions

At three places of the new highway these localized low areas of limited size and medium severity were found. These were accompanied by cracking. These are different from settlement where large area is affected. The probable causes included

i) Inadequate compaction of subbase and base courses
ii) Inadequate drainage.

7.9 Joint/Reflective Cracking from PCC Slab

No signs of joint/reflective cracking from PCC slab were observed as this type of distress is only a trade mark of asphalt-cement pavements.

7.10 Lane/Shoulder Drop off or Heave

No difference of level in elevation between the traffic lane and shoulder were observed on the new highway. The shoulder of the new highway is treated one, while the old highway was through out its length had a difference of atleast 4" - 6" between the shoulder and the outer lane as shown in photograph 7.10. Repair work and construction of a paved shoulder was in progress.

Plate 7.7-1 High severity rutting. Material shoved along the both sides of the rutted wheel paths on Old Carriageway.

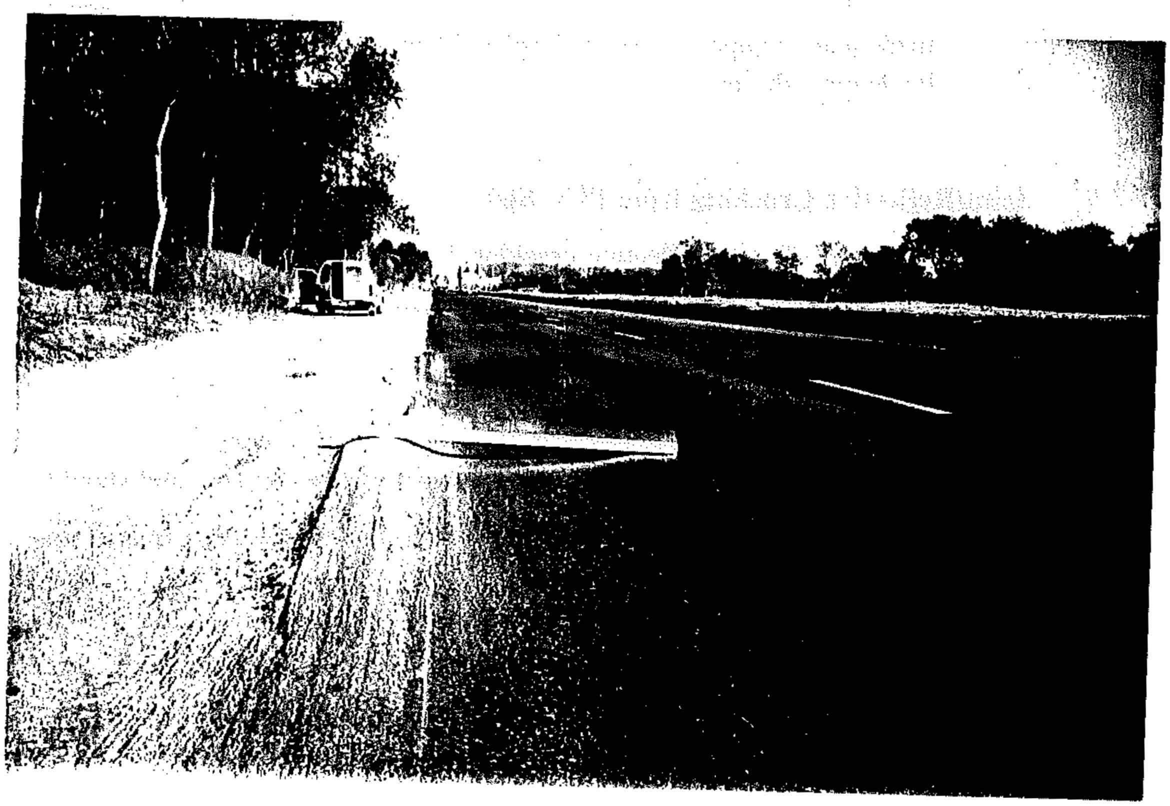


Plate 7.7-2 Signs of shoving of asphalt concrete on New Carriageway.

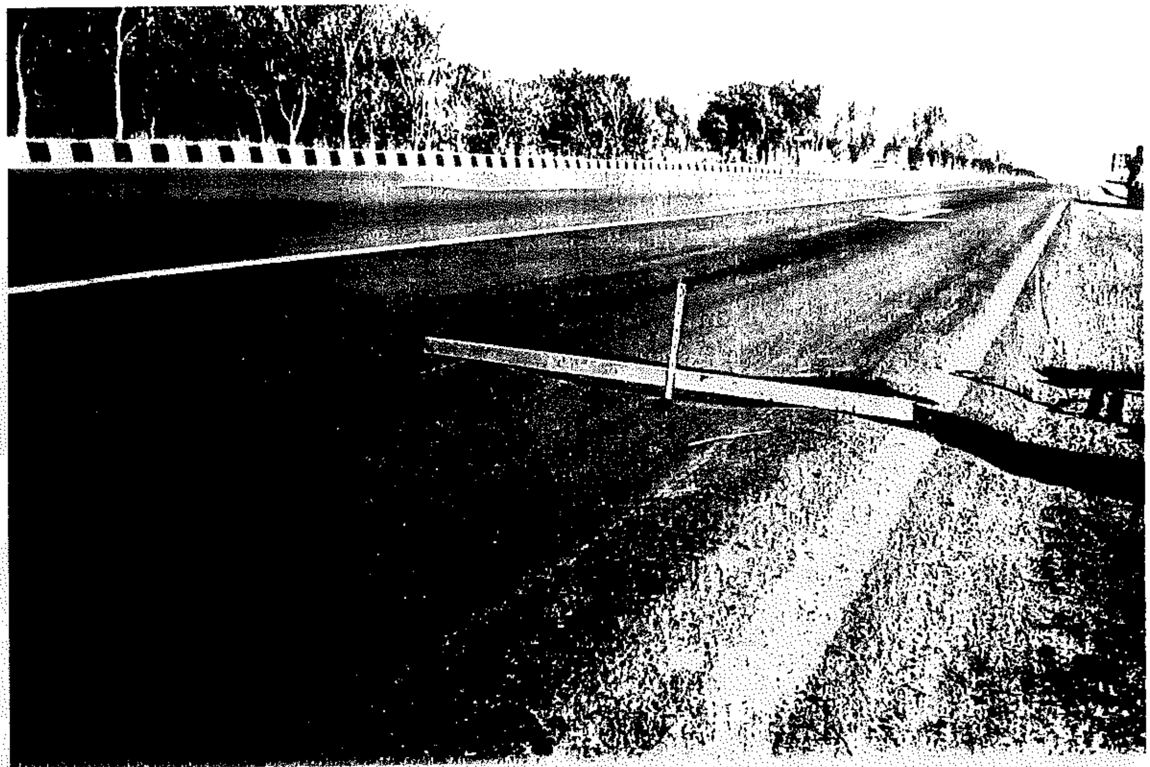


Plate 7.10 An eight inch shoulder drop-off accompanined with edge cracking

7.11 Lane/Shoulder Separation

No signs of widening of joint between traffic lane and shoulder were observed.

7.12 Longitudinal & Transverse Cracking

Signs of low-medium longitudinal and transverse cracking were observed on many sections of the new carriageway. The asphalt mix appeared stiff and dry. Longitudinal cracks were found on four sections of the new carriageway, all located in large fill areas. These cracks were running parallel to the direction of the pavement and were sometimes two, three and four in numbers. They varied in lengths, ranging from 9-30 meters.

Transverse cracks were mostly found at regular intervals in the wheel paths of the outer lane, having a size of approximately one meter in each wheel track. More than fifteen locations were marked with such cracks. The investigations showed that these cracks were propagating from top toward the bottom of asphalt layer. At two locations cores were drilled, which broke into pieces as the cracks have propagated to bottom.

The causes of such cracks were found to be:-

(a) The tensile strength (marshal stability) of the asphalt mix was low.
(b) Temperature variations have caused the age hardening of asphalt mix and heavy axle loads have aggravated the problem.
(c) Volume changes in subgrade might have also been responsible for longitudinal cracks.
(d) Volatility of bitumen was high, and was not suitable to environmental requirements.
(e) Perhaps, to avoid rutting, a hard grade bitumen was used, which resulted in a stiff mix.

If instant repairs are not carried out, structural damage would occur. Photographs 7.12-1 and 7.12-2 show the picture.

7.13 Patch Deterioration

Three patched areas were observed during the survey on the new highway, having a length of 50 to 100 meters, while a quarter length of the old highway is patched particularly in the outer lane. These patches are spread over several

Plate 7.12-1 Clearly visible longitudinal cracks. Structural damage is also visible on New Carriageway.

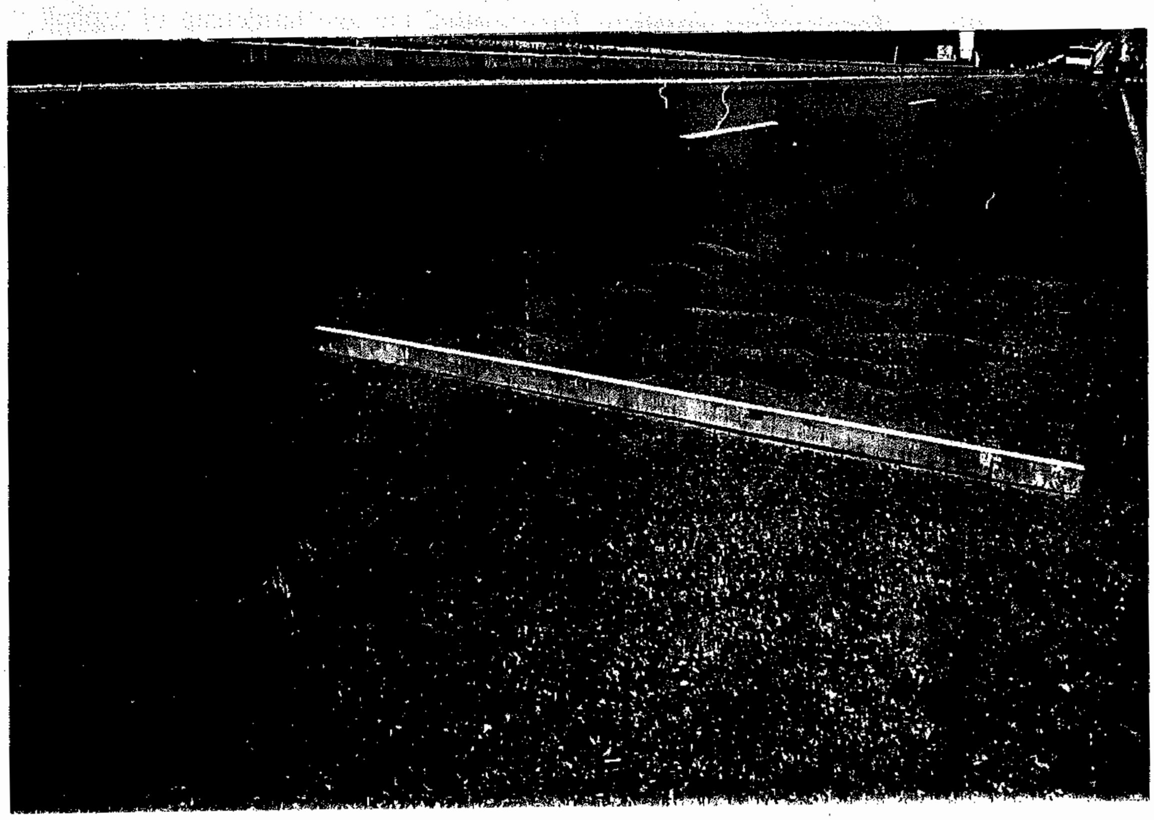


Plate 7.12-2 Transverse cracks on New Carriageway.

locations. The patches on the new highway are in satisfactory condition. While parts of patched areas of the old highway have peeled off due to lack of bond between the patched layers and improper application of tack coat.

7.14 Polished Aggregates

Significant signs of polishing of aggregates were observed at several locations and aggregates were found to be protruding above asphalt surface and were not rough at several locations on the new carriageway. Some polishing of aggregates on the right lane of the old carriageway was also observed. Nearly a quarter of the highway is patched and approximately half is milled, while a quarter is extremely rutted. These milled and rutted sections have very polished aggregates, which reduces skid resistance. The photographs 7.14-1 and 7.14-2 show the picture.

7.15 Potholes

Potholes, the bowl-shaped holes of various sizes were found on only two locations of the new highway while at eight locations these potholes were found on old highway. Similarly in cracked areas, it was observed that if no remedial measures will be taken, potholes would develop quickly due to accumulation of water. Potholes are ultimate stage of raveling. These are caused by alligator cracking, reveling, pounding etc. and can be avoided by regular maintenance. The photographs 7.15-1 and 7.15-2 show the picture.

7.16 Pumping and Water Bleeding

No signs of pumping and water bleeding were observed.

7.17 Raveling and Weathering/Stripping

Raveling is a measure of durability of asphalt concrete. Signs of raveling, weathering (stripping), which is the progressive separation of aggregates from pavement and separation of binder from aggregates respectively, were observed under wheel paths almost throughout the length of the new carriageway. Old highway had fewer signs. At places "resin" of pavement has started. The possible causes are:

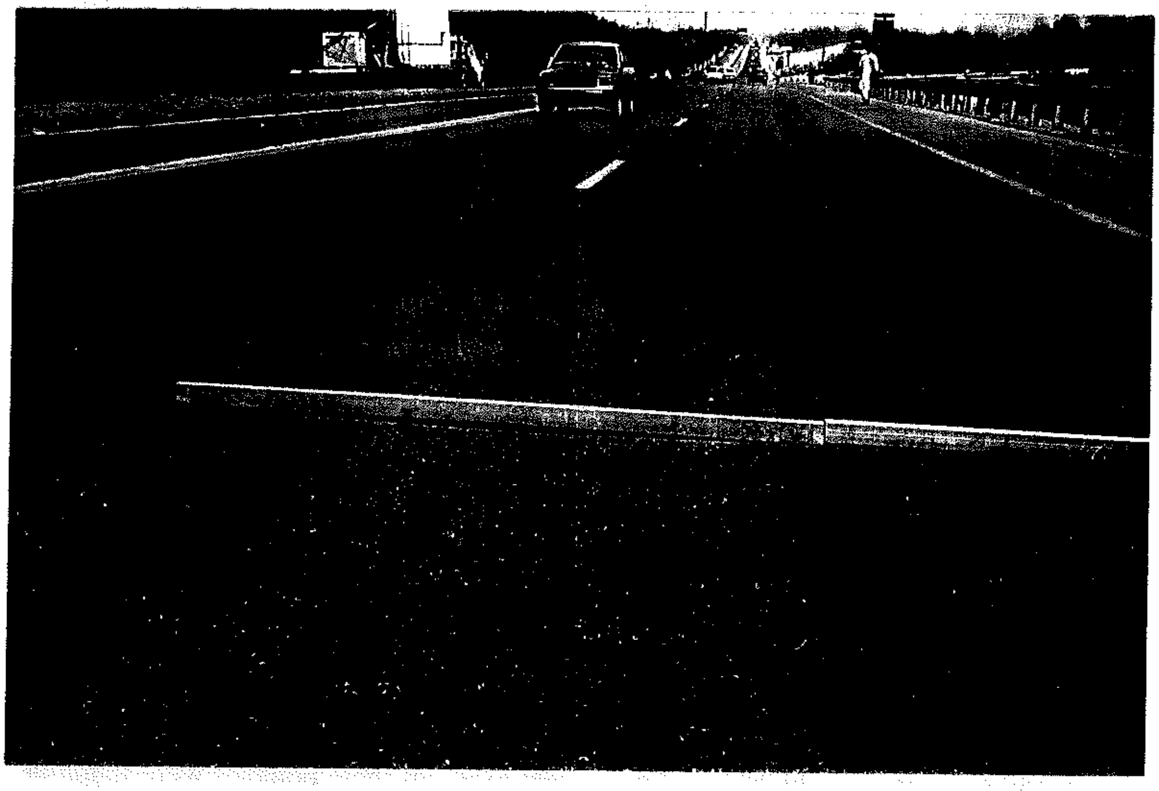
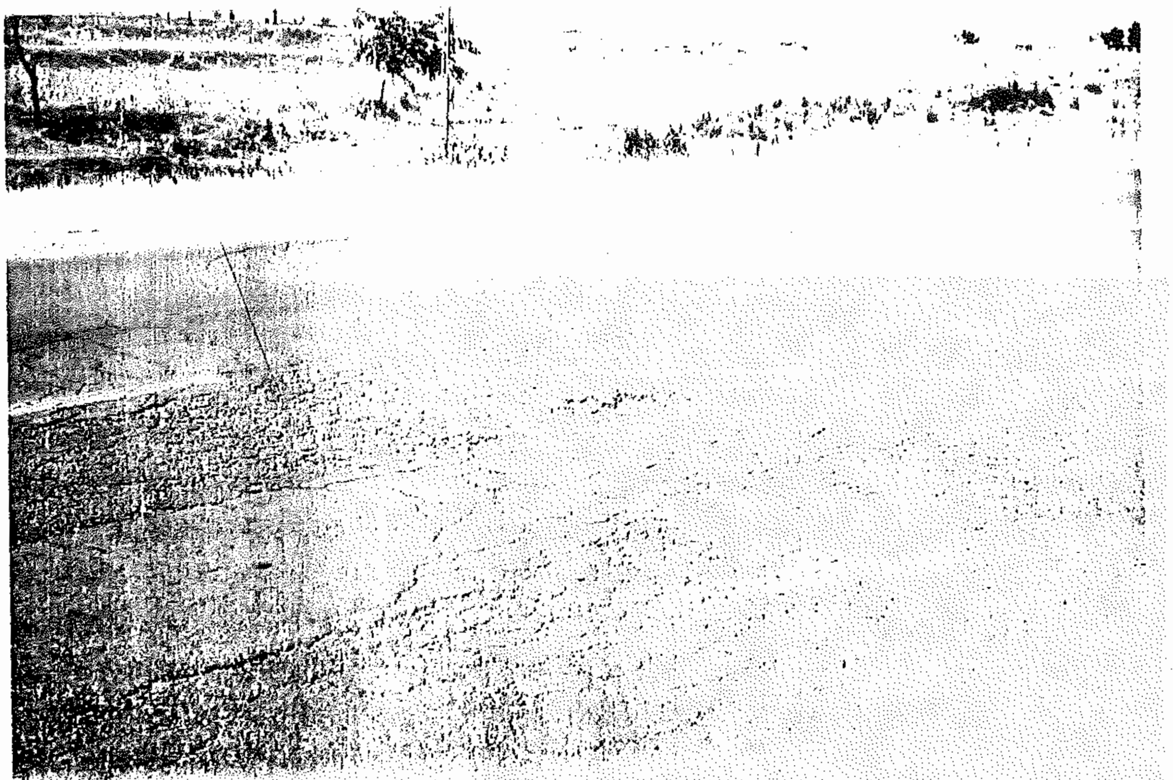
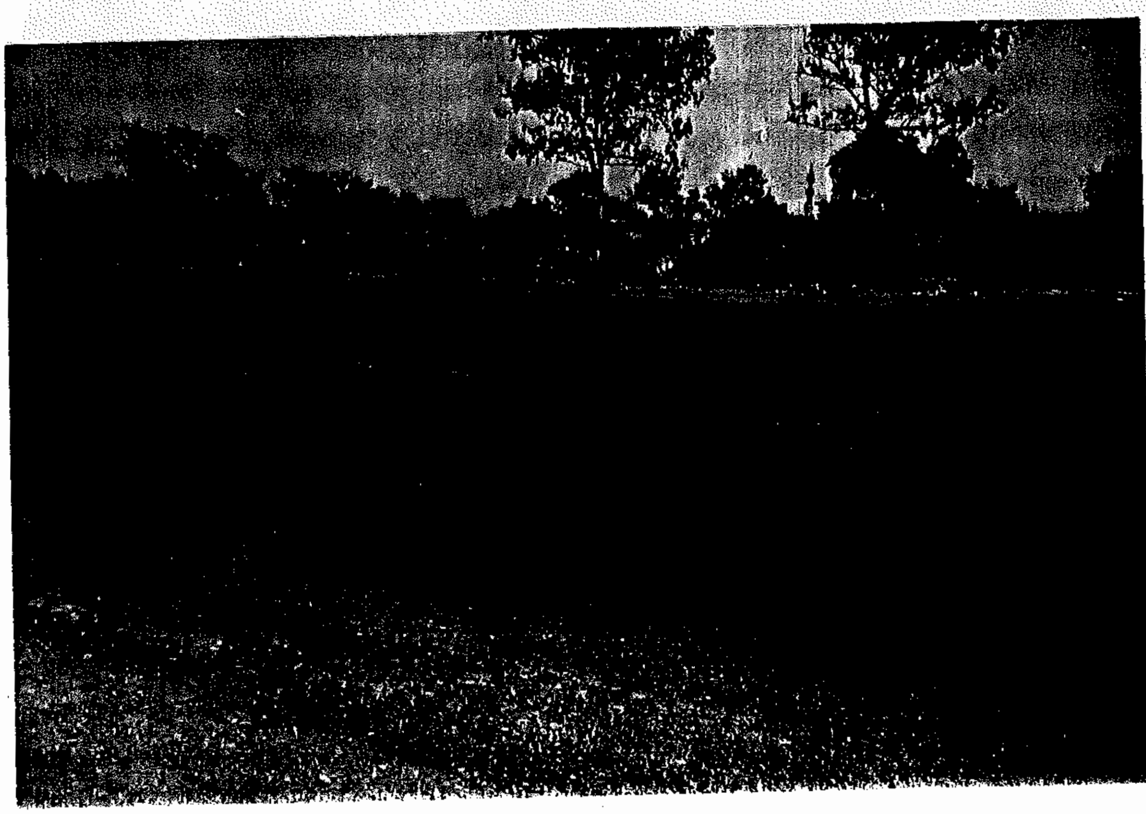


Plate 7.14-1 A view of polished aggregates on New Carriageway.

Plate 7.14-2 A view of polished aggregates on Old Carriageway.

Plate 7.15-1 Severe alligator cracking & potholing on Old Carriageway.





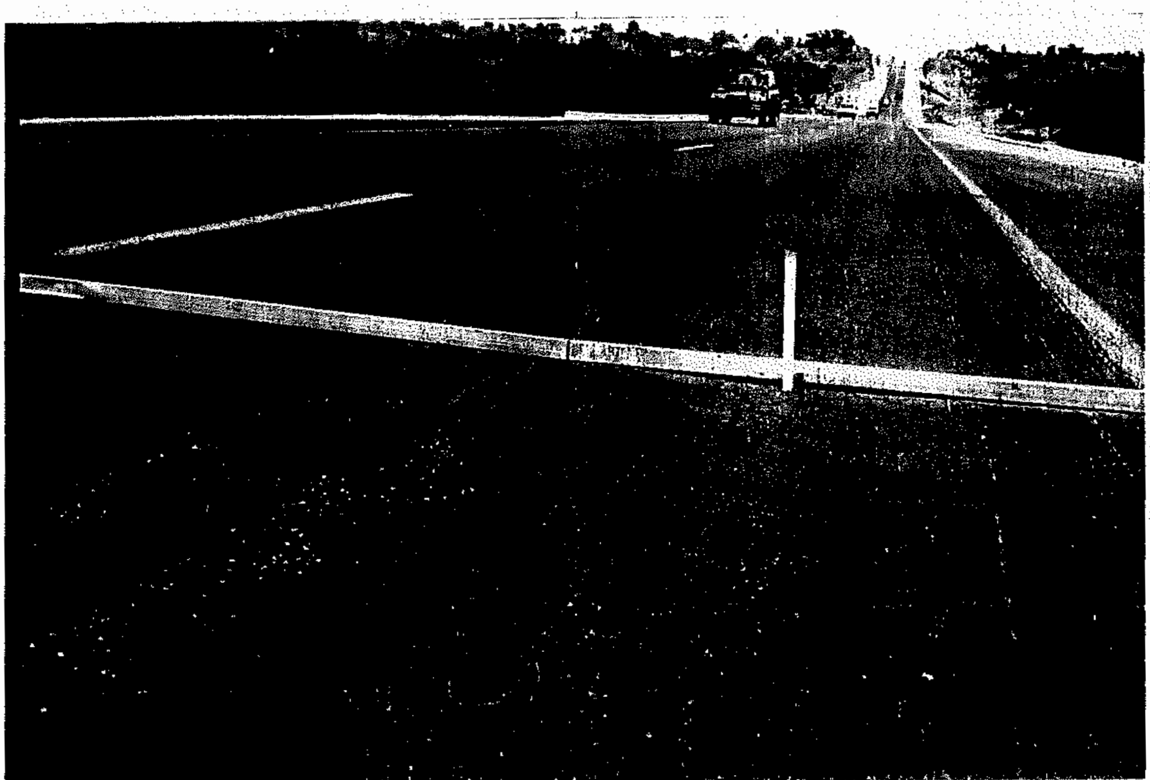


Plate 7.15-2 Initiation of potholing on New Carriageway.

Plate 7.17-1 Medium severity stripping of aggregates from the pavement on New Carriageway.

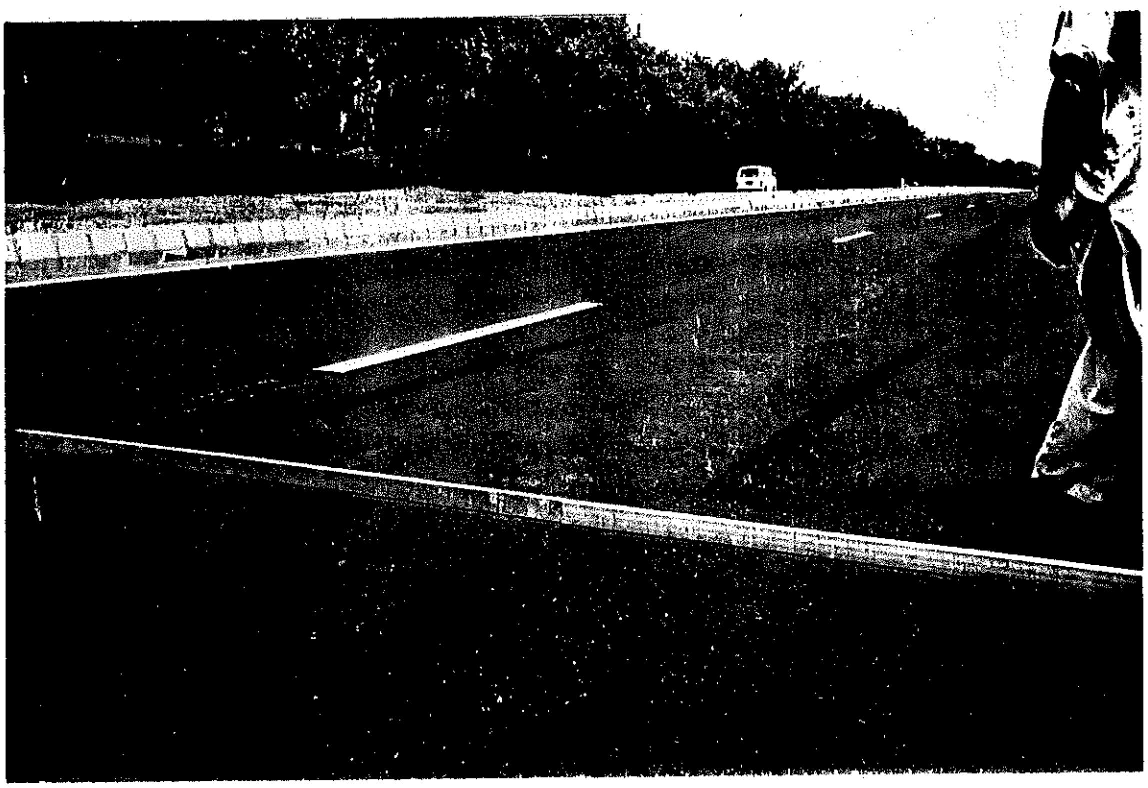


Plate 7.17-2 Medium severity stripping of aggregates from the pavement on New Carriageway.

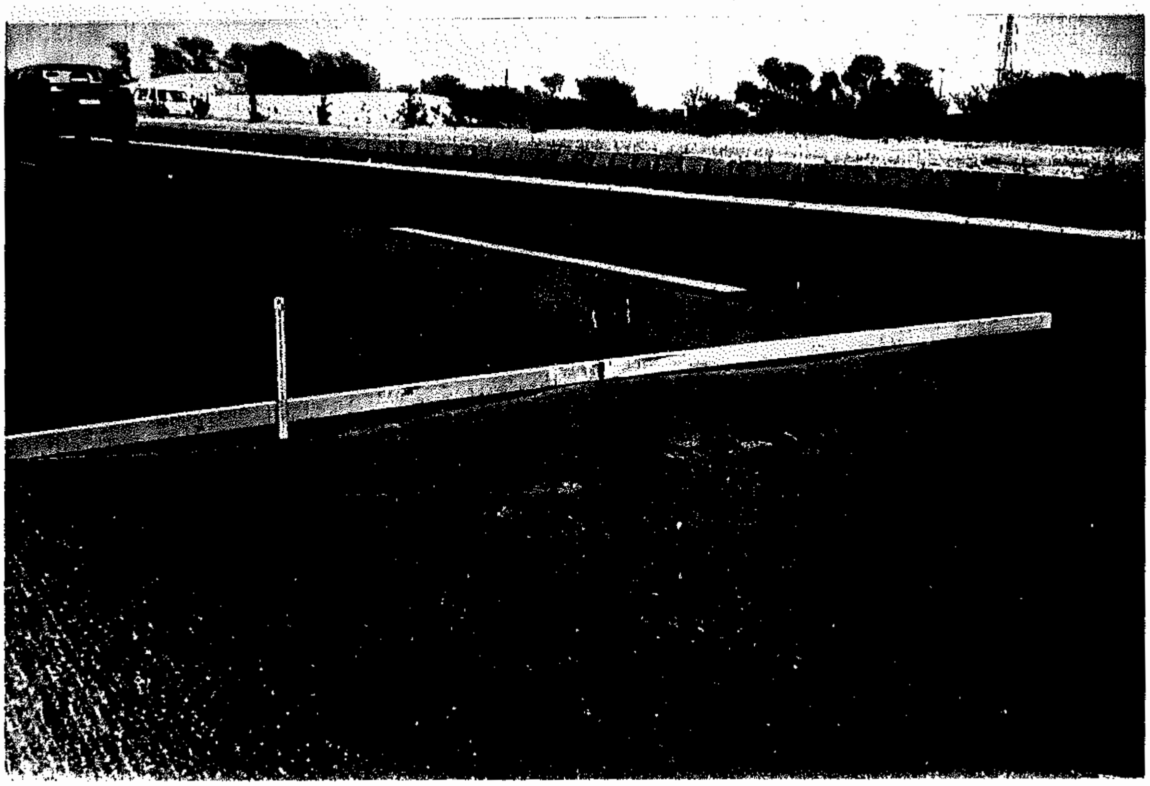


Plate 7.18-1 Severe rutting on New Carriageway (40 mm).

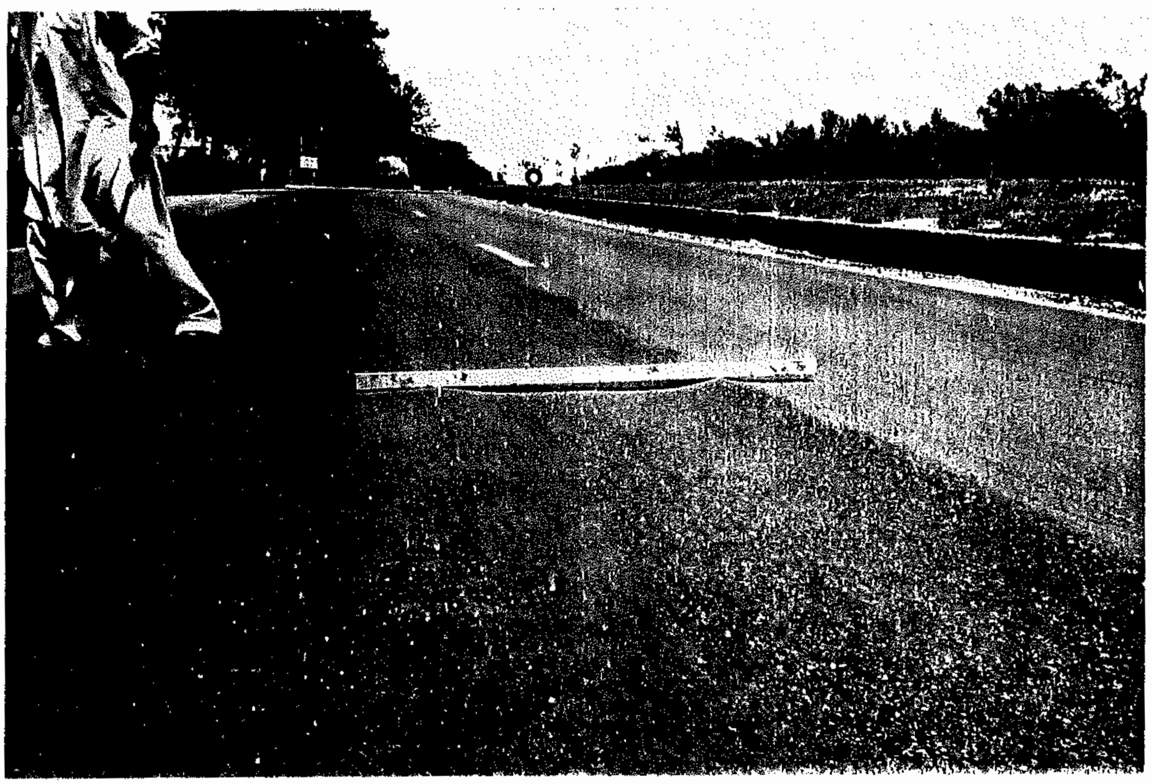


Plate 7.18-2 Severe rutting on Old Carriageway (50 mm).

i) Construction during wet or cold weather
ii) Dirty aggregates
iii) Perhaps, the asphalt was over-heated
iv) Aging of asphalt plays an important role.

The raveling was of medium severity on new highway while old highway had the problem of polished aggregates.

7.18 Rutting

Ruts, the channelized depressions which develop in the wheel-tracks, are considered as one of the most important failures of asphalt concrete pavements. Rutting is a big problem on modern Pakistani highways, especially because of heavy axle loads.

Ruts are developed by the accumulation of the permanent deformation in one or more of the underlying layers or in bituminous layers.

The outer lane of the new carriageway has developed ruts of low, medium and high severity at many sections. Only six sections of 50 meter to 150 meters long were observed 'Rut free'. Rut depth as high as 30 - 40 mm was observed on three locations, while eighteen locations had rut depth of upto 25 mm. Several sections had rut depths of 5 - 15 mm. At three locations milling has been carried out. The photographs 7.18-1 to 7.18-4 show the picture.

As already mentioned that the outer lane of the old highway is in a dilapidated condition, the rut depth of 120 mm was observed on one location. Nearly all the sections have been rutted due to passage of heavy axle loads. The plastic flow (shoving) conditions were evident on a number of locations.

It became obvious from the variation in height of drilled cores, carried out at the adjacent lane/section that the principal rutting has taken place in the bituminous layer, while at many milled locations the core (asphalt concrete) thickness was very small (as small as 75 mm on the old highway) as compared to the "accumulated" portion. The most probable causes of bitumen layer rutting are:

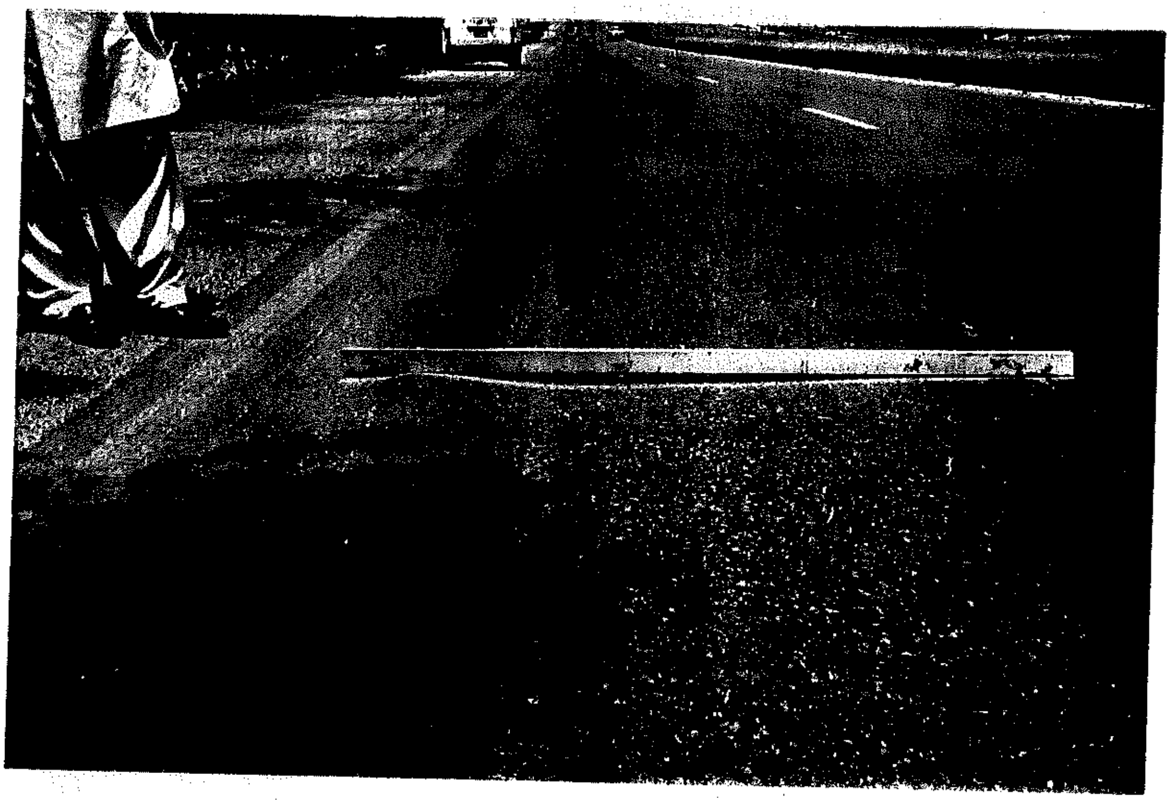


Plate 7-18-3 Severe rutting being observed and shoving along the side of rut is clearly visible on Old Carriageway.

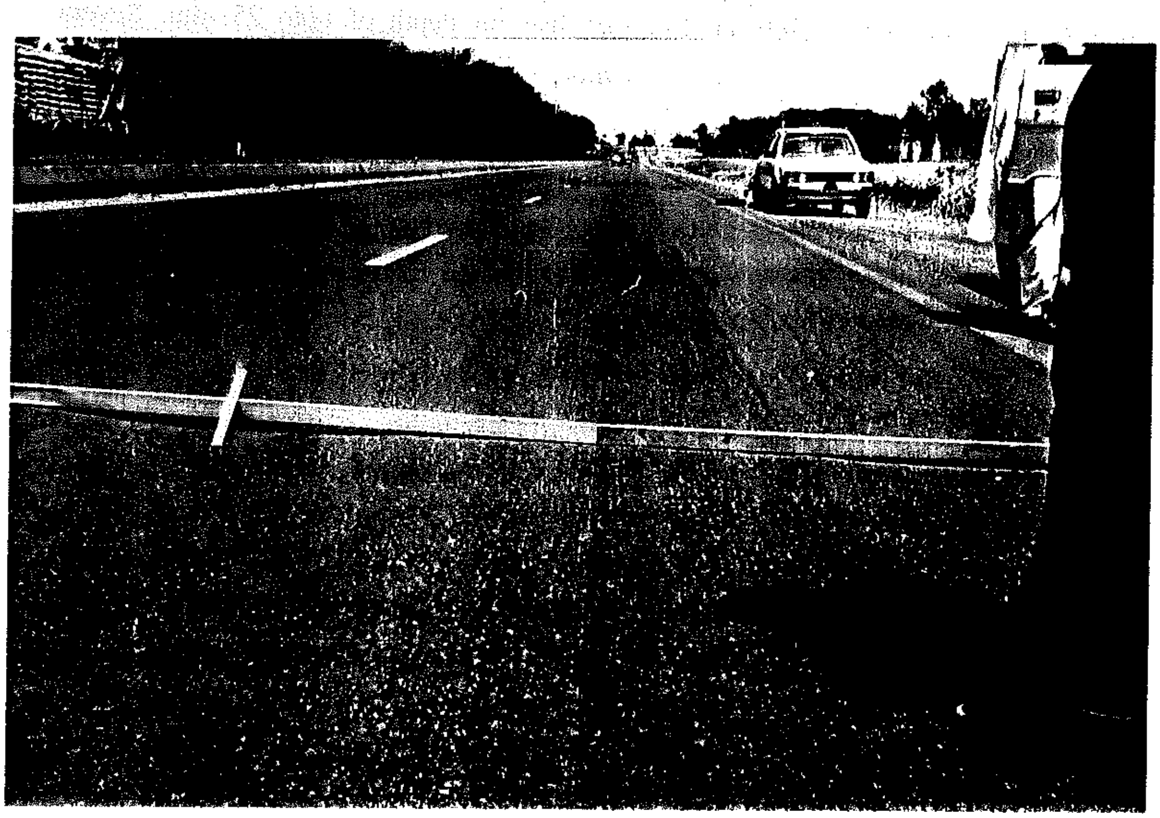


Plate 7.18-4 A view of milled section of new carriageway and re-development of severe rutting on New Carriageway.

a) Inadequate stability of the asphaltic concrete mix, which inturn is dependent on:

i) High bitumen content in the mix
ii) High filler content in the mix
iii) Utilization of round aggregates
iv) Utilization of high penetration grade bitumen

b) Inadequate compaction of the bituminous courses

c) Over compaction of the bituminous layer due to heavy and channeled traffic.

Rutting is also influenced by heavy channelised traffic, high temperature, high tire pressure and low speed.

The possible causes listed in (a) were analyzed in laboratory by carrying out tests on the extracted cores. The results show that:-

i) The quantity of bitumen was close to the designed values and there was no significant difference in the bitumen content of the unfailed (control) and failed sections.

ii) The filler asphalt content ratio was found to be above the limiting value (i.e. 0.6 - 1.2). Therefore, not only aggregate to aggregate content decreased but also the excessive fines affected the bitumen quality, thereby causing a decrease in the stability of asphalt.

iii) The aggregates were found to be angular as required. (But the mineral filler was found to be having clay traces).

iv) Another, probable cause can be the usage of soft asphalt. While there is no denying the fact that factors listed at (b) and (c) are also one of the major contributing factors .

7.19 Slippage Cracking

No signs of slippage cracking were observed.

7.20 Swell

No swelling signs were observed in the carriageways.

7.21 Shoving/Corrugation

Shoving, a localized building of asphaltic concrete surface is a form of plastic movement. Shoving was observed on three locations of new highway while 12 locations were marked on the old highway. Shoving, like rutting is caused by lack of stability in asphaltic concrete. It was observed that at signals, rising lanes, at sharp turns the shoving was of high severity. The photographs 7.7-1,2 &7.18-1 to 4 show the picture.

7.22 Settlements/Subsidence

Settlements are not directly related with the behavior of the bituminous pavement. They are a reflection of the large depressions and settlement occurring in the underlying layers.

Two very large areas and three small areas were observed to be affected by settlement. Settlement occurred along the centerline in the outside lane, in the longitudinal direction. The asphalt pavement followed the settlement and cracked and cracks are open enough to allow free ingress of water inside the pavement, thereby making it more instable. The large fill (embankments) areas because of lack of lateral support and dumping of material without appropriate compaction.

7.23 Drainage Condition

Side drain which runs along the new carriage was found clogged at the discharge points. Soil has been washed-in from the bare slopes and now vegetation is growing in the drain. Accumulation of water would prove detrimental to the highway. The photographs 7.23-1 to 7.23-2 show the picture.

7.24 Traffic Characteristics

Traffic was heavy, a rough estimate revealed that around 1000 to 1500 vehicles per hour were traveling in two lane carriageway. It was observed that commercial vehicles like trucks and buses preferred to travel in the outer lanes while other vehicles like cars and jeeps preferred right lane. The traffic like cars, jeeps etc. were traveling approximately at speeds of 80 - 110 km/hrs. Trucks were found plying at snail pace on the upside of the hilly section. It was very difficult, sometimes, to judge between a stationery vehicle and a moving one, as shown in figure-7.24.

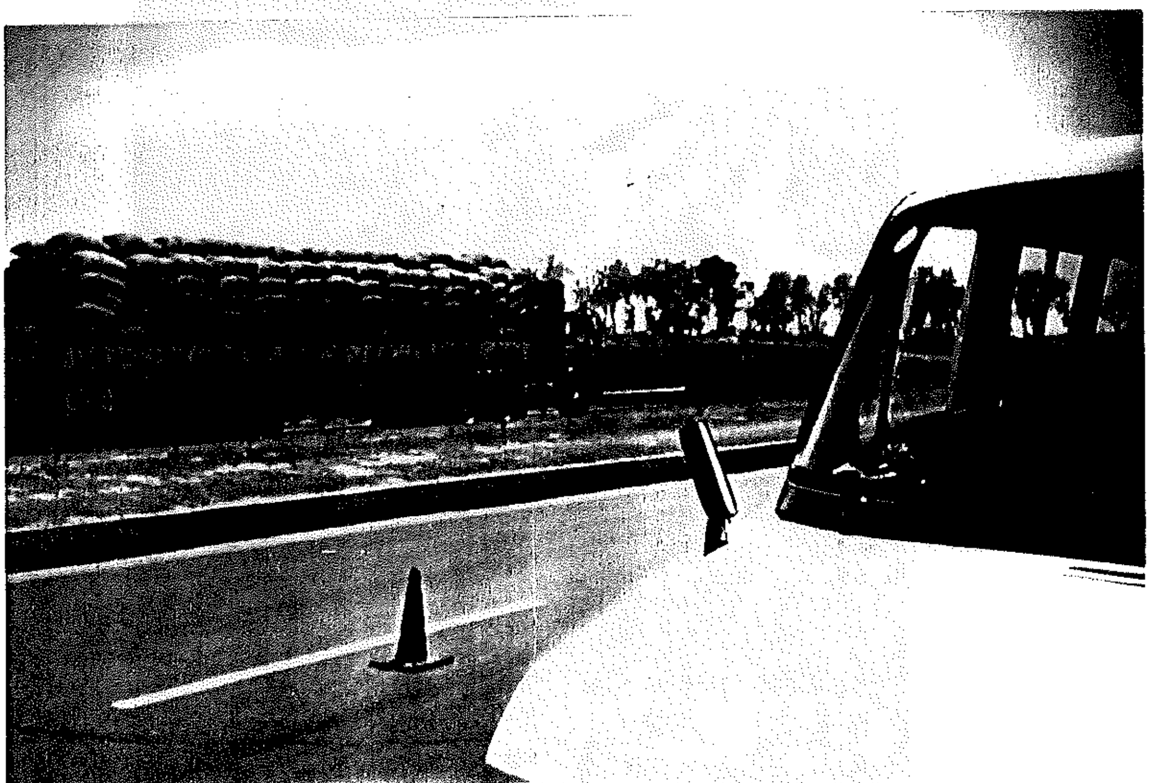


Plate 7.22 Signs of subsidence (Volume change) in subgrade of old highway. In the background a heavily loaded truck (60 tonnes approximately) is also visibile on Old Carriageway.

Plate 7.23-1 A view of a pass made on the drain. The utility of drain is wiped out as the debris is lying in the drain and only one pipe has been provided that too has clogged (in shade)

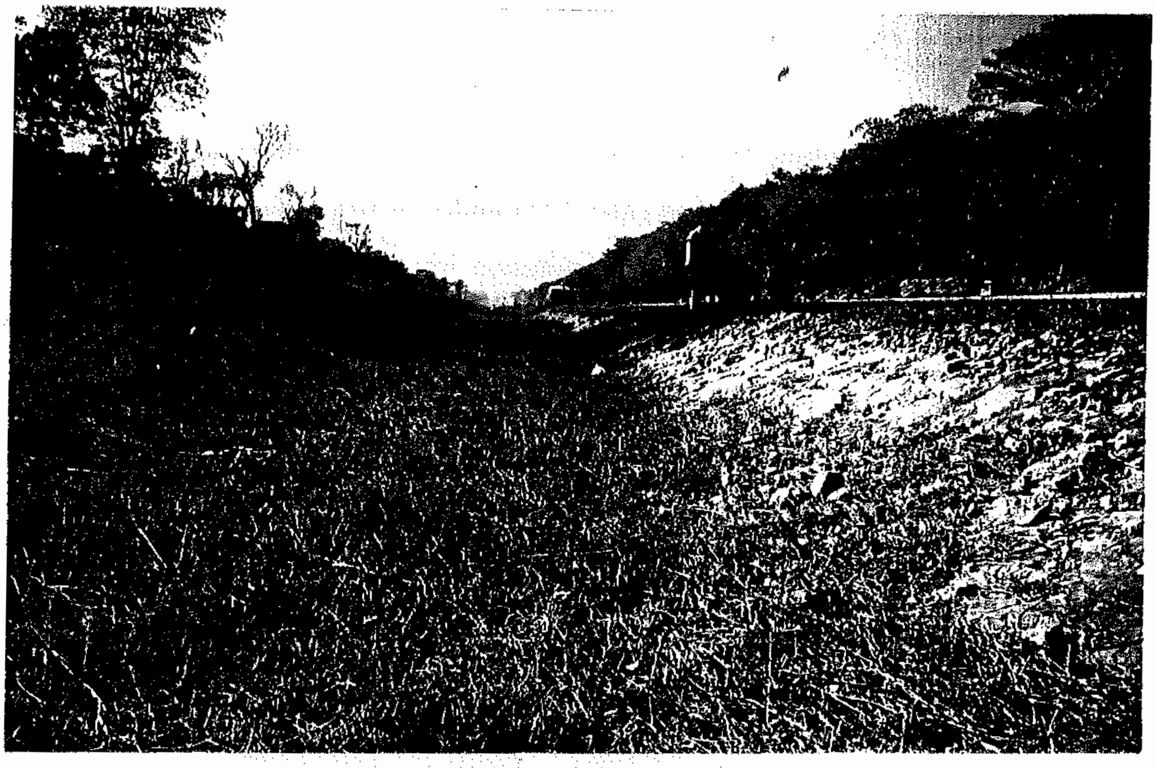


Plate 7.23-2(a) Completely clogged side drain of new carriageway. Already a large section of Kashmir Highway from Zero Point to Aabpara has failed due to drainage problem.

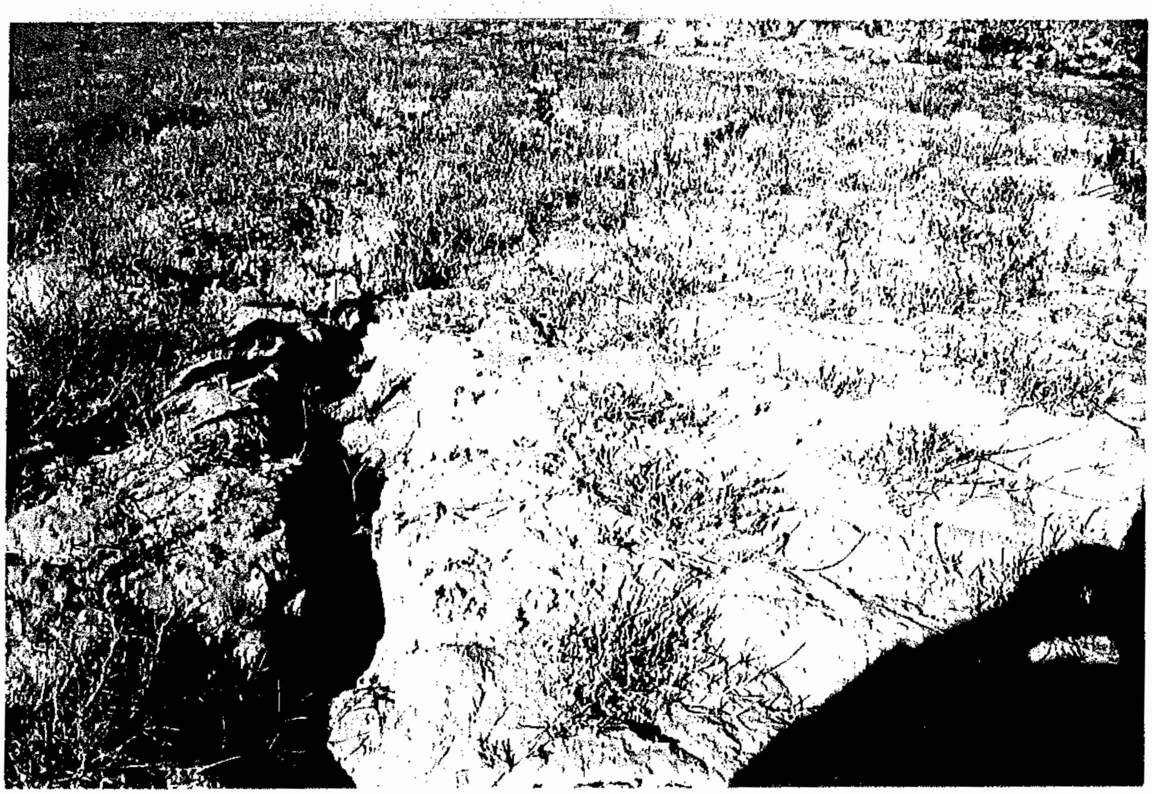


Plate 7.23-2(b) A view of unstable slope. Water crosses carrying soil to the drain are clearly visible.

8 : Laboratory Analysis

The location of the drilled out cores is shown in the map 8.1. The cores were secured in Premark containers and their raw and sawed measurements were taken & are given in table 8.1. The table shows that the extracted cores are smaller in length due to the effect of rutting and stripping. Several cores from old carriageway did not have the wearing course which had either been milled or stripped off. The photographs 8.1 and 2 show a few cores. Close examination was made to determine the overall thickness and gradation of wearing and base courses. Following tests were carried out on cores:-

i) Bulk specific gravity and density determination of compacted bituminous mixture using saturated surface dry specimens as per ASTM D2726-89/AASHTO T 166-88

ii) Quantitative extraction of bitumen from bituminous paving mixtures as per ASTM D2172-88/AASHTO T 164-90

iii) Gradation of material as per AASHTO T 30-87.

iv) Marshall Stability ASTM D1559-76/AASHTO T 245-90

The tables 8.2 and 8.3 show the results of the above mentioned tests.

8.1 Discussion on Results:

By analyzing specific gravity, density, air voids and asphalt content some indication of the probable causes of failures is obtained.

8.1.1 Bulk Specific Gravity and Density

The bulk specific gravity and density of cores was determined after sawing the cores into wearing and base course.

The average bulk specific gravity of wearing courses extracted from the distressed sections of the new carriageway was 2.39 $\pm$ 0.00 while that of control (unfailed) sections was 2.37 $\pm$ 0.01.

Similarly, the average bulk specific gravity of base courses extracted from the distressed section of the new carriageway was 2.41 $\pm$ 0.01 while that from the control (unfailed) sections was 2.39 $\pm$ 0.01.

Table : 8-1

PAVEMENT CROSS-SECTION DETERMINED THROUGH EXTRACTED CORES (mm)

NEW CARRIAGEWAY

S.No	Wearing Course	Base Course	Total	Remarks
1	49	75	124	Rut
2	51	86	137	Crack
3	45	98	143	Rut
3A	56	93	149	Control
5	55	91	146	Control
8	53	93	146	Control
9	56	96	152	Control
10	62	96	158	Control

OLD CARRIAGEWAY

S.No	Wearing Course	Base Course	Total	Remarks
1	59	94	152	Control
2A	20	60	80	Rut
2B	38	77	115	Control
3	42	78	120	Control
4	41	80	121	Control
4A	35	67	102	Rut
5	33	69	99	Rut
6A	-	73	73	Rut
6B	50	102	152	Control
7A	-	59	59	Rut
7B	53	74	127	Control

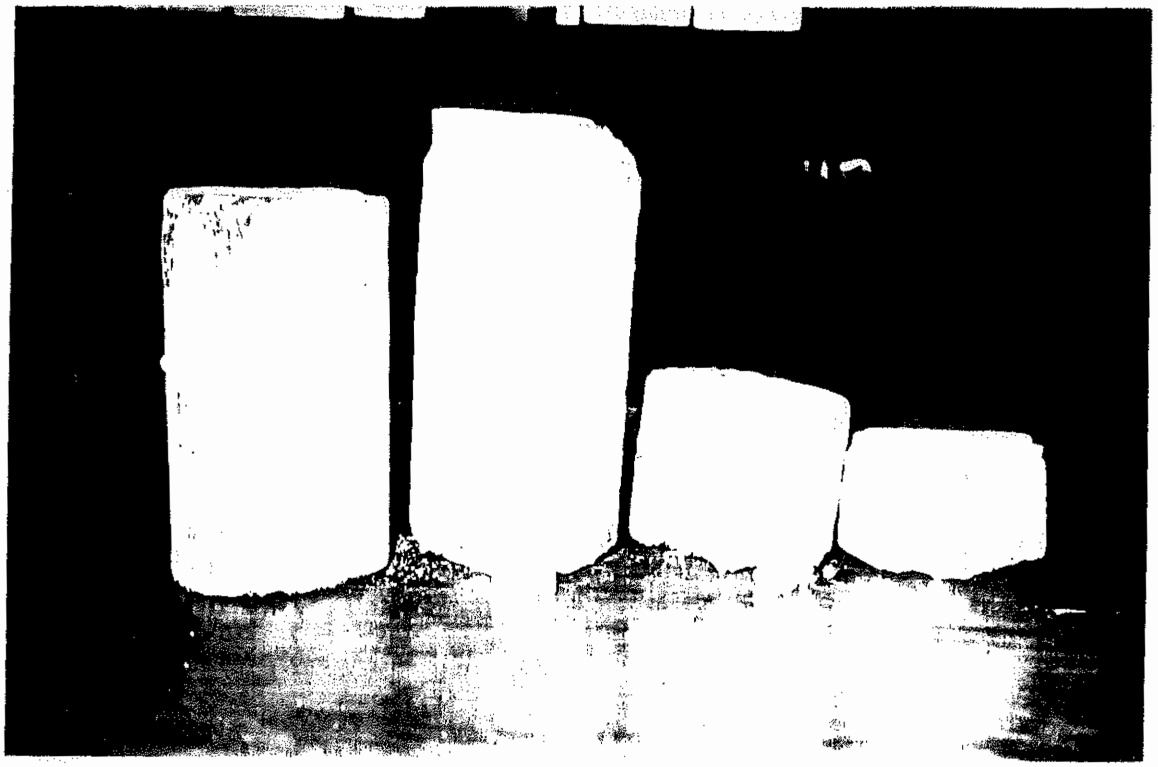


Plate 8.1 A view of extracted cores, clearly visible are cores having a small depth on Old Carriageway.

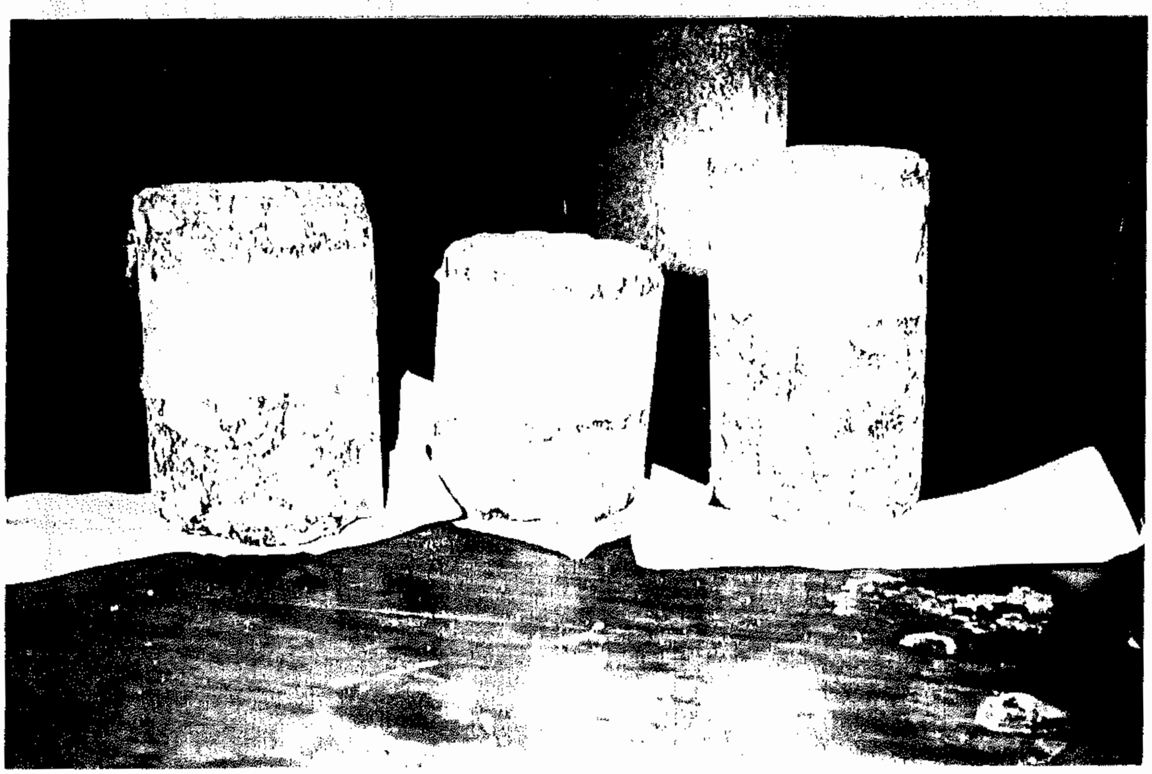


Plate 8.2 A view of cores extracted from the distress and control sections of New Carriageway.

Table 8-2 Results of Laboratory Analysis

New Carriageway (Towards G.T Road)

Wearing Course

		Bitumen Content %				Percent Passing								
	Core No.	By Mix.	By Agg.	Sp.Gr	Density gm/cc	1-1/2"	1"	3/4"	1/2"	3/8"	4No.	10No.	50No.	200No.
Distress														
Rutted	1	4.00	4.29	2.38	2.39	100	100	100	90	79	53	35	14	8
Cracked	2	4.33	4.41	2.38	2.3[illegible]	100	100	100	87	75	50	32	18	9
Rutted	3	4.35	4.57	2.39	2.40	100	100	100	96	82	59	36	14	9
AVERAGE		4.23	4.43	2.39	2.38	100.00	100.00	100.00	91.00	78.67	54.00	34.33	15.33	8.67
STD.DEV.		0.16	0.11	0.00	0.02	0.00	0.00	0.00	3.74	2.87	3.74	1.70	1.89	0.47
VAR.		0.03	0.01	0.00	0.00	0.00	0.00	0.00	14.00	8.22	14.00	2.89	3.56	0.22
Good Sec.														
Control	3A	4.15	4.29	2.36	2.37	100	100	100	81	70	49	29	10	6
Control	5	4.35	4.65	2.39	2.36	100	100	100	82	66	44	29	11	6
Control	8	4.18	4.41	2.37	2.37	100	100	100	88	75	51	32	9	4
AVERAGE		4.23	4.45	2.37	2.37	100.00	100.00	100.00	83.67	70.33	48.00	30.00	10.00	5.33
STD.DEV.		0.09	0.15	0.01	0.00	0.00	0.00	0.00	3.09	3.68	2.94	1.41	0.82	0.94
VAR.		0.01	0.02	0.00	0.00	0.00	0.00	0.00	9.56	13.56	8.67	2.00	0.67	0.89

Base Course

		Bitumen Content %				Percent Passing								
	Core No.	By Mix.	By Agg.	Sp.Gr	Density gm/cc	1-1/2"	1"	3/4"	1/2"	3/8"	4No.	10No.	50No.	200No.
Distress														
Rutted	1	3.56	3.79	2.42	2.40	100	100	90	74	67	50	32	12	8
Cracked	2	3.49	3.65	2.39	2.42	100	93	70	62	50	35	23	9	6
Rutted	3	3.64	3.84	2.40	[illegible]8	100	95	84	75	65	48	31	11	7
AVERAGE		3.56	3.76	2.41	2.40	100.00	96.00	81.33	70.33	60.67	44.33	28.67	10.67	7.00
STD.DEV.		0.06	0.08	0.01	0.02	0.00	2.94	8.38	5.91	7.59	6.65	4.03	1.25	0.82
VAR.		0.00	0.01	0.00	0.00	0.00	8.67	70.22	34.89	57.56	44.22	16.22	1.56	0.67
Good Sec.														
Control	3A	3.71	3.86	2.38	2.38	100	95	80	69	63	55	28	9	5
Control	5	3.65	3.83	2.40	2.39	100	83	69	52	43	32	19	7	4
Control	8	3.69	3.86	2.40	2.41	100	93	75	56	48	34	21	6	5
AVERAGE		3.68	3.85	2.39	2.39	100.00	90.33	74.67	59.00	51.33	40.33	22.67	7.33	4.67
STD.DEV.		0.02	0.01	0.01	0.01	0.00	5.25	4.50	7.26	8.50	10.40	3.86	1.25	0.47
VAR.		0.00	0.00	0.00	0.00	0.00	27.56	20.22	52.67	72.22	[illegible]3.22	14.89	1.56	0.22

Table 8-3 Results of Laboratory Analysis

Wearing Course Old Carriageway (Towards Peshawer More)

		Bitumen Content %				Percent Passing								
		By Mix.	By Agg.	Sp.Gr	Density gm/cc	1-1/2"	1"	3/4"	1/2"	3/8"	4No.	10No.	50No.	200No.
Distress														
Rutted	2A	4.56	4.64	2.42	2.40	100	100	100	85	75	57	27	13	5
Rutted/Cracked	4A	4.90	4.98	2.44	2.41	100	100	100	87	74	48	27	7	4
Rutted	5	4.81	4.89	2.43	2.44	100	100	100	92	82	58	37	18	5
AVERAGE		4.76	4.84	2.43	2.42	100.00	100.00	100.00	88.00	77.00	54.33	30.33	12.67	4.67
STD.DEV.		0.14	0.15	0.01	0.02	0.00	0.00	0.00	2.94	3.56	4.50	4.71	4.50	0.47
VAR.		0.02	0.02	0.00	0.00	0.00	0.00	0.00	8.67	12.67	20.22	22.22	20.22	0.22
Good Sec.														
Control	1	4.65	4.73	2.40	2.41	100	100	100	91	80	57	35	11	6
Control	2B	4.77	4.85	2.41	2.40	100	100	100	88	75	47	30	12	4
Control	3	4.34	4.42	2.38	2.39	100	100	100	85	77	51	31	13	5
Control	4	4.51	4.60	2.42	2.40	100	100	100	91	81	54	30	10	5
AVERAGE		4.57	4.65	2.40	2.40	100.00	100.00	100.00	88.75	78.25	52.25	31.50	11.50	5.00
STD.DEV.		0.16	0.16	0.01	0.01	0.00	0.00	0.00	2.49	2.38	3.70	2.06	1.12	0.71
VAR.		0.03	0.03	0.00	0.00	0.00	0.00	0.00	6.19	5.69	13.69	4.25	1.25	0.50

Base Course

		Bitumen Content %				Percent Passing								
Distress		By Mix.	By Agg.	Sp.Gr	Density gm/cc	1-1/2"	1"	3/4"	1/2"	3/8"	4No.	10No.	50No.	200No.
Rutted	2A	4.78	4.86	2.39	2.40	100	94	87	62	52	38	26	8	5
Rutted/Cracked	4A	4.98	5.07	2.44	2.42	100	100	80	54	45	33	22	9	4
Rutted	5	4.87	4.95	2.42	2.42	100	100	100	80	66	40	24	11	4
Rutted	6A	4.45	4.50	2.40	2.39	100	97	91	77	68	46	29	9	5
Rutted	7A	4.51	4.59	2.39	2.40	100	95	81	69	58	47	25	12	5
AVERAGE		4.70	4.78	2.41	2.41	100.00	98.00	88.00	70.00	59.25	41.50	25.00	10.25	4.50
STD.DEV.		0.23	0.24	0.02	0.01	0.00.	2.12	8.15	10.07	9.04	5.59	2.55	1.30	0.50
VAR.		0.05	0.06	0.00	0.00	0.00	4.50	66.50	101.50	81.69	31.25	6.50	1.69	0.25
Good Sec.														
Control	1	4.65	4.73	2.40	2.39	100	95	81	62	57	41	23	7	4
Control	2B	4.70	4.78	2.42	2.39	100	100	80	57	50	40	27	12	4
Control	3	4.59	4.69	2.40	2.41	100	100	97	71	58	41	26	9	5
Control	4	4.47	4.51	2.42	2.45	100	97	85	62	53	37	24	10	5
Control	6B	4.39	4.41	2.40	2.38	100	99	89	72	52	43	27	10	6
Control	7B	4.46	4.55	2.38	2.34	100	99	88	82	60	42	25	9	5
AVERAGE		4.54	4.61	2.40	2.39	100.00	98.[illegible]	[illegible]	67.67	56.67	40.67	25.33	9.50	4.83
STD.DEV.		0.11	0.13	0.01	0.03	0.00	1.80	5.68	8.30	4.07	1.89	1.49	1.50	0.69
VAR.		0.01	0.02	0.00	0.00	0.00	3.22	32.22	68.89	16.56	3.56	2.22	2.25	0.47

The average bulk specific gravity of asphalt concrete wearing course extracted from the distressed section of the old carriageway was found as 2.43 $\pm$ 0.01 and that from the control section was 2.40 $\pm$ 0.02.

The average bulk specific gravity of asphalt concrete base course extracted from the distressed section of the old carriageway was found as 2.41 $\pm$ 0.02 and that from the control sections was 2.40 $\pm$ 0.02.

The average density of wearing courses extracted from the distressed section of the new carriageway was 2.38 $\pm$ 0.02 while that of control sections was 2.37 $\pm$ 0.00.

The average density of base courses extracted from the distressed section of the new carriageway was 2.40 $\pm$ 0.02 while that of control sections was 2.39 $\pm$ 0.01.

The average density of asphalt concrete wearing course extracted from the distressed section of the old carriageway was found as 2.42 $\pm$ 0.02 and that from the control section was 2.40 $\pm$ 0.01.

The average density of asphalt concrete base course extracted from the distressed section of the old carriageway was found as 2.41 $\pm$ 0.01 and that from the control sections was 2.39 $\pm$ 0.03.

It can be concluded that the average bulk specific gravity and density of the distressed sections is a bit higher then the control sections because of secondary compaction caused by the passage of heavy trucks.

8.1.2 Gradation

Gradation plays an important role in the stability of asphalt mix. The aggregates of asphalt wearing course and base course were graded separately.

After extraction of bitumen, the aggregates were graded in accordance with the standard procedures as already mentioned. The Marshal method is applicable to asphalt mixes containing aggregates with maximum size of 25 mm (1 inch) or less. While laboratory results showed that the percentage of aggregates passing 25 mm sieve size on the average is 96% for distressed sections and 90% for control sections for the new carriageway. It is also pointed out that the pass percentage of 96% for distressed sections is high because of the effects of pulverization, as explained below.

In case of wearing course, the percentage passing 20 mm (3/4") was 100%, which is the normal required criterion. When the gradation curves for new carriageway are compared, it was found that the average gradation of distressed sections and that of control sections have a marked difference between them for wearing and base courses. The average percent passing the designated sieve sizes is significantly higher for distressed section as compared to control section. Moreover the percentage of fines is significantly higher when compared with normal range of 5% $\pm$ 1. This phenomena is most probably the result of pulverization of aggregates under heavy vehicle loads and because of low soundness of aggregates. As regards the quality of filler is concerned, it was found that clay traces were present which is detrimental to the quality of asphalt.

The above statements bring out the fact that poor quality control was exercised during construction.

As regards old highway, the gradation curves show no significant difference among the distressed and control sections, thereby substantiating the earlier statement that bitumen content was higher and that decreased the interlocking role of aggregates and facilitated the rutting. Since quantity and quality of aggregates controls the properties of the mix, it is pertinent to point out that Heavy Axle Loads, high tire pressure, high repetition of loads and slow speeds of vehicles forced the aggregates and bitumen into voids, and later on after filling of voids the asphalt concrete shoved along wheel tracks.

8.1.3 Particle Shape

The particle shape was closely examined. The particles were of very suitable shape for an asphalt mix, providing good interlocking/stability to the mix.

8.1.4 Surface Texture and Resistance to Skidding

Aggregates were separated from the extracted cores after washing and were found of suitable quality to increase resistance to skidding.

8.1.5 Affinity of Bitumen and Stripping

The shape and size of aggregates were of required quality and it can be concluded that the bitumen most probably had low affinity to aggregates (binding property).

8.1.6 Bitumen Content

The bitumen content in asphalt concrete mix should be such that it provides a proper balance of stability and durability. The bitumen content of cores extracted from the distress sections and those from the control sections (unfailed) was determined. Similarly, the bitumen content of asphalt wearing course and asphalt base course was determined separately.

The average bitumen content in wearing course of the distressed sections of the new carriageway was found to be 4.23 $\pm$ 0.16% by mix, while that from control section was also found to be 4.23 $\pm$ 0.09 by mix.

The average bitumen content in base course of the distressed sections of the new carriageway was found to be 3.56 $\pm$ 0.06% by mix, while that from control section was found to be 3.68 $\pm$ 0.02 by mix.

The slightly higher percentage of bitumen content in the wearing and base courses of control sections, which were extracted from inner lanes except one, is indicative of the fact that age hardening (bitumen quality) and heavy vehicle loads worked hand in hand and caused cracking and stripping in the outer lane and decreased the bitumen content in outer lane.

As regards the old carriageway; the average bitumen content in wearing course of the distressed sections was found to be 4.76 $\pm$ 0.14% by mix, while that from control sections was found to be 4.57 $\pm$ 0.16 by mix.

The average bitumen content in base course of the distressed sections of the old carriageway was found to be 4.70 $\pm$ 0.23% by mix, while that from control sections was found to be 4.54 $\pm$ 0.11 by mix.

The high percentage of bitumen content in the old carriageway is self explanatory as mostly one type of distress, i.e. rutting was dominant on the carriageway. This carriageway has been milled and patched extensively, that might have also been responsible for high bitumen content.

8.1.7 Marshall Stability

The two principal features of the Marshall method of mix design are density voids analysis and a stability flow test.

8.1.7-1 Density-Voids

The first principal relationship of density-voids analysis could not be carried out and compared with that determined in NTRC's laboratory as CDA did not provide the requisite data. This key relationship would have provided an insight in the determination of degree of pavement compaction (AASHTO T-230-68 (1986)) and percent air voids in compacted pavement (AASHTO T-3203-75).

8.1.7-2 Stability Flow

Marshal stability tests were carried out on the extracted cores. The results clearly showed that the average Marshall stability of distressed cores was significantly higher then those from the controlled sections only because of secondary compaction of pavement. On the other hand, average Marshall flow of distressed sections was significantly lesser then those of the cores obtained from the controlled section.

It can be concluded from above discussions on laboratory analysis that:

i) The percentage of bitumen (i.e. quantity of bitumen) is not responsible for the rutting problem.

ii) A variety of distress signs are indicative of the fact that the source of bitumen at various times of construction might be different (i.e. quality).

iii) The quality of bitumen might have caused excessive stripping and cracking of the pavement.

iv) Since the bitumen content found in the cores of distressed sections and those from the controlled sections does not differ significantly, therefore the quality of bitumen used, compaction carried out and the laying environment were most probably were very different from each other, i.e. a poor quality control was exercised.

9 : Conclusions and Recommendations

By analyzing the distress data and laboratory results, following conclusions are drawn and recommendations are made:-

Conclusions:

The rapid deterioration of the new carriageway of Kashmir Highway with a variety of distress types indicates that:-

I) Pavement was designed with insufficient structural strength.
ii) Heavy traffic loads were not incorporated in design.
iii) Quality of construction was poor through lack of quality control.

Recommendations

- Many forms of distress are closely interconnected and at later stages it becomes difficult to identify the primary cause. Therefore, pavement evaluation survey (PSI/CPI) shall be regularly carried out in order to apply specific remedial measures to mitigate that distress type.

- Cracks must be sealed immediately otherwise water will further weaken the water susceptible layers of the pavement.

- Potholes must filled at the earliest.

- Debris from drains shall be immediately removed and they must be made functional, as already a large section of this highway has failed in the past because of this problem.

- Quality control must be exercised at each stage of pavement construction.

- To optimize the design and construction techniques it is proposed that:-

- Compressive strength of bituminous mixtures (ASTM D 1074-80/AASHTO T167- 84) be determined so that its suitability for use under given loading conditions (Rutting) and environment as paving material can be evaluated.

- A high percentage of fines in the distressed cores requires that Aggregate Durability Index Test ASTM D 3744-79/AASHTO T 210-84 (1995) be made part of material testing to evaluate the relative resistance of aggregates to produce detrimental clay like fines, alongwith the most applied Los Angeles test ASTM C 131-81, AASHTO T 96-87.

- Test to determine resistance of compacted Bituminous Mixes to Moisture Induced damage AASHTO T 283-89 be done to the predict stripping susceptibility.

- It would be much better if alongwith Marshal test, the Refusal Density design or NAASRA are tested on a few stretches where reconstruction is to be carried out. This would enable optimization of design techniques.

- Research organizations, like NTRC, NUST must be associated with such projects since planning and stage design so as to render low-cost timely advice.

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