NATIONAL TRANSPORT RESEARCH CENTRE

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MONITORING

OF

H-8/H-9 SERVICE ROAD, ISLAMABAD

NTRC-228

Mr M. Naeem
Assistant Chief

Mr Khizer Javed
Research Officer

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EXECUTIVE SUMMARY

CDA has recently constructed 4.2 km long service road from Peshawar More to I.J.P. (Pirvedahi) road with conventional design of aggregate base course, sub-base and triple surface treatment (TST). The road was opened to traffic in August, 2000, but started showing signs of distress soon afterward.

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

Visual Characteristics

1. The riding quality of newly constructed road is generally poor
2. Bleeding was observed more than 40% of the road surface
3. Shoving was observed in about 20 to 25 m length.

Laboratory Analysis

1. In the TST layers the aggregate quantity was found less than the specified limit of 43 Kg/Sq.m.
2. The aggregate quantity used in TST layers was generally higher in unbled area as compared to distressed area.
3. Variation in the aggregate quantity was up to 47% in the sample collected.
4. The bitumen content of bled area was found higher than the un-bled area.
5. Variation in the bitumen content was upto 38% in the sample taken from different locations.

Conclusion:

1. The surface levels of road were not even

2. The spreading of aggregate in TST layer was not uniform

3. The quantity of the asphalt in TST layer was not uniform

4. Quality of construction was not in accordance with standards and specifications

Recommendations

1. The aggregate base course material must be evenly spread by using paver in accordance with both longitudinal and transverse control

2. The mechanical aggregate (Chip Spreader) may be used to spread the aggregates for TST to achieve uniform spreading of aggregates

3. Mechanical distributor may be used to spray the asphalt uniformly

4. The shoving area needs urgent rectification

5. Complete quality control must be exercised at each stage of pavement construction

6. Drains must be kept clear.

CHAPTER-1

INTRODUCTION:

1.1 General:

Unfortunately, even well designed highways sometimes fail prematurely in the developed countries. However, such failures have reached alarming proportions in developing countries. Such failures become a burden on the national exchequer besides jeopardizing the credibility of highway/ construction engineers. The main factors responsible for failure in pavement are namely, design failure, lack of quality control, drainage system and inadequate maintenance etc.

CDA has recently constructed 4.2 kilometer long H-8/H-9 service road after a lapse of around three years. This service road acts as a by-pass (by passing Rawalpindi city) for the truck traffic, the trucks off-take from Sawan Camp More and after passing through Islamabad highway use this service road to get on to the G.T. Road again through Kashmir Highway.

A team of NTRC engineers carried out the pavement condition survey to assess the construction quality and to determine the causes of distress/failure. The team made several visits and thoroughly inspected the road pavement and road environment and made various qualitative assessment and quantitative measurement as well as took photographs to agument the report. Samples were collected from the bled and un-bled section of the road and evaluate the properties in NTRC laboratories.

1.2 Objective of the Study:

Most of the roads fail prematurely resulting in loss of billions of rupees. Various factors attributed to present condition are lack of quality control, use of sub-standard material, lack of technical knowledge etc. The main objective of study is to collect the samples from H-8/H-9 service road & to determine different factors responsible for different type of distresses such as bleeding, surface roughness, shoving etc.

1.3 Methodology:

The methodology adopted for the study consist of the following:-

i) Selection and identification of test points/number and types of tests to be performed

ii) Field sampling

iii) Field testing

iv) Laboratory testing of sample material

v) Analysis of data

vi) Results

vii) Recommendations

CHAPTER - 2

COMPONENT OF A FLEXIBLE PAVEMENT

The basic function of a pavement is to support the traffic loading with acceptable riding quality and without undue deterioration over the period for which it is designed. To achieve this purpose, the pavement must efficiently distribute the loading to prevent significant permanent deformation.

2.1 Flexible Pavement

A flexible pavement may consist of one or more layers of material classified as the surface course, base course, sub-base course and sub-grade. The terms used to describe the various highway component are shown diagrammatically in figure-I.

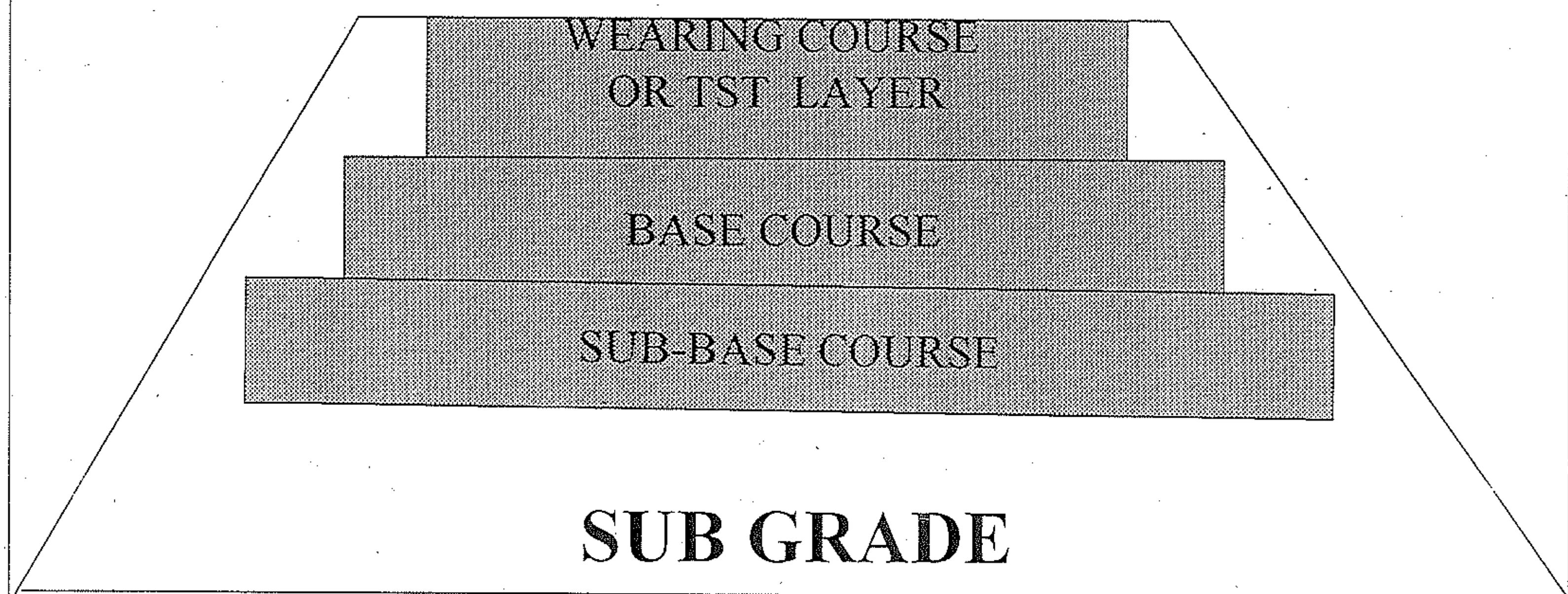
2.1-1 Surface Course

It consists of a mixture of bituminous material and aggregate. It has three principal functions; to water-proof the base against ingress of water from the surface, to protect it from the abrasive and disintegrating effects of traffic and to distribute the load. The causes of failure in surface course are durability, i.e. the ability to withstand the abrasive effect of traffic, resist weathering effects, ability of aggregates to resist abrasion and binding quality of bitumen to hold aggregates together.

Bituminous Surface Treatments

The bituminous surface treatments (single or multiple) means thin surface coverings with bituminous or asphaltic materials and mineral aggregate. These types of surface treatments are generally so thin that they have very little load supporting value in themselves and must, therefore, depend on the adequacy of the base course. These treatments are relatively economical but are not highly resistant to the effect of severe traffic conditions, especially when wheel loads are heavy.

FLEXIBLE PAVEMENT COMPONENTS



TYPICAL X-SECTION

Figure - 1

Single Surface Treatment

A single-surface treatment is a wearing surface of bituminous material and aggregate in which the aggregate is placed uniformly over the applied bituminous material in a single layer. The thickness of layer approximates the nominal maximum size of the used aggregate. Single surface treatment is provided only for very low traffic and favorable field conditions.

Multiple Surface Treatment

A multiple surface treatment (double or preferably triple) is a wearing surface composed of bituminous material and aggregate in which the coarser aggregate is placed uniformly over an initial application of bituminous material and followed by subsequent applications of bituminous material and finer aggregate. Generally, the maximum size of the smaller aggregate is one-half that of the aggregate used in the preceding application. Each application of aggregate should be placed uniformly in single layer, the thickness of which approximates the nominal maximum size of the aggregate. Out of these, a triple surface treatment is considered most appropriate.

2.1-2 Base Course

The base course which is placed directly beneath the surface course, may consist of treated or untreated crushed stone or granular material mixed with various types of binder. The function of the base course is to offset the high shearing stresses imposed by concentrated loads at the surface and should have sufficient density to provide resistance to subsequent consolidation to avoid any distortion of the wearing surface.

2.1-3 Sub-base Course

The sub-base of a flexible pavement generally consists of locally available materials. The function of sub-base is to increase the structural stability of pavement as a whole. It is a structural support for the base and frost and salt heave. The basic functions are to offset the volume changes of a poor sub-grade soil.

2.1-4 Sub-grade

Sub-grade 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 strength of the sub-grade is the main factor in determining the thickness of the pavement. In Pakistan it is usually determined on the basis of CBR test.

CHAPTER - 3

QUALITY CONTROL & TESTING PROCEDURE

The quality control for the materials and methods of construction should be strict as to conform to the required specification. The quality of asphalt (bitumen) and aggregates must be checked periodically and any deviation must be brought out immediately. The bituminous materials should be tested to ensure that they conform to the standard specifications applicable to the type selected. The aggregate should also be tested for its suitability in accordance with standard specifications. The results of these laboratory testing should be analyzed properly. The methods of construction should be followed carefully as given in General Specification Dec., 1998.

3.1 Sample Collection

The samples were collected randomly and were free from bias. The samples were of adequate size, number and represented the true nature and condition (Plate No. 1).

3.2 Laboratory Testing

Representative of samples of materials related to all layers of the pavement were brought from the selected locations and were tested according to ASTM/AASHTO/NHA's standards in addition to the field tests. The results are placed in proceeding paras:-

3.3 Sub-grade

Following standard tests for the assessment of sub-grade material based on the methods described in ASTM standard specifications were conducted.

i) Determination of moisture content of soil as per ASTM D2216-80 Vol. 04.08

ii) Sieve analysis of fine aggregate as per ASTM C136-84 of Volume 04-02

iii) Liquid limit, plastic limit and plasticity index of soil as per ASTM D4318-84 of Vol. 04-08

iv) Moisture-density relations of soils as per ASTM D698-78 of Vol. 04-08

v) California bearing ratio of laboratory compacted soils as per ASTM D1883-87 of Vol. 04-08

vi) Field density measurement results by sand cone method.

3.4 **Sub Base Course**

The tests were conducted on the sub base course material are:

i) Moisture content determination as per ASTM D2216-80
ii) Gradation of material as per ASTM D698-78
iii) Moisture-density relationship as per ASTM D698-78
iv) CBR (96 hours soaked) as per ASTM D1883-87

3.5 **Base Course**

The tests were conducted on the base course material are:

i) Moisture content determination as per ASTM
ii) Gradation of base course material as per ASTM
iii) Moisture density relations as per ASTM
iv) CBR determination as per ASTM (96 hours socked)

3.6 **TST Layers**

Tests conducted on the TST layers i.e.

1. Quantity of the aggregate
2. Bitumen spray quantity only for TST layer
3. Bitumen grade

CHAPTER - 4

DIFFERENT TYPE OF DISTRESSES IN ASPHALTIC AND TST LAYERS

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 riding quality and safety issues. Pavement 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

CHAPTER – 5

FINDING OF CONDITION SURVEY

5.1 H-8/H-9 Service Road

CDA has recently constructed 4.2 km H-8/H-9 service road. The service road acts as a by-pass to Rawalpindi city for the truck traffic. The trucks off-take from I.J. Prinicipal Road and after passing through Islamabad Highway use this service road to get on to the GT Road again through Kashmir Highway.

CDA has used 18" gara as a sub-base and 18" crush aggregate as a base course with triple surface treatment (TST). The typical X-section may be seen at Fig. No. 2)

5.2 Visual Inspection

Visual inspection was carried out to assess and locate the signs of distress like cracking, surface irregularities, shoulder drop off etc.

5.3 Roughness

Roughness is pavements surface's irregularity that affect riding quality. The general condition of the newly constructed service road is not to the standard. The surface was observed to be uneven and a six feet straight edge revealed difference 6 to 18 mm when placed perpendicular and 2 to 8 mm when placed to parallel to central line of the road causes vibration during travelling (Plate No 2 & 3).

5.4 Bleeding

During visual inspection bleeding i.e. a film of bituminous material on the surface was observed on 40-50% area of the newly constructed road. This is due to the non-uniform spray of bitumen and aggregates for TST layer. The quantity of aggregate as specified in NHA specification manual is 43 kg/sq.m for TST layer. The quantity of aggregates for the samples taken from the un-bled section was 22.7 kg/sq.m and 42.9 kg/sq.m. and in bled area, it was 37.62 kg/sq.m. and 36.16 kg/sq.m. The bitumen quantity in un-bled area was 2.8 ltr/sq.m and 1.76 ltr/sq.m and in bled area, it was 3.33 ltr/sq.m and 3.12 ltr/sq.m. It was found that the quantity of aggregate was less and bitumen quantity was more in the bled area which could be one cause of bleeding. Bleeding is a great safety hazard and reduces the skid resistance of the pavement surface. This is showed in plate No. 5 and results may be seen in Table No. 7.1.

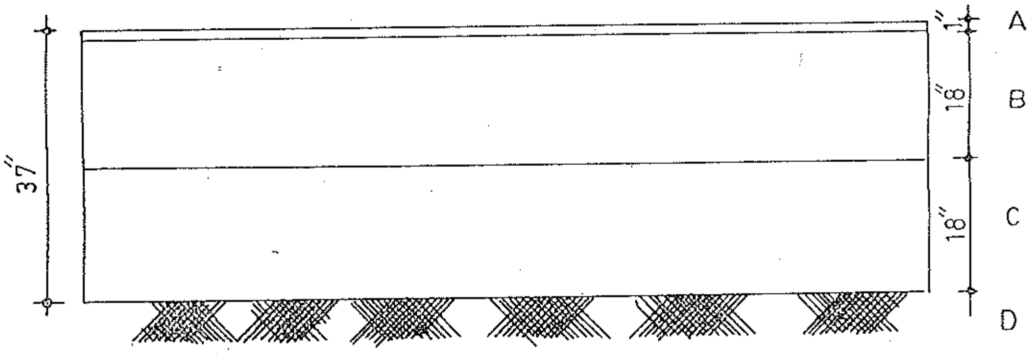
5.5 Shoving

Shoving was observed in about 20m length shown in plate No.4.

5.6 Other Distresses

No sign of other distresses such as alligator/block/fatigue cracks, potholes, swell were observed.

TYPICAL CROSS - SECTION OF THE ROAD



A = 1" TRIPLE SURFACE TREATMENT (TST)

B = 18" AGGREGATE BASE COURSE

C = 18" GARA SUB - BASE COURSE

D = SUB - GRADE

Figure - 2

CHAPTER – 6

LABORATORY TESTING

Samples obtained from H-8/H-9 service road were tested in laboratory in accordance with the standard practice, the following results were observed:

6.1 Gradation & Atterberg Limits

The gradation of base course and sub-base course material was checked and it was found that the both gradations were within the specified limits but some over size aggregates were found in the base course. The table No. 6.1 and 6.2 show the grading and the Atterberg Limits.

6.2 Particle Shape

The shape of the particles used in TST layer were closely checked and found desirable for TST. The aggregates were clean and free from organic matters.

6.3 Surface Textures

Aggregates used in TST were found of suitable quality to increase the resistance to skidding but due to less quantity of aggregates bleeding occurred which is a safety hazard.

6.4 Los Angles Abrasion Value

The average Los Angles Abrasion value of the base course materials was found as 25% which is within the specified limits.

6.5 Compaction

The compaction of the base course was checked and found as an average of 95% which was according to specified limits but it was after the secondary compaction of the base course because the road is in use since the last four months (Table No. 6.5).

Table No. 6.1

SUMMARY OF THE RESULTS

Sample No	Gradation (% passing)											
	2-1/2"	2"	1-1/2"	1"	¾"	½"	3/8"	#4	#10	#50	#200	
1.Sub-grade	-	-	-	100	97	96	94	92	91	88	81	W
2.Sub-grade	-	-	-	-	-	-	100	99	98	95	94	W
3.Sub-grade	-	-	-	-	100	93	91	89	87	84	80	W

Sub-Base

Sample No	Gradation (% passing)											
	2-1/2"	2"	1-1/2"	1"	¾"	½"	3/8"	#4	#10	#50	#200	
1. Sub-base	100	84	78	63	57	50	49	45	31	14	6	D
	100	85	80	65	58	55	53	50	47	42	36	W
2. Sub-base	-	100	83	63	57	48	45	33	24	8	1	D
	-	100	84	65	58	51	47	41	37	29	20	W
3. Sub-base	100	92	90	73	69	59	56	51	45	28	3	D
3. Sub-base	100	92	90	74	70	60	57	53	49	40	20	W

Base Course

Sample No	Gradation (% passing)											
	2-1/2"	2"	1-1/2"	1"	¾"	½"	3/8"	#4	#10	#50	#200	
1.Base Course	-	100	93	79	69	54	48	36	24	8	2	D
	-	100	93	80	75	57	51	39	29	16	10	W
2.Base Course	-	100	95	72	65	58	52	40	24	4	1	D
	-	100	97	74	68	61	55	44	31	15	8	W

* **D** : Dry

W : Wet

Table No. 6.2

Atterberg Limits

Sample No.	Description	LL%	PL%	PI	
1	Gravelly base material	18	14	4	NP
2	Gravelly base material	17	14	3	NP
3	Gravelly base material	18	15	4	NP
4	Gravelly base material	21	15	6	SP

* NP = Non Plastic

SP = Slightly Plastic

6.7 CBR Value

The CBR value of the material used in base course was determined in the laboratory and it was found average 80% which is the minimum required in the specified limits (Table No. 6.5).

Table No. 6.5

Sample No.	Description	Field Compaction		Laboratory Compaction		CBR
		Dry density (pcf)	Degree of Comp. (%)	MDD (pcf)	OMC (%)	At 100 (%)
1	Gravelly base material	144	99	145	6.5	80
2	Gravelly base material	140	97	145	6.4	89
3	Gravelly base material	131	98	134	4.5	76
4	Gravelly base material	140	98	143	6.5	79

CHAPTER - 7

LABORATORY ANALYSIS & DISCUSSION

7.1 Bitumen Quantity in TST Layers

Four samples were collected from four different locations of bled and un-bled area. The bitumen quantity was determined and maximum variation upto 38% was observed among the four values. The quantity of bitumen was more in bled area as compared to un-bled areas and also it was found that the bitumen was not uniformly spread and at places where the quantity of bitumen was higher, after wetting the aggregate surfaces and filling the voids, it was pumped out of the TST layers and made a thin shiny film on the surface of the road (Table No 7.1).

7.2 Aggregate Quantity in TST Layers

The quantity of the aggregates spread for TST was also determined at four locations and maximum variation was upto 47% and it was revealed that aggregates quantity was higher in un-bled area as compared to the bituminous bled area. This can be one cause of bleeding because the surface area to be wetted by the bitumen was less and voids to be filled in by the bitumen were minimum and due to the secondary compaction voids further minimized and therefore the bitumen was pumped out of the surface and made a thin shiny film on the surface of the road (Table No. 7.1).

7.3 Bitumen Quantity in First Spray

The bitumen samples collected during the first spray of triple surface treatment were found 30% less than the required quantity of bitumen (Table 7.3).

Table No. 7.1

Un-Bled Area

Sample No. 1

Weight of the Sample	=	4254 gm
Weight of aggregate after extraction of bitumen	=	3991 gm
Weight of bitumen	=	263 gm
Weight of Aggregates sprayed	=	42.9 kg/sq.m
Weight of Bitumen sprayed	=	2.84 ltr/sq.m

Sample No. 2

Weight of the Sample	=	2278.7 gm
Weight of aggregate after extraction of bitumen	=	2115.00 gm
Weight of bitumen	=	163.7 gm
Weight of Aggregates sprayed	=	22.77 kg/sq.m
Weight of Bitumen sprayed	=	1.76 ltr/sq.m

Bled Area

Sample No. 1

Weight of the Sample	=	3805 gm
Weight of aggregate after extraction of bitumen	=	3495 gm
Weight of bitumen	=	310 gm
Weight of aggregates sprayed	=	37.62 kg/sq.m
Weight of Bitumen sprayed	=	3.33 ltr/sqm

Sample No. 2

Weight of the Sample	=	3650 gm
Weight of aggregate after extraction of bitumen	=	3360 gm
Weight of bitumen	=	290 gm
Weight of Aggregates sprayed	=	36.16 kg/sq.m
Weight of Bitumen sprayed	=	3.12 ltr/sqm

Table No. 7.3

SPRAY RATE OF BITUMEN IN LAYER OF TST

Sample No. 1	
Weight of Sample	115.84 gm
Weight of Pad	25.07 gm
Weight of Bitumen	90.77 gm
Required weight of bitumen	1.90 ltr/sq.m
Sprayed quantity of bitumen	1.184 ltr/sq.m
Percentage	37% less than required

Sample No. 2	
Weight of Sample	123.59 gm
Weight of Pad	25.07 gm
Weight of Bitumen	98.44 gm
Required weight of bitumen	1.90 ltr/sq.m
Sprayed quantity of bitumen	1.285 ltr/sq.m
Percentage	32% less than required

CHAPTER - 8

CONCLUSION AND RECOMMENDATIONS

Through Observations, by analyzing the distress data and laboratory testing the following are drawn and conclusion suggested :-

- The bleeding occurred due to:-

  - In-sufficient aggregates quantity in TST layer
  - The non uniformity of/in spray of bitumen and aggregates in TST layer

- Quality of construction was poor through lack of quality control

Recommendations

- Shoving area must be rectified.

- Kerb stones may be fixed at the edge of open drain as a safety protection.

- Chip spreader may be used to spread the aggregates for TST to control the uniform spreading of aggregates.

- Poor control of the surface levels of road affect the riding quality which can be controlled by using mechanical paver.

- The liquid asphalt may be sprayed by mechanical distributor so that uniform quantity may be sprayed.

- Many distresses are closely interconnected and at later stage, it becomes difficult to identify the primary cause, therefore, pavement monitoring survey should be regularly carried out in order to apply timely remedial measures.

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PLATES

Plate 1 : COLLECTION OF SAMPLES

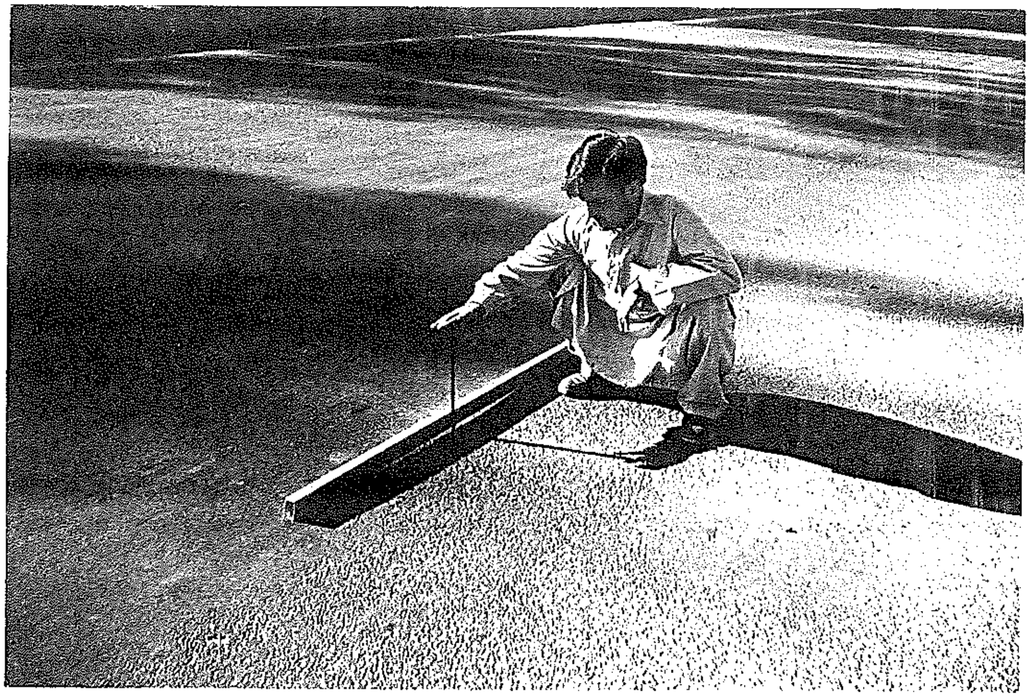

Plate 2 : SURFACE ROUGHNESS IS BEING CHECKED WITH STRAIGHT EDGE

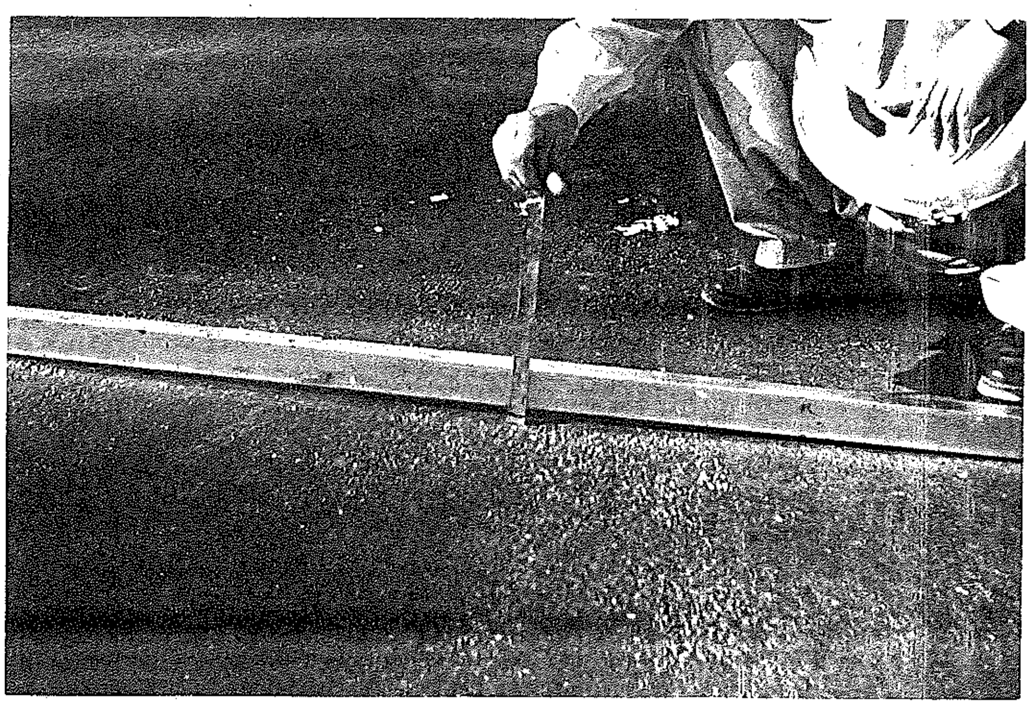

Plate 3 : CHECKING OF SURFACE UNDULIATION WITH STRAIGHT EDGE

Plate 4 : EXTENSIVE SHOVING IS VISIBLE

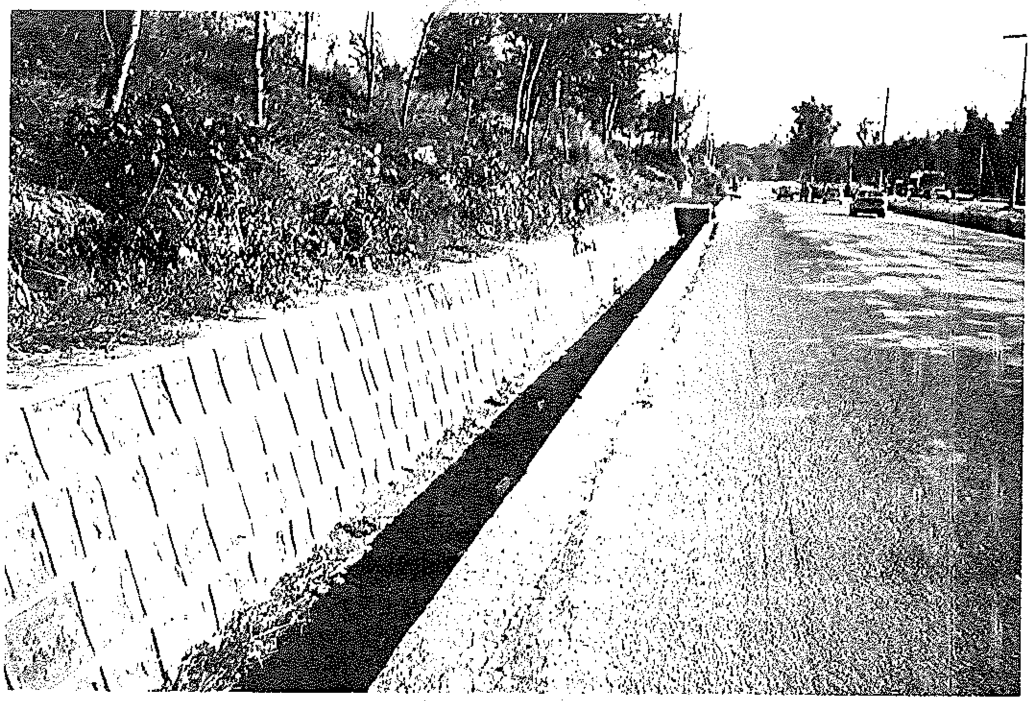

Plate 5 : SIDE DRAIN WITHOUT SAFETY PROTECTION AND BLEEDING IS ALSO VISIBLE

ANNEXURES

<u>**QUANTITIES OF MATERIALS FOR BITUMINOUS SURFACE TREATMENTS(NHA)**</u>

Surface Treatment		**Aggregate**		**Bitumin Material**	
Type	Application	Size No	Quanity Kg/Sq.M	Qty. Lires /Sq.M	Type
Single	Single	2	12.5	1.19	(a)
				1.63	(b)
Double	First	1	24.0	1.90	(a)
				2.14	(b)
	Second	3	12.5	1.19	(a)
				1.63	(b)
Triple	First	1	24.0	1.90	(a)
				2.14	(b)
	Second	2	12.5	1.19	(b)
				1.63	(b)
	Third	3	6.5	0.68	(c)
Seal With	Coat/Pad Aggregate	4	4	0.5	(c)

Note:

i) Bituminous material types are (a) asphalt cement, (b) cut-back or emulsified and (c)asphalt cement, cut-back and emulsified.

ii) Quantities of bituminous material may be varied by the Engineer by +15% depending on site conditions.

iii) Prime coat shall be applied prior to the surface treatment for the newly constructed pavement at the rate as specified in the item 302.3.2.

PAVEMENT DESIGN FOR PESHAWAR MOR-PIRWADAHI ROAD

S.No	Pavement Layer Thicknesses, inches			Modulus, psi			Surface Deflection mils	Compressive Strain microns	Allowable Strain microns
	ABC	GSB	SG	ABC	GSB	SG			
1	12	24	-	30,000	15,000	7,500	42.7	236	143
2	12	24	-	50,000	20,000	10,000	28.5	169	143
3	12	24	-	60,000	30,000	10,000	23	132	143
4	18	18	-	30,000	15,000	7,500	40.1	221	143
5	18	18	-	50,000	20,000	10,000	26	155	143
6	18	18	-	60,000	30,000	10,000	22.4	124	143
7	21	18	-	30,000	15,000	7,500	39.1	187	143
8	21	18	-	50,000	20,000	10,000	25.4	131	143
9	21	18	-	60,000	30,000	10,000	21.7	105	143

Note: Water Bound Macadam (WBM) or Aggregate Base Gradation close to WBM with fines not greater than 5% having P.I <3 with proper compaction may give modulus of 60,000 psi. Another very important factor, the upper layer can only be compacted to its desired strength if the lower layer have sufficient strength. So keeping in view the above limitation and cost of materials option 3 is recommended for 60 million ESALs.

FATIGUE CRITERIA

Allowable Tensile Strain at Bottom of Asphalt Layer

Basic Equation: Strain (allowable) = A * (N/10^6)^B * (E/3000)^c

Where, A, B, C are coefficients, E is the modulus of asphalt (MPa), and N is the number of load repititions

Model	A	B	C	N	E	Allowable Strain
Asphalt Institute, USA	0.000240	-0.302	-0.85	60,000,000	3,103	68
Shell 1977	0.000054	-0.250	0.00	60,000,000	3,103	19
NAASRA, Australia	0.000227	-0.200	0.00	60,000,000	3,103	100
Illinois, Class 1 cracking	0.000059	-0.333	0.00	60,000,000	3,103	15
University of Nottingham, DBM pen = 200	0.000094	-0.347	0.00	60,000,000	3,103	23
University of Nottingham, DBM pen = 100	0.000133	-0.285	0.00	60,000,000	3,103	41
University of Nottingham, HRA	0.000209	-0.204	0.00	60,000,000	3,103	91
Thin continuously graded mixes, South Africa	0.000279	-0.183	0.00	60,000,000	3,103	132
Thin gap-graded mixes, South Africa	0.000331	-0.137	0.00	60,000,000	3,103	189
Verstraeten, CRR, Belgium	0.000088	-0.210	0.00	60,000,000	3,103	37
Nardo Italia, 1983	0.000165	-0.243	0.00	60,000,000	3,103	61
Giannini & Camomilla Italia	0.000142	-0.234	0.00	60,000,000	3,103	54
					Minimum	15
					Maximum	189
					Std. Dev.	49
					Median	58
					Average	69

SUBGRADE STRAIN CRITERIA

Allowable Vertical Strain at Top of Subgrade

Basic Equation: Strain (allowable) = A * (N/10^6)^B

Where, A and B are coefficients, and N is the number of load repititions

Model	A	B	N		Allowable Strain
Shell 1978, 50% probability	0.000885	-0.250	60,000,000		318
Shell 1978, 84% probability	0.000696	-0.250	60,000,000		250
Shell 1978, 95% probability	0.000569	-0.200	60,000,000		251
Chevron, mean rut 10 mm	0.000482	-0.223	60,000,000		193
University of Nottingham, mean rut 13 mm	0.000451	-0.280	60,000,000		143
South Africa, Terminal PSI = 1.5	0.001005	-0.100	60,000,000		667
South Africa, Terminal PSI = 2.0	0.000728	-0.100	60,000,000		483
South Africa, Terminal PSI = 2.5	0.000495	-0.088	60,000,000		345
NAASRA, Australia	0.001212	-0.141	60,000,000		680
Verstraeten, rut less than15 mm	0.000459	-0.230	60,000,000		179
Kenya	0.001318	-0.245	60,000,000		483
Giannini & Camomilla Italia	0.000675	-0.202	60,000,000		295
				Minimum	143
				Maximum	680
				Std. Dev.	174
				Median	307
				Average	357