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NATIONAL TRANSPORT RESEARCH CENTRE

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EVALUATION OF ADDITIONAL CARRIAGEWAY N-5

(MIANCHANNU-SAHIWAL SECTION)

NTRC- 208

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EXECUTIVE SUMMARY

National Transport Research Center (NTRC) on the request of Accountibility and Co-ordination Cell,has evaluated the Mianchannu-Sahiwal Section of the additional carriageway of National Highway N-5 to ascertain the possible causes of structural failure of the road.

2. The 81 Km additional carriageway consisting of two lanes (2 meter embankment) was constructed by the National Highway Authority (NHA) during 1990-93, as contract 6, under the Fourth Highway Project. Financed by the World Bank at a cost of Rs. 1.015 billion. The road was opened to traffic in May, 1993.

3. The road evaluation was carried out as per AASHTO methodology duly approved by the World Bank. The sallient observations are as follows:-

- During last five years (1993-98) nearly 140 million Equivalent Standard Axles (ESAL's) have passed over the road.
- Extensive surface distresses in the form of alligator cracks and rut in the wheel tracks of left lane of additional carriageway were observed..
- The cracks penetrated to full depth in the asphaltic layers.
- Under lying layers i.e granular base and sub-base were found to be intact.
- The air voids in the asphalt mix were found to be very high (initially more than 6%).

CONCLUSIONS:

4. Based on the preceeding, the following conclusion are drawn:-

- Lack of quality control in laying and compaction of the bituminous mix as obvious by very high air voids in the body of mix which has produced rather brittle mixture, prone to excessive cracking and rutting.

- The traffic was under estimated and as a result, the road was under designed. Even the traffic in terms of the Equivalent Standard Axles passed so far, require greater thickness.

1. PAVEMENT AND RELATED ISSUES

Pavement is defined as a structure consisting of different layers of materials placed on well-compacted surface called subgrade. Its function is to support the incoming traffic load and distribute it to the roadbed. There are two types of pavement namely; a) Flexible pavement that depends on aggregate interlock, particle friction and cohesion for stability; b) Rigid pavement that distributes the load by bending or beam action.

In Pakistan most of the Highway pavements are of Flexible type. These Pavements are considered to support the applied load by spreading action (distribution of the load from the stronger upper layer to the weaker lower layers) as shown in Fig. 1 (1, 2).

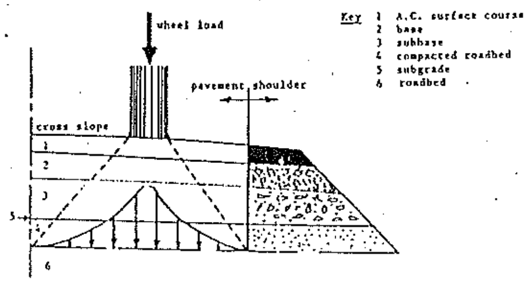


Fig. 1 **Typical flexible pavement cross-section**

1.1 PAVEMENT SYSTEM

Pavements are always designed and built for a certain time period and load applications (ESAL's) called pavement design life. Flexible pavements are generally designed for a period of 10 to 20 years with basic input of anticipated load applications. In this context, design life does not mean that at the end of the period the pavement will be completely worn out and in need of reconstruction; it means that towards the end of period, the pavement will need to be strengthened so that it can continue to carry traffic satisfactorily. For pavement to achieve its design life it is must that it should be designed properly, built up to the specifications (quality Control) and continually maintained. The pavement may also be resurfaced by applying thin overlay, once or twice during its design life. Therefore, it is always necessary that during construction of road projects, strong checks should be kept on materials quality and on its lying. Similarly, after the construction, existing flexible pavement should be periodically monitor/evaluated during its whole life, at network or project level (3, 4,).

1.2 EVALUTION OF EXISTING HIGHWAY PAVEMENT

Pavement monitoring and evaluation are analogous to the physical tests and/or check-ups of human beings. The evaluation assists the physician in determining the history of the persons's health, detecting the possible initiation of illnesses, and prescribing the proper preventive dieting and/or medications. Similarly, long term pavement monitoring assist the highway engineer in determining the state of health of the pavement. Estimating pavement's rate of deterioration, and detecting the possible initiation and sources of pavement distress. There are four components to a pavement evaluation namely; a) Functional evaluation, b) Structural evaluation, c) Traffic volume and load evaluation, d) Drainage evaluation.

1.2.1 PAVEMENT FUNCTIONAL EVALUATION: The pavement functional evaluation consists of a visually based pavement surface distress survey and quantitative measurement of roughness (evenness) of the pavement surface. Pavement's functional capability is associated with ability of the pavement to provide comfort (ride quality), safety (Skid resistance) and economical benefits to its users (saving in VOC).

a) PAVEMENT SURFACE CONDITION: Pavement surface distress or conditional survey are conducted by experienced Pavement Engineers, who visually inspects the pavement and reports on the type and extent of the pavement defects, there are three common modes of distress in any pavement namely; a) Fracture; b) Disintegration; c) Deformation. Surface distress survey is always needed for the Functional as well as Structural evaluation of the pavement. Chart below indicates some of the distress types, which may observe in any pavement i.e.: -

Distress Mode	Distress Type	Distress Sub-type
Fracture	**Cracking**	Alligator Longitudinal Transverse Block
Disintegration	**Ravelling** **Potholing** **Bleeding**	
Deformation	**Depression** **Rutting**	

b) PAVEMENT ROUGHNESS: Roughness can be defined as pavement surface irregularities that adversely affect ride quality, safety, and vehicle operating costs. Riding quality of any pavement is judged by roughness measurements conducted by either a vehicle mounted Bump Integrator by running at a constant speed of 20 mile/hr or an IRI tester. Pavement is termed as functionally fail if roughness is more than 2800 mm/km that is 2.5 PSI according to AASHTO and 4.0 IRI by IBRD (World Bank) standards.

1.2.2 **PAVEMENT STRUCTURAL EVALUATION:** The objective of the structural evaluation of a pavement section is to obtain the needed information to identify the structural condition of that section along its length and across the lanes. Pavement's structural capability is associated with ability of the pavement to carry design load. Considering following points can develop the structural evaluation of a pavement section:-

a) Existing pavement distresses that are primarily caused by traffic loadings provide direct information concerning the effects of previous traffic on the pavement structure. The key load-related structural distresses in asphalt concrete pavement are:

Alligator Cracking: > 25 % Area

Rutting at wheel tracks: 0.5 inch (13 mm) (mean).

Pavement is termed as structurally fail and rehabilitation should be considered when distress levels exceed the values shown above. If a significant amount of load-related distress has confirmed from the surface condition survey, then it is apparent that a structural deficiency exists. However, it is desirable to conduct non-destructive and/or destructive testing to obtain further knowledge of the structural condition.

b) Destructive testing (coring and sampling for laboratory testing) can be performed to obtain the type, thickness and condition of the various pavement layers. This information can be used to conduct a component analysis in which structural coefficients are assigned to each layer based on the structural adequacy of each layer as described in AASHTO Guide for the Design of Pavements (5).

c) Non-destructive testing (NDT), used in conjunction with the distress survey, is most reliable method for determining the structural adequacy of the pavement.

1.2.3 **TRAFFIC LOAD EVALUATION:** Highway traffic is typically a combination of many different types of vehicles having different gross weights and axle configurations. However, many design procedures require that these applied loads be converted into an equivalent number of applications of a standard axle load. The 18-kip (8136-kg) equivalent single axle load (18 -kip ESAL) is the standard used most widely by highway agencies.

The measurement and projection of traffic volumes and weights is subject to much variability and interpretation. This fact has lead many engineer to consider traffic estimation relatively unimportant. However, it is important to do a good job of characterizing traffic in order to develop good rehabilitation and pavement design inputs. Small errors carried through the project design life can produce unexpected results, such as extreme under design and premature failure or over design and unnecessary expense. Thus, this extremely difficult task is also extremely important and an effort must be made to remove as much speculation as possible from the traffic estimation process. .

1.2.4 **DRAINAGE EVALUATION**: The importance of drainage to a durable pavement has been recognized since very long. The presence of excessive moisture in the pavement material often accelerates pavement deterioration. For example: once pavement cracks, moisture infiltration to the underlying materials will increase and weaken the base, sub-base and sub-grade layers. This in turn causes the cracks to widen and/or cause new cracks.

1.3 PRE-MATURE FAILURE OF PAVEMENT

Pre-mature failure of a pavement is happened, when pavement reaches to its critical state that is at the structural failure before its design period. Therefore, it is necessary for economical reasons that a pavement should reach to its critical state after providing the service for a time period nearly equal to its design life.

Pre-mature failures of Highways are the most common phenomena in our country. The happening of this not only causes the disturbance and inconvenience to the road users but also become a burden on the national ex-chequre, besides jeopardizing the credibility of the highway designers and construction engineers.

Nevertheless, it is the task of pavement designer to estimate all likely variations in estimation of ESAL's, material properties and job execution so that the end product that is the Pavement should lasts its design life.

2. PROJECT BACKGROUND

Road transport has emerged as the dominant mode of transport carrying about 85 % of inland passenger and freight traffic in the country. The total length of roads in Pakistan is about 216,000 km, consisting of 116,000 km of paved roads and 100,000 km of unpaved roads. National Highway Authority (NHA) is responsible for the 6,600-km long national highways. Pakistans's primary traffic artery is 1760 km Karachi-Lahore-Peshawar corridor called N-5. The corridor's transport system serves domestic needs and also links upper country (Punjab & NWFP) with international markets through Karachi area ports. About 60 % of the port traffic moves to and from upper country along the corridor (6).

2.1 ADDITIONAL CARRIAGE WAY OF N-5

The additional carriage way of N-5 (Mianchannu – Sahiwal) was constructed during 1990-93, under the Fourth Highway Project of NHA, financed by the Government of Pakistan and the World Bank (Loan 2814-PAK). Mianchhanu – Sahiwal section under the project was covered in contract 6, which was further sub-divided in to two contracts called 6a and 6b. Project location plan is placed at Fig.2.

2.1.1 CONTRACT 6a (Mianchannu – Chak Behni): Contract 6a comprised the construction of a 7.3 meter wide carriage way between Mianchannu and Chak Behni including the Kassowal Overhead bridge and bypasses for Iqbal Nagar and Chicha watni. The total length of the contract is 39.6 km. Basic contract data is as follows:

Contractor:	Husnain Construction Co. Ltd.
PC-1 Estimate:	Rs. 230.2 millions
Bid Amount.	Rs. 276.5 millions
Constructed Cost:	Rs. 567.5 millions
Date of Commencement:	08 August 1998
Contract time:	799 days
Actual Contract time:	1376 days
Actual Completion Date:	15 May 1993
Supervisory Consultants	Freeman Fox Ltd. In association with Associated Consulting Engineers (ACE)

2.1.2 CONTRACT 6b (Chak Behni - Sahiwal): Contract 6b comprised the construction of a 7.3 meter wide carriage way between Chak Behni and Sahiwal including the Harapa and Sahiwal bypasses. The total length of the contract is 41.4 km. Basic contract data is as follows:

Contractor:	Sadullah Khan & Brothers
PC-1 Estimate:	Rs. 243.1 millions
Bid Amount.	Rs. 250.2 millions
Constructed Cost:	Rs. 447.2 millions
Date of Commencement:	08 August 1998
Contract time:	799 days
Actual Contract time:	1376 days
Actual Completion Date:	15 May 1993
Supervisory Consultants.	Freeman Fox Ltd. In association with Associated Consulting Engineers (ACE)

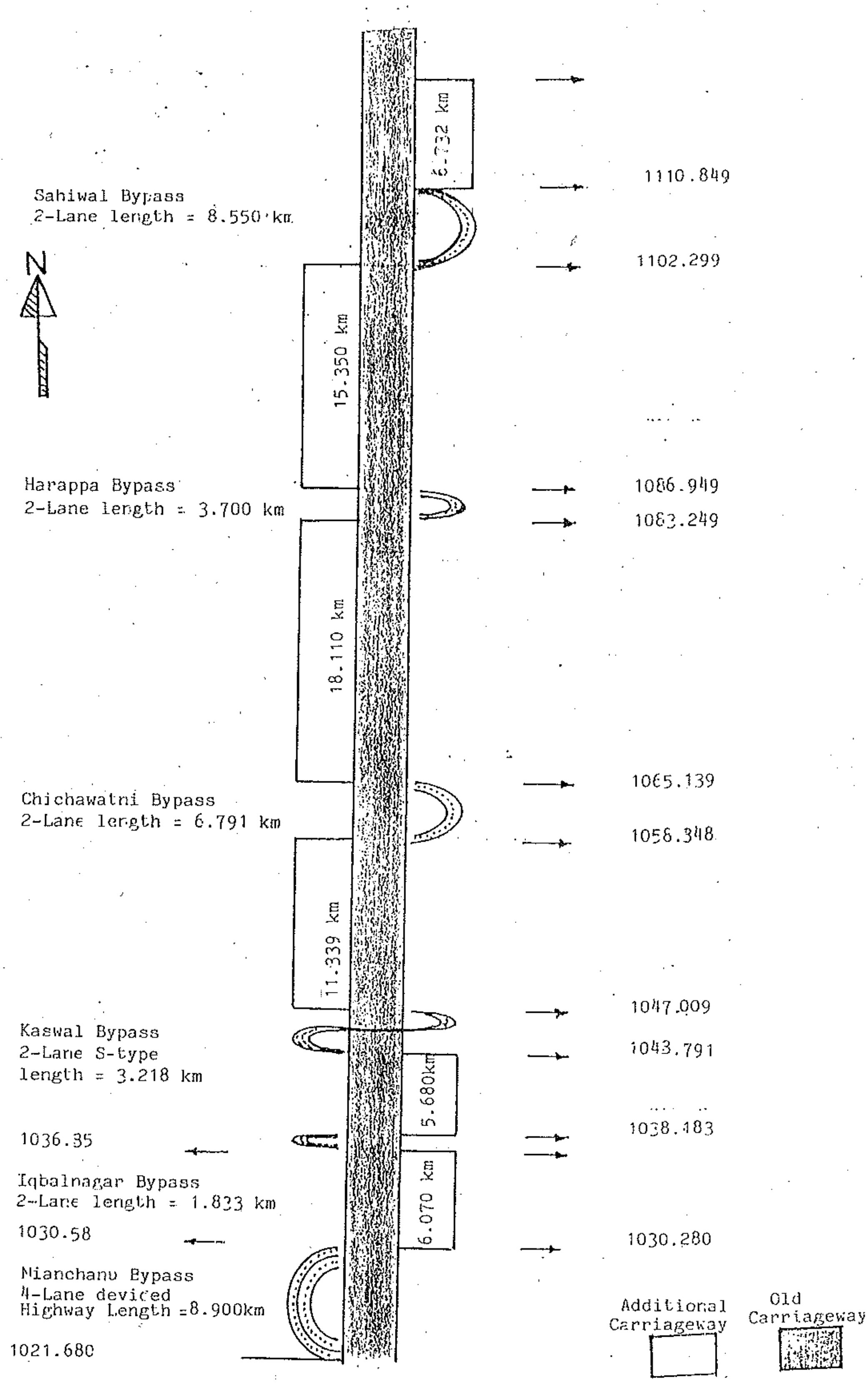


Fig. 1 Block Diagram of the Project

3. METHODOLOGY

Methodology adopted for evaluation and finding the cause of premature failure of N-5 additional carriageway (Mianchannu – Sahiwal Section) has been on the lines proposed by AASHTO and the World Bank. Investigations carried out for the exercise is as follows: -

3.1 PAVEMENT SURFACE CONDITION SURVEY

A visual survey in order to assess the surface condition of the existing pavement had been carried all through the road section (80-km). The pavement surface distresses like Alligator cracking in wheel track; Rutting and Potholing were accounted.

3.2 ROUGHNESS SURVEY

Road Roughness of the section had been assessed with the help of a vehicle mounted Bump Integrator. By running the vehicle at constant speed of 20 mile/hr in the left lane of road section.

3.3 STRUCTURAL EVALUATION

As the distress survey of road section had confirmed the presence of critical structural distresses over the road surface. Therefore, for getting the further information related to bearing capacity of the existing pavement, cores from Asphaltic Concrete layers were drilled at selected locations. Also Deep Cone Penetrometer (DCP) was applied at same locations in order to verify the strength and thickness of the unbounded layers. As the visual survey and the DCP testing results had given the idea that the problem is related to the asphaltic concrete layers.

3.3.1 **MATERIAL TESTING :**Cores drilled from the asphaltic layers of the road were than tested in the NTRC laboratory for gradation, In-situ density and voids in the mix.

3.4 ROAD TRAFFIC AND AXLE LOAD ANALYSIS

On the basis of previous years traffic data and axle load survey carried by NTRC on the section in 1994, an estimation of the damage already happened to the pavement in terms of ESAL's was estimated.

3.5 REPORTING

After the detail analysis of all the information collected from the field testing, as well as the laboratory tests results conclusions were drawn and reported.

4. FUNCTIONAL EVALUATION RESULT

The additional carriageway of N-5 (Mianchannu – Sahiwal Section) is 2 lanes 7.3 meters wide highway with 2 meters sealed shoulders on both sides. The particular section starts from chainage 1030.280 km of additional carriage way of N-5 and ends at 1110.849 km. It has length of about 80.569 km. From chainage 1030.28 to 1043.791 km additional carriage way runs in the south direction, while from chainage 1043.791 to 1110.849 it runs in north direction, parallel to N-5 old alignment. In between, it has got five bypasses running through small cities.

4.1 SURFACE CONDITION MEASUREMENT

Visual survey was started from chainage 1030.28 of the additional carriageway by a vehicle moving in the left lane at a speed of 10 km/hr steadily and stops whenever needed to record the severity of defect. Pavement surface defects describe in following para's were noted for each 1 km of the road length:

- Rutting
- Cracking
- Potholes

4.1.1 **RUTTING**: Rut depth is measured by placing a two-meter straight edge transversely, to the road edge over the wheel path at both lanes of the road. The deepest part of the depression beneath the straight edge is measured and recorded as the rut depth using a calibrated wedge or steel scale. Measurements are made at only one point on each 500meter intervals along the road and in the two wheel tracks nearest the edge on both sides of the road, and higher of the two rutting values with the mean of 1 km is recorded. For rutting five classes were established according to the severity of the defect. Table below shows the rutting condition values adopted for the survey.

RUTTING CONDITION VALUE

	Condition Value	Mean Rut depth in mm
1	None	≤ 20
2	Minor	≤ 30
3	Significant	< 40
4	Extensive	< 50
5	Severe	> 50

While, with the help of Table-4.1 the distribution of the % length of the road effected by above rutting class is as follows:

1. None Class Rutting = 15 % of road length.
2. Minor Class Rutting = 63 %
3. Significant = 20%
4. Extensive = 2%

Whereas, AASHTO suggests 50% of the road length effected by rutting more than 13 mm should declared as structurally failed.

Photographs taking from the road site and presented at Plat. 1 and 2 show extensive severity and extent of rutting at the Iqbal Nagar bypass.

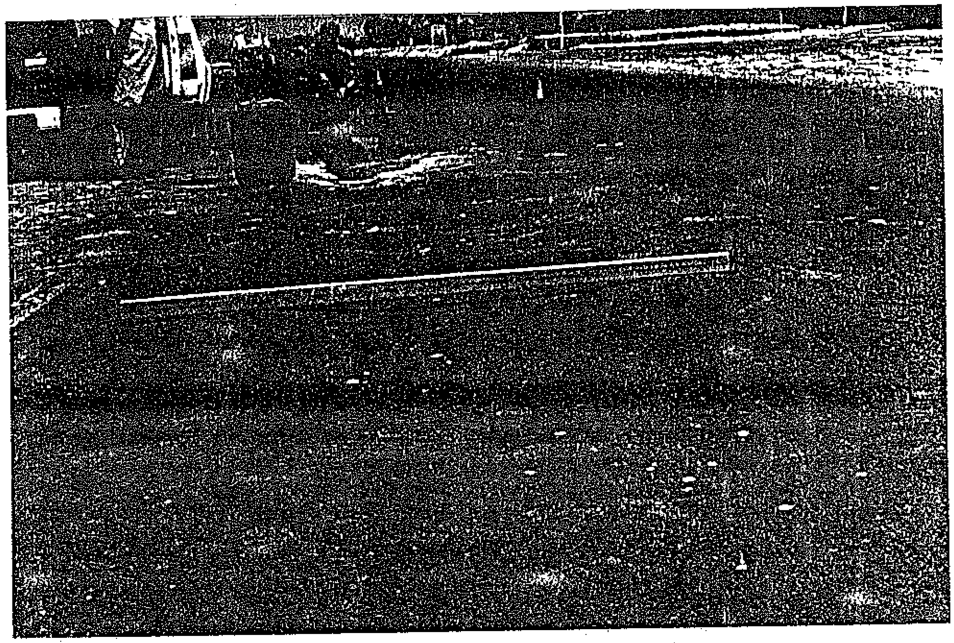
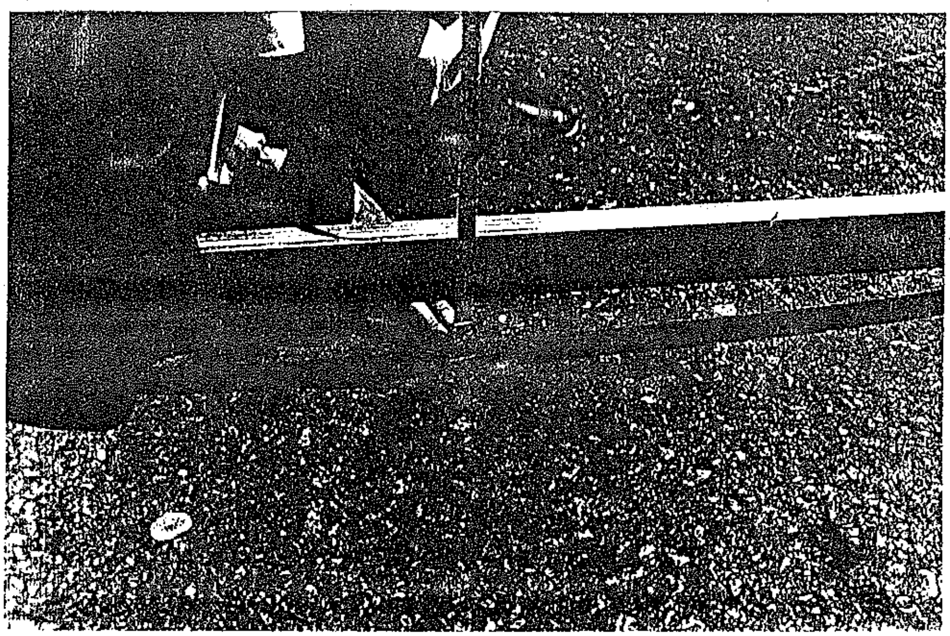


Plate 1. Severe Rutting in Wheel Track



Plat 2. Another View of Wheel Track Rutting

4.1.2 **ALLIGATOR CRACKING**: During survey alligator cracking had been recorded according to the severity of cracking across the road. For the alligator cracking in the wheel track, five classes were established according to the width of the crack. Table below shows the cracking condition values adopted for the condition survey. While, Plat.3 and 4 show the presence of extensive alligator cracking at the site.

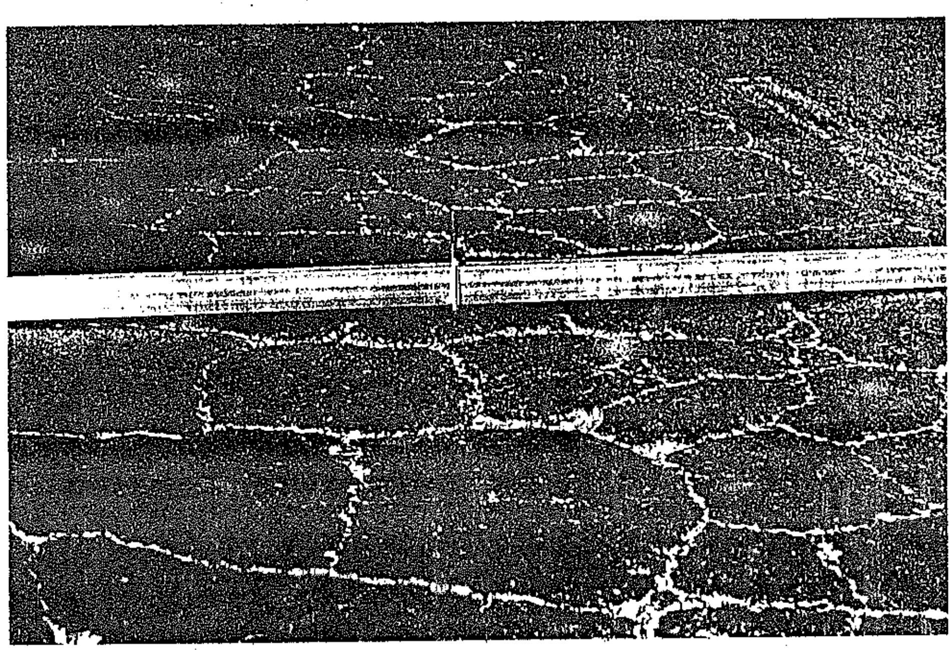
ALLEGATOR CRACKING CONDITION VALUE

Condition Value		Width of the crack in (mm)
1	None	< 2
2	Minor	< 5
3	.Significant	< 10
4	Extensive	< 20
5	Severe	> 20

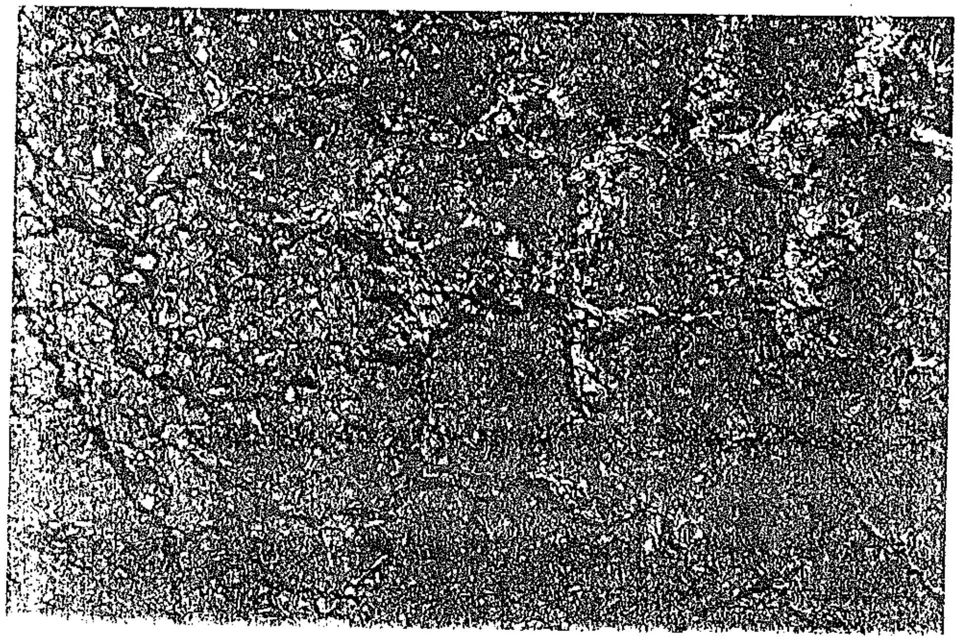
With the help of Table-4.1 the distribution of the % length of the road effected by above cracking classes is as follows:

5. None Class Cracking = 15 % of road length.
6. Minor Class Cracking = 8 %
7. Significant = 43%
8. Extensive = 34%

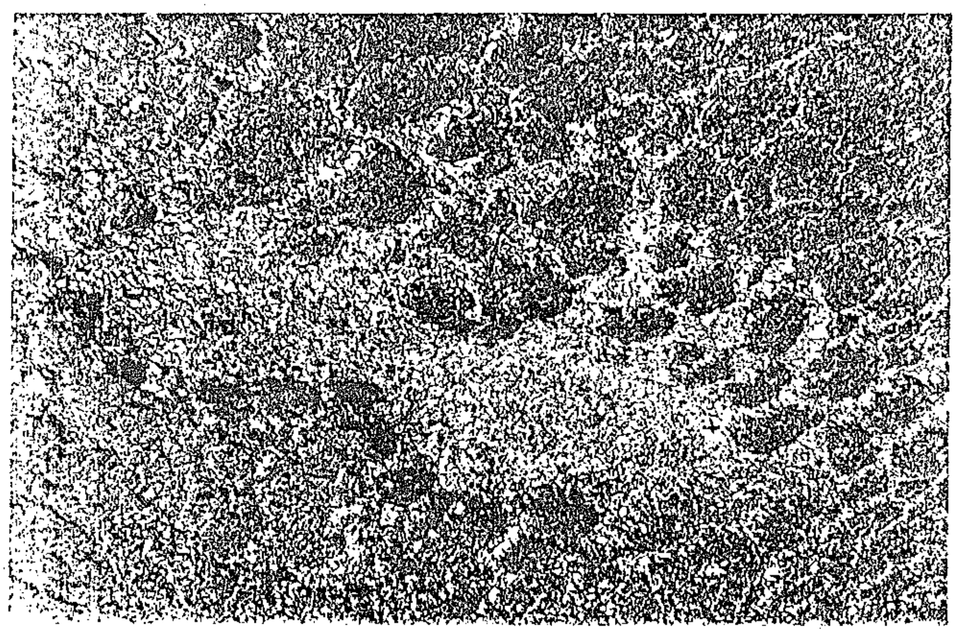
Whereas, AASHTO suggests 25% of the road length effected by alligator cracking of more than 5 mm should declared as structurally failed.



Plat 5 Alligator Cracks in Wheel Track.



Plat 6. View of Severe Alligator Cracking.



Plat 7. Presence of Pot-Holes at road surface.

4.1.3 **DECRIPTION OF RESULT:** The distress survey clearly show that nearly all of the road section of additional carriage way has severe surface distresses either in the form of rutting or the alligator cracking. Detail condition of each kilometer of the road section is placed at Annex-A, Table. 4.1. On bypasses where the traffic move in both direction the situation is worst. Similarly no severe distresses have been observed on sections from chainage 1030 + 280 to 1036+355 and from chainage 1038 + 183 to 1043 + 791. On the other hand Sahiwal bypass had been found worst according to conditional survey.

4.3 **ROUGHNESS SURVEY RESULT**

For getting the information related to the riding quality of the road section. Roughness had been measured with the help of a vehicle mounted Bump Integrator. Roughness of each kilometer had been recorded and placed at table.4.1. At only 15 % of the road length the roughness value has been equal or less than 1500 mm/km and at 35 % of the road length has roughness value between 1500 – 2000 mm/km. While, other 60 % road length has roughness more than 2000 mm/km. whereas, as per AASHTO for a pavement to be functionally suitable it must has a roughness less than 2800 mm/km.

5. STRUCTURAL EVALUATION RESULT

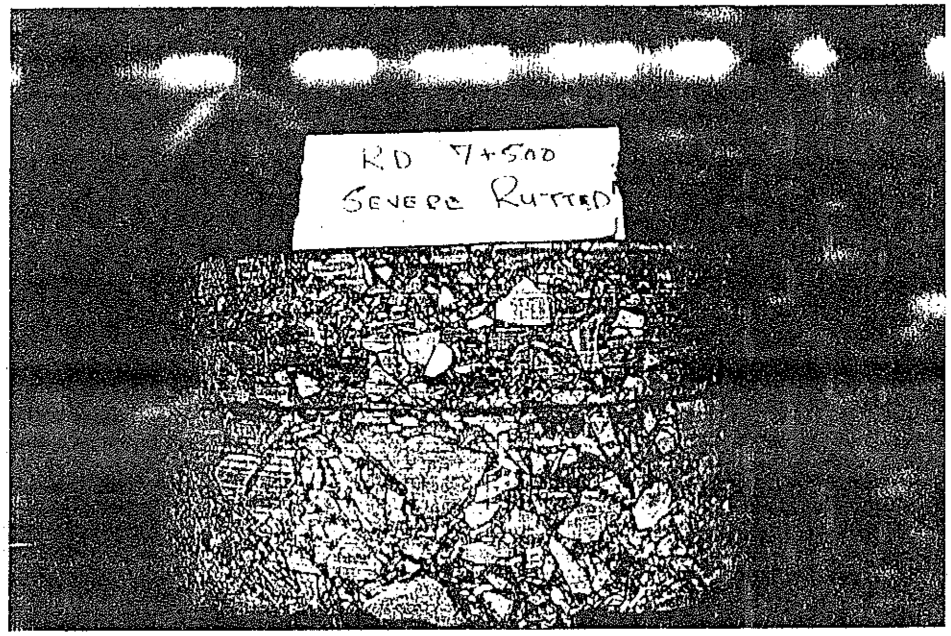
The structural evaluation of pavement structure requires accurate information related to the in-situ thickness of layers within the structure, and the in-situ strength of material used in these layers. Mostly the elastic modules of the existing pavement is assessed with the help of deflection measuring devices and using back calculation computer program. The other way of getting information related to the modules of existing asphaltic concrete layers, core are drilled from these layers and tested in laboratory for air voids content, bitumen content and gradation. While the in-situ modules of under lying layers, Deep Cone Penetrometer (DCP) apparatus can be used.

5.1 **CORING SURVEY**: Five cores from Asphaltic concrete (i.e. Wearing plus Base Course layers) at three locations, along the whole length of the road section were drilled. A high-speed portable drill capable of producing spindle speed of 300 to 500 rpm, with a cutting bit was used. A water pump had been connected to the drill in order to wash out the cutting as coring progress and to avoid any damage to core. Locations for coring were selected in such a manner so that representative cores from locations those are severely rutted and cracked was drilled. Similarly, for control section the area, which shows no sign of distress, was selected and two cores drilled from that location. Core specimens were than preserve for testing in laboratory. Where, by using the diamond saw, wearing and base course layers are separated.

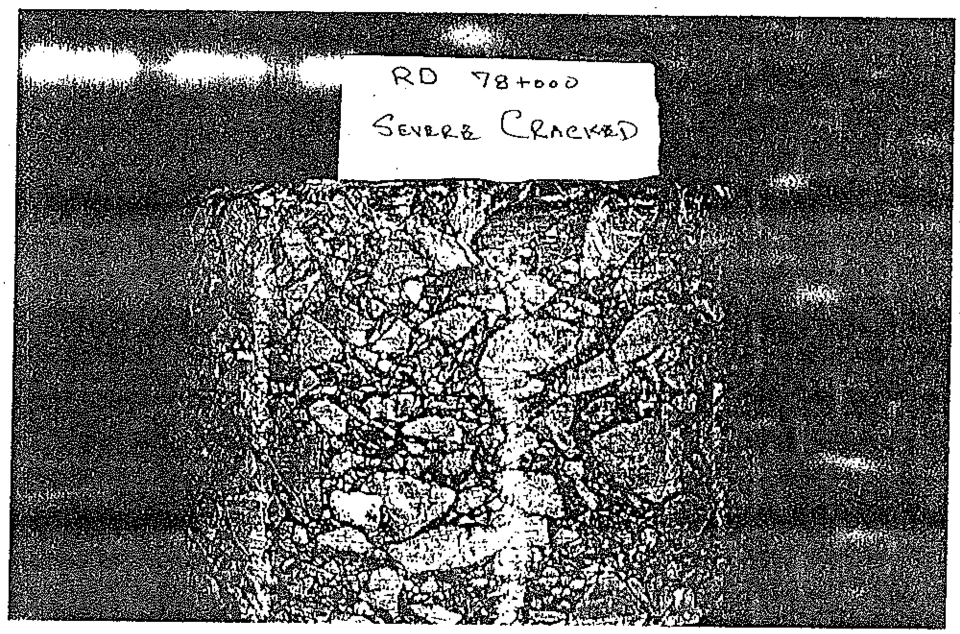
Exact location from where cores were drilled and their thickness are shown in Table 5.1. While, Plat 8. - 12 show the condition of cores, confirming full depth cracking in the asphaltic layers, densification of Asphaltic concrete due to severe rutting and very high voids in cores drilled form control section.

Table- 5.1 DATA RELATED CORES DRILLED FROM THE PAVEMENT

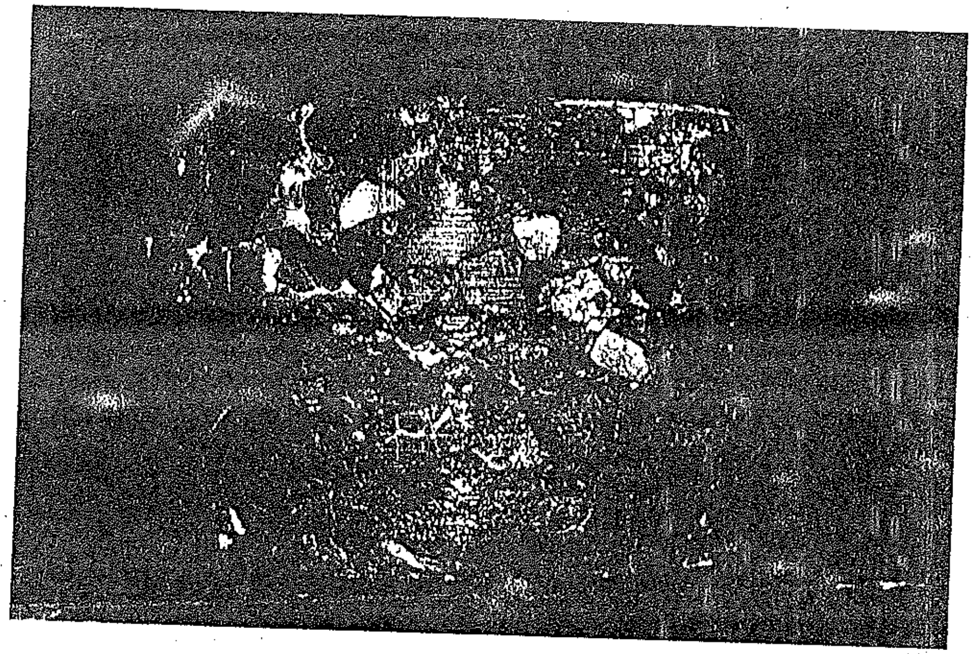
S.No	Core Location on N-5 Chainage (km)	Off set (feet)	Asphaltic Concrete Thickness (mm)		No of Core	Surface Condition
			Wearing Course	Binder Course		
1	1036 + 500	10	35	46	R1	Rut
2	1108 + 000	5	39	62	C1	Cracked
3	1108 + 000	10	39	61	C1	Cracked
4	1032 + 300	5	37	58	CT1	Perfect
5	1032 + 300	10	39	58	CT1	Perfect



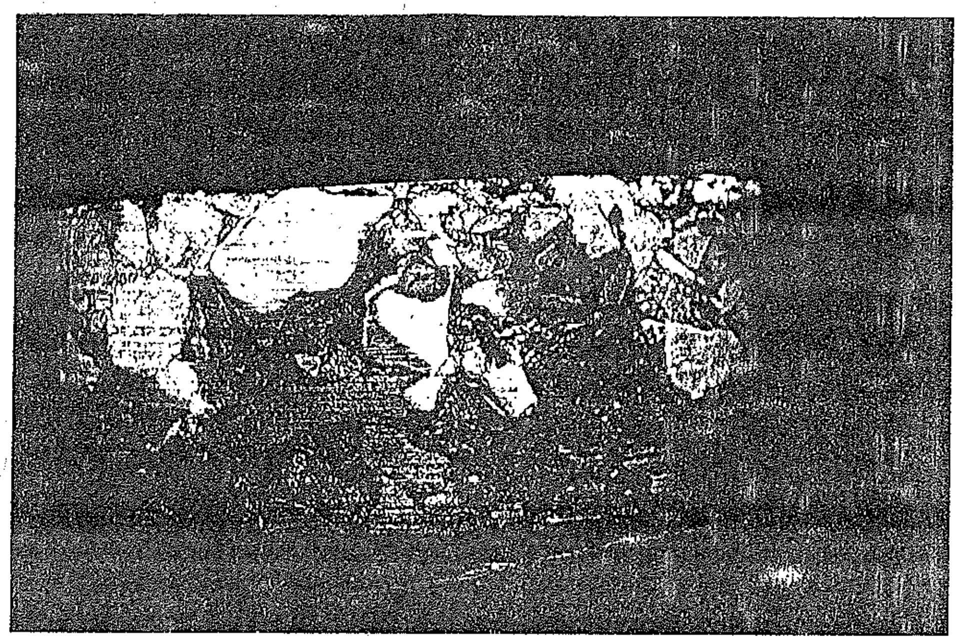
Plat 8. A view of core drilled from severe rutted area.



Plat 9. View of Core drilled from very severe cracked area.



Plat 11 Close view of core confirming full depth cracking in Asphaltic layers.



Plat 11. Close view of core drilled from control section confirming high air voids in asphaltic base.

5.2 ANALYSIS OF BITUMINOUS MIX: In order to analyze the mix properties of the bituminous material, cores from five locations along the length of the road section were drilled by a core drilling machine. Bituminous samples have been prepared for testing after careful removal of all particles of base material or other foreign matter. All the Asphaltic concrete cores have been split at the interface of layers prior to testing. Splitting cores at the interface of construction layers have been accomplished by sawing with a stone saw. Standard tests like the measurement of bulk specific gravity and density of the compacted mix (ASTM D-2726), measurement of maximum theoretical specific gravity of the loose paving mixture (ASTM D-2041), determination of bitumen content (ASTM D-2172), recovery of Bitumen (ASTM D-1856) and Voids analysis (ASTM D-3203) were carried on each sample.

5.2.1 DENSITY OF COMPACTED MIX: Density data has been obtained from cored specimens by adopting standard method (ASTM D-2726) and tabulated in Table - 5.2.1 for consultation:-

Table - 5.2.1 Mix Density (lb.cft) at Different Locations

Location	Mix Density (lb/cft)		No of Core
From Mianchannu	Wearing Course	Binder Course	
1036 + 500	153	154	R1
1108 + 000	146	146	C1
1108 + 000	146	149	C1
1032 + 300	147	146	CT1
1032 + 300	146	147	CT1

5.2.2 BULK SPECIFIC GRAVITY OF COMPACTED MIX : In order to find out bulk specific gravity of the compacted mix cores were cut in to two slices in order to get information related to each layer . Result are tabulated in Table-5.2.2:-

Table - 5.5.2 Bulk Sp.Gravity of Mix at different locations

Location	Layer		No of Core
From Mianchannu	Wearing Course	Binder Course	
1036 + 500	2.452	2.474	R1
1108 + 000	2.343	2.345	C1
1108 + 000	2.340	2.390	C1
1032 + 300	2.362	2.349	CT1
1032 + 300	2.346	2.362	CT1

5.2.3 MAXIMUM THEORETICAL SPECIFIC GRAVITY OF LOOSE MIX:- Maximum theoretical specific gravity of the loose mixture by standard Rice's method (ASTM D-2041 - 90) has been calculated for the wearing and binder layers of Asphaltic concrete and result are placed in Table-5.2.3:-

Table - 5.2.3 Maximum Theoretical Specific Gravity Of Loose Mixes.

Location	Th. Maximum Specific Gravity of Loose Mix	
From Mianchannu	Wearing Course	Binder Course
1108 + 500	2.498	2.500
1032 + 300	2.499	2.502

5.2.4 AIR VOIDS ANALYSIS:- With the help of Table- 5.2.2 and 5.2.3 , Air voids in mixes at different locations have been worked out using the following relation as per ASTM D 3203-88 and result are tabulated in Table- 5.2.4 :-

Percentage Air Voids In Compacted Mix = 100 (1- (bulk sp.gravity / theoretical maximum sp.gravity))

Table - 5.2.4 % Air Voids By Mix at Different Locations

Location	% Air Voids in Mix		No of Core
From Mianchannu	Wearing Course	Binder Course	
1036 + 500	2	1	RI
1108 + 000	6	6	CI
1108 + 000	6	4	CI
1032 + 300	5	6	CTI
1032 + 300	6	6	CTI

5.2.5 BITUMEN CONTENT IN THE MIX: In order to confirm the Bitumen content in different layers of overlay, at different locations of runway, standard test for recovery of Bitumen (ASTM D-2172) have been carried out . Result are presented in Table - 5.2.5 for consultation:

Table 5.2.5 % Bitumen Content of Compacted Mix

Location	% Bitumen Content of Compacted Mix		No of Core
From Mianchannu	Wearing Course	Binder Course	
1036 + 500	4.82	4.67	RI
1108 + 000	4.26	4.66	CI
1032 + 300	4.82	4.58	CTI

5.2.6 GRADATION OF EXTRACTED BITUMINOUS MATERIAL: Wearing and base course materials had been examined by recording the gradation of extracted aggregates, results are presented in table 5.2.6:

Table 5.2.6 Gradation of Extracted Mix

Location From Mianchannu	% Passing Sieve No.								
	1- ½"	1"	3/4"	1/2"	3/8"	No.4	No.10	No.50	No.200
Wearing									
1036 + 500	100	100	100	100	81	52	40	13	4
1108 + 000	100	100	100	100	67	45	31	11	4
1032 + 300	100	100	100	100	80	51	44	17	6
Binder									
1036 + 500	100	100	88	72	62	43	25	9	5
1108 + 000	100	100	90	78	71	54	32	10	4
1032 + 300	100	98	80	56	45	26	19	8	3

5.3 IN-SITU PROPERTIES OF UN-BOUNDED LAYERS

For the assessment of in-situ properties of un-bonded layers, under the asphaltic concrete layer, Deep Cone Penetrometer was used. The equipment was used at the same locations from asphaltic cores were drilled. Results of DCP testing is placed at Annex-B. While, a summery of result is placed at Table. 5.3: -

Table 5.3 UN-BOUNDED LAYERS IN-SITU PROPERTIES

S.No	Location	Base Thickness (mm)	Base In-situ CBR	Sub-grade In-situ CBR	Pavement Condition
1	1036 + 500	490	> 100 %	24 %	Rutted
2	1108 + 000	492	> 100 %	19 %	Cracked
3	1032 + 300	492	> 100 %	19 %	Perfect

5.4 DISSCUSSION ABOUT RESULT

Without question, air voids in mix design is the most important parameter. Perhaps the best over all accepted value for the air voids in mix is 4%, based on a maximum mix density value determined by the vacuum immersion technique (Rice Test) and corrected for absorbed water in the case of porous aggregate. Whereas in this case the percentage of air voids at control location has been found to be 6%. Similarly, at extensive rutted location its value is as low as 1%. This proves that initially the voids left in the mix body were more than 6%. Which causes the excessive densification of the mix by the traffic results extensive rutting. Similarly, due to very high air voids, rapid oxidation of the bitumen in the mix makes the asphaltic layer brittle and caused cracking on the application of heavy loads.

6. TRAFFIC & AXLE LOAD ANALYSIS

National Highway Authority (NHA) in association with the National Transport Research Center (NTRC) performed periodic traffic count on different national highways in order to get information related to Average Daily Traffic (ADT) on these highways annually. Also in 1994 an axle load survey was carried by NTRC on the request of NHA, in order to ascertain the loading pattern and to develop load equivalency factors for different types of trucks plying on these highways.

6.1 **TRAFFIC ESTIMATE:** In order to estimate the truck traffic already passed over the additional carriage way of N-5 (Mianchannu – Sahiwal Section) an exercise has been attempted using the above mentioned periodic traffic count survey data. Using the actual traffic counts for years 1993-1996 and estimated traffic for years 1997 –1998. The estimation of the annual average growth of different types of goods vehicles is placed in Table-6.1: -

Average Daily Traffic on Additional Carriage way of N-5 (Mianchannu - Sahiwal)

	Survey Date		Truck Classification				
		Buses	Type 2	Type 3	2 - S2	2 - S3	3 - S3
1	14/03/93	636	1873	977	402	37	87
2	12/03/94	638	2119	1117	448	38	99
3	02/02/95	640	2666	1469	594	50	108
4	29/01/96	649	2912	1609	640	51	120
	Growth Rate	2%	55%	65%	59%	38%	38%
Av. Annual Growth Rate		1%	14%	16%	15%	9%	9%

6.2 **ESTIMATION OF EQVALENT STANDARD AXLES (ESAL's):** By using the axle load data collected during 1994 on the Mianchannu – Sahiwal section and average annual growth factors of traffic the number of standard axles (ESAL's) already trafficked over the pavement are calculated. Result is placed in Table-6.2, while the detail survey analysis for section is placed at Annex-C.

Table-6.2 CALCULATION OF ESAL's UP TO 1998

Year		Bus	Type2	Type3	2 - S2	2 -S3	3 -S3	Total
1993		232140	683645	356605	146730	13505	31755	1464380
1994		232870	773435	407705	163520	13870	36135	1627535
1995		233600	973090	536185	216810	18250	39420	2017355
1996		236885	1062880	587285	233600	18615	43800	2183065
1997		238095	1210282	682260	268175	20376	47953	2467142
1998		239312	1378125	792595	307868	22303	52501	2792704
		1412903	6081456	3362636	1336703	106919	251564	12552181
	L.E:Factor Loaded	0.32	5.85	20.07	28.7	19.59	43.18	
	L.E.Factor Empty	N.A	0.043	0.72	0.08	0.084	0.165	
	Loaded	1412903	5473311	3026372	1203033	96227	226408	
	Empty	-	608146	336264	133670	10692	25156	
		452128	32045018	60981400	34537728	1885991	9780439	139682705
								140 million

6.3 **PAVEMENT DESIGN ANALYSIS**: After the calculation of ESAL's, the pavement thickness for this traffic has been worked out with the help of a computer program DNPS, which is based on the AASHTO design procedure. The pavement design for the above-mentioned traffic comes as.

Asphaltic Base = 11 inch

Granular Base = 8 inch

Granular Sub-base = 10 inch.

The detail analysis of pavement design is placed at Annex-D for consultation. This has led to the conclusion that the thickness provided for Asphaltic Concrete (4 inches) was not appropriate for such a heavy traffic plying on the road section.

7. CONCLUSIONS

The main conclusions drawn from the study are mentioned below:-

- Extensive road surface distresses in the form of alligator cracking and rutting in the wheel tracks of left lane of additional carriageway were observed.
- Pavement has been found structurally weak, as full depth cracks in the asphaltic layers was confirmed.
- Uunder lying layers like granular base and sub-base were found to be sufficiently strong.
- Pavement during the service of the nearly six years (1993-98) has been trafficked by nearly 140 million EASL's.
- Pavement has been found under design for the existing traffic plying on the road section.
- The improper laying and compaction of the bituminous mix is obvious due to very high air voids in the body of mix (initially more than 6%) which has produced rather brittle mixture, prone to excessive cracking and

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Annex - A

Table 4.1 CONDITION SURVEY RESULT OF ADDITIONAL CARRIAGE WAY OF N-5 (Mianchannu - Sahiwal Section)

Lenghth	N-5 Chainage		Description	Av. Roughness	Condition Values		
Km	From	To		mm/km	Rutting	Cracking	Potholes
1	1030	1031	Starting point of Section 1	1118	None	None	None
2	1031	1032	Traffic moving Towards	1340	None	None	None
3	1032	1033	South.	1251	None	None	None
4	1033	1034		1196	None	None	None
5	1034	1035		1207	None	None	None
6	1035	1036		1196	None	None	None
7	1036	1037	Iqbal Nagar By Pass	2118	Extensive	Minor	None
8	1037	1038	Traffic miving both direction	2451	Extensive	Minor	None
9	1038	1039	Starting point of Section 2	1118	None	None	None
10	1039	1040	Traffic moving Towards	1096	None	None	None
11	1040	1041	South.	1329	None	None	None
12	1041	1042		1340	None	None	None
13	1042	1043		1285	None	None	None
14	1043	1044	End of Section 2	1296	None	None	None
15	1044	1045	Starting Kasowal Bypass	2562	Minor	Minor	Significant
16	1045	1046	Traffic moving both direction	2118	Minor	Mionr	Minor
17	1046	1047	End of Kasoowal Bypass	1929	Minor	Minor	Minor
18	1047	1048	Starting Section 3	2007	Minor	Significant	None
19	1048	1049	Traffic moving Towards	2062	Minor	Significant	None
20	1049	1050	North.	2118	Minor	Significant	None
21	1050	1051		1562	Significant	Significant	None
22	1051	1052		1696	Minor	Significant	None
23	1052	1053		1762	Minor	Significant	None
24	1053	1054		1784	Minor	Significant	None
25	1054	1055		1840	Significant	Significant	None
26	1055	1056		1851	Minor	Significant	None
27	1056	1057		1951	Minor	Significant	None
28	1057	1058	End of Section 3	1784	Minor	Significant	None
29	1058	1059	Starting Chichawatni Bypass	1629	Significant	Extensive	Minor
30	1059	1060	Traffic moving both direction	2562	Significant	Extensive	Significant
31	1060	1061		2606	Minor	Extensive	None
32	1061	1062		2451	Significant	Significant	Minor
33	1062	1063		2484	Minor	Extensive	Significant
34	1063	1064		2562	Significant	Significant	Minor
35	1064	1065	End of Chichwatni bypass	1562	Significant	Extensive	Minor
36	1065	1066	Starting of Section 4	2395	Minor	Significant	None
37	1066	1067	Traffic moving North	1473	Minor	Significant	None
38	1067	1068		2084	Minor	Significant	None
39	1068	1069		2062	Minor	Significant	None
40	1069	1070		2673	Minor	Significant	Significant
41	1070	1071		1651	Minor	Extensive	None
42	1071	1072		1618	Minor	Significant	None
43	1072	1073		2373	Minor	Significant	None
44	1073	1074		3284	Minor	Extensive	Significant
45	1074	1075		2506	Significant	Significant	None
46	1075	1076		3951	Minor	Extensive	Significant
47	1076	1077		2351	Minor	Significant	None
48	1077	1078		1896	Minor	Significant	None
49	1078	1079		1873	Minor	Significant	Minor
50	1079	1080		2073	Significant	Extensive	None
51	1080	1081		2195	Minor	Significant	None
52	1081	1082		2751	Minor	Significant	Minor

Table 4.1 Contd.

Lenghth	N-5 Chainage		Description	Av. Roughness		Condition Values	
Km	From	To		mm/km	Rutting	Cracking	Potholes
53	1082	1083	End of Section 4	2840	Minor	Significant	Minor
54	1083	1084	Starting Harapa Bypass	2506	Significant	Extensive	Minor
55	1084	1085	Traffic moving both direction	1762	Significant	Extensive	Minor
56	1085	1086	End of Harrapa Bypass	1696	Significant	Extensive	Minor
57	1086	1087	Starting of Section 5	2629	Minor	Significant	Minor
58	1087	1088	Traffic moving North	1784	Minor	Significant	None
59	1088	1089		1840	Minor	Significant	None
60	1089	1090		1784	Minor	Significant	None
61	1090	1091		1618	Minor	Significant	None
62	1091	1092		1118	Minor	Minor	None
63	1092	1093		1340	Minor	Minor	None
64	1093	1094		1729	Minor	Significant	None
65	1094	1095		1673	Minor	Extensive	Minor
66	1095	1096		2395	Minor	Significant	None
67	1096	1097		2673	Minor	Significant	Significant
68	1097	1098		2618	Significant	Extensive	Minor
69	1098	1099		1584	Minor	Significant	None
70	1099	1100		1751	Minor	Significant	None
71	1100	1101		1840	Minor	Extensive	Minor
72	1101	1102	End of the Section 5	2806	Minor	Significant	Minor
73	1102	1103	Starting Sahiwal Bypass	2695	Minor	Significant	Minor
74	1103	1104		2718	Minor	Extensive	Minor
75	1104	1105	Traffic moving both direction	3340	Minor	Extensive	Significant
76	1105	1106		2962	Significant	Extensive	None
77	1106	1107		3651	Minor	Extensive	None
78	1107	1108		2729	Minor	Extensive	Minor
79	1108	1109		3673	Significant	Extensive	None
80	1109	1110		3951	Minor	Extensive	Significant
81	1110	1111	End of Sahiwal Bypass	3895	Significant	Extensive	Minor
82	1111	1112					

Annex - B

TRRL Dynamic Cone Penetrometer

Data file : mian1

19/04/98

Site	N - 5	Date	2/4/98
Section no.	Mianchannu - Sahiwal	Start layer	Granular Base Course
Test no.	1	Condition	Rutted
Chainage	1036+500	Zero error (mm)	10
Direction/lane	Towards Sahiwal	Surf thick (mm)	82
Position/offset	10 feet from edge	Extens @ line	0

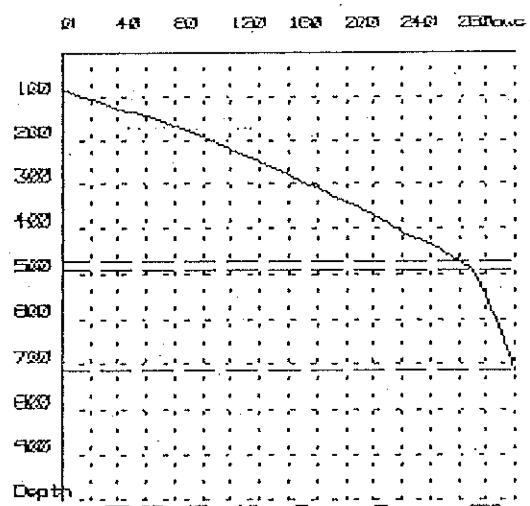
	Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng
1		92	11	100	202	21	200	351	31	300	560	41		
2	10	105	12	110	215	22	210	366	32	310	640	42		
3	20	116	13	120	230	23	220	382	33	320	720	43		
4	30	127	14	130	245	24	230	401	34			44		
5	40	138	15	140	261	25	240	417	35			45		
6	50	145	16	150	276	26	250	432	36			46		
7	60	153	17	160	291	27	260	445	37			47		
8	70	164	18	170	306	28	270	462	38			48		
9	80	176	19	180	320	29	280	480	39			49		
10	90	188	20	190	337	30	290	500	40			50		
51			61			71			81			91		
52			62			72			82			92		
53			63			73			83			93		
54			64			74			84			94		
55			65			75			85			95		
56			66			76			86			96		
57			67			77			87			97		
58			68			78			88			98		
59			69			79			89			99		
60			70			80			90			100		

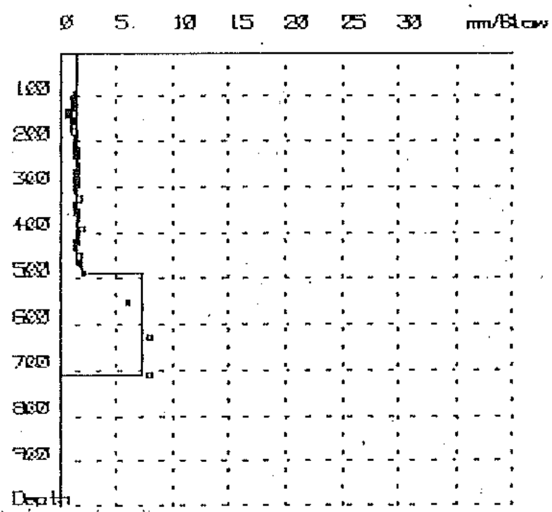
E1 : 1.00 E2 : 2.00 E3 : 4.00 E4 : 5.00 EM : 1.20

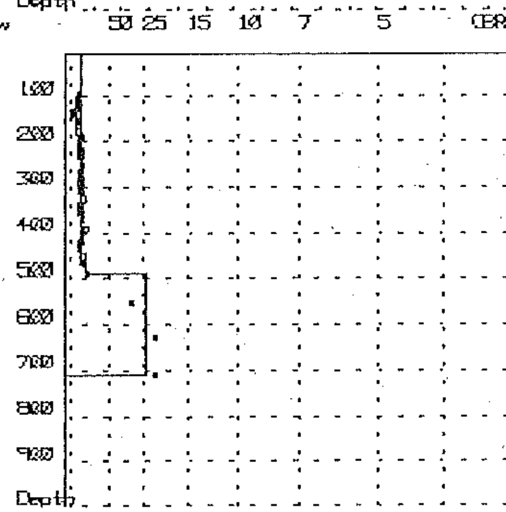
Layer	Strength mm/blow	CBR	Thick mm	Depth mm
1	1.39	171	388	470
Trans	2.00	111	20	490
2	7.33	24	220	710

User defined equation - log10(CBR) = 2.4 - 1.18 * log10(STRENGTH)

Data file	mian1
Site	N 5
Section no.	Mianchannu Sahiwal
Test no.	1
Chainage	1035+500
Direction/lane	Towards Sahiwal
Position/offset	10 feet from edge
Date	2/4/98
Start layer	Granular Base Course
Condition	Rutted
Zero error (mm)	10
Surf thick (mm)	82







TRRL Dynamic Cone Penetrometer — Data file : mian2

19/04/98

Site	N - 5	Date	3/4/98
Section no.	Mianchannu - Sahiwal	Start layer	Granular Base Course
Test no.	2	Condition	Alligator Cracking
Chainage	1108+ 000	Zero error (mm)	10
Direction/lane	Towards Sahiwal	Surf thick (mm)	100
Position/offset	10 feet from edge	Extens @ line	0

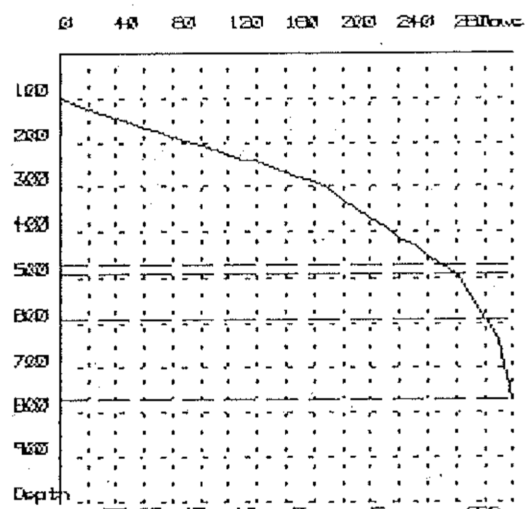
	Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng
1		110	11	100	215	21	200	340	31	300	600	41		
2	10	120	12	110	226	22	210	360	32	310	650	42		
3	20	133	13	120	238	23	220	380	33	320	780	43		
4	30	143	14	130	249	24	230	401	34			44		
5	40	154	15	140	252	25	240	422	35			45		
6	50	165	16	150	265	26	250	438	36			46		
7	60	177	17	160	278	27	260	461	37			47		
8	70	182	18	170	289	28	270	481	38			48		
9	80	195	19	180	300	29	280	502	39			49		
10	90	206	20	190	315	30	290	550	40			50		
51			61			71			81			91		
52			62			72			82			92		
53			63			73			83			93		
54			64			74			84			94		
55			65			75			85			95		
56			66			76			86			96		
57			67			77			87			97		
58			68			78			88			98		
59			69			79			89			99		
60			70			80			90			100		

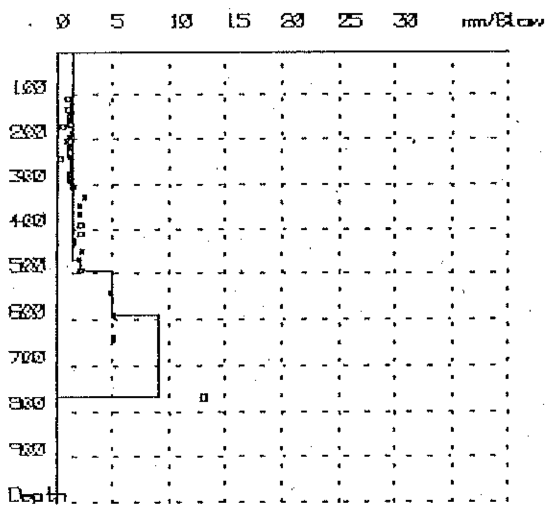
E1 : 1.00 E2 : 2.00 E3 : 4.00 E4 : 5.00 EM : 1.20

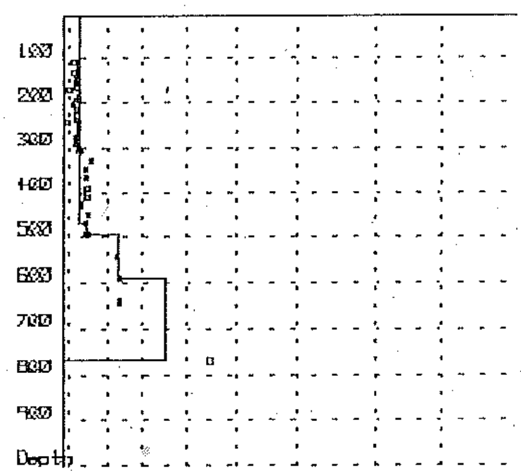
Layer	Strength mm/blow	CBR	Thick mm	Depth mm
1	1.37	173	371	471
Trans	2.10	105	21	492
2	4.90	39	98	590
Trans	9.00	19	180	770

User defined equation - log10(CBR) = 2.4 - 1.18 * log10(STRENGTH)

Data file	mian2
Site	N 5
Section no.	Mianchannu Sahiwal
Test no.	2
Chainage	110B+ 000
Direction/lane	Towards Sahiwal
Position/offset	10 feet from edge
Date	3/4/98
Start layer	Granular Base Course
Condition	Alligator Cracking
Zero error (mm)	10
Surf thick (mm)	100







TRRL Dynamic Cone Penetrometer Data file : mian3

19/04/98

Site	N - 5	Date	3/4/98
Section no.	Mianchannu - Sahiwal	Start layer	Granular Base Course
Test no.	3	Condition	Alligator Cracking
Chainage	1032+300	Zero error (mm)	10
Direction/lane	Towards Mianchannu	Surf thick (mm)	100
Position/offset	10 feet from edge	Extens @ line	0

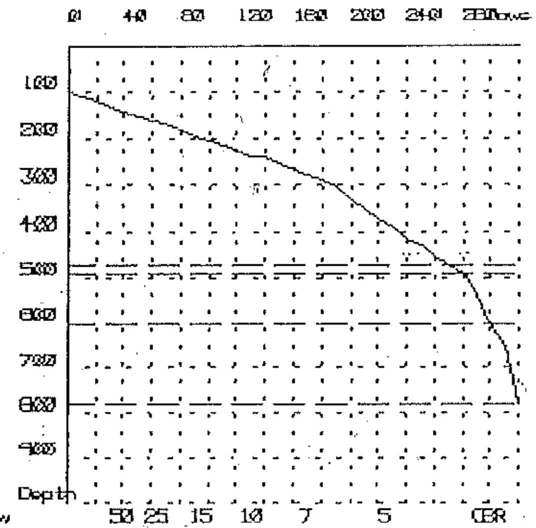
	Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng		Blw	Rdng
1		110	11	100	215	21	200	340	31	300	610	41		
2	10	118	12	110	226	22	210	361	32	310	660	42		
3	20	130	13	120	238	23	220	380	33	320	790	43		
4	30	145	14	130	249	24	230	400	34			44		
5	40	152	15	140	252	25	240	422	35			45		
6	50	163	16	150	265	26	250	438	36			46		
7	60	171	17	160	278	27	260	461	37			47		
8	70	180	18	170	289	28	270	481	38			48		
9	80	192	19	180	300	29	280	502	39			49		
10	90	206	20	190	315	30	290	550	40			50		
51			61			71			81			91		
52			62			72			82			92		
53			63			73			83			93		
54			64			74			84			94		
55			65			75			85			95		
56			66			76			86			96		
57			67			77			87			97		
58			68			78			88			98		
59			69			79			89			99		
60			70			80			90			100		

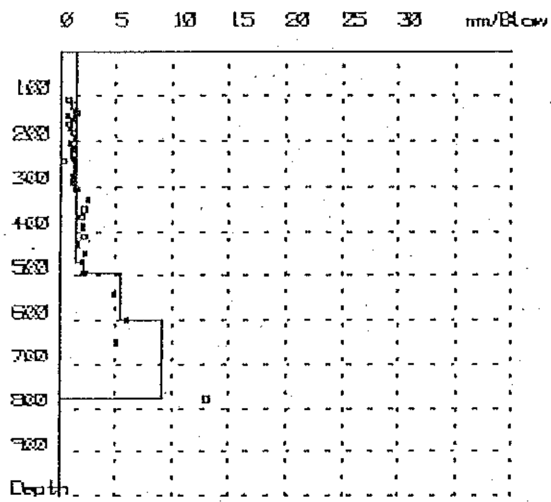
E1 : 1.00 E2 : 2.00 E3 : 4.00 E4 : 5.00 EM : 1.50

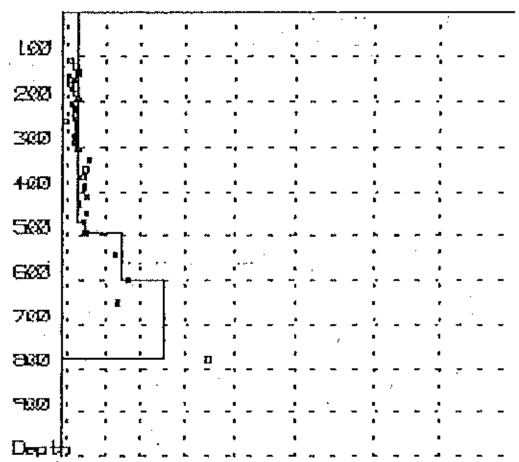
Layer	Strength mm/blow	CBR	Thick mm	Depth mm
1	1.37	173	371	471
Trans	2.10	105	21	492
2	5.40	34	108	600
Trans	9.00	19	180	780

User defined equation - log10(CBR) = 2.4 - 1.18 * log10(STRENGTH)

Data file	mian3
Site	N 5
Section no.	Mianchannu Gahiwal
Test no.	3
Chainage	1032+300
Direction/lane	Towards Mianchannu
Position/offset	10 feet from edge
Date	3/4/98
Start layer	Granular Base Course
Condition	Alligator Cracking
Zero error (mm)	10
Surf thick (mm)	100







Annex - C

Sahiwal Multan Station on from 7-9 May 1994 near Katch Khu										
FRM NO.	MK CD	TB CD	CM CD	AX CD	FRT AXL	REAR AX-1	Gross Weight	ESAL Front	ESAL Rear	ESAL per truck
2088	B	FU	A	2	5.18	13.54	18.72	0.13	9.74	9.87
2089	B	FU	A	2	4.41	7.68	12.09	0.06	0.76	0.82
2091	B	FU	A	2	6.36	14.71	21.07	0.32	14.14	14.47
2122	B	FU	A	2	4.50	11.60	16.10	0.07	4.86	4.92
2131	B	FU	A	2	4.70	10.30	15.00	0.08	2.84	2.93
2164	B	FU	A	2	6.51	12.42	18.93	0.36	6.60	6.96
2168	B	FU	A	2	5.43	12.32	17.75	0.16	6.37	6.53
2178	B	FU	A	2	4.70	12.74	17.44	0.08	7.40	7.49
2194	B	FU	A	2	6.10	12.18	18.28	0.27	6.05	6.32
2195	B	FU	A	2	6.36	12.39	18.75	0.32	6.53	6.86
2128	I	FU	A	2	6.90	13.60	20.50	0.47	9.93	10.40
2129	I	FU	A	2	6.10	15.35	21.45	0.27	17.13	17.40
2050	B	FU	A01	2	5.35	10.88	16.23	0.15	3.64	3.79
2135	B	FU	A01	2	4.45	7.45	11.90	0.07	0.66	0.73
2207	B	FU	A01	2	3.20	5.05	8.25	0.01	0.12	0.13
2090	B	FU	AN	2	4.51	6.76	11.27	0.07	0.43	0.50
2206	B	FU	AN	2	4.25	5.30	9.55	0.05	0.14	0.20
2215	B	FU	AN	2	3.36	6.70	10.06	0.02	0.41	0.43
2086	B	FU	BM	2	3.81	6.14	9.95	0.03	0.28	0.31
2113	B	FU	BM	2	4.70	8.25	12.95	0.08	1.05	1.13
2169	B	FU	BM	2	4.43	9.13	13.56	0.06	1.65	1.72
2193	B	FU	BM	2	4.86	6.90	11.76	0.10	0.47	0.57
2093	H	FU	BM	2	9.28	5.90	15.18	1.78	0.23	2.01
2075	B	FU	BUM	2	5.45	12.78	18.23	0.16	7.51	7.67
2079	B	FU	BUM	2	5.09	10.25	15.34	0.12	2.78	2.90
2176	B	FU	BUM	2	5.39	13.06	18.45	0.15	8.28	8.43
2192	B	FU	BUM	2	4.87	13.90	18.77	0.10	10.96	11.06
2214	B	FU	BUM	2	4.60	11.70	16.30	0.08	5.05	5.12
2173	B	C	F	2	4.53	12.08	16.61	0.07	5.83	5.90
2209	B	C	F	2	4.80	12.50	17.30	0.09	6.80	6.89
2053	B	FU	F	2	6.43	14.65	21.08	0.34	13.88	14.22
2054	B	FU	F	2	5.70	11.11	16.81	0.20	4.00	4.20
2063	B	FU	F	2	5.39	10.80	16.19	0.15	3.52	3.67
2073	B	FU	F	2	3.90	6.30	10.20	0.04	0.31	0.35
2087	B	FU	F	2	4.05	12.83	16.88	0.04	7.64	7.68
2095	B	FU	F	2	4.45	11.31	15.76	0.07	4.33	4.40
2096	B	FU	F	2	4.14	12.60	16.74	0.05	7.04	7.09
2098	B	FU	F	2	4.76	14.11	18.87	0.09	11.72	11.81
2100	B	FU	F	2	6.32	14.27	20.59	0.32	12.33	12.65
2111	B	FU	F	2	4.80	10.63	15.43	0.09	3.28	3.37
2127	B	FU	F	2	3.90	4.40	8.30	0.04	0.06	0.10
2144	B	FU	F	2	5.40	11.19	16.59	0.16	4.13	4.29
2145	B	FU	F	2	4.50	10.89	15.39	0.07	3.65	3.72
2163	B	FU	F	2	6.25	12.50	18.75	0.30	6.80	7.10
2167	B	FU	F	2	5.58	11.64	17.22	0.18	4.93	5.11
2170	B	FU	F	2	5.26	12.70	17.96	0.14	7.30	7.44
2174	B	FU	F	2	4.69	12.90	17.59	0.08	7.83	7.91
2179	B	FU	F	2	4.63	10.87	15.50	0.08	3.62	3.70
2180	B	FU	F	2	4.97	13.01	17.98	0.11	8.14	8.24
2182	B	FU	F	2	6.40	11.98	18.38	0.33	5.61	5.95
2185	B	FU	F	2	5.60	11.32	16.92	0.18	4.35	4.53
2186	B	FU	F	2	4.48	10.74	15.22	0.07	3.43	3.50
2202	B	FU	F	2	4.10	8.20	12.30	0.05	1.02	1.06
2213	I	FU	F	2	6.90	14.10	21.00	0.47	11.69	12.16
2146	B	C	FL	2	2.29	5.36	7.65	0.00	0.15	0.15
2183	B	C	FL	2	4.73	12.64	17.37	0.09	7.15	7.23
2184	N	C	FL	2	5.24	13.08	18.32	0.14	8.34	8.47
2190	H	C	FL	2	4.95	13.65	18.60	0.11	10.10	10.20
2057	B	FU	FL	2	5.52	11.70	17.22	0.17	5.05	5.22
2166	B	FU	FL	2	4.24	12.69	16.93	0.05	7.27	7.33
2198	B	FU	FL	2	4.60	10.70	15.30	0.08	3.38	3.45
2199	B	FU	FL	2	4.85	12.10	16.95	0.10	5.87	5.97
2197	H	F	MM	2	6.00	9.15	15.15	0.25	1.67	1.92
2051	B	FU	MM	2	4.92	8.69	13.61	0.10	1.32	1.43
2052	B	FU	MM	2	5.66	12.90	18.56	0.19	7.83	8.02
2056	B	FU	MM	2	5.75	13.27	19.02	0.21	8.89	9.10
2058	B	FU	MM	2	6.10	13.41	19.51	0.27	9.32	9.59

FRM NO.	MK CD	TB CD	CM CD	AX CD	FRT AXL	REAR AX-1	Gross Weight	ESAL Front	ESAL Rear	ESAL per truck
2064	B	FU	MM	2	6.50	13.60	20.10	0.36	9.93	10.29
2065	B	FU	MM	2	6.55	13.63	20.18	0.37	10.03	10.40
2074	B	FU	MM	2	5.64	13.25	18.89	0.19	8.83	9.02
2078	B	FU	MM	2	4.33	9.92	14.25	0.06	2.40	2.46
2081	B	FU	MM	2	5.16	9.52	14.68	0.13	2.00	2.12
2085	B	FU	MM	2	4.07	7.45	11.52	0.04	0.66	0.71
2106	B	FU	MM	2	3.74	11.68	15.42	0.03	5.01	5.04
2124	B	FU	MM	2	3.85	15.15	19.00	0.03	16.15	16.18
2140	B	FU	MM	2	4.10	8.10	12.20	0.05	0.96	1.01
2055	B	FU	MQ	2	5.72	12.91	18.63	0.20	7.86	8.06
2097	B	FU	MQ	2	5.50	13.80	19.30	0.17	10.61	10.78
2070	I	FU	MQ	2	6.40	11.30	17.70	0.33	4.32	4.65
2119	I	C	RM	2	5.00	13.75	18.75	0.11	10.44	10.55
				Maximum	9.28	15.35	21.45			17.40
				Minimum	2.29	4.40	7.65			0.10
				Mean	5.10	11.15	16.25			5.85
				Variance	1.06	7.24	10.72			17.07
				S.Deviation	1.03	2.69	3.27			4.13
				COV	20	24	20			71

FRM NO.	MK CD	TB CD	CM CD	AX CD	FRT AXL	REAR AX-1	REAR AX-2	Gross Weight	ESAL Front	ESAL Rear1	ESAL Rear2	ESAL per truck
2049	H	FU	A	3	8.58	12.68	13.02	34.28	1.25	7.25	8.16	16.66
2059	H	FU	A	3	8.58	13.60	13.31	35.49	1.25	9.93	9.02	20.20
2099	H	FU	A	3	5.28	13.02	14.49	32.79	0.14	8.16	13.21	21.52
2120	H	FU	A	3	7.70	11.10	12.90	31.70	0.77	3.98	7.83	12.58
2204	I	FU	A	3	5.10	12.90	12.40	30.40	0.12	7.83	6.56	14.51
2171	N	FU	A	3	7.81	11.53	15.45	34.79	0.82	4.73	17.63	23.18
2203	N	FU	A	3	7.80	15.00	13.20	36.00	0.81	15.44	8.69	24.94
2080	H	FU	AN	3	5.64	7.30	5.82	18.76	0.19	0.60	0.22	1.01
2121	H	FU	AN	3	5.00	6.75	7.00	18.75	0.11	0.42	0.50	1.03
2112	B	FU	BM	3	5.00	9.07	9.65	23.72	0.11	1.60	2.12	3.84
2136	H	FU	BM	3	6.25	12.10	12.40	30.75	0.30	5.87	6.56	12.73
2139	H	FU	BM	3	6.92	16.40	17.00	41.12	0.47	23.07	33.35	56.89
2211	H	FU	BM	3	10.35	13.80	12.90	37.05	2.91	10.61	7.83	21.35
2155	N	FU	BM	3	7.05	16.70	17.70	41.45	0.52	25.03	32.51	58.06
2181	N	FU	BM	3	9.40	13.16	12.20	34.76	1.88	8.57	6.09	16.55
2152	M	FU	BUM	3	8.05	13.90	13.68	35.63	0.94	10.96	10.20	22.10
2143	H	FU	BUM	3	6.81	13.79	16.70	37.30	0.44	10.57	25.03	36.04
2216	H	FU	BUM	3	9.25	15.10	14.84	39.19	1.75	15.91	14.71	32.37
2133	N	FU	BUM	3	6.84	14.00	16.40	37.24	0.45	11.32	23.07	34.84
2134	N	FU	BUM	3	9.21	12.20	13.80	35.21	1.72	6.09	10.61	18.42
2137	N	FU	BUM	3	9.30	13.10	15.70	38.10	1.80	8.39	18.96	29.15
2141	N	FU	BUM	3	7.90	13.10	13.42	34.42	0.86	8.39	9.36	18.61
2172	N	FU	BUM	3	8.34	11.80	15.73	35.87	1.10	5.24	19.12	25.46
2108	M	FU	F	3	8.98	13.77	16.90	39.65	1.53	10.51	26.41	38.44
2125	N	FU	F	3	5.70	9.10	9.40	24.20	0.20	1.63	1.88	3.71
2130	N	FU	F	3	7.70	8.75	8.30	24.75	0.77	1.37	1.08	3.21
2177	H	C	FL	3	5.83	12.83	11.79	30.45	0.22	7.64	5.22	13.09
2208	H	C	FL	3	5.00	9.50	10.90	25.40	0.11	1.98	3.67	5.76
2212	H	FU	FL	3	7.30	11.15	12.55	31.00	0.60	4.06	6.92	11.59
2138	I	C	FL	3	7.60	8.20	10.70	26.50	0.72	1.02	3.38	5.12
2132	N	C	FL	3	6.05	12.05	9.20	27.30	0.26	5.76	1.71	7.73
2142	N	C	FL	3	4.90	8.91	9.00	22.81	0.10	1.48	1.55	3.13
2153	N	C	FL	3	6.11	12.25	9.20	27.56	0.27	6.21	1.71	8.19
2154	N	C	FL	3	7.85	8.30	10.70	26.85	0.84	1.08	3.38	5.29
2188	N	C	FL	3	5.77	10.53	10.01	26.31	0.21	3.14	2.50	5.85
2189	N	C	FL	3	6.55	11.16	10.10	27.81	0.37	4.08	2.60	7.06
2196	N	C	FL	3	8.78	11.13	13.88	33.79	1.39	4.03	10.89	16.31
2200	N	C	FL	3	5.10	10.00	9.65	24.75	0.12	2.49	2.12	4.73
2210	N	C	FL	3	4.25	10.30	10.75	25.30	0.05	2.84	3.45	6.34
2062	H	FU	MM	3	7.25	11.32	11.12	29.69	0.59	4.35	4.01	8.95
2092	H	H	MM	3	4.35	9.00	8.53	21.88	0.06	1.55	1.22	2.83
2205	N	FU	MM	3	7.70	14.25	15.30	37.25	0.77	12.26	16.88	29.90
2046	H	FU	MQ	3	6.81	12.25	12.73	31.79	0.44	6.21	7.38	14.03
2047	H	FU	MQ	3	5.28	11.93	12.52	29.73	0.14	5.51	6.85	12.50
2048	H	FU	MQ	3	9.83	13.05	12.66	35.54	2.31	8.25	7.20	17.75
2066	H	FU	MQ	3	7.62	13.20	12.90	33.72	0.73	8.69	7.83	17.25
2068	H	FU	MQ	3	7.30	11.04	11.30	29.64	0.60	3.89	4.32	8.81
2084	H	FU	MQ	3	8.37	13.90	14.07	36.34	1.12	10.96	11.57	23.65
2102	H	FU	MQ	3	7.39	19.27	14.99	41.65	0.64	47.66	15.39	63.69
2104	H	FU	MQ	3	8.96	17.38	15.11	41.45	1.52	29.95	15.95	47.43
2107	H	FU	MQ	3	8.17	15.96	16.91	41.04	1.00	20.41	26.48	47.89
2109	H	FU	MQ	3	7.45	13.95	13.80	35.20	0.66	11.14	10.61	22.41
2110	H	FU	MQ	3	7.04	15.82	17.18	40.04	0.51	19.62	28.43	48.56
2060	N	FU	MQ	3	7.07	14.80	15.07	36.94	0.52	14.53	15.77	30.82
2061	N	FU	MQ	3	8.66	15.12	13.66	37.44	1.30	16.00	10.13	27.44
2067	N	FU	MQ	3	4.95	12.76	12.62	30.33	0.11	7.46	7.10	14.56
2069	N	FU	MQ	3	5.70	11.64	10.94	28.28	0.20	4.93	3.73	8.86
2072	N	FU	MQ	3	5.54	12.25	12.90	30.69	0.17	6.21	7.83	14.21
2094	N	FU	MQ	3	8.30	14.83	15.12	38.25	1.08	14.67	16.00	31.75
2101	N	FU	MQ	3	8.39	15.26	16.65	40.30	1.13	16.68	24.69	42.50
2105	N	FU	MQ	3	8.43	17.81	15.21	41.45	1.15	33.43	16.44	51.02
2123	N	FU	MQ	3	9.70	14.15	14.55	38.40	2.17	11.87	13.46	27.51
2117	H	C	RM	3	6.88	12.55	10.40	29.83	0.46	6.92	2.97	10.35
2114	N	C	RM	3	6.70	12.20	8.75	27.65	0.41	6.09	1.37	7.87
2115	N	C	RM	3	7.30	11.50	12.00	30.80	0.60	4.67	5.66	10.93
2118	N	C	RM	3	6.64	13.30	12.60	32.54	0.39	8.99	7.04	16.42
2126	N	C	RM	3	7.47	13.85	12.00	33.32	0.67	10.78	5.66	17.11
				Mini	4.25	6.75	5.82	18.75				1.01

				Maxi	10.35	19.27	17.80	41.65				63.69
				Mear	7.18	12.60	12.76	32.54				20.07
				Vari	2.17	6.28	7.23	34.09				229.54
				S.De	1.47	2.51	2.69	5.84				15.15
				COV	21	20	21	18				75

FRM NO.	MK CD	TB CD	CM CD	AX CD	FRT AXL	REAR AX-1	REAR AX-2	REAR AX-3	Gross Weight	ESAL Front	ESAL Rear1	ESAL Rear2	ESAL Rear3	ESAL per Truck
2148	I	F	BUM	2-S2	5.71	11.50	14.48	9.70	41.39	0.20	4.67	13.17	2.17	20.21
2149	I	F	BUM	2-S2	5.20	11.50	15.36	8.95	41.01	0.13	4.67	17.18	1.51	23.49
2045	N	C	MM	2-S2	4.66	13.56	10.30	8.67	37.19	0.08	9.80	2.84	1.31	14.04
2103	N	F	FL	2-S2	4.66	10.44	7.59	9.83	32.52	0.08	3.02	0.72	2.31	6.13
2147	N	C	MM	2-S2	4.80	14.38	14.59	9.56	43.33	0.09	12.77	13.63	2.03	28.52
2156	N	F	BUM	2-S2	5.30	16.90	10.70	9.10	42.00	0.14	26.41	3.38	1.63	31.55
2157	N	F	BUM	2-S2	5.70	15.00	11.10	9.70	41.50	0.20	15.44	3.98	2.17	21.79
2158	N	F	BUM	2-S2	5.60	15.52	11.36	9.50	41.98	0.18	18.00	4.42	1.98	24.58
2165	N	F	MM	2-S2	9.35	16.44	19.65	18.91	64.35	1.84	23.32	52.04	43.78	120.98
2175	N	C	FL	2-S2	5.16	12.64	10.72	11.90	40.42	0.13	7.15	3.40	5.45	16.12
2187	N	C	FL	2-S2	6.12	11.97	10.86	11.85	40.80	0.27	5.59	3.61	5.34	14.82
2191	N	C	FL	2-S2	5.48	12.55	11.81	11.90	41.74	0.17	6.92	5.26	5.45	17.80
2201	N	FU	BUM	2-S2	5.30	15.52	12.25	11.36	44.43	0.14	18.00	6.21	4.42	28.77
				Maximum	9.35	16.90	19.65	18.91	64.35					120.98
				Minimum	4.66	10.44	7.59	8.67	32.52					6.13
				Mean	5.62	13.69	12.37	10.84	42.51					28.37
				Varaince	1.44	4.36	9.10	7.25	51.87					823.43
				S.Deviation	1.20	2.09	3.02	2.69	7.20					28.70
				COF	21	15	24	25	17					101

FRM NO.	MK CD	TB CD	CM CD	AX CD	FRT AXL	REAR AX-1	REAR AX-2	REAR AX-3	REAR AX-4	REAR AX-5	Gross Weight	ESAL Front	ESAL Rear1	ESAL Rear2	ESAL Rear3	ESAL Rear4	ESAL Rear5	ESAL per Truck
2159	MI	F	BUM	3-S3	7.61	12.43	13.37	13.86	14.18	11.00	72.45	0.728	6.627	9.200	10.618	11.988	3.824	43.18
2160	MI	F	BUM	3-S3	8.02	12.53	13.68	13.92	14.74	12.05	74.94	0.923	6.870	10.200	11.030	14.270	5.763	49.06
2161	MI	F	BUM	3-S3	7.70	14.30	13.83	13.81	13.61	11.90	75.15	0.768	12.451	10.713	10.643	9.967	5.447	49.99
2162	MI	F	BUM	3-S3	7.75	9.14	13.28	13.64	12.12	12.04	67.97	0.791	1.661	8.925	10.066	5.915	5.741	33.10
				Maximum	8.02	14.30	13.83	13.92	14.74	12.05	75.15							
				Minimum	7.61	9.14	13.28	13.64	12.12	11.00	67.97							
				Mean	7.77	12.10	13.54	13.81	13.66	11.75	72.63							
				Variance	0.03	4.63	0.07	0.01	1.27	0.25	11.14							
				S.Deviation	0.18	2.15	0.26	0.12	1.13	0.50	3.34							43.83
				COF	2.27	17.79	1.91	0.87	8.25	4.28	4.60							

Annex - D

DNPS86 (2)

* * * PROBLEM NUMBER AND DESCRIPTION * * *

PROBLEM NUMBER 3 2

PROBLEM DESCRIPTION
Mianchannu - Sahiwal Section
Additional Carriageway

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * GENERAL DESIGN INPUT REQUIREMENTS * * *

ANALYSIS PERIOD (YEARS)	20.0
DISCOUNT RATE (PERCENT)	0.00
NUMBER OF TRAFFIC LANES (ONE DIRECTION)	2
LANE WIDTH (FEET)	12.00
COMBINED WIDTH OF SHOULDERS (FEET, ONE DIRECTION)	12.00

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * ROADBED SOIL RESILIENT MODULI * * *

Season No.	Resilient Modulus (psi)	Season No.	Resilient Modulus (psi)
1	8000	13	0
2	0	14	0

3	0	15	0
4	0	16	0
5	0	17	0
6	0	18	0
7	0	19	0
8	0	20	0
9	0	21	0
10	0	22	0
11	0	23	0
12	0	24	0

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

ROAD SURFACE
(P)aved or (A)ggregate . . . . P

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * DESIGN INPUTS FOR FLEXIBLE AND RIGID PAVEMENTS * * *

DESIRED LEVEL OF RELIABILITY (PERCENT) 90.00

DESIGN TERMINAL SERVICEABILITY 2.50

ROADBED SOIL SWELLING AND/OR FROST HEAVE
Consider? (Y)es or (N)o . . . . N

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNP(_.6 (2) No. 3 2

PAVEMENT TYPE
(F)lexible or (R)igid . . . . F

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * FLEXIBLE PAVEMENT DESIGN INPUTS * * *

PERFORMANCE PERIOD FOR INITIAL PAVEMENT (YEARS) .	10.0
SERVICEABILITY INDEX AFTER INITIAL CONSTRUCTION .	4.50
TRAFFIC	
Growth Rate (percent per year)	0.00
(S)imple or (C)ompound Growth	C
Initial Yearly 18-kip ESAL (both directions) .	14000000
Directional Distribution Factor (percent) . . .	100
Lane Distribution Factor (percent)	100
Calculated Total 18-kip ESAL During the Analysis Period (in the design lane)	280000000
OVERALL STANDARD DEVIATION (LOG REPETITIONS) . .	0.490

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * ADDITIONAL FLEXIBLE PAVEMENT DESIGN INPUTS * * *
AND ASSOCIATED COSTS

PAVEMENT LAYER CHARACTERISTICS, MATERIAL PROPERTIES & COSTS

No.	Description	Spcfd Thick	Layer Coef	Elastic Modulus	Drain Coef	Unit Cost	Salv Value

		(in.)		(psi)		($/CY)	(%)
1	As.Base	11.00	0.44	450000	1.00	0.00	0
2	C.Agg	8.00	0.14	50000	1.00	0.00	0
3	S.Base	10.00	0.11	20000	1.00	0.00	0
4		0.00	0.00	0	1.00	0.00	0
5		0.00	0.00	0	1.00	0.00	0

OTHER CONSTRUCTION RELATED COSTS

Shoulders, If Not Full Strength ($/linear ft) .	0.00
Drainage ($/linear foot)	0.00
Mobilization and Other Fixed Costs ($/lin ft) .	0.00

MAINTENANCE COST

Initial Year Costs Begin to Accrue	0
Yearly Increase ($/lane mile/year)	0.00

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * ADDITIONAL FLEXIBLE PAVEMENT DESIGN INPUTS * * *
AND ASSOCIATED COSTS

PAVEMENT LAYER CHARACTERISTICS, MATERIAL PROPERTIES & COSTS

No.	Description	Spcfd Thick (in.)	Layer Coef	Elastic Modulus (psi)	Drain Coef	Unit Cost ($/CY)	Salv Value (%)
1	As.Base	11.00	0.44	450000	1.00	0.00	0
2	C.Agg	8.00	0.14	50000	1.00	0.00	0
3	S.Base	10.00	0.11	20000	1.00	0.00	0
4		0.00	0.00	0	1.00	0.00	0
5		0.00	0.00	0	1.00	0.00	0

OTHER CONSTRUCTION RELATED COSTS

Shoulders, If Not Full Strength ($/linear ft) .	0.00
Drainage ($/linear foot)	0.00
Mobilization and Other Fixed Costs ($/lin ft) .	0.00

MAINTENANCE COST

Initial Year Costs Begi. to Accrue	0
Yearly Increase ($/lane mile/year)	0.00

F1: HELP F2: IMPORT/STORE F3: ANALYZE/PRINT/EXIT F4: DISPLAY RESULTS

DNPS86 (2) No. 3 2

* * * SOLUTION FOR INPUT DATA FILE: motorway.dat * * *

FLEXIBLE PAVEMENT STRUCTURAL DESIGN

Performance Life (yrs) 10.0
18-kip ESAL Repetitions 140000000.

Layer No.	Layer Description	Required Thickness (inches)
1	As.Base	11.00
2	C.Agg	8.00
3	S.Base	9.76
4		
5		

DESIGN FOR PROJECTED FUTURE OVERLAY(S)

First Second

LIFE CYCLE COSTS ($/SY)

Initial Pavement	
Construction	.00
Maintenance	.00
Salvage Value	.00
First Overlay	
Construction	.00
Maintenance	.00
Salvage Value	.00
Second Overlay	
Construction	.00
Maintenance	.00
Salvage Value	.00

Overlay Type	Asphaltic
Req'd Thick (in)	5.65
Perf Life (yrs)	10.0
8-kip ESAL Reps	140000000.

Net Present Value .00

Press Any Key to Continue ...