NATIONAL TRANSPORT RESEARCH CENTRE

MINISTRY OF COMMUNICATIONS

RUTTING OF KASHMIR HIGHWAY ISLAMABAD

NTRC-162

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I. TEXT

CHAPTER | **PAGE NO.**

II. ANNEXURES

1. INTRODUCTION

The two lane Kashmir Highway joining Grand Trunkroad and Murree Road is a major road of the capital Islamabad. This road was constructed by Pakistan PWD during the years 1963 and 1964. In 1988-89, the road was recarpetted with 1.5"(Av) of asphaltic concrete wearing course laid over 2"(Av) asphaltic concrete binder course. Severe rutting has appeared on sections of this highway. It was decided to investigate the reasons for the rutting of this important Metropolitan Highway and make recommendations for improvement of this highway to normal condition. Rutting causes serious hazards to traffic as ruts tend to catch the wheels of the vehicles causing obstruction to drivers as they attempt to change lane to overtake on this 2 lane road.

2. FIELD INSPECTION

i) Rutting :

An inspection of the Kashmir Highway revealed severe rutting of the incoming lane from Peshawar side.The out of shape pavement causes impact stresses that seriously damage the vehicle and the pavement. The rutting tends to slow up traffic and reduce lane capacity. Since drivers can not veer freely because ofthe deep ruts, they cause crowding, erratic driving and other driver reactions which are conducive to accidents. Five to six inches deep rutting was observed on rutted sections of the Kashmir Highway.

ii) Traffic :

There is heavy traffic on the Kashmir Highway. A 24 hour traffic count revealed a high volume of 12669 vehicles of various types out of which 4148 were trucks. Most of these trucks are heavily laden with construction materials which they bring via GT road from the stone crushers located near Taxila and Hasan Abdal. Rutting was also observed on sections of the GT road which are also traversed by these Bajri (Aggregate) and sand loaded trucks.

iii) <u>Drainage Ditches</u> :

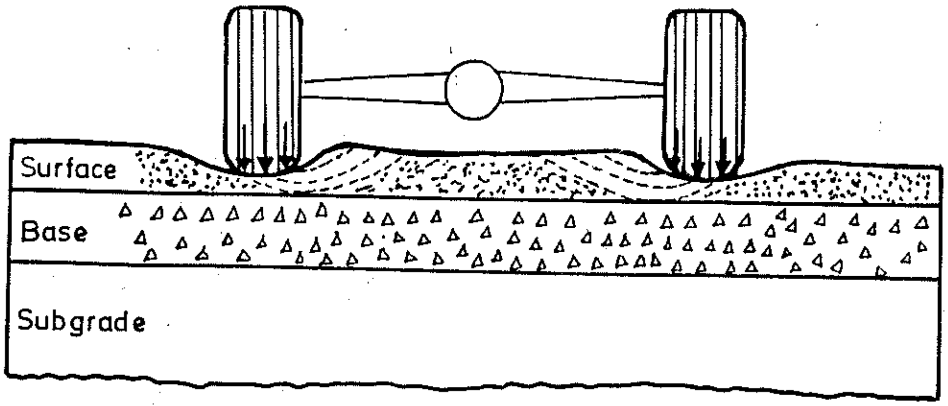
At places drainage ditches along the Kashmir Highway were full of debris/silt causing water overflow on shoulders and pavement area during heavy run off.

3. THE PHENOMENA OF RUTTING

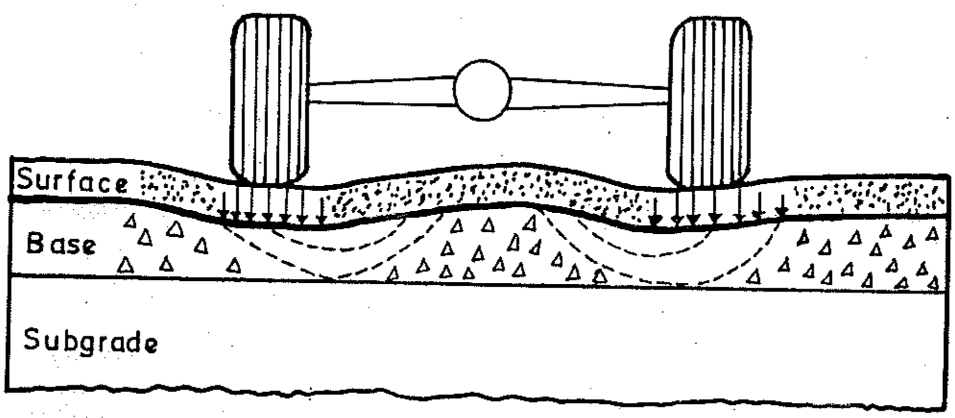
Rutting is longitudinal depressions along the lines between wheel tracks and generally presumed to be attributable to high bitumen content in the asphaltic surface. It is not only the unstable asphaltic surface which after displacement in the wheel tracks forms the ruts but base and subgrade failures can also cause rutting of the roadway surface. All the three types of failures which cause rutting are shown diagrammatically in Fig 3.1.

The pavement design is some what parallel to structural design. While the vehicle is over a bridge,the vehicle loads are transferred from bridge deck to the pier's foundation through successive members of the bridge. Similarly, in the case a pavement structure, the vehilce load on its surface is transferred through successive layers of base and sub-base to the undisturbed soil on which it rests.

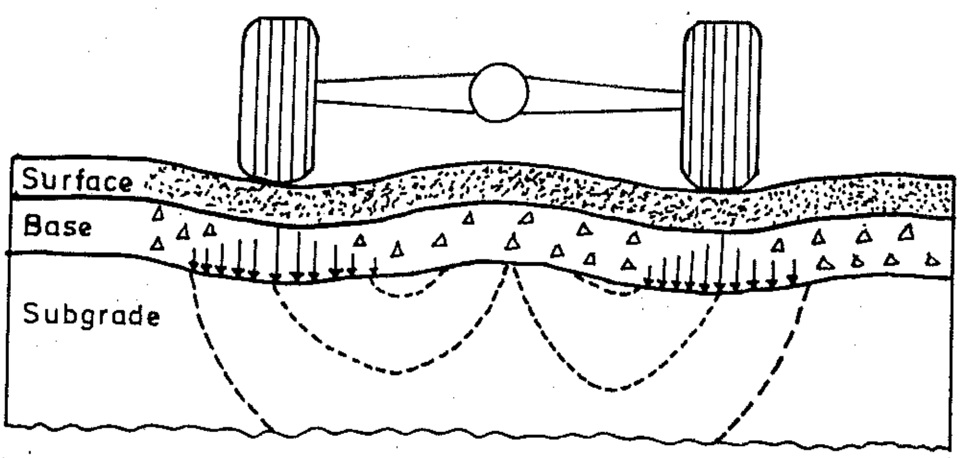
The pavement is subjected to the wheel loads of motor vehicles which number several millions over the period of years. Each time a load passes, some deflection of the surface and the underlying layers occurs. If the load is excessive and the supporting layers are lacking in strength, repeated applications will cause rutting, roughening and cracking that ultimately leads to complete failure.



(I) Rutting due to Surface Failure



(II) Rutting due to Base Failure



(III) Rutting due to Subgrade Failure

Figure 3·1 : Deformation in Surface Base & Subgrade which cause rutting of surface

A properly designed pavement for the anticipated axle load repetitions will perform within the elastic limits. The surface returns to its original position after the load passes and no permanent unevenness occurs. With highly resilient soils, however, deflections under repeated heavy wheel loads can cause fatigue failures in the bituminous surface, commonly known as alligator cracks but without rutting. Rutting occurs when under heavy loads small deformations of each repetition of load accummulate until the affected layers become consolidated. Since highway vehicles normally track in almost the same paths, load repetitions are more numerous in these paths than elsewhere. Excessive consolidation results in an objectionable amount of rutting.

In case of pavement of inadequate thickness,plastic deformation of subgrade occurs when heavy load pressures laterally displace the subgrade and resultantly the base and surface materials are also displaced, following the same pattern as subgrade. Deflection resulting from plastic deformation is progressive under load repetitions, it constitutes one of the major causes of failure of roadway surface. Figure 3.1 shows the three occurences of rutting. Each of the three is the result of a failure accompanied by movement in the affected layers. Pavement, base and subgrade are all susceptible. However, the perimeter along which the failure occurs has the least length if the shortcoming is in the surface layer and becomes longer as the source of trouble moves to greater depths.

4. METHODOLOGY OF STUDY

Kashmir highway is a two lane metropolitan road facility. Trucks comprise about one third of its traffic. The inbound lane takes heavily overloaded trucks which turn on to Kashmir highway from the National Highway N-5 (G.T Road). These trucks mostly carry sand and aggregates for the construction projects in and around the capital city. Field inspection of the Kashmir Highway pavement revealed that the in bound lane is subjected to deep rutting whereas the out bound lane pavement bears no sign of any such distress. Almost all inbound trucks are loaded.

It is most probable that the rutting has been caused by the heavily over loaded aggregates and sand trucks. Consequently, the following methodology was adopted to investigate the pavement rutting of Kashmir Highway :

i) Axle Load Survey : To assess the extent of overloading an axle load survey of trucks using the Kashmir Highway was carried out (Anex I).

ii) Traffic Count : A 24-Hour traffic count was taken to find traffic loading on Kashmir Highway pavement (Annex II).

iii) Coring and Pit : A one kilometer section of the Kashmir Highway, 2.5 Km. from Zero Point was selected for the study (Annex III).

iv) **Material Testing in Laboratory :** Laboratory Tests for determination of bitumen content in the asphaltic concrete surface cores and sieve analysis for grading of base material were done (Annex IV and XIII).

v) **Analysis and Tabulation of Field Data** : All the field data pertaining to Axle load survey, traffic count and cores/pit was analysed and tabulated. It appears in the Annexures to this study.

vi) **Determination of Serviceability** : Based upon the information collected from field, serviceability of the pavement in place was determined (Annex V).

vii) **Conclusions and Recommendations** : Based upon analysis of field data and investigations, conclusions were drawn and recommendations made.

5. FINDINGS OF SURVEYS/INVESTIGATIONS

i) Axle Load Survey :

About one third of vehicles on the Kashmir Highway are trucks having two to six axles, of these 86% trucks are 2 axle - 10 ton trucks and remaining are multiple axle trucks of 3 to 6 axles. The axle configurations of trucks using the Kashmir Highway are shown in Annexure-VI. Most of these trucks bring construction materials to Islamabad and have been found to be over loaded 2 to 3 times (Annexure VII) their permitted load. The maximum Equivalent Standard Axle (ESA) equivalency factors for various axle configurations were found to be from 59.88 to 82.08 (Annexure VIII). These aggregates and sand carrying trucks have severely damaged the road pavement along their route which they traverse in loaded condition. This includes the G.T. road and Kashmir Highway, sections of which are in a damaged condition. The average ESA factor for Kashmir Highway has been found to be 14.856 (Annexure IX) which is extremely high as compared to the high ESA factors of 3.97 for the 2 axle and 7.92 for the multiple axle trucks used in the pavement design of Lahore-Islamabad Motorway (M-I).

ii) <u>Traffic Count</u> :

A 24-hour traffic count (Annexure II) on Kashmir Highway revealed a high volume of 12,627 motorised vehicles of various types as following :

Motor Cycles/Scooters	=	615
Cars/Jeeps/LCVS	=	7262
Wagons/Mini Buses	=	419
Buses	=	183
Trucks	=	4148
Total :		12627

Most of the trucks (86%) are 2 axle - 10 Ton trucks followed by 3 axle, 4 axle, 5 axle, 6 axle trucks and tractor/trollies. Details of the trucks traffic appear in Annexure X.

Kashmir Highway is a two lane facility having a maximum capacity for 8000 vehicles per day whereas the present ADT is more than 12000 vehicles. The Capital Development Authority (CDA) has drawn plans for the second 2 lane carriageway for the Kashmir Highway and has also prepared tentative pavement design (Annexure XI) for it.

iii) Coring and Pit :

Four cores were drilled at the selected sites as shown in Annexure-III. The sites were selected in the rutted and normal condition pavement areas. The thicknesses of these four cores were found (Annexure XII) to be 112 mm, 82 mm, 88 mm and 107 mm which tally with the 90 mm (3.5") to 104 mm(4") average thickness asphaltic concrete overlay laid by CDA. The thicknesses of the core samples in the wheel trucks rule out the rutting because of asphaltic surface failure. The bitumen content of the asphaltic surface material has been found to be between 4 to 5 percent (Annexure IV) which is normal. Rutting is generally thought to be attributable due to high bitumen content in the asphaltic concrete surface job mix formula but this is not the case with Kashmir Highway as its surfacing material has been found to be normal.

A pit was dug on the shoulder edge near the pavement to observe the thicknesses of base and sub-base and take materials samples for laboratory sieve analysis. The pit revealed a water bound macadam base 9 inches thick laid on a granular subbase of 9 inches thickness. Laboratory sieve analysis (Annexure XIII) revealed base crushed stone material to be of uneven grading with a high percentage of fine material. The condition of base and sub-base layers and their thicknesses in place revealed that these have not failed. The rutting at the surface is not due to pavement base failure.

6. SERVICEABILITY OF EXISTING PAVEMENT

The existing pavement of the Kashmir Highway was built by the Pakistan PWD during the years 1963 and 1964. No record of the pavement design or any "As Built" pavement drawing was available from Pak PWD or CDA. In 1988-89, the road was recarpetted with 1.5"(AV) asphaltic concrete wearing course laid over 2"(AV) asphaltic concrete binder course.

The thickness of the various component layers of the in place pavement was measured by digging a pit on edge of the pavement. The pavement section appears in Annexure-V. The overall pavement thickness is 21.5 inches. A CBR value of 6.8 for the road bed soil of Kashmir Highway was obtained from CDA testing laboratory.

According to the latest design procedures laid in Road Note 31, incorporating structural number principles of AASHTO guide, 1986, the serviceability of the in place pavement of Kashmir Highway has been found to be in the range of 6 to 10 million ESAs. During the last 10 years (1983 to 1992), the Kashmir Highway pavement was subjected to a loading of 82.77 million ESAs, 8 times its capacity.

7. CONCLUSIONS

i) Over Loading :

The present loading on the pavement of Kashmir Highway has been found to be of the magnitude of 30,811 ESAs per day. This is an extremely heavy loading due to over loading by the sand and aggregates carrying trucks. During the 10 years period from 1983 to 1992, the Kashmir Highway pavement was subjected to 82.77 million ESAs. This is indicative of an exceptional pavement loading condition. The 10 years (1996-2005) ESAs for the Lahore-Islamabad Motorway (M-I) are 31.15 millions whereas Kashmir Highway accounted for nearly the same (31.865 million) ESAs for the 3 years period from 1990 to 1992. This is because of the excessive over loading by the aggregate and sand carrying trucks, some of which were found to have a very high equivalence factor of 82.

ii) Inadequate Pavement Thickness :

To sustain a loading of 82.77 million equivalent standard axles for a design life of 10 years, generally used for flexible pavements, a minimum structural thickness of 30 inches for water bound macadam base and 26 inches for the bituminous base is required for the pavement. The details of the pavement design are given in Annexure-XV and XVI. The pavement in place has a structural thickness of 21 inches which is inadequate. Plastic deformation of the subgrade has occured and it has displaced laterally, causing the base and surface layers to adjust to its rutted shape and displaced pattern as explained in detail in chapter 3 under the phenomena of rutting, figure 3.1 (iii).

8. RECOMMENDATIONS

1. Kashmir Highway pavement should be upgraded to with stand the heavy axle loading of 82.77millions ESAs. Its present structural thickness of 21.5 inches suffices for a life of 10 million ESAs only whereas it has been subjected to about 153 million ESAs ever since its construction in 1963.

2. There is need for effective control on excessive overloading by trucks travelling on our roads. Truck axle loads on roads serving docks, quarries, cement and fertilizers plants, sugar factories and wheat godowns should be regularly monitored. Axle loads have to be kept within the permissible limits as notified by the concerned Highway Authority. Highway police must enforce axle load regulations and check axle loads of heavy vehicles under a well planned and organised programme.

3. Road pavements should be designed after undertaking axle load surveys so that actual field loading conditions are taken into account in the pavement structural designs. Even in the developed countries, some overloading is accounted for in

the design of pavements. But in the developing countries, the tendency for overloading is much more and it has to be checked as well as provided for in the structural design of our road pavements.

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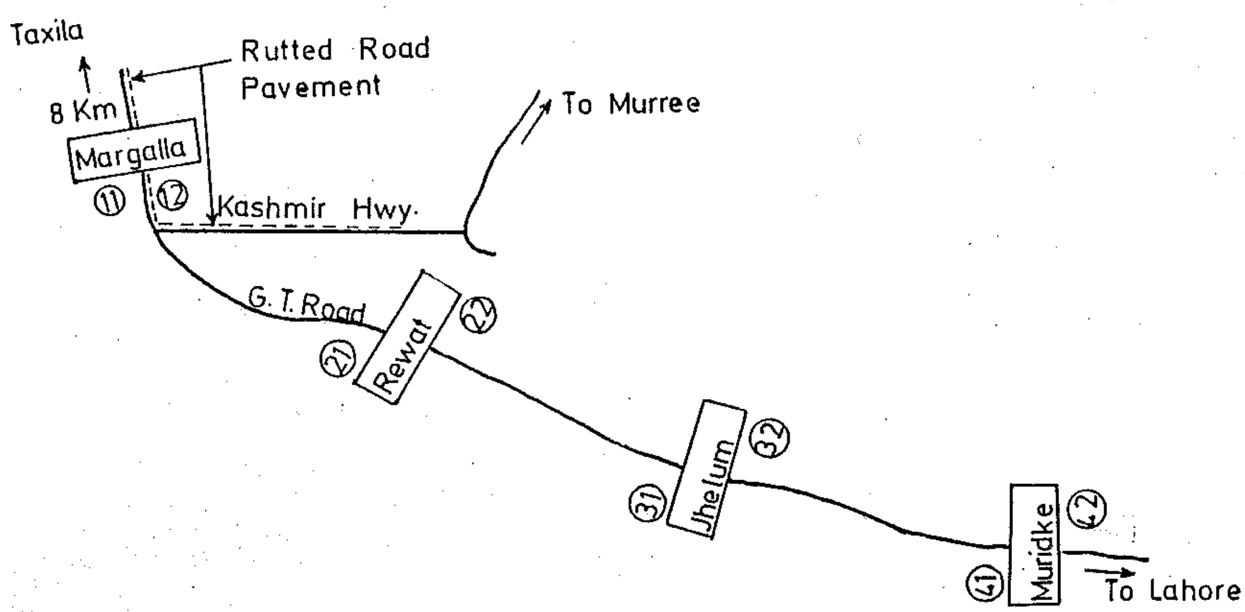
ANNEXURE-I

AXLE LOAD SURVEY ON G.T. ROAD

(By Students of Military College of Engineering, Risalpur)

Date of Survey
at Station (12) : 13 October, 1992



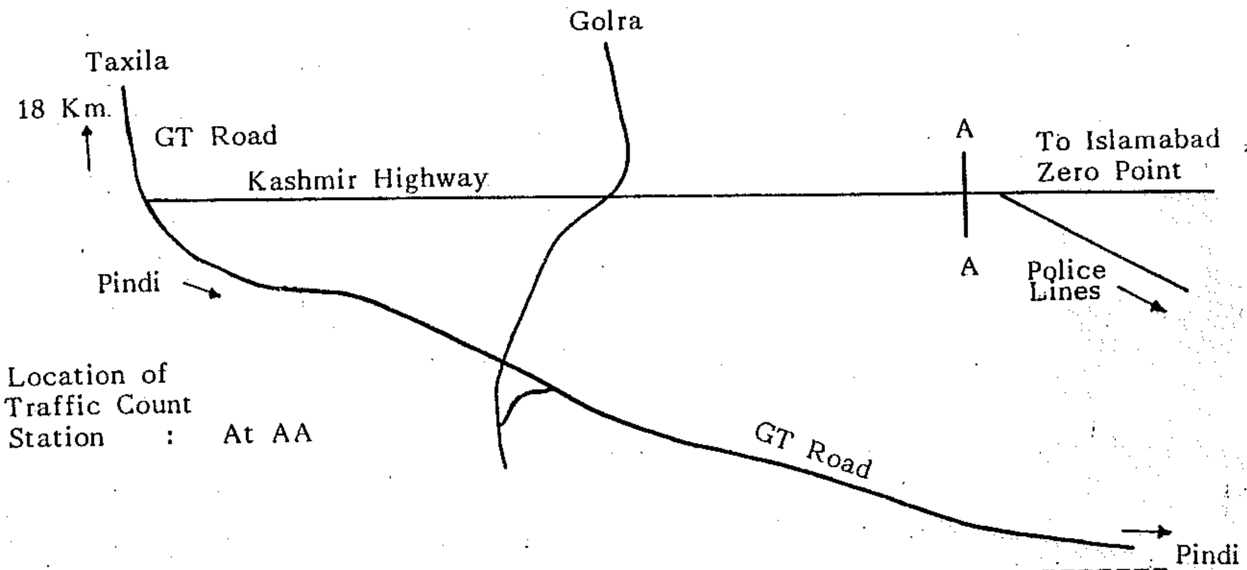
Location on GT Road	Margalla		Rewat		Jhelum		Muridke	
Station No.	11	12	21	22	31	32	41	42
Av. ESA	5.91	14.86	1.49	3.61	3.81	4.97	3.10	0.39

ANNEXURE-II

24 - HOURS TRAFFIC COUNT

KASHMIR HIGHWAY, ISLAMABAD

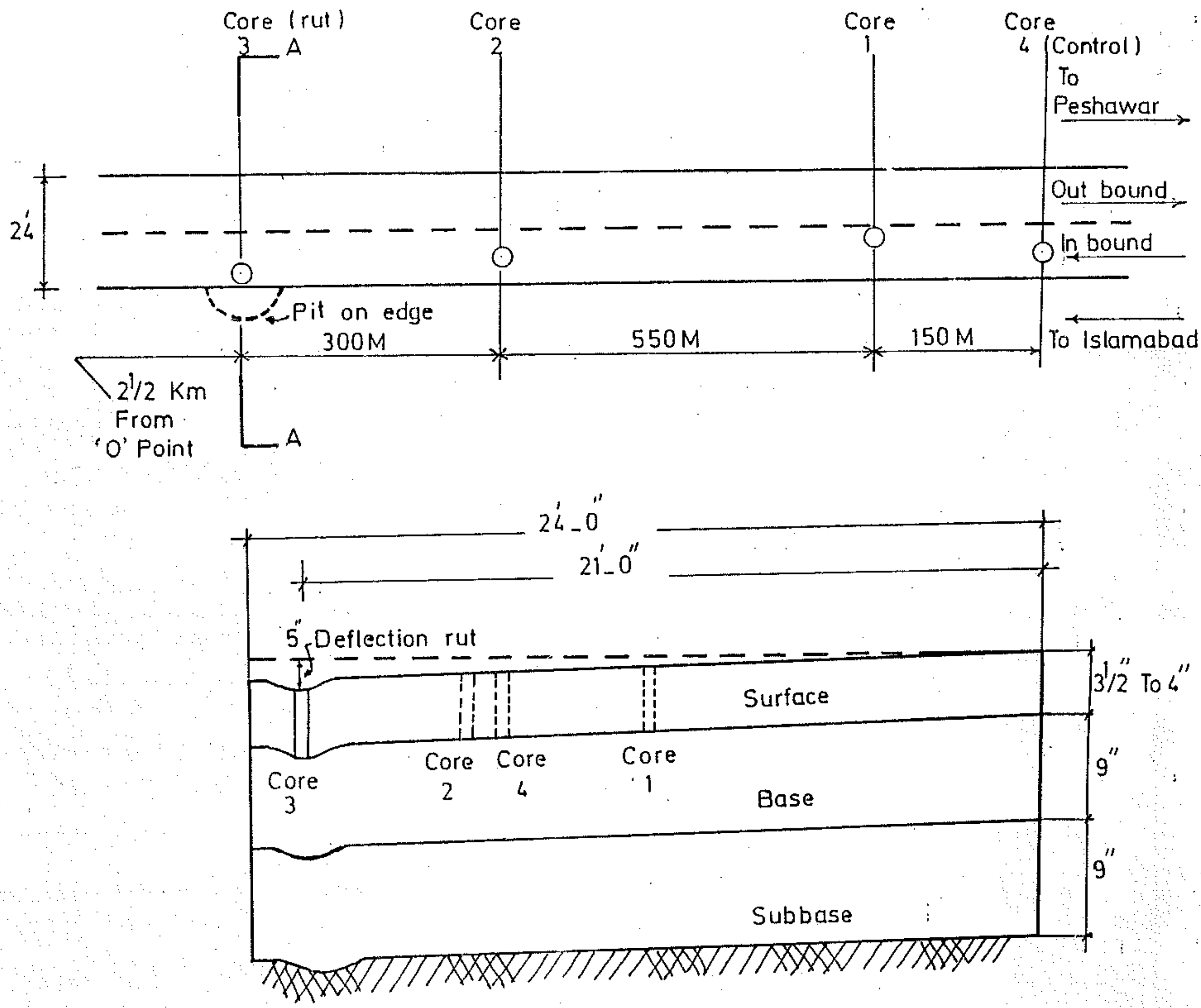
TIME/DATE/DAY : 8 : AM NOV 16, 1992 (MONDAY) TO
8 : AM NOV 17, 1992 (TUESDAY) - 24 HOURS



Location of Traffic Count Station : At AA

Sr. No.	Vehicle Type	In Bound To Ibd.	Out Bound From Ibd.	Both Directions
	1	2	3	4 (2+3)
1.	Pedal Cycles	28	11	39
2.	Animal Drawn	02	01	03
3.	Motor Cycles/ Scooters	289	326	615
4.	Cars,Jeeps,Pickups and LCVs	3443	3819	7262
5.	Wagons/Minibuses	157	262	419
6.	Buses	46	137	183
7.	2 Axle Trucks	1707	1877	3584
8.	3 Axle Trucks	203	166	369
9.	3 Axle Trailer	40	16	56
10.	4 Axle Truck & Trailer	26	42	68
11.	5 Axle Truck & Trailer	10	20	30
12.	6 Axle Truck & Trailer	16	14	30
13.	Tractor/Trolley	7	4	11
	Total :	5974	6695	12669

ANNEXURE-III



SECTION AT AA

Location of Pit and Core Cuts on Kashmir Highway

Date of Field Inspection And Core Cuts	:	31-08-1992
Date of Pit Digging	:	22-10-1992

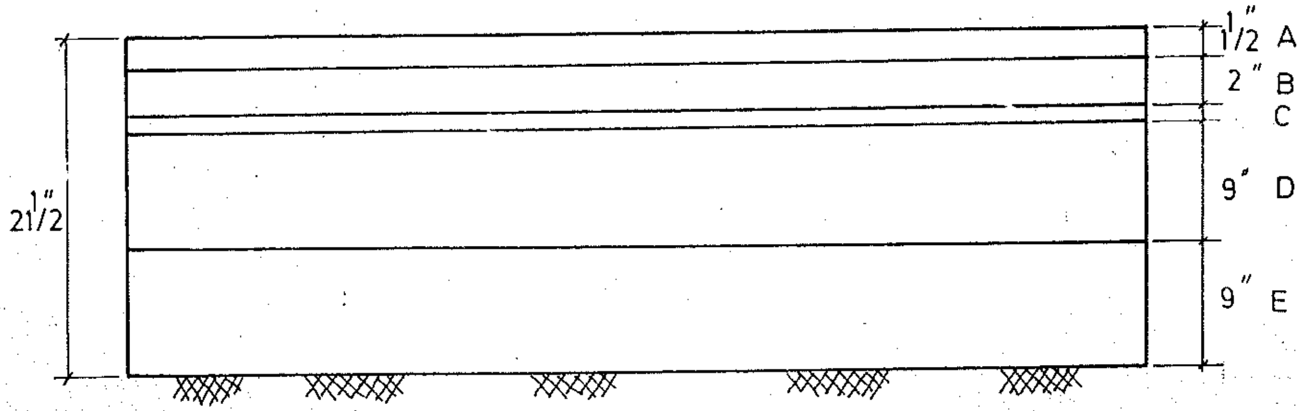
ANNE XURE - IV

LABORATORY TESTS ON KASHMIR HIGHWAY SURFACING CORES AND BASE MATERIAL FINES

Core Sample	1.5" (40 MM) Wearing Surface Course			2" (50 MM) Binder Course of Surface			Atterberg Limits Base Material Fines		
	Density	Sp. Gr.	% Age of Bitumen in Mix	Density	Sp. Gr.	% Age of Bitumen in Mix	LL	PL	PI
1 1J	2.46	2.47	4.75	2.43	2.46	5.04	16.5	Non Plastic (NP)	-
2	2.39	2.45	4.05	2.43	2.46	3.43	16	NP	-
3 (In Rut)	2.40	2.46	4.58	2.41	2.46	4.35	14.8	NP	-
4 (Controll)	2.37	2.45	5.01	2.36	2.57	4.06	15	NP	-

ANNEXURE-V

KASHMIR HIGHWAY PAVEMENT IN PLACE

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

        +--
First   ! C =   Old Triple Surface Treatment (TST)
Time    !
Const.  ! D =   9" Base Course of 2" Down Crushed Stone
by PWD  !
1963    ! E =   9" Sub-base 1.5" Down Crushed Stone
        +--
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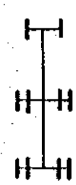
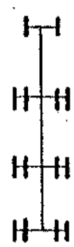
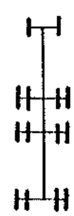
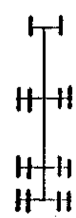
Serviceability Assessment : 6 to 10 Million ESAs

As per Road Note 31 (Draft)/AASHTO, 1986,
Subgrade, S3 (CBR 5-7)
Traffic Category T6, Chart 5

ANNEXURE-VI

AXLE CONFIGURATION OF TRUCKS ON KASHMIR HIGHWAY

2 Axle Single	3 Axle Single	3 Axle Tandem	4 Axle Single	4 Axle Mid Tandem	4 Axle Rear Tandem	5 Axle Tandem	6 Axle Tandem
							
1	2	3	4	5	6	7	8

ANNEXURE-VII

GROSS LOADS OF 10 TONS PAY LOAD - 2 AXLE TRUCKS AS REVEALED BY THE AXLE LOAD SURVEY ON G.T. ROAD, NEAR TAXILA ON 13-10-1992

Tonnes

28.1	29.7	28.1	26.7
25.3	20.7	20.9	24.2
23.4	20.8	20.5	27.4
21.0	25.2	36.5	29.2
21.6	25.3	21.6	20.8
23.3	27.6	20.4	23.4
21.4	20.0	20.3	26.6
21.2	20.2	21.0	20.4
20.1	26.2	22.5	22.1

The Trucks Carry more than double the permitted Pay Load (10 Tons).

ANNEXURE-VIII

EQUIVALENCE FACTORS FOR DIFFERENT AXLE LOADS

Wheel Load (Kg)	Axle Load (Kg)	Equivalence Factor
1500	3000	0.01
2000	4000	0.04
2500	5000	0.11
3000	6000	0.25
3500	7000	0.50
4000	8000	0.91
4500	9000	1.55
5000	10000	2.50
5500	11000	3.83
6000	12000	5.67
6500	13000	8.13
7000	14000	11.3
7500	15000	15.5
8000	16000	20.7
8500	17000	27.2
9000	18000	35.2
9500	19000	44.9
10000	20000	56.5

$$\text{EQUIVALENCE FACTOR} = (\text{Axle Load in Tonnes} \div 8.165)^{4.5}$$

ANNEXURE-IX

SOME AV. AND MAX. ESAs IN PAKISTAN

Sr. No.	Av. ESA For Design	Max. ESA Encountered on Kashmir Highway	Av. ESA used For Design of M-I Motorway
1	2 Axle Trucks	77.91	3.97
2	3 Axle Trucks	82.08	7.92 (For all Multi Axle trucks)
3	4 Axle Tractor/ Trailer	-	
4	5 " " "	59.88	
5	6 " " "	66.89	

ANNEXURE-X

(Date of Axle Load Survey : 13-10-1992)

ESTIMATES OF ESA ON KASHMIR HIGHWAY @ 14.856 PER TRUCK

YEAR	AVERAGE DAILY TRAFFIC								INBOUND TRUCKS ONLY			
	CYC	AD	MCY	CAR	WGN	BUS	TRK	TOTAL	NOS	ESA	YEAR/000	CUM/MILL
1964	8	1	120	1421	82	36	811	2478	406	6028	2200	2.20
1965	8	1	128	1506	87	38	860	2627	430	6389	2332	4.40
1966	9	1	135	1596	92	40	912	2785	456	6773	2472	6.73
1967	9	1	143	1692	98	43	966	2952	483	7179	2620	9.20
1968	10	1	152	1794	103	45	1024	3129	512	7610	2778	11.82
1969	10	1	161	1901	110	48	1086	3317	543	8066	2944	14.60
1970	11	1	171	2015	116	51	1151	3516	576	8550	3121	17.55
1971	11	1	181	2136	123	54	1220	3727	610	9063	3308	20.67
1972	12	1	192	2264	131	57	1293	3950	647	9607	3507	23.98
1973	13	1	203	2400	138	60	1371	4187	685	10184	3717	27.48
1974	14	1	215	2544	147	64	1453	4439	727	10795	3940	31.20
1975	14	1	228	2697	156	68	1540	4705	770	11442	4176	35.14
1976	15	1	242	2859	165	72	1633	4987	816	12129	4427	39.32
1977	16	1	257	3030	175	76	1731	5286	865	12856	4693	43.74
1978	17	1	272	3212	185	81	1835	5604	917	13628	4974	48.43
1979	18	1	288	3405	196	86	1945	5940	972	14446	5273	53.41
1980	19	1	306	3609	208	91	2061	6296	1031	15312	5589	58.68
1981	21	2	324	3826	221	96	2185	6674	1093	16231	5924	64.27
1982	22	2	343	4055	234	102	2316	7074	1158	17205	6280	70.20
1983	23	2	364	4298	248	108	2455	7499	1228	18237	6657	76.47
1984	24	2	386	4556	263	115	2603	7949	1301	19331	7056	83.13
1985	26	2	409	4830	279	122	2759	8426	1379	20491	7479	90.19
1986	27	2	434	5119	295	129	2924	8931	1462	21721	7928	97.67
1987	29	2	460	5427	313	137	3100	9467	1550	23024	8404	105.59
1988	31	2	487	5752	332	145	3286	10035	1643	24405	8908	114.00
1989	33	3	516	6097	352	154	3483	10637	1741	25870	9442	122.91
1990	35	3	547	6463	373	163	3692	11275	1846	27422	10009	132.35
1991	37	3	580	6851	395	173	3913	11952	1957	29067	10610	142.36
1992	39	3	615	7262	419	183	4148	12669	2074	30811	11246	152.97

1992 Daily Trucks	=	4148
Daily in Bound Trucks	=	2074
Annual Traffic Growth Rate	=	6%
ESAs (1964-74)	=	31.20 Millions
ESAs (1974-83)	=	48.99 Millions
10 Years ESAs (1983-92)	=	82.77 Millions
20 Years ESAs (1973-92)	=	129 Millions

ANNEXURE-XI

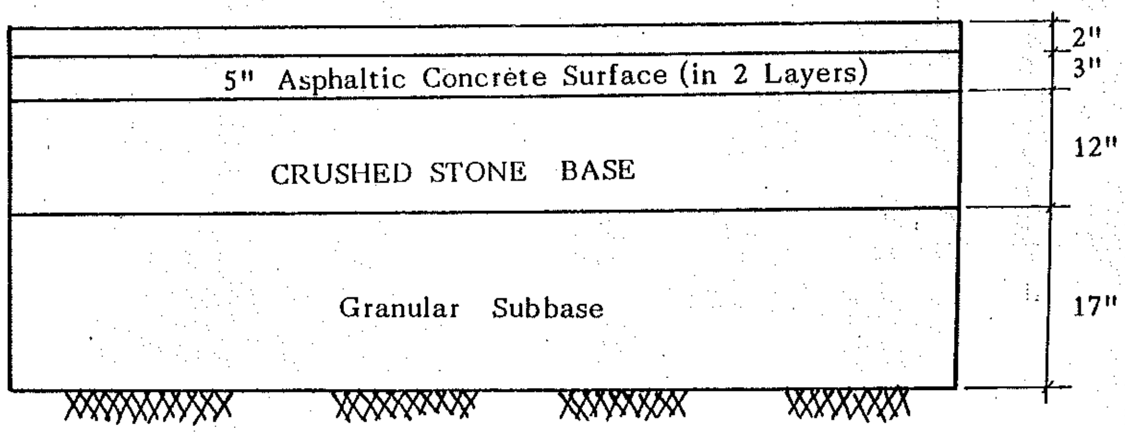
TRUCK TRAFFIC VOLUME ON KASHMIR HIGHWAY, ISLAMABAD

TIME/DATE/DAY : 8:00 AM NOV 16, 1992 (MONDAY) TO
8:00 AM NOV 17, 1992 (TUESDAY) - 24 HRS.

Sr. No.	Vehicle Type	In Bound To Ibd.	Out Bound From Ibd.	Trucks in Both Directions
	1	2	3	4 (2+3)
1.	2 Axle Truck	1707	1877	3584
2.	3 Axle Truck	203	166	369
3.	3 Axle Trailer	40	16	56
4.	4 Axle Truck/ Trailer	26	42	68
5.	5 Axle " "	10	20	30
6.	6 Axle " "	16	14	30
7.	Tractor/Trolley	7	4	11
	Total	2009	2139	4149

ANNEXURE-XII

DESIGN OF KASHMIR HIGHWAY 2ND CARRIAGEWAY (TENTATIVE) - C.D.A



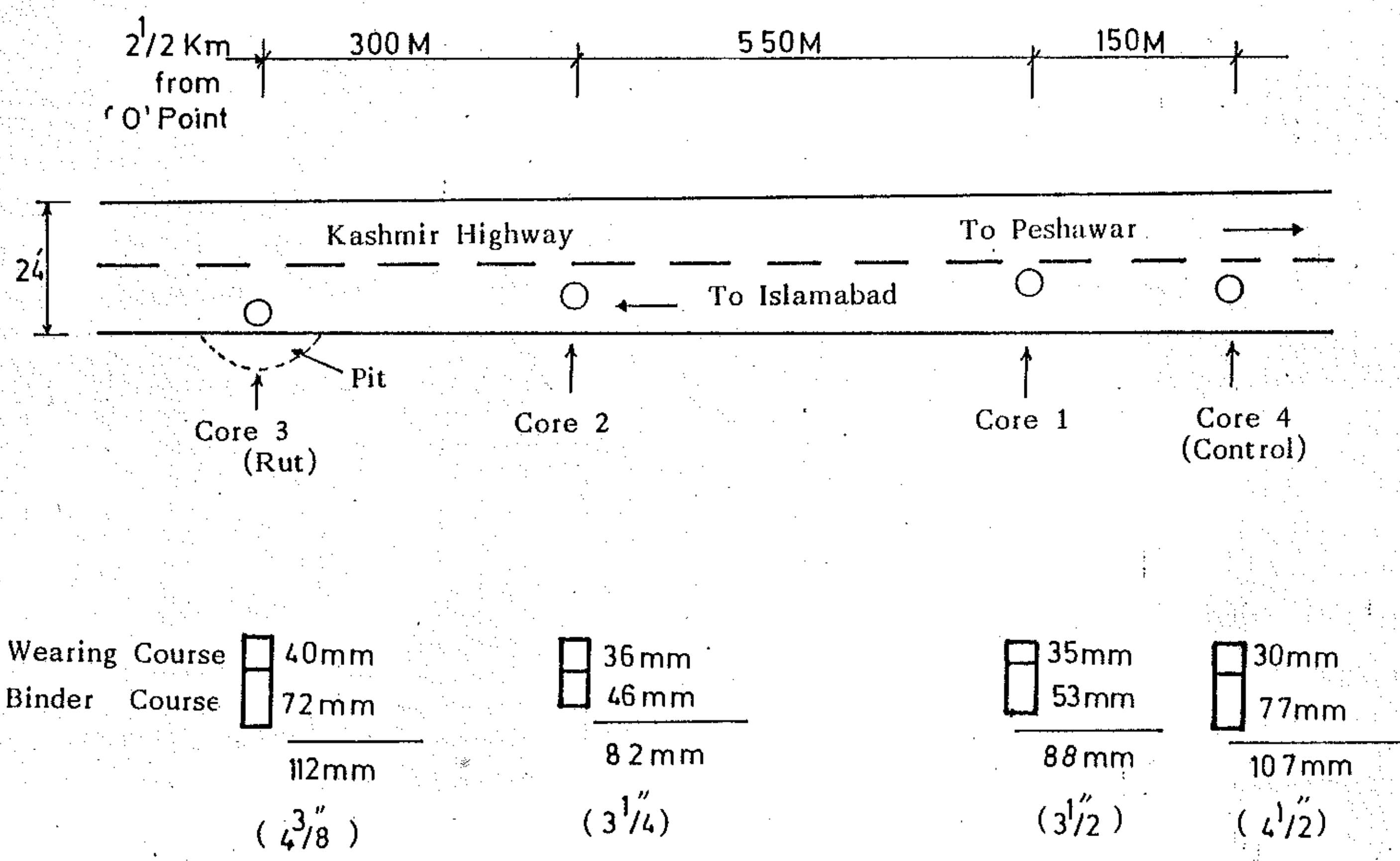
C.B.R = 6.8

E.S.A = 113.20 Millions

ANNEXURE-XIII

THICKNESSES OF SURFACING CORES CUT IN A KILOMETER OF KASHMIR HIGHWAY

Date of Core Drilling : 31-08-1992
Date of Pit Digging : 22-10-1992



Asp. Concrete Wearing Course = 1.5" Av = 40 MM Av

Asp. Concrete Binder Course = 2" to 2.5" = 50 MM to 64 MM

Asp. Concrete Surface Laid By CDA, 1988-89 = 90 MM to 104 MM

ANNEXURE-XIV

GRADATION OF WATER BOUND MACADAM BASE COURSE MATERIAL

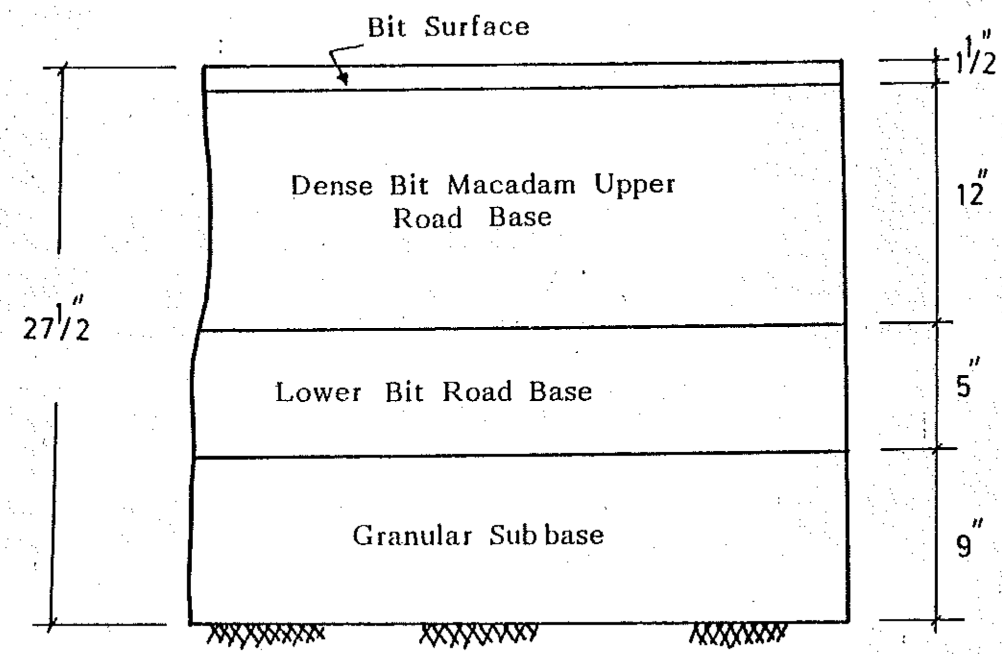
Percent Passing

	Sieve Size Sq. Mesh	Standard AASHO M77-64	Grading of Base Material at Core			
			1	2	3 (Rut)	4 (Control)
Course Aggregate	3"	100	100	100	100	100
	2.5"	90-100	100	100	100	100
	1.5"	25-60	90	100	100	90
	3/4"	0-10	64	74	75	59
Screenings	3/8"	100	50	59	69	49
	No. 4	85-100	40	50	51	42
	No.100	5-25	14	19	18	9

ANNEXURE–XV

DESIGN OF PAVEMENT

E.S.As = 129×10^{6}
Design Life = 20 Years
C.B.R. = 5

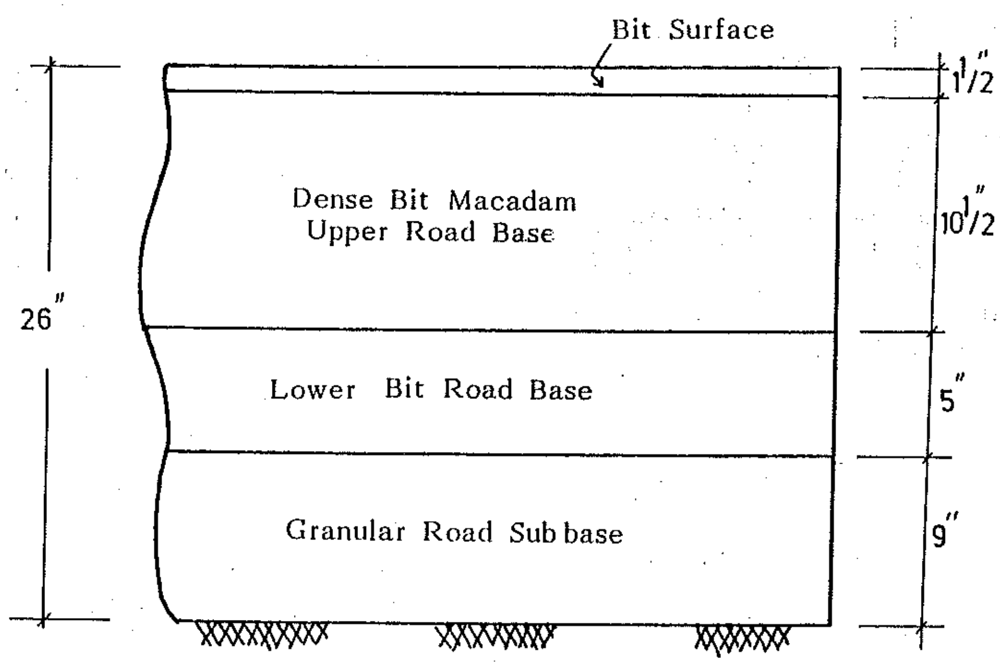


Design Based on TRRL Laboratory Report 1132, 1984

ANNEXURE-XVI

DESIGN OF PAVEMENT

E.S.As	=	82.77×10^{6}
Design Life	=	10 YEARs
C.B.R.	=	5



Design Based on TRRL Laboratory Report 1132, 1984.

ANNEXURE-XVII

DESIGN OF PAVEMENT - AASHO -1972

C.B.R = 6.8

Daily E.S.A = 10,000
(1973 Traffic of Kashmir Highway)