DESIGN CONSIDERATION

OF

KHULNA–MONGLA ROAD

A PROJECT REPORT

BY

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Submitted to the Department of Civil Engineering, Bangladesh University Of Engineering & Technology, Dhaka in partial fulfilment of the requirement for the degree

of

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DECLARATION

I hereby declare that the project work submitted herewith has been performed by me and that this work has not been submitted for any other degree.

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ABSTRACT

For designing any road some design criteria is required to be fixed up, which is governed by the importance of the road. The design speed, design life, side slope, horizontal and vertical curves, maximum rate of superelevation and capacity of the road are the vital aspects to be taken into consideration in designing a road or highway. It is not possible to proceed with the design of a road before the design criteria are fixed up.

The specifications and design criteria adopted in the Khulna-Mongla Road Project have been reviewed in this report. An analysis of Traffic loads, Traffic analysis, the Design considerations and the Pavement evaluation have also been reviewed and findings of the same have been furnished in the chapter : 3, 4, 5, 6 and 7.

Traffic loads mainly carried by the trucks indicates that the loadings adopted in the design of pavement of Khulna-Mongla Road were reasonable. The Bangladesh Transport Survey (BTS) study moreover indicates that a differentiation in loadings between inter-district (in the case of this road,port-derived) and intra-district (local) traffic could more accurately represent loading behaviour in the area. It is noted that access to the Khulna-Mongla Road will be limited and that control of vehicle loads on the road should be relatively easy.

The Traffic analysis based on the historical traffic data, population growth, changing vehicle owership patterns and the likely demands on the transportation system which will be made by the Mongla Port. On the basis of this analysis the traffic projections have been made.

In designing pavement of the Khulna-Mongla Road Project, the consultant followed London RRL, Road Note: 29 and London

TRRL, Road Note: 31, which is also followed by the R&H Department in designing road pavements.London RRL, Road Note: 29 is applied, when traffic volume is large and London TRRL,Road Note: 31 is applied traffic volume is less.

According to London RRL, Road Note: 29 the pavement life of Khulna-Mongla Road comes to 20 years as against a life of 12 years according to London TRRL,Road Note: 31 for the same traffic load i.e 2.3 MESAL considered in Khulna-Mongla Road.

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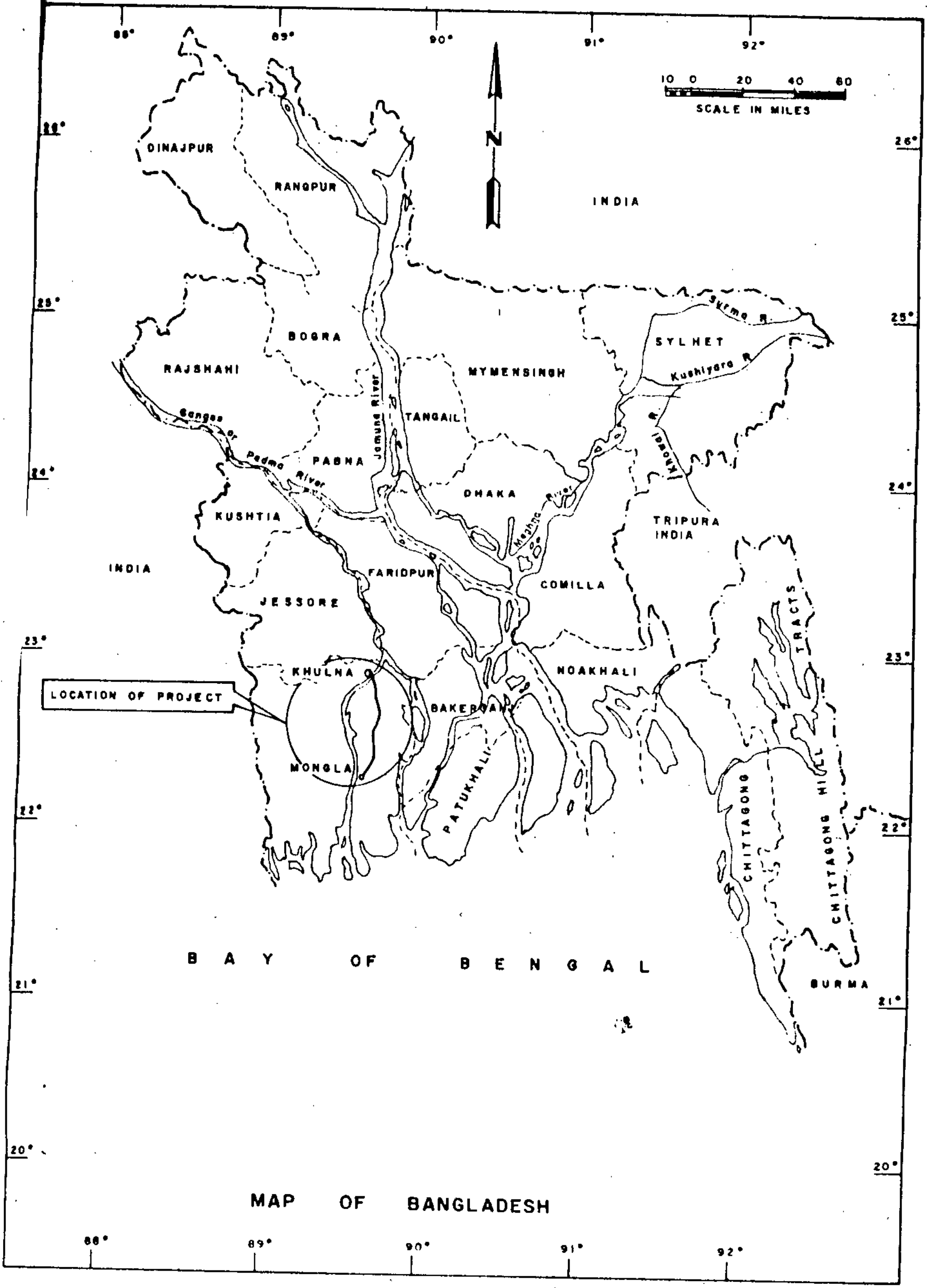
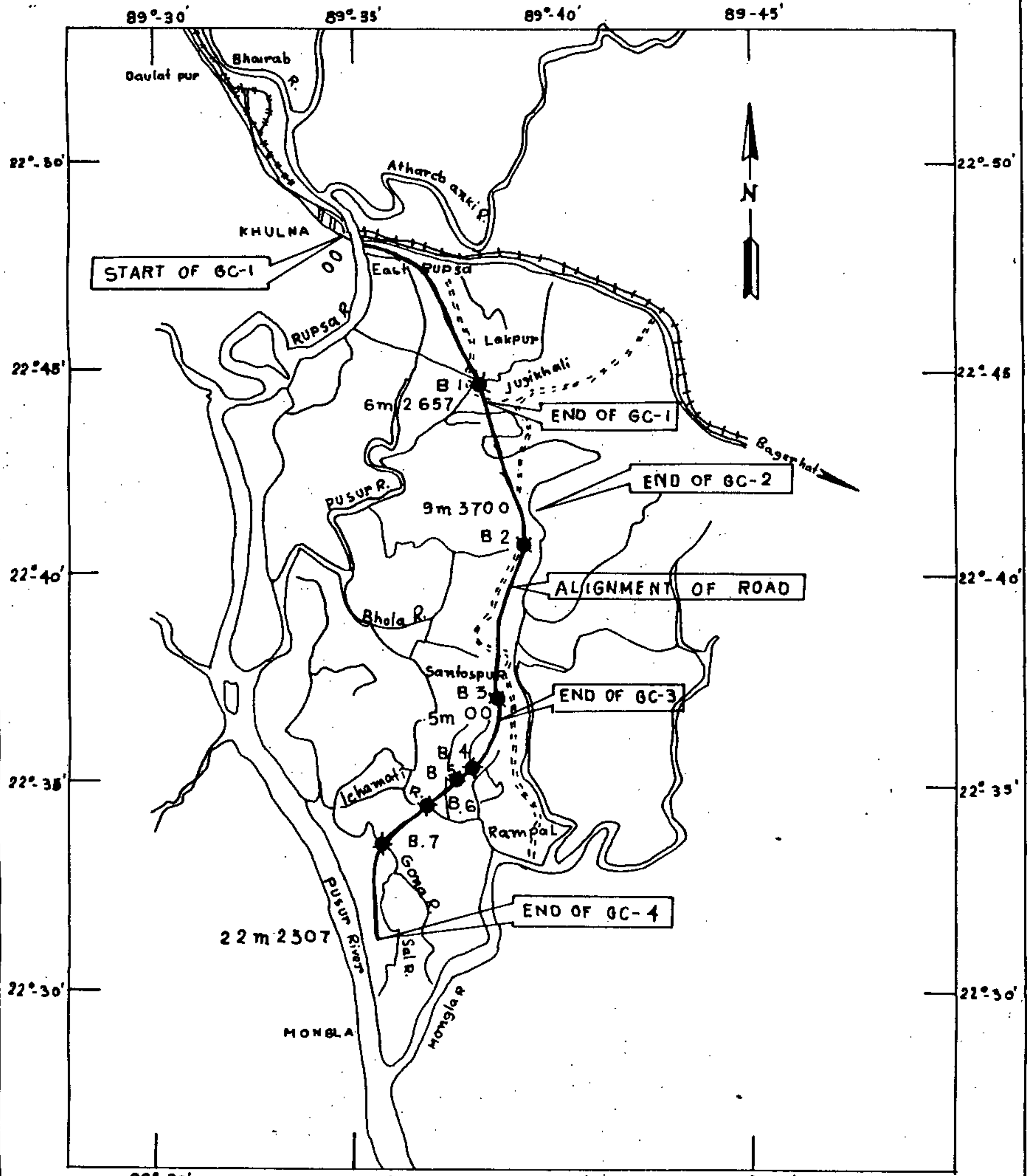
ABBREVIATIONS

AASHO	American Association of State Highway Official
ADB	Asian Development Bank
CBR	California Bearing Ratio
DMR	Department of Main Roads
DTN	Design Traffic Number
ESAL	Equivalent Standard Axle Load
MESAL	Million Equivalent Standard Axle Load
NAASRA	National Association of Australian State Road Authorities
SAL	Single Axle Load
SARC	South Asian Regional Co-Operation



MAP OF BANGLADESH



Bridges
Metalled Road
Unmetalled Road
Railway, broad gauge
Railway, meter gauge
River or water channel.

FIG. 2

LOCATION MAP
KHULNA-MONGLA ROAD PROJECT
Scale: 1: 250,000

Chapter 1

INTRODUCTION

1.1 General

The principal design criteria for highways are: Traffic Volume, Character and Composition of traffic, design speed and control of access. These determine the pricipal geometric features of a road. Other controls and criteria such as topograpy, Physical features, Capacity, safety and economics are important, but are either reflected in the major controls or have to do with more detailed design features which are not included in the general designation.

The location of a highway and its design elements are influenced to a considerable degree by the topography, physical features and land use of the area traversed. These are positive design controls and information regarding them is essential. Topography is a major factor in determining the physical location of rural highway and generally affects the alignment, gradients, sight distance, cross-section and other design elements.

Geometric design is intimately related to the capabilities and limitations of the roadway user and his vehicle. Traffic volume, speed and composition are three major items to be considered in striving to provide safe, efficient and economic traffic operations.

In preparing the design of a new road or the redesign of an old one, the highway engineer must give attention to the following basic considerations :

1. The design must be adequate for the estimated future traffic volume both average daily traffic and design peak hour, for the character of vehicles and for the design speed.

2. The design must be safe for driving and should instill confidence in the majority of drivers.

3. The design must be consistent and must avoid surprise changes in alignment, grade or sight distandce.

4. The design must be complete. It must include the necessary roadside treatment and provide essential traffic control devices, such as markings and signs and proper lighting.

5. The design must be as economical as possible relative to initial costs and maintenance costs.

1.2 Objectives

This study has been made with the following objectives:

1. To study the specifications adopted for the Khulna-Mongla Road Project.

2. To study the design criteria adopted for the Khulna-Mongla Road Project.

3. To analyse the design considerations and to give comment on the justification for adopting the same.

Chapter 2

CLASSIFICATION OF ROADS AND GEOMETRIC DESIGN STANDARDS

2.1 Classification of Roads:

In the absence of standard classification it was becoming very difficult to adopt suitable geometric standards for different types of roads/highways in Bangladesh.

Therefore the Road system in Bangladesh has been classified into five categories on the basis of their traffic volume, socio-economic and strategic importance etc. These are : (1) National Highways (2) Regional Highways (3) District Roads (4) Feeder Roads (5) Rural Roads.

"Traffic flow" is no doubt the main criteria on which the classification should be based. But the level of traffic flow as is used in developed countries, can not be used as it is for our situation, because the traffic composition and side conditions of our roads (such as our roads are mostly multi-purpose roads with liberal accessibility to predestrians, animals, besides its use for drying of foodgrains etc.) are completely different from that of developed countries. In view of this, a reduced level of traffic flow has been adopted as the basis of our road classification.

Categories and their specifications are given in Table 2-1.

Table 2-1

ROAD CLASSIFICATION AND GEOMETRIC STANDARDS

AS PER R & H DEPARTMENT

Sl. No.	Type of Roads	Definition	Crest Width	Pavement Width	Shoulder with in each side	Remarks
	ARTERIAL ROADS:					
1.	National Highways.	Highways connecting national capital with different regional and international Highways.				There shall not be more than one national hihgways for a region.
	Category-A		40'-0" (12.12)	22'-0" (6.7)	9'-0" (2.74)	
	Category-B		40'-0" (12.12)	18'-0" (5.49)	11'-0" (3.35)	
2.	Regional Highways.	Highway connecting different regions				
	Category-A		36'-0" (10.98)	18'-0" (5.49)	9'-0" (2.74)	
	Category-B		36'-0" (10.98)	12'-0" (3.66)	12'-0" (3.66)	
3.	District Roads	Roads connecting district H.Q.with sub-Divisional and inter Sub-Divisional connection.	24'-0" (7.32)	12'-0" (3.66)	9'-0" (2.74)	
	FEEDER ROADS:	Roads connecting H.Q. and other growth centres with the arterial road system	24'-0" (7.32)	12'-0" (3.66)	6'-0" (1.83)	
	RURAL ROADS :					
1.	Thana Roads	Road connecting Union HQs/markets with the Thana HQ of road system.	16'-0" (4.88)	-	-	
2.	Union Road	Roads connecting villages and farms to local markets.	12'-0" (3.66)	-	-	
3.	Village Roads	Roads connecting mosques, wells and different parts of the villate.	8'-0" (2.44)	-	-	

Note : Figures within perenthesis are in meters.

Source : R & H Department.

2.2 Geometric Design Standard :

Commensurate with the above classification the following geometric design standards are recommended for adoption as shown in Table 2-2, 2-3, 2-4, 2-5, 2-6, 2-7, 2-8 and 2-9.

Table 2-2

GEOMETRIC DESIGN STANDARD

Sl. No.	Class of Roads standards	National	Regional	District	Feeder	Rural
1.	Volume of traffic in PCE (Per hour in both direction)	500 or above	200-500 (in 1990)	50-200 (in 1990)	0.50 (in 1990)	-
2.	Design Speed (mph)					
	a) Flat Topography	50	40	30	20	-
	b) Rolling Topography	40	30	25	18	-
	c) Mountainous Topography	30	25	20	15	-
3.	Number of lanes	2	2 or 1	1	1	-
4.	Width of lane in feet	11' or 9'	9'-0" each for 2 lanes, 12'-0" for single lane	12'-0"	10'-0"	-

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July 1980.

Table 2-3

MAXIMUM DEGREE OF CURVE AND MINIMUM RADIUS FOR DIFFERENT VALUES OF MAXIMUM SUPERELEVATION

Design speed (mph)	Maximum e	Total e&f	Minimum Radius (ft)	Maximum design of curve (degree)	Maximum degrees of curve (rounded)
20	0.04	0.20	230	24.00	24.00
30	0.06	0.22	328	17.50	18.00
40	0.06	0.21	508	11.30	11.50
50	0.06	0.20	833	6.90	7.00

Note : e = rate of road way superelevation, feet per feet.

f = Side friction factor for design.

Superelevation is necessary when Degree of Curvature is more than 1.75°.

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July, 1980.

Table 2-4

MINIMUM LENGTH FOR SUPERELEVATION RUN OFF FOR PAVEMENTS

Superelevation Rate feet per feet	L = Length of run off in feet for design speed in			
	20	30	40	50
0.02	50	100	125	150
0.04	50	100	125	150
0.06	50	110	125	150
0.08	50	145	170	190

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commision, July, 1980.

Table 2-5

EXTRA WIDTH ON CURVES WITH RADIUS LESS THAN 2460FT.

Degree of Curve	Widening in feet for 2 lane pavements on curves for width of pavement on tangent of				
	22' wide pavement Design speed(MPH)			18' wide pavement Design speed (MPH)	
	30	40	50	30	40
4 to 5	0.00	0	2	0	0
6	0.00	0	2	0	0
7	0.00	2	2.50	0	2.0
8	2.00	2	2.50	2	2.0
9 to 10	2.00	2	-	2	2.50
11 - 13	2.50	3	-	2	2.50
14 - 17	3.00	-	-	2	-
18 - 21	3.50	-	-	2.50	-

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July, 1980,

Table 2-6

MAXIMUM GRADES IN PERCENT

Type of Topography	Design speed (mph)			
	20	30	40	50
Flat	6	6	5	4
Rolling	7	7	6	5
Mountainous	9	9	8	7

Source : Bangladesh Road Classification And Geometric Design Standars, Planning Commission, July 1980.

Sight Distance :

Minimum stopping sight distance for all highways and passing sight distance for 2-lane highways shall be as shown in Table2-7.Criteria for measuring sight distance, both vertical and horizontal, shall be :

For stopping sight distance,height of eye 3.75 feet and height of object 0.50 feet, from the road surface. For passing sight distance, height of eye 3.75 feet and height of object 4.50 feet from the road surface.

Table 2-7

MINIMUM SIGHT DISTANCE IN FEET

Design Speed (mph)	20	30	40	50
Stopping sight distance Minimum stopping S.D.feet	170	200	275	350
'K' value of crest vertical curve	25	28	55	85
Sag Verticle curve	30	35	55	75
Descrable S.S.C. feet	170	200	300	450
'K' value for crest vertical curve	25	28	65	145
Sag verticle curve	30	35	60	100
Passing sight distance feet, 2-lane	900	1100	1500	1800
'K' value for crest vertical curve	300	365	686	985
Horizontal sight distance	170	200	275	350

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July, 1980.

Table 2-8

NORMAL PAVEMENT CROSS SLOPES

Surface type	Range in rate of cross slope	
	Inch per feet	feet per feet
High	$\frac{1}{8} - \frac{1}{4}$	0.01 - 0.02
Intermediate	$\frac{3}{16} - \frac{3}{8}$	0.015 - 0.03
Low	$\frac{1}{4} - \frac{1}{2}$	0.02 - 0.04

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July 1980.

Table 2-9

DESIGN LOADING AND ROADWAY WIDTH FOR BRIDGES AND CULVERTS

Road	Design loading	Minimum loading	Roadway width (out to out) for culvert and minor bridge span 30"	Clear Road way width major bridge span more than 30 feet
1. National Highway				
Category - A	H_{20}-S_{16}	H_{20}-S_{16}	Full crest width of embankment	24'
Category - B	H_{20}-S_{16}			
2. Regional Highways				
Category - A	H_{20}-S_{16}	H_{20}-S_{16}	–	24'
Category - B	H_{20}-S_{16}	H_{20}-S_{16}	–	24'
3. District Roads	H_{20}-S_{16}	H_{20}-S_{16}	–	24'
4. Feeder Roads	H_{20}-S_{16}	H_{20}-S_{16}	–	22'
5. Rural Roads	H_{20}	H_{20}	–	–

Source : Bangladesh Road Classification And Geometric Design Standards, Planning Commission, July, 1980.

Chapter 3

TRAFFIC LOADS

3.1 Assessment of Traffic Loads for Pavement Design:

The earliest systems of traffic load assessment classified traffic, by qualitative categories. Such systems are still used in design for roads where traffic data are limited for development roads designed for stage construction and particularly for rural roads. The qualitative classification is vague and has obvious disadvantages. This system is not recommended for the Khulna-Mongla Road Project.

It has long been recognised that the damaging effect of traffic depends on :

a) the number of vehicles using the road
b) the weights or loads of vehicles using the road.

Early attempts to allow for the more severe damaging effict of heavier vehicles was to classify light and heavy vehicles (e.g. heavy or commercial vehicles of gross weight 3 ton or more) and assess the flow of heavy traffic. In stipulating a design period, vehicle class and traffic volumes (of that class) at the end of the period, this load classification system makes some allowance for the accumulative effect of traffic.

3.2 The ESAL Method of Traffic Load Assessment:

In recent times it has becomes common to assess the accumulative damaging effect of traffic loads on a lane in terms of repetitions of equivalent standard axle loads (ESAL) on that lane. The standard axle load is taken as an 18,000 lb load carried by a pair of dual wheels. This cumulative axle load system is used by both London RRL Road Note 29[1/] and London TRRL, -Road Note 31[2/].

The Design Traffic Number (DTN) of the Asphalt Institute method can also be related to an equivalent number of cumulative standard axle loads. The only disadvantage of the Asphalt Institute's method (DTN), compared with the ESAL method, is the use of an averaging "traffic growth factor" which fixes the DTN to a linear growth pattern. The ESAL system is more flexible, is used in the Road Note methods and is recommended for use on the Khulna-Mongla Road Project.

The basis of classification for the ESAL method is a standard axle load consisting of a four-wheel (two dual-wheel) axle bearing 18,000 lb. This is a lighter loading than a 9,000 lb single-wheel load. The method of calculation is the arithmetic accumulation (over any adopted design period) of axle loads, non-standard axles being counted as a number of Equivalent standard Axle Loads (ESAL).

The assessing of non-standard axles is achieved by means of equivalance factors. These are the damaging powers of particular axles expressed as an equivalent number of standard axles. The AASHO Road Test showed that the relative damaging power or distress effect for a given arrangement of loads was approximately equal to the fourth power of the ratio of the actual loads. Thus the equivalent damaging power of a four-wheel axle bearing a single axle load of SAL lb would be (Road Note 29):

$$ESAL = \left(\frac{SAL}{18,000}\right)^{3.9} \text{ approximately.}$$

Note : 1/ ROAD RESEARCH LABORATORY. Aguide to the structural design of Pavements for new roads. Department of the Environment, Road Note No.29, London 1970 (HM stationary office, 3rd Edition.

2/ TRANSPORT & ROAD RESEARCH LABORATORY. A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries. Department of the Environment, Road Note 31, London 1977 (HM stationery office) 3rd, Edition.

The subject currently of most debate in the ESAL method of traffic load assessment is the equivalence of different arrangements of loads. The assessment of damaging power of non-standard axles was obtained in terms of ESAL by means of equivalence factors are shown in Table 3-1. The load distributions on vehicles are shown in Table 3-2.

Table 3-1

FACTORS FOR CONVERTING NUMBERS OF AXLES TO THE EQUIVALENT NUMBER OF STANDARD 8200 KG (18000 lb)AXLES

Axle load		Equivalance factor
Kg	lb	
910	2000	0.0002
1810	4000	0.0025
2720	6000	0.01
3630	8000	0.04
4540	10000	0.08
5440	12000	0.2
6350	14000	0.3
7260	16000	0.6
8160	18000	1.0
9070	20000	1.6
9980	22000	2.4
10890	24000	3.6
11740	26000	5.2
12700	28000	7.2
13610	30000	9.9
14520	32000	13.3
15430	34000	17.6
16320	36000	22.9
17230	38000	29.4
18140	40000	37.3
19070	42000	47.0
19980	44000	58.0
20880	46000	72.0
21790	48000	87.0

Source : Road Note 31.

Table 3-2

ESTIMATED LOAD DISTRIBUTIONS ON VEHICLES (% OF AUW CARRIED BY AXLE).

Loading Case		Front Axle	Rear Axle
Empty Trucks	Original Design	67	33
	Recommended Loading	50	50
Full Trucks	Original Design	42	58
	Rated capacity	40	60
	Recommended Loading	33	67
	Over loaded case	25	75
Empty buses	Original design	50	50
	Recommended loading	40	40
Full Buses	Original design	50	50
	Rated capacity	40	60
	Recommended loading	37	63
	Over loaded case	37	63

Source : Monthly Report No. 39, Khulna-Mongla Road.

The equivalence factors depend on wheel and axle spacings, tyre sizes, the relative importance of scuffing and other variables, but typical equivalence factors may be adopted as follows (for unit load on any axle arrangement) are shown in Table 3-3.

Table 3-3

EQUIVALENCE FACTORS

Type of axle and wheels	Factors
Single axle, dual wheels, damaging power	1.0
Single axle, single wheels, damaging power	1.5
Tandem axles, dual wheels, damaging power	0.6

Source : Monthly Report No. 1 in Khulna-Mongla Road Project.

3.3 Design Traffic Loads for Khulna-Mongla Road Project

Traffic projections include a large proportion of non-motorised vehicular traffic and non-vehicular traffic which would have little damaging effect on pavements.

In order to provide an upper-bound and a lower-bound estimate of traffic loads for the purpose of pavement design, traffic loads have been analysed both to include and to exclude light and non-motorised traffic. For the upper-bound estimate a switch from light and non-motorises traffic to heavier vehicles has been assumed.

3.3.1 Lower-bound Estimate of Design Traffic Loads

The lower-bound estimate of traffic loads considers only three categories of vehicle namely :

a) Trucks

b) Buses

c) Jeeps, Cars and Taxis.

a) Trucks

As for the ADB Appraisal Mission Report, 7 ton capacity trucks have been assumed with a load factor of 0.67. Typically two-axle trucks, the front axle having two wheels, the rear axle four wheels.

Equivalance factors for full and empty trucks can be estimated as followes (refer to Table 3-2).

i) Empty Truck	- Front axle	=	1.5 x 0.0025 ESAL
		=	0.0038 ESAL
	Rear axle	=	1.0 x 0.0002 ESAL
		=	0.0002 ESAL
	Total	=	0.0040 ESAL
ii) Full Truck	- Front axle	=	1.5 x 0.08 ESAL
		=	0.12 ESAL
	Rear axle	=	1.0 x 0.20
		=	0.20 ESAL
	Total	=	0.32 ESAL

Hence the average equivalence factor of the envisaged truck traffic is estimated to be 0.21 ESAL/truck.

The truck-load flow is expected to be asymmetric and as a consequence the design load contributed by trucks is assumed to be two-thirds of the total two-way truck-load flow.

b) Buses

It has been assumed that the average load per bus is 45 passengers. Assuming in addition baggage and other freight to the order of 10%. The average bus load can be estimated at, say, 2.7 tons.

Assuming equal distribution of load between two 2 wheel axles the equivalent traffic load per bus is approximately 0.03 ESAL. Bus traffic should be equally distributed between the Mongla and Khulna directions.

c) Cars, Jeeps and Taxis

The loads imposed by private cars donot contribute significantly to the structural damage caused to road pavements by traffic. Therefore for the purposes of structural design, cars can be ignored and only the total number and the axle loading of the commercial vehicles that will use the road during its design life need to be considered. In this context a commercial vehicle is defined as any goods or public service vehicle that has an unloaded weight of 1.5 tons or more. However, to demonstrate this point, the equivalent traffic load which can be attributed to cars and other light vehicles has been calculated as shown Table 3-4

Assuming a gross vehicle weight of 1.5 tons for cars etc. with the load distributed equally between two 2-wheel axles, the equivalent load per car is approximately 0.0004 ESAL.

The lower-bound Estimate of design traffic load estimates are shown in Table 3-4.

Table 3-4

LOWER-BOUND ESTIMATE OF ACCUMULATIVE EQUIVALENT TRAFFIC LOADS
(10^3 ESAL)

Vehicle category	Design Period 1981-1986	1981-1991	1981-1996	1981-2001
Trucks	130	258	406	578
Buses	4	8	15	24
Car etc.	0.04	0.09	0.17	0.30
Total :	134	266	421	602

Source : Monthly report No. 1, Khulna-Mongla Road Project.

3.3.2 Upper-Bound Estimate of Design Traffic Loads:

In developing an upper-bound estimate of design traffic loads it is assumed that the traffic projections are adequate but, in addition to the base traffic loads estimated of this chapter that the higher traffic will switch to heavier vehicles as follows :

a) Auto-rickshaw/baby taxi traffic will switch to minibuses
b) Motor-cycle/bycycle traffic will switch to taxis
c) Rickshaw/Pedestrian traffic will switch to buses
d) bullock-cart traffic will switch to light commercial vehicles.

The total upper-bound design traffic load estimates are shown in table 3-5.

Table 3-5

UPPER-BOUND ESTIMATE OF ACCUMULATIVE EQUIVALENT TRAFFIC LOADS
(10^3 ESAL)

Vehicle category	Design Period			
	1981-1986	1981-1991	1981-1996	1981-2001
Base Traffic	134	266	421	602
LCV's	0.5	1.0	1.6	2.3
Cars etc.	0.3	0.6	1.0	1.5
Buses	5.8	11.6	18.2	25.9
Total :	141	279	442	632

Note : LCV's are light commercial vehicles such as minibuses, pick -ups etc.

Source : Monthly report No.1, Khulna-Mongla Road .

The additional traffic loads which would result rarely change the estimated damaging power of the total traffic. For structural design purposes, the damaging power of the trucks predominate. It is important, however, that the total volume of traffic (rather than the ESAL Load) will largely determine the amount of surface wear which will occur.

Chapter-4

TRAFFIC ANALYSIS

4.1 Introduction:

In Khulna-Mongla Road, the traffic analysis is based on historical traffic data, population growth, changing vehicle ownership patterns and the likely demands on the transportation system which will be made by the Mongla port. On the basis of this analysis the following traffic projections have been made. The projection are intended to be conservative(Upper-bound) estimates are shown in Table 4-1.

Table 4-1

ESTIMATED AVERAGE DAILY TRAFFIC FOR KHULNA-MONGLA ROAD

Traffice Category	Average growth % P.A.	Year				
		1981	1986	1991	1996	2001
A.D.T in P.C.E*						
Trucks & Buses	4	1431	1755	2157	2637	3198
Light Motorised vehicles.	8	125	192	284	398	532
Total for Motor vehicles.	4	1556	1947	2441	3035	3750
NOn-Motorised vehicles(Bullock Carts,Bicycles etc.)	3	1193	1383	1603	1858	2154
Total all vehicles	4	2749	3330	4044	4893	5884
Pedestrians	3	2470	2863	3319	3848	4461

Note:* P.C.E = Passenger Car Equivalance

Source: Monthly Report No:1, Khulna-Mongla Road Project

4.2 Port Traffic:

The traffic projections for the project consisted of two main components : traffic derived from the new port, and the local traffic. The port-derived traffic predominated in determining pavement design.The "local" traffic predominated in determining geometric design.

In the design it was assumed that 675,000tons per annual (P.a) initially would be deverted to road transport via the Khulna-Mongla Road and that port-derived truck traffic would thereafter grow at an annual rate of about 3%.

4.2.1 Basis of Projections of Port Handling:

In making the projections it has been assumed that the political climate and economic growth of Bangladesh will not deteriorate. It has been assumed that total cargo handled by the port will grow steadily from a level of about 1.4million tons in 1972 to 1.8million tons in 1980,thereafter to grow a rate of 3% p.a.to 2.1 million tons in 1985,and thereafter to grow at a rate of 2.5% p.a. to about 3.0 million tons in 2000.

Historically import cargo growth has been greater at the port than the growth in export cargo handled. In 1978 imports exceeded exports by more than 0.3 million tons (or by approximately 50% of the total export volume handled). This asymmetry of flow, if reflected in the loads diverted to trucks, would result in a concentration of truck loads in one lane and hence increase pavement design loads. It has therefore been assumed that the growth of imports at least initially will continue to grow at a faster rate than exports.

It has been assumed that import cargo from the port will grow steadily from a level of about 0.75 million tons in 1971 to about 1.15 million tons in 1980,thereafter to grow at a rate of 4.5% p.a. to 1.4 million tons in 1985 and thereafter to grow at a rate of 2.5% p.m. to about 2.0 million tons in 2000. The corresponding estimates of export cargo handled at the port are as follows:

* 1972	0.6 million tons
* 1980	0.65 million tons
* 1985	0.7 million tons
* 2000	1.0 million tons

4.3 Local Traffic:

In the short-term, locally-derived traffic potential in the region must be lower than in nearly regions where roads already exist. In the long-term the locally-derived traffic potential for the project road would also be relatively low because of the relatively low population in the area and because of the large areas of low-lying and/or salt-affected terrain with low agricultural potential in the region.

4.3.1 Projected Local Traffic Volumes:

The estimates of local traffic can be summarised as follows, in terms of total two-way average daily traffic:

* Upper-bound estimate--

First year	100
Tenth year	156
Twentieth year	231

*Lower-bound estimate--

First year	26
Tenth year	38
Twentieth	56

The lower-bound estimate includes approximately 46% trucks, 39% buses and 15% light vehicles, the Upper-bound 35% trucks, 38% buses and 27% light vehicles.

4.4 Traffic Forecasts

4.4.1 Bus Traffic:

The ADB Appraisal Mission carried out a comparative analysis of the costs of passenger transport by river launch and by bus and determined that passenger traffic between Khulna and Mongla would be significantly cheaper by bus. With the assistance of Roads and Highways Department (RHD), origin-destination surveys were also carried out, which indicated that some 705,000 passengers would be induced to divert from river launches to buses.

In summary at present it could be estimated that potentially some 955,000 passengers per annum could be expected to utilize bus services on the Khulna-Mongla Road. This would be equivalent to approximately 57 buses/day.

The Bangladesh Transport Survey (Nov.1974) concluded that passenger travel in rural areas is growing at approximately 6% P.a. Considering the population growth in the Khulna District it has been assumed that bus traffic will grow (Until 1981, Potentially) initially at a rate of about 10% per annum. During the periods 1981-1991 and 1991-2001 respectively growth rates of 8% per annum and 6% per annum respectively have been assumed.

4.4.2 Truck Traffic:

The ADB Appraisal Mission estimated that the five berths at Mongla (Proposed for completion in 1980) would have a through-put capacity of 675,000 tons/P.a. with handling by labour. Because of the cost advantage of road transport (trucks) over river barges this wharfside cargo is expected to be transported to Khulna by trucks. With the possibility of two further wharves being put into operation at some later stage and to allow for the possible development of local truck traffic based on agriculture,it has been assumed that the truck traffic will grow at an annual rate of about 3%P.a. should the projected increase in the district's truck fleet occur.

4.4.3 Light Vehicle Traffic:

The ADB Appraisal Mission considered that generally,economic activity in the project area would generate insignificant traffic (Insignificant that is,in its effect on the feasibility of the project). For the purposes of traffic prediction for design however an estimate of the induced traffic(increased agricultural production,heightened business interaction between Khulna and Mongla etc.) is required.

The ratio of light motorised vehicles to buses is expected to decline from 3.6 in 1981 to 1.3 in 2001. This compares with an average ratio of 2.6 for the Jessore--Khulna Road traffic counts. It has been assumed for the purpose of traffic projection that the ratio of light motor vehicles to buses will be approximately 1.5 and that the light motor vehicles will consist of cars, auto-rickshaws and motor cycles in proportion to their projected numbers by registration.

It has been assumed that bicycle,rickshaw, animal-drawn cart and pedestrian traffic will grow at about 3% P.a.

Based on the above data, the following estimates of traffic on the Khulna-Mongla Road Project can be made are shown in Table 4-2.

Table 4-2

KHULNA-MONGLA ROAD PROJECT

PROJECTED AVERAGE DAILY TRAFFIC

Vehicle Category	Average Daily Traffic in Year				
	1981	1986	1991	1996	2001
Trucks	394	457	530	614	712
Buses	83	128	189	265	354
Jeeps,Cars&Taxis	52	92	153	238	348
Auto-Rickshaws & Baby Taxis	14	19	25	30	35
Motor Cycles	59	81	106	130	149
Bicycles	1247	1446	1676	1943	2252
Rickshaws	1138	1319	1529	1773	2055
Bullock-Carts	29	34	39	45	52
Pedestrians	2470	2863	3319	3848	4461

Source: Monthly Report No:1, Khulna-Mongla Road Project

Chapter 5

PAVEMENT DESIGN

5.1 Flexible Pavement Designs by London TRRL, Road Note 31

5.1.1 General. London TRRL, Road Note 31[1/] specifically allows for stage construction within the following constraints,

"In general for roads which will carry not more than about 300 commercial vehicles per day (in both directions) at the time of construction, the most economical solution will be to choose a double surface dressing on a 6 inch base initially and to add a 2 inch bituminous surfacing some years later".

The design system is fixed on a double surface dressing with a standard base thickness of 6 inches (with variable thickness of subbase to allow for different subgrade strengths) for traffic loads of up to about 0.5 million ESAL (Per lane).

For greater traffic loads upto about 2.5 million ESAL alternative designs are allowed-

- Double surface dressing, 8 inch base, variable subbase
- 2 inch bituminous concrete, 6 inch base, variable subbase.

5.1.2 Full Period Thickness Design. The first possibility for flexible pavement thickness design is to design for the initial construction of a pavement to accommodate the estimated design traffic loads for the full design period (i.e. for 32000 ESAL). According to the Road Note 31 design method, such a pavement would consist of an eight inch upper layer (either 2 inches

Note : 1/ TRANSPORT & ROAD RESEARCH LABORATORY. A guide to the structural design of bitumens - surface roads in tropical and sub-tropical contries, Department of the Environment, Road Note 31, London, 1977. (HM stationery office), 3rd Edition.

of bituminous concrete plus 6inches of granular base or a double bituminous surface dressing plus 8 inches of base) overlying a subbase of variable thickness (thickness varying according to subgrade strength).

5.1.2.1 Subbase Design :

The subbase thickness required (according to the design CBR values of the subgrade) are shown in Table 5-1.

Table 5-1

SUBBASE THICKNESS REQUIRED FOR

FULL-LIFE PAVEMENT

Subgrade CBR Value (%)	Minimum Subbase Thickness		Design Thickness (Inches)
	(mm)	(Inches)	
2	430	16.9	17
3	325	12.8	13
4	250	9.8	10
5	200	7.9	8
6	160	6.3	6.5
7	120	4.7	5
8-24	100	3.9	4

Source: Monthly Report No:1,Khunla-Mongla Road Project

The subbase to be provided according to London TRRL, Road Note 31 will normally be a naturally-occuring gravel or gravel-sand-clay should have a CBR of 25% or more at the density and moisture content expected in the field. However if good subbase material is scarce, the quality of the material used beneath the top 4 inch layer of the subbase can be relaxed, provided it has a CBR of at least 8% when tested at the worst moisture condition likely to occur.

For the Khulna-Mongla Road locally occuring materials which meet the above requirements for subbase have not been found. Investigations are proceeding to determine whether local materials could be stabilised (either machanically or with cement) to satisfy these requirements.If such a stabilised material proves economical it will consist of a mixture of several of the following :

* Local silt-clay
* Local silt-sands
* Imported (ex-Sylhet or ex-India) aggregate
* Cement

5.1.2.2 Base Course Design :

London TRRL, Road Note 31 design charts are arranged on the assumption that the base course will consist of one of the following materials :

* Mechanically-Stable natural gravel or Crushed gravel
* Crushed rock
* Cement or Lime-Stabilised soil
* Bitumen-Stabilised sand

In Bangladesh the typical base course material used in a bitumen- bound penetration macadam which would also be of adequate quality.

5.1.3 Designs For Stage Construction :

For an initial pavement design to accommodate the 5 year, 10 year or 15 year design traffic loads, because the design loads are less than 0.5 million ESAL, by London TRRL, Road Note 31 an initial construction consisting of :

* Double surface dressing
* 6 inch base course
* Variable thickness subbase

would be acceptable.

The variable subbase thickness, according to the above three design lives are showes in Table 5-2.

Table 5-2

SUBBASE THICKNESSES FOR VARIOUS DESIGN LIFES

Subgrade CBR Strength (%)	Subbase Thickness For Design Lifes Of: 5 years (mm)	5 years (inches)	10 years (mm)	10 years (inches)	15 years (mm)	15 years (inches)
2	420	16.5	450	17.7	470	18.5
3	320	12.6	340	13.4	360	14.2
4	260	10.2	275	10.8	285	11.2
5	210	8.3	225	8.9	235	9.3
6	170	6.7	180	7.1	190	7.5
7	130	5.1	140	5.5	150	5.9
8-24	100	3.9	100	3.9	100	3.9

Source : Monthly Report No : 2, Khulna-Mongla Road Project

A comparison of total pavement thickness for 5 year, 10 year, 15 year and 20 year designs are showes in Table 5-3. In accordance with normal practice the thickness of a surface dressing is ignored (as it does not contribute significantly to the structural strength of the pavement).

Table 5-3

TOTAL PAVEMENT THICKNESS FOR VARIOUS DESIGN LIVES

Subgrade CBR (%)	Total Pavement Thickness For Design Lives Of:			
	5 year (inches)	10 year (inches)	15 year (inches)	20 year (inches)
2	22.5	23.7	24.5	24.9
3	18.6	19.4	20.2	20.8
4	16.2	16.8	17.2	17.8
5	14.3	14.9	15.3	15.9
6	12.7	13.1	13.5	14.3
7	11.1	11.5	11.9	12.7
8-24	9.9	9.9	9.9	9.9

Source : Monthly Report No:2, Khulna-Mongla Road Project

5.1.4 Preliminary Design By London TRRL, Road Note 31

For the purpose of preliminary design cost comparisons the Road Note 31 design can be summarised as consisting of :

* 2" bituminous concrete
* 6" base course
* Variable subbase thickness (according to subgrade strength).

5.2 Flexible Pavement Designs By London RRL, Road Note 29

5.2.1 Subbase Design :

For design traffic loads up to 0.5 million ESAL a subbase of CBR value 20% or more is satisfactory;

for traffic in excess of 0.5 million ESAL (the case with the Khulna-Mongla Road), the minimum subbase CBR strength is 30%. Actual CBR strength testing is not required for materials conforming to the specified requirements of Type 1 subbase, Type 2 subbase containing more than 10% retained on the 20.0mm BS Sieve (3/4 inches) nor for standard stabilised materials. All of these materials can be assumed to fulfil the CBR 30% requirement without CBR testing.

Subbase thicknesses required for the full 20 year design life by London RRL, Road Note 29 are shown in Table 5-4.

Table 5-4

SUBBASE THICKNESS REQUIREMENT

Subgrade CBR	Subbase Thickness Minimum		Design Thickness
(%)	mm	inches	inches
2	425	16.7	17.0
3	320	12.6	13.0
4	250	9.8	10.0
5	205	8.1	8.5
6	155	6.1	6.5
7	150	5.9	6.0
8-24	150	5.9	6.0

Source : Monthly Report No:2, Khulna-Mongla Road

Note:

Granular subbase(Type 1) - Crushed rock, crushed slag, crushed concrete or well-burnt non-plastic shale (alter-natively crushed well-burnt bricks); the material is coarse (3 inches maximum size) but well-graded and non-plastic.

Granular subbase(Type 2) - Natural sands, gravels, crushed rock, crushed slag, crushed concrete or well burnt non-plastic shale (Crush well-burnt bricks); the material is coarse (3 inches maximum size) but well graded (although the grading limits are more open than for Type 1); the fines shall have a maximum plasticity index of 6%.

5.2.2 Surfacing Design

In the London RRL, Road Note 29 design method, for the design traffic loads estimated, a surfacing course of at least 63mm (2.5 inches) is required. This is a two-layer course consisting of an upper 3/4 inch thickness wearing course of rolled asphalt or equivalent, overlaying $1^3/4$ inch thickness of rolled asphalt, dense bitumen macadam, or single course bitumen macadam.

5.2.3 Base Course Design

A variety of basecourse (road base) materials are allowed by London RRL, Road Note 29. For the design traffic loads estimated, the basecourse design thickness required for the various alternatives are :

* 3 inches rolled asphalt road base
* 3.5 inches dense macadam road base
* 5.5 inches soil cement, cement bound granular material or lean concrete
* 5.5 inches wet-mix and dry-bound macadam road base.

5.3 Earlier Pavement Designs

5.3.1 Introduction :

Owing to the scarcity and cost of providing naturally occuring aggregate for pavement construction, Whole brick or crushed brick is invariably use (in Bangladesh) for subbase and base courses with a wearing surface which is asphaltic concrete. Since it takes about 300 tons of imported coal to make enough bricks to form a road 1 mile long, 18 feet wide and 13 inches thick.

Suggested alternatives for study are :

a) The importation by waterways of suitable hard stone from India.

b) Using soil stabilisation techniques. Because of the widespread availability of low plasticity and non-plastic subsoils the potential for (lime) stabilisation of alluvial flood plain soils was investigated.

The possibility of providing a bituminous surface treatment instead of a more expensive bituminous concrete surfacing has also been considered. However, in view of the relatively high traffic volumes it is considered that maintenance costs would make a bituminous surface treatment uneconomical.

* Bitumen stabilisation is only economically effective for virtually non-plastic materials;the only locally available such materials are silt-sands of little mechnical strength and stabilisation of these materials with bitumem would be very expensive.

* Lime stabilisation is particularly effective with two types of material –

  - Plastic highly-active(e.g. montmorillonite) clays.
  - Well-graded materials of low but slightly excessive plasticity (e.g. plasticity index from about 12% to 20%) neither of which are available in the project area.

The possibility of stabilisation to achieve low-cost pavement materials is being pursued from two view points :

* Mechanical stabilisation of local materials with imported aggregate
* Cement stabilisation of local materials.

5.3.3 <u>ADB Pavement Design</u>

The ADB Assessment of pavement requirements was necessarily conservative, being an aid appraisal mission. It is considered that the final pavement design may be less expensive than that considered by ADB namely :

* $1\frac{1}{2}$ inch bitumen surface
* 5 inch bitumen macadam
* 9 inch brick base
* Brick soling
* 3 inch sand layer.

5.4 Pavement Design Adopted In Khulna-Mongla Road :

The RHD made the following provision for pavement in the project proforma :

* 2 inch dense bituminous concrete
* 3 inch grouted bituminous macadam
* 3 inch water-bound macadam
* 10 inch subbase

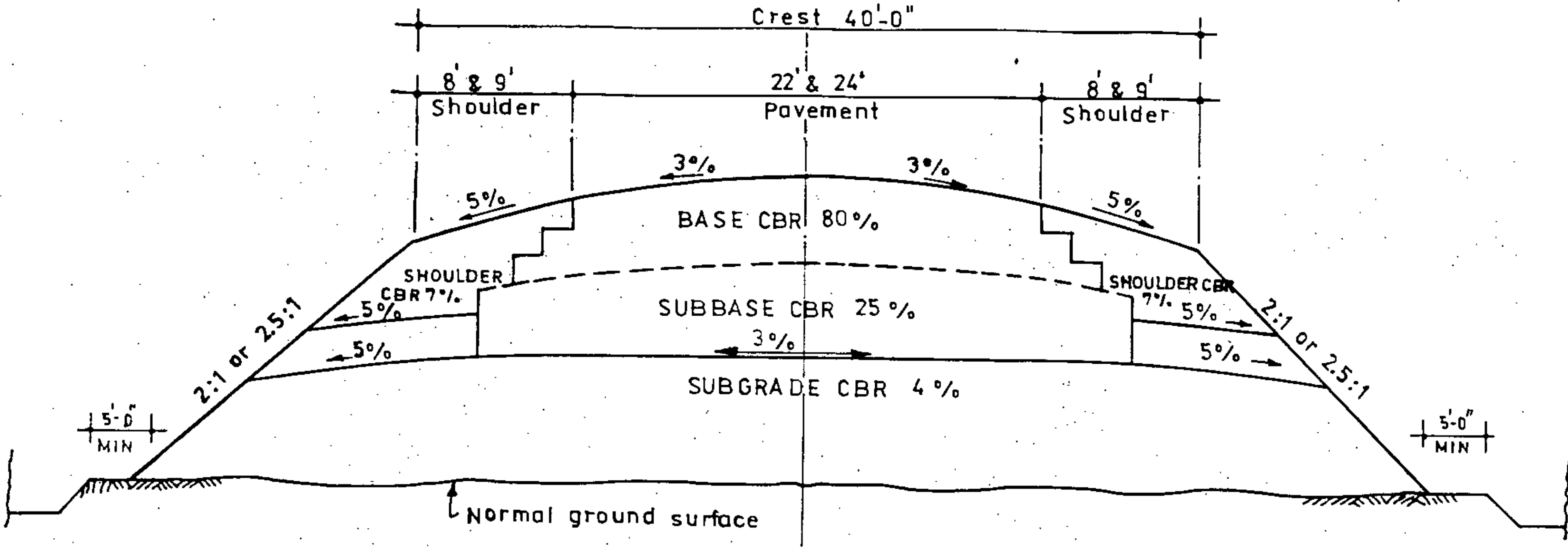


FIG. 3 A TYPICAL ROADWAY SECTION

Chapter 6

STRUCTURAL DESIGNS OF PAVEMENT

6.1 Design of Pavement in Khulna-Mongla Road

The original pavement design consisted of:

* 2" dense bituminous concrete
* 3" grouted bituminous macadam
* 4" Water-bound macadam
* 10"Sub-base

Over a subgrade with CBR 4% minimum.

In accordance with Road Note 31, this pavement would have a design traffic capacity of at least 0.95 MESAL which for the design loads recommended, and a design life of at least 12 years.

In accordance with Road Note 29, this pavement would have a design traffic capacity of at least 2.5 MESAL and a design life of 20 years.

The RHD requested a reduction of the pavement to:

* 2" dense bituminous concerete
* 3" grouted bituminous macadam
* 3" Water-bound macadam
* 10" Sub-base

This pavement would have a capacity in the range 0.65-1.20 MESAL.

For the order of traffic estimated for the Project road, a check of pavement deflections under load is advisable to preclude fatique craking in the surface. This is particularly important in pavements which include bound layers as these are more sensitive to deflection is a gravel pavement will tolerate approximately twice the deflection of a pavement containing thick bound layers.

Both the original and modified (by RHD) pavements include a substantial thickness of bitumen bound material. A deflection check using the NAASRA method indicates that the pavements have a traffic capacity of 1.5 MESAL (life of 14 years) for the original design and a traffic capacity of at least 0.95 MESAL (life of 10 years) for the modified design.

To achieve the 20 year life capacity for the road (2.3 MESAL) means that, either, a thicker pavement is constructed now or, that the pavement is overlayed with bituminous concrete or a waterbound macadam with bituminous seal as the traffic load approaches the roads capacity.

6.2 Alternative Structural designs :

The following alternative designs assume a subgrade strength of CBR 4% minimum.

The first alternative is to design for a 20-year life in the upper-bound case; for a design capacity of approximately 6.24 MESAL, well in excess of the capacity of the Road Note 31 method. For such loads Road Note 29 must be used and the following alternative pavements are indicated:

* 3.5" dense bituminous concrete
* 5.1" dense bitumen macadam roadbase
* 11.8" sub-base (CBR 30% minimum)

or

* 4.0" dense bituminous concrete
* 8.0" water-bound macadam roadbase
* 11.8" sub-base (CBR 30% minimum)

For an approximate 10-year life in the upper-bound case and a 20-year life at the recommended loads, a pavement capacity of approximately 2.3 MESAL is required and Road Note 29 indicates the following alternative designs:

* 3.0" dense bituminous concrete
* 4.3" bitumen macadam
* 10.9" sub-base (CBR 30% minimum)

In this case Road Note 31 applied and indicates:

* flush seal
* 8" water-bound macadam
* 13.5" sub-base (CBR 25% minimum)

These various design imply "layer equivalence factors" for the various materials, one inch of each material being approximately equivalent to the following thickness of water-bound macadam:

* bituminous concrete - 1.0"
* bituminous macadam - 1.65"
* sub-base (CBR 30% min.) - 0.85"
* sub-base (CBR 25% min.) - 0.80"

The "structure equivalence" of the various design is thus :

* For 6.25 MESAL - 22" water-bound macadam
* For 2.3 MESAL - 19" water-bound macadam
* For original design - 19" water bound macadam

The following pavement designs adopted -

<u>For First 9.7 miles of road</u> (GC 1 & 2)

- Surface dressing (Primer - Seal)
- 6" bitumen macadam comprising two equal layers
- 3" water bound macadam base course
- 10" sub-base (Two equal layers)

<u>For REmaining 12.4 miles of road</u> (GC 5)

- Surface dressing (Primer - Seal)
- 5" bitumen macadam (Two equal layers)
- 4" water bound macadam base course
- 10" sub-base (Two equal layers)

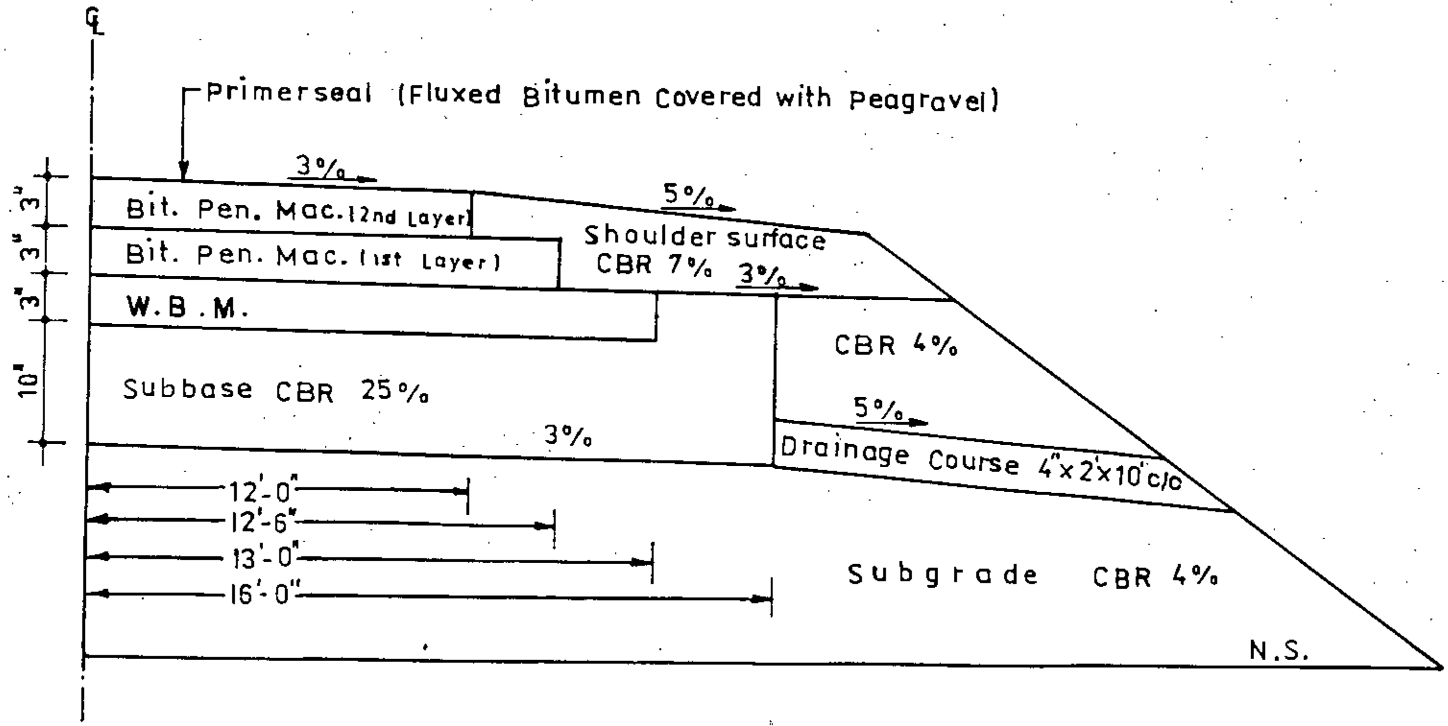


FIG. 4 PAVEMENT SECTION FOR 1ST 9.7 MILES

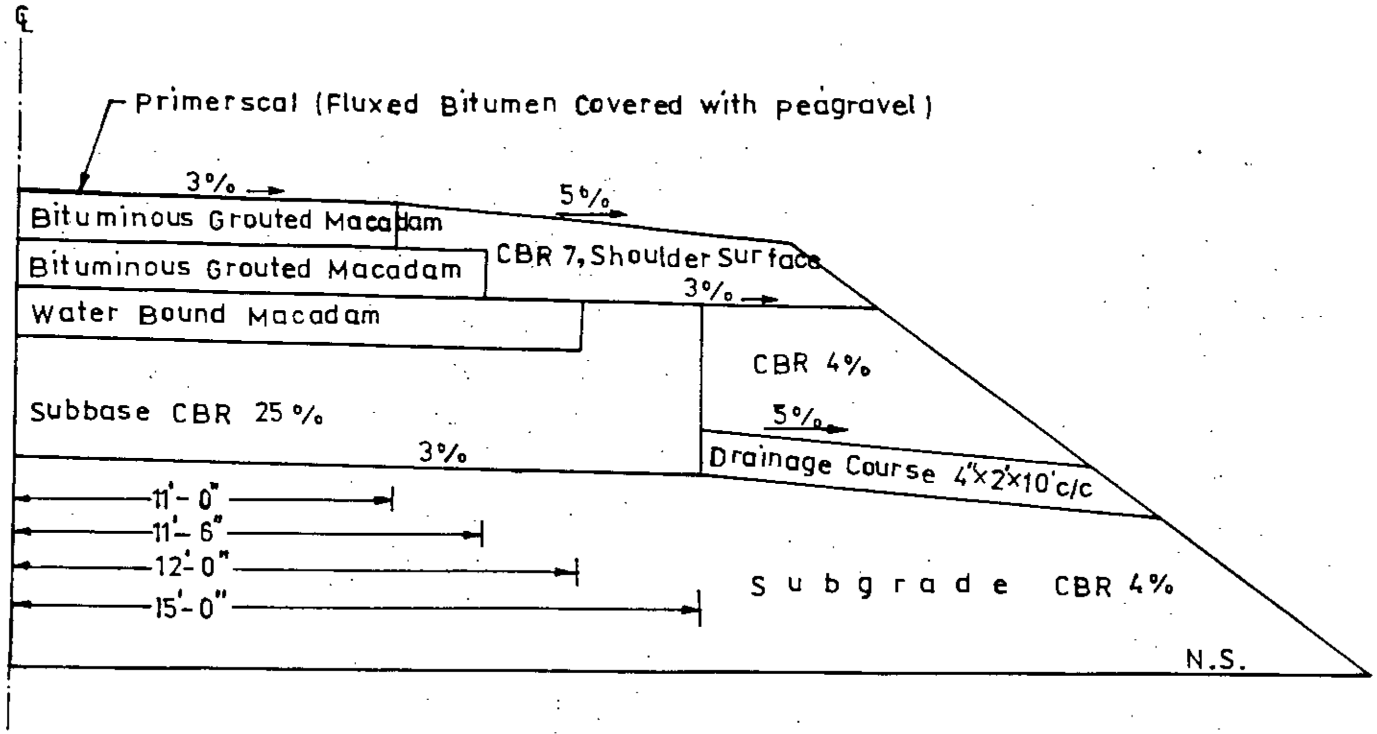


FIG. 5 PAVEMENT SECTION FOR LAST 12.74 MILES

Chapter 7

PAVEMENT EVALUATION OF KHULNA – MONGLA ROAD

7.1 Introduction :

The pavement design review for Khulna-Mongla Road consequently entailed a complete review of the design loading: Cargo carried, Passangers carried, Gross loads of vehicles, Distribution of loads on vehicles, Damaging effects of axle loads, Channelisation of traffic,etc. Snowy Mountains Corporation, Australia was confirmed that the life of the original design according to London RRL, Road Note 29 was probably 20 years(Using London TRRL, Road Note 31 at least 12 years). The conclusion of the review was that the original design should be adequate but that a phased construction approach be adopted incorporating monitoring of traffic and pavement performance and control of loads.

Pavement design review was done by the Snowy Mountains Engineering Corporation, Australia by the request of Roads and Highway Department. Roads and Highway Department requested because they have no, well controlled bituminous concrete batching plants, when Khulna-Mongla Road were constructed. The original design included a 2" bituminous concrete surfacing, therefore RHD requested a review of the design, to enable construction for at least a 10 year life, but without use of bituminous concrete.

The various designs (Including the original design for the project) were also checked against fatigue cracking by means of the new NAASRA deflection method which was not available at the time of the original pavement design. This design method, designs against surface cracking which could permit penetration of surface water into the pavement structure ultimately causing a deep-seated failure resulting from weakening of the lower layers of the pavement and of the sub-grade.

In pavement evaluation report of Snowy Mountains Engineering Corporation, Australia have confirmed that the original pavement design,according to the CBR methods, was structurally adequate for the re-evaluated best-estimate to traffic loads. The deflection checks however indicated that to some degree the Road Note methods appeared not to cater adequately for fatigue cracking of stiffer materials such as bituminous concrete and bitumen-penetration macadam. The deflection checks indicated be adequate under the re - evaluated best-estimate of traffic loads for somewhere in the range of 9 years to 17 years.

Khulna-Mongla Road is currently only serving light traffic as the two ferries, to be provided under the project for the Rupsa River crossing at Khulna, are yet to arrive and the port of Mongla has yet to be commissioned. Consequently, at this point in time, it is not possible to monitor the traffic, vehicle loads and the performamce of the pavement under these loads. These tasks will have to await the arrival of the ferries and the commissioning of the port.

7.2 Pavement Evaluation Methodology

"Construction of pavement without Bituminous contrete" highlighted what may be construed as a deficiency in the CBR pavement design methods of Road Notes 29 and 31, namely performance of pavement incorporating thick bound layers from a fatigue cracking viewpoint.

The Benkleman Beam was selected as the most appropriate means of evaluating the pavement by deflection criterion. The Transient Test Method, as detailed in TRRL laboratory Reports 835, 935 and LR 525 was adopted.

The methodology finally selected for evaluation of the condition of the pavement was that incorporated in the DMR[1/] (NSW) publication, pavement thickness Design, (M.R.Form 76). The timing of the investigation was considered of prime importance as it was viewed as vital to conduct the deflection testing at a time which most closely approximated the worst

1/ DMR = Department of Main Roads.

condition, that of the soaked condition. The 1983 Monsoon in the project area, was most severe with the rains beginnings in early May and continuing until the third week of october.The rainfall recorded in this period was 68.17 inches compared with the average of 60.74 inches. The Benkleman Beam survey commenced virtually the day the rains ceased and the prevailing on-shore or Southerly winds swung to the North. The deflections were thus recorded under, most probably, the worst conditions the pavement will have to endure during its service life especially considering the fact that the water proving surfacing, the primerseal, was not completed until well into the Monsoon. It can reasonably be assumed that the deflections recorded would in fact be maximum deflections.

Transient deflection tests were conducted at 100 ft. intervals for both wheelpaths in both carriageways. Adjustment of measured deflections are normally made to correct for moisture and temperature. As stated previously the investigation was conducted when the subgrade was at its weakest condition so no correction for moisture was considered necessary. It is interesting to note that the literature on the suliject. indicates that increases in deflections of over 60% can be expected from Dry Season measurements to Wet Season measurements.

The prevailing temperatures in October and November were very high and correction for temperature correction methods have been postulated for many different parts of the world. Some such methods examined were those for Kenya, Malaysia, Australia and the United Kingdom. Hundreds of Tests were carried out at selected locations at different times of the day and both deflection and temperature measurements were recorded. The method of correction of temperature which gave the best correlation with the conditions of the project was the method for Australia, where extreme variations in daily temperatures are recorded, especially in outback areas.

The measured deflections were corrected by dividing by a factor, F, where :

$$F = 1 + (T-25)Y \qquad \text{(i)}$$

Where, T is the pavement temparature at the time of measurement (at a specified depth to layer thickness).

Y is equal to 0.015 for bitumin macadam 150 mm (6 in.) thick.

The road was then divided into homogeneous sub-section based on the variation of deflections along the road. For the sake of convenience the road was analysed on a mile by mile basis and not from a deflection criterion.

The representative deflection was then determined for each mile of the road by the following equation which is approximately the 85 th. percentile value (Refer DMR-(NSW) publication):

$$dr = \bar{d} + S \quad .. \quad .. \quad \text{(ii)}$$

Where, dr = representative deflection

$\bar{d}$ = mean deflection

S = Standard deviation of the deflections in that mile or part thereof.

Table 7-1 presents the breakdown into homogeneous sub-sections.

Table 7-2 presents the statistical information for derivation of representative deflections.

Note : DMR = Department of Main Roads.

Table 7-1

SUB-SECTION BREAKDOWN

Sub-Section No.	Initial Point	Final Point
1	0 + 3000	1M + 1800
2	1M + 1800	1M + 2100
3	1M + 2100	2M + 3600
4	2M + 3600	3M + 0600
5	3M + 0600	3M + 2400
6	3M + 2400	3M + 3200
7	3M + 3200	4M + 0500
8	4M + 0500	5M + 0000
9	5M + 0000	5M + 1400
10	5M + 1400	5M + 4000
11	5M + 1400	5M + 4600
12	5M + 4600	5M + 4700
13	5M + 4900	5M + 5100
14	5M + 5100	6M + 0400
15	6M + 0400	6M + 1400
16	6M + 1400	6M + 4800
17	6M + 4800	7M + 1100
18	7M + 1100	7M + 4600
19	7M + 4600	8M + 0000
20	8M + 0000	8M + 0900
21	8M + 0900	8M + 2700
22	8M + 2700	9M + 1000
23	9M + 1000	9M + 3200
24	9M + 3200	9M + 3700
25	9M + 3700	(IOM) Rupsa West Ferry Terminal
26	Rupsa East Ferry Terminal	
27	10M + 000	11M + 0000
28	11M + 000	12M + 0000
29	12M + 000	13M + 0000
30	13M + 000	14M + 0000
31	14M + 000	15M + 0000
32	15M + 000	16M + 0000
33	16M + 000	17M + 0000
34	17M + 000	18M + 0000
35	18M + 000	19M + 0000
36	19M + 000	20M + 0000
37	20M + 000	21M + 0000
38	21M + 000	22M + 0000
39	22M + 000	End 0000

Source : Pavement Evaluation Report
i) Contracts Gc 1 & 2, Volume 1
ii) Contracts Gc 5 Volume 1.

Table 7-2

STATISTICAL PRESENTATION OF BENKLEMAN BEAM AVERAGE DEFLECTIONS PER SUB-SECTION

Sub-Section No.	Standard Deviation S	Mean Deflection d
1	0.1107208	0.5429166
2	0.1205703	0.6708333
3	0.1168635	0.6056984
4	0.101737	0.6019564
5	0.0[illegible]33148	0.5995833
6	0.0040871	0.6375
7	0.091606	0.6747845
8	0.0859518	0.6440624
9	0.0851946	0.5944642
10	0.0891015	0.7736538
11	0.089441	0.5870833
12	-	0.74
13	0.1725	0.94
14	0.1207211	0.5820832
15	0.1003894	0.7155
16	0.1517186	0.7346323
17	0.0747201	0.4782812
18	0.0980493	0.6303571
19	0.1250113	0.7092857
20	0.1206682	0.6394444
21	0.1072203	0.6197221
22	0.0707728	0.4527082
23	0.094772	0.6358522
24	0.0783279	0.858
25	0.0957431	0.751
26	-	-
27	0.1021772	0.675
28	0.1104587	0.654
29	0.0937999	0.677
30	0.1204722	0.639
31	0.0871495	0.560
32	0.09891	0.680
33	0.1191697	0.709
34	0.0968879	0.663
35	0.1609176	0.681
36	0.1178635	0.663
37	0.1163035	0.622
38	0.0967605	0.701
39	0.1021342	0.683

Source : Pavement Evaluation Report

i) Contracts GC 1 & 2

ii) Contracts GC 5.

In considering the evaluation by representative deflection of a section of pavement, the DMR (NSW) publication states "An improvement of drainage on a sub-section will normally result in lower deflections and, hence, a lower representative deflection. Unless a control section of pavement is set up.. to determine the effect of drainage improvement, no allowance in the final overlay design can be mode. The section will be probably over designed, and the reliability of the design will be higher than expected...... No deflection overlay method allows for improved conditions".

The above statement should be borne in mind when examining the results of the current evaluation. Improved drainage conditions will result from the completion of the primerseal as excess moisture present in the pavement layers and subgrade drains away with time and further surface moisture intrusion is prevented by the primerseal. A special design feature incorporated into Khulna-Mongla Road is the construction of drainage courses at 10 ft. centres on both sides of the road (except on the high side of superelevated curves) at subgrade level outletting through the shoulders. This special feature should accelerate the expected improved drainage and result in lower deflections for the service life of the road than were recorded in this investigation.

7.3 Analysis of Results

The recently developed NAASRA fatigue cracking deflection theory was used to evaluate the conditions of the pavement. This approach is conservative compared with the methods outlined in the Road Notes.

A further method of evaluation was examined in some detail; namely that of elastic theory. A statistically large sample of tests was carried out for each type of pavement material as well as subgrade material. The modulus of elasticity

Note: DMR = Department of Main Roads.

was then back-calculated for each type of material using Burmister's multi-layer elastic theory and allowable deflections at each level of construction were calculated. Table 7-3 sumarises the elastic theory results.

Table 7-3

MODULI OF ELASTICITY AND ALLOWABLE DEFLECTIONS FOR PAVEMENT [KHULNA-MONGLA ROAD] FROM ELASTIC THEORY

Layer / Item	Sub grade	Sub-base Ist layer	Sub-base 2nd layer	Water-bound base course	Bit macadam 1st layer	Bit macadam 2nd layer
Design Thickness cm (in)	-	12.7 (5)	12.7 (5)	10.16 (4)	6.35 (2.5)	6.35 (2.5)
Calculated Moduluses of Elasticity, E (kgf/cm^2)	214	1241	1241	3618	11904	11904
Allowable Deflection, da (mm)	5.0	3.7	2.3	1.4	1.2	1.0

Source : Pavement Evaluation Report, Vol.I, Snowy Mountains Engineering Corporation, Australia.

It will be seen later that the tolerable deflection from fatigue cracking theory is some 25% less than the allowable deflection (at top of pavement level) from elastic theory. Time may well demonstrate that the fatigue cracking approach is over - conservative , however it is considered appropriate at this stage to evaluate the pavement for the most stringent criteria.

The original pavement design was prepared for a pavement life which catered for 1.0 MESAL (one million equivalent standared axle loads) however the 1981 Pavement Design Review subsequently considered a best-estimate to traffic loads, after examination of the then new data, of 2.3 MESAL. This figure allows for a certain amount of overloading, comparative with similar roads in Bangladesh, however does not cater for the extreme overloading case as it was assumed that load controls will be implemented. The Review stated that, if overloading was permitted to continue unchecked, the road communication network of Bangladesh would be bankrupted rapidly.

At this stage it is pertinent to state that the construction of Khulna-Mongla Road posed some unique problems from a geotechnical view point. The road is located entirely within the tidal zone and traverses very recently deposited alluvial materials. The surrounding land, especially in the lower reaches, is inundated for the greater part of the year. There is a great scarcity of material suitable for embankment construction, however detailed materials searches and selective borrowing made it possible to construct an embankment which yielded the design subgrade CBR (soaked) value of 4% at 95% standard or proctor compaction. Extensive field and laboratory testing confirmed that the design subgrade CBR value was nearly right however the result was that the composition of the embankment (and subgrade) varies significantly along the road with some materials being for more susceptible to soaking than others. The breaking down of the road (first 9.7 miles) into 26 homogeneous subsections on a deflection basis highlights this and each subsection nearly perfectly coincides with changes in the nature of the subgrade material.

In the last 12.4 miles, the shortage of suitable embankment material was for more critical and for large areas, material had to be dredged from isolated pockets of sand (located by extensive materials searches) and pumped, in some cases will over a miles, for hydraulic placement as embankment.

Other unique, for Bangladesh, measures adopted on the project to overcome the difficult geotechnical conditions are listed below :

- the incorporation of a sand filter layer in the embankment to minimise the effect of capillary rise in the embankment.

- the incorporation of drainage courses at 10 ft. centres along the road except in sections of sand embankment, to improve pavement and subgrade drainage properties.

- the need to stage construct the high fill approaches to the bridges.

- the need to preload the embankments at the bridge sites to minimise the downdrage effects on the abutment pile groups.

- all embankments were constructed with a 10% height surcharge to accelerate the expected time dependent settlement so as to provide a stable road-bed prior to pavement construction.

- incorporation of settlement - plates along the road to enable monitoring of the settlement as it took place and assessment of when settlement was complete.

- the need to past-load many of the Khal crossings which were infilled and where it was not physically possible to compact the infill material. In the last 12.7 miles, area it was not economically feasible to post-load the rest number of khal crossings.

Now to evaluate the results of the Benkleman Beam deflection investigation, numerical charting of the deflection results for the four wheelpaths considered. Table 7-4, presents from equation (ii) and compares them with the toterable deflection for the pavement design as calculated from the NAASRA fatique cracking method, and with the allowable deflection from elastic theory.

Table 7-5 presents the number of years of service that can be expected from the pavement, based on fatigue cracking theory, against the accumulative equivalent standard axle loads for the best-estimate to traffic loads as recommended in the 1981 Pavement Design Review.

From Table 7-4, it can be seen that the whole first 9.7 mil section and the remaining 12.4 mile section of the pavement satisfy the allowable deflection of 1.0 mm. from elastic theory. Accordingly from elastic theory it can be concluded that a design life of 20+ years can be expected from the pavement.

Table 7-4

REPRESENTATIVE DEFLECTIONS

Sub-Section	Length of sub-section ft	Representative Deflection dr(mm)	Predicted Traffic Capacity (MESAL)	Predicted Pavement life (Years)
1	4080	0.65	3.8	26+
2	300	0.79	1.4	15
3	6780	0.72	2.3	20
4	2280	0.70	2.5	21
5	1800	0.68	3.0	24
6	800	0.71	2.4	20
7	2580	0.76	1.7	17
8	4780	0.72	2.3	20
9	1400	0.68	3.0	24
10	2600	0.85	1.0	12
11	600	0.67	3.2	25
12	100	0.74	1.9	18
13	200	1.11	0.3	6
14	580	0.70	2.5	21
15	1000	0.81	1.5	16
16	3400	0.88	0.9	12
17	1580	0.55	11.0	26+
18	3500	0.72	2.3	20
19	680	0.83	1.1	13
20	900	0.76	1.7	17
21	1800	0.73	2.1	19
22	3580	0.52	19.0	26+
23	2200	0.73	2.1	19
24	500	0.93	0.7	10
25	1540	0.84	1.1	13
26	-	-	-	-
27	5280	0.78	1.5	16
28	5280	0.76	1.7	17
29	5280	0.76	1.7	17
30	5280	0.75	1.8	18
31	5280	0.75	3.8	26+
32	5280	0.76	1.7	17
33	5280	0.81	1.3	14
34	5280	0.75	1.8	18
35	5280	0.85	1.0	12
36	5280	0.78	1.5	16
37	5280	0.73	2.1	19
38	5280	0.80	1.4	15
39	2900	0.78	1.5	16

Source : Pavement Evaluation Report.

i) Contract GC 1 & 2 (ii) Contract GC 5.

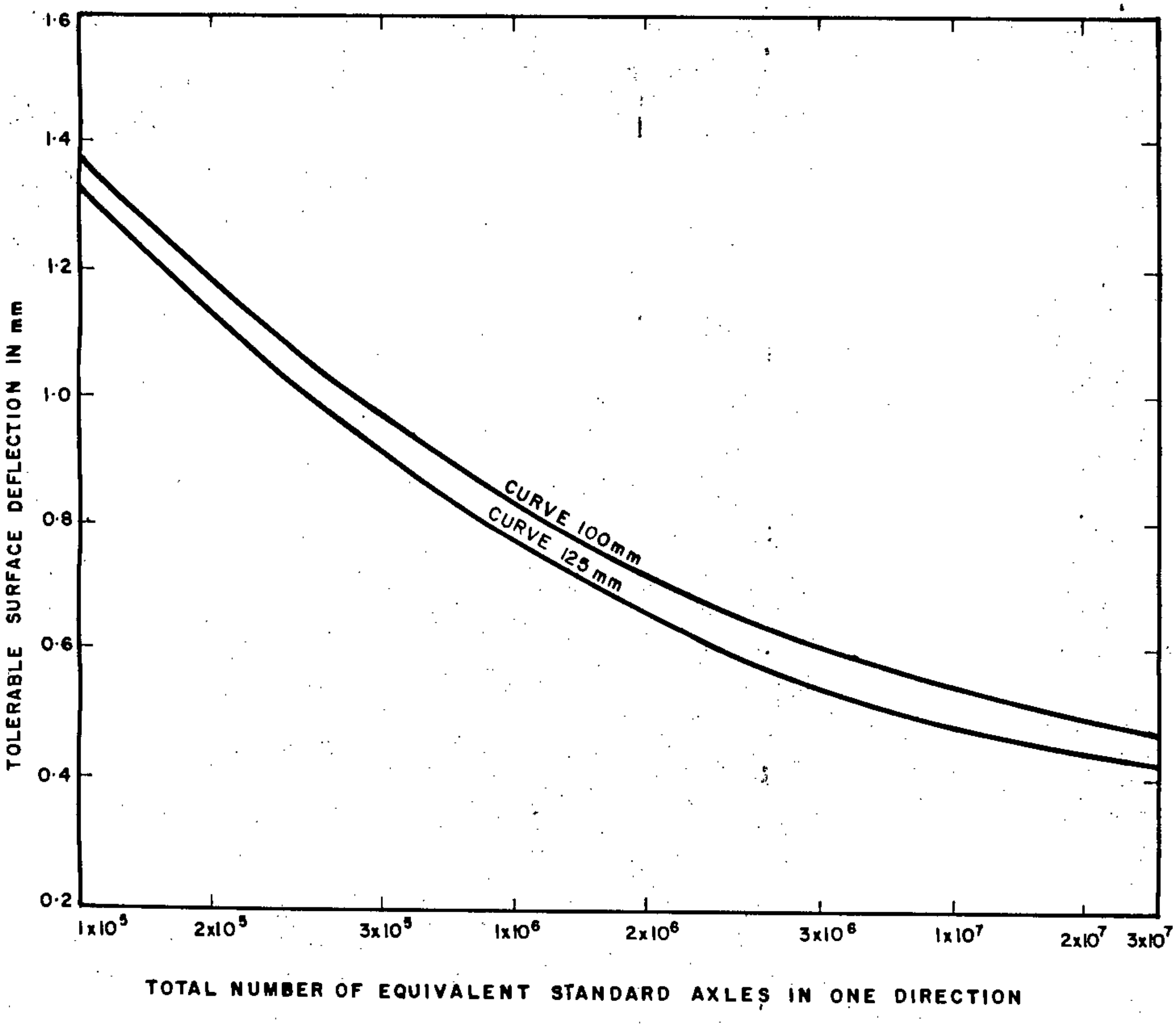
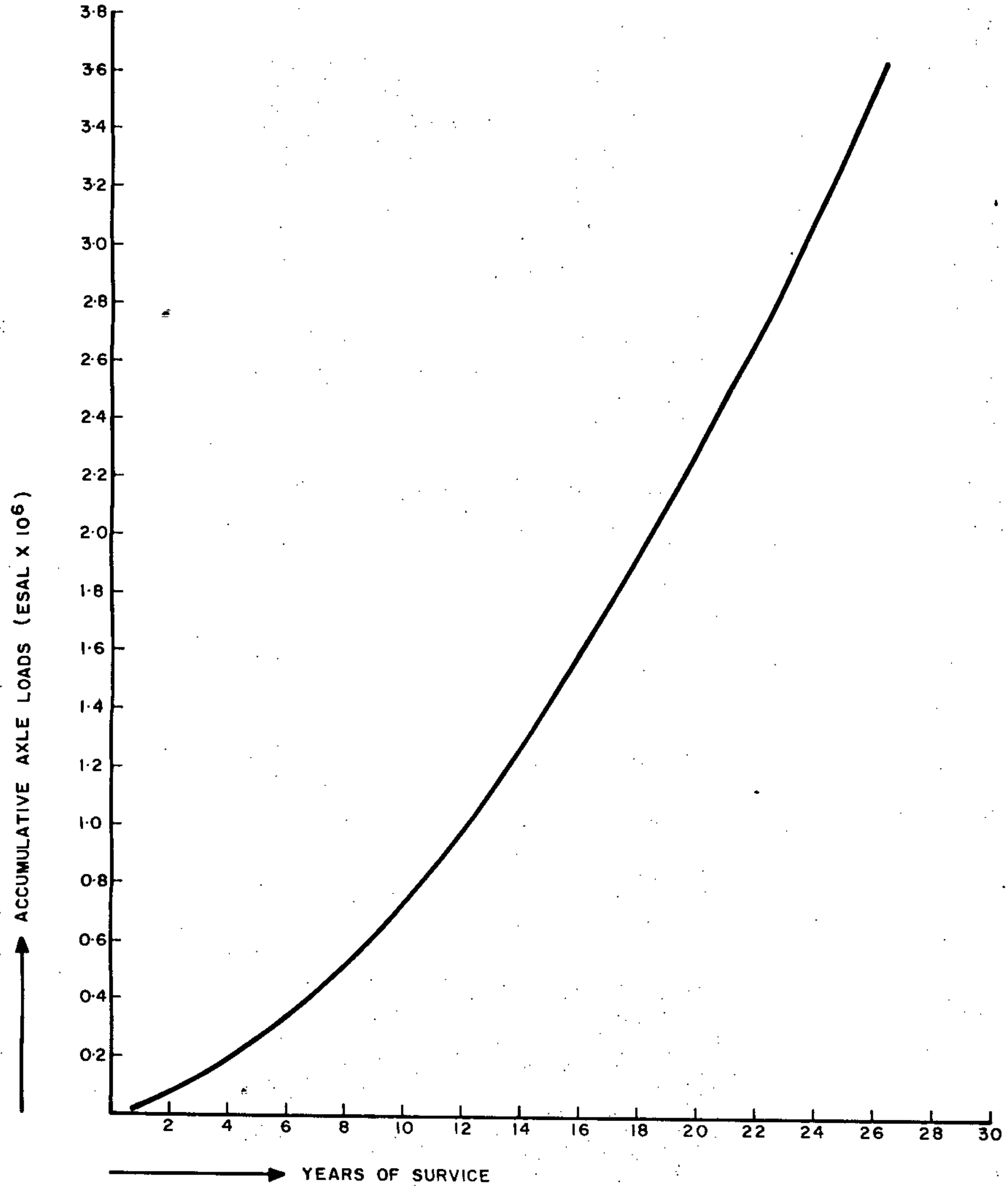


FIG. 6 MAXIMUM TOLERABLE DEFLECTIONS



3·8
3·6
3·4
3·2
3·0
2·8
2·6
2·4
2·2
2·0
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
ACCUMULATIVE AXLE LOADS (ESAL X 10^6)
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
YEARS OF SURVICE

Table 7-5

YEARS OF SERVICE (FROM TAFIGUE CRACKING THEOTY) AGAINST ACCUMULATIVE EQUIVALENT STANDARD AXLE LOADS (ESAL'S)

Year of Service	Accumulative Axle loads (Millions of ESAL'S)
1	0.034
6	0.332
11	0.861
16	1.593
21	2.493
26	3.598

Source : Pavement Evaluation Report.
Snowy Mojntains Engineering Corporation, Australia.

Table 7-6 summarises the findings from fatigue cracking theory (First 9.7 miles of the road pavement)

Table 7-6

SUMMARY OF FINDINGS FROM FATIGUE CRACKING THEORY (First 9.7 miles of the road pavement)

Predicted pavement life (years)	Percentage of Road with this predicted life
5-9	0.4%
10-15	15.6%
16-19	17.9%
20 +	66.1%

Table 7-6, summarises the findings from fatigue cracking theory (Remaining 12.4 miles of road)

Table 7-6

SUMMARY OF FINDINGS FROM FATIGUE CRACKING THEORY (Remaining 12.4 miles of road pavement)

Predicted pavement life (years)	percentage of Road with this predicted life
12-14	17.8%
15-19	74.4%
20 +	7.8%

The extensive sub-grade investigation programme ensured that the design sub-grade CBR was achieved prior to handing over of sections of embankment to the contractor for pavement construction.

Chapter 8

FINDINGS AND RECOMMENDATIONS

Findings

From the detail investigation of traffic and load data design methodology and pavement evaluation of Khulna-MOngla road it is resonable to conclude that the pavement design objectives will be achived with respect to both structural adequacy and pavement performance. Other major finding and observation are summarise are follows :

1) ESAL method of equivalent load calculation has been one of the best method for estimating the traffic load for pavement design because it takes into consideration both the number of vehicles and the loads of vehicles. For Khulna-Mongla road the average equivalence factors are estimated to be 0.21 ESAL/Truck, 0.03 ESAL/Bus and 0.0004 ESAL/Car or Jeep or Taxis.

2) On the basis of the equivalent factor as stated above the lower bound estimates for the accumulative equivalent traffic load are estimated to be 134×10^3, 266×10^3, 421×10^3 and 602×10^3 ESAL for design periods 1981-1986, 1981-1991, 1981-1996 and 1981-2001 respectively. The upper bound estimates for equmulative equivalent traffic loads for simillar periods are 141×10^3, 279×10^3, 442×10^3 and 632×10^3 respectively. Upper bound estimates of equivalent traffic loads differ from lower bound estimates by approximately 5%.

3) The estimated motor vehicle traffic on average daily basis is 1556 for the year 1981, the projected motor vehicle traffic for the 2001 is 3750 vehicles/day on average daily basis. This reflet on annual average growth of approximately 7%. In contruct the annual average growth of Non-motorise vehicle (bullock carts, bicycles etc) for Khulna-Mongla road is about 4%. Numerically, the quamtum of Non-motorise vehicle is 1193 for the year 1981 and 2154 for the year 2001.

4) The estimated export cargo to be handle by the Mongla port for the year 2000 is determine to be 1.0 million tons while the quentity of import cargo for the same year is determine to be the 2.0 million tons. Relative to the base year these reflect average annual growth of 2.2% for export cagro and 5.5% for import cargo.

5) Base on alternate pavement design the following pavement structure are selected for Khulna-Mongla road.

<u>First 9.7 miles of road</u> :

- Surface dressing (Primer - seal)
- 6" bitumen macadam compresing two equal layers
- 10" sub-base (Two equal layers)

<u>Remaining 12.4 miles of road</u> :

- Surface dressing (Primer - seal)
- 5" bitumen macadam (Two equal layers)
- 4" water bound macadam base course
- 10" sub-base (Two equal layers)

6) From an analysis of benkleman beam deflection estudies on the basis of elastic theory, a pavement life in excess of 20 years may be achieved.

From an analysis of benkleman beam deflection data on the basis of fatic cracking theory it is enticepited that the first 9.7-mile section of the pavement may achieved a life in excess of the RHD stipulated 10 years, with 84% of the road achieving in excess of 20 years life.

From fatigue cracking theory, the remaining 12.4 mile of the pavement may achieve a life in excess of the RHD stipulated 10 years, with 82.2% of the road achieving in excess of 15 years life and 7.8% achieving in excess of 20 years life.

Recommendations :

It has not been possible at this time to evaluate the accuracy of the projected best estimate to traffic loads as adopted from the 1981 pavement design as the port of Mongla has yet to be commissioned, the Road is only open to light traffic and the ferries for the Rupsa River crossing has not yet arrived. During the post construction pavement evaluation for the remaining portion of the Road, it is proposed, with the assistance of RHD to conduct traffic counts and axle load surveys to gain an initial impression of the accuracy of the 1981 projection. It will be worth while to do this type of survey on a regular and continuing basis throughout the service life of the Pavement to enable rational and scientific appraisal of when pavement will require to be strengthened.

As stated in the body of this report the best-estimate to traffic loads was adopted based on data available. It may be mentioned that Khulna-Mongla Road is ideally suited for implementation of traffic load controls since there is only one point of entry at Khulna and similarly at Mongla.

The pavement is expected to achieve the desired life providing load controls are implemented and the pavement structure is properly maintained in future. Bangladesh has obtained an infrastructural asset in Khulna-Mongla Road of high quality and standard and it would be unfortunate to see the huge capital investment wasted through lack of proper maintenance. The road has been designed so as to minimise maintenance needs however the two items detailed below warrant specific attention :

- the water proof surfacing adopted for Khulna-Mongla Road is a primerseal which is a technical innovation to Bangladesh. The finished product is very satisfactory and was achieved using labour- intensive methods. The cost of this type of surfacing is significantly cheaper than the conventional ½ inch thick seal coat,yet should achieve a similar life of 3-5 years. The surfacing should be maintained to prevent water intrusion into the pavement layers and soaking of the subgrade with the resultant weakening of the pavement and reduction in pavement life. It is recommended that inspections of the surfacing be carried out well in advance of each Monsoon and the necessary, repairs,if any be carried out to a similar standard. These inspection would also enable proper planning and budgetting for re-sealing when it becomes necessary.

- the road only traverses "high ground" in a few places and it is important that the table drains in these locations be maintained and cleaned on a regular basis. The drainage courses installed as a special feature for the road must not be obstructed. The outlets through the embankment batters are hidden from view (by grassing),however the local village people should be discouraged from placement of fill up against the road embankment for shops or other such purposes as such a practice would render the drainage courses ineffective. If such filling is considered desirable from a social view point, a table drain should be constructed between the road embankment and the filling with access provided by culvert pipes, bamboo bridges or similar structures.

Regular maintenance of a minimal nature should be carried out to maximise the life of Khulna-Mongla Road.

APPENDIX-A

BENKLEMAN BEAM

(a) Details of the Beam

The Beam has been named as Benkleman Beam after the name of its designer A.C.Benkleman. It is used in conjunction with a loaded lorry to measure the deflection of pavement. The beam has a long slender pivoted arm which can be placed between the dual rear wheels of a lorry.

The pivot is one third of the way along the beam and is carried by a frame which is supported on three adjustable legs. A dial guage is mounted on the frame in such a way that it measures movement of the toe of the beam resting on the road surface. The principle dimensions of the beam is given in the figure enclosed herewith. The beam can be split into two parts for ease of transportation and it is therefore essential that the connecting plates are tightly secured before use.

(b) The Loaded Lorry

(i) The specification adopted by the overseas Unit

For the deflection method used by the overseas unit of the Transport and Road Research Laboratory a two axle lorry, with twin wheels sets on each end of the rear axle, is loaded so that the load on the rear axle is (6350 kgf), equally divided between the twin wheel assemblies.

Blocks of dense concrete or boxed scrap metal are ideal materials for loading the lorry. It is important that the load should not be able to move, nor should it be capable of absorbing or trapping water which would cause the magnitude of the axle load to change.

The general dimensions and weights of the vehicles recommended for use are given the in the table below. The use of cross-ply tyres rather than radial tyres is recommended because it is normally easier to obtain correct gap between the walls of the tyres on the dual wheels with cross-ply tyres. If the tyres other than those recommended are used then the tyre pressures may have to be adjusted to achieve contact areas as indicated in the Table 1 below and Figure 2 enclosed herewith.

Table 1. Details of vehicles suitable for deflection testing

Characteristics	Specifications
Rear axle load	6350 kgf ± 5%
Dual wheel load	3175 kgf ± 5%
Front axle load	(2300-3300 kgf)
Wheel base	3.85 m (approx.)
Tyre size	7.50 x 20, 8.25 x 20 Preferred; 9.00 x 20 acceptable
Tyre pressure	85 psi
Gap between walls of dual rear wheels	25-40 mm (> 30 mm is recommended)
Gap between contact area of dual rear wheels	100-150 mm
Contract area of twin rear wheels	Similar to that shown in Figure 2.

(ii) Other Specifications

A common alternative to the specification as given in the above table involve the use of vehicles with a rear axle load of 8165 kgf, with consequently larger tyres. Care must be taken however not to confuse the deflection criteria applicable to one axle load with those applicable to the other. The advantage of using 6350 kgf rear axle load are that a smaller lorry can be used and running costs will be generally lower. With few exceptions the mangitudes of the deflections measured in the two cases are directly proportional to the wheel loads used.

(c) Methods of using the Benkleman Beam

Thre are two basic methods which are commonly used for operating the deflection beam

(i) The Transient Deflection Test

This type of test has been adopted for measuring deflections in the United Kingdom and is the method used by the overseas unit of the Transport and Road Research Laboratory in Developing countries.

The procedure is to mark the test point in the verge side wheelpath and to possition the lorry parallel to the road edge with its rear axle 1.3 m behind the test point. The Lorry is sligned such that when it mvoes towards the test point the test point bisects the distance between the tyres of the verge side dual wheels. With the lorry in the initial stationary position a deflection beam is positioned centrally between the dual rear wheels with its measuring toe resting on the test point, 1.3 m in front of the rear axle. By using the adjustable legs and the 'built in' spirit level the frame of the beam is levelled transversely and having checked the alignment of the beam and adjusted it if necessary, the locking system on the beam is released. Adjustment of the rear foot will ensure that the free end of the sunshade is clear of the beam and that there is adequate travel of the dial guage spindle to record the deflection.

The vibrator is switched on and the dial gauge scale is rotated until a reading of zero is indicated. After the completion of preparation for test, the lorry can be driven forward at creep speed to a point such that the rear axle is not less than 5 m beyond the test points. The time taken for the lorry to move the distance from the starting position should be between 9 to 11 seconds.

Sometimes during the period between setting the dial gauge to zero and the actually starting to move, the dial gauge reading may change slightly. It is recommended that this new reading is recorded as the initial reading rather than resetting the dial gauge to zero.

Records are kept of the initial maximum and final dial gauge readings. The difference between the initial and the maximum readings is proportional to the transient loading deflection and the difference between the maximum and final reading is proportional to the transient recovery deflection. Because the lengths of the arms of the pivoted beam are in the ratio of 2:1 the differences between the maximum and final reading is proportional to the transient recovery deflection. Because the lengths of the arms of the pivoted team are in the ratio of 2:1 the differences between the dial gauge readings must be doubled to obtain the actual deflection and recovery of the road surface. The transient deflection is the mean of the loading and recovery deflections in the transient test.

Two tests are generally carried out on each test point and the difference between the tests should be within limits recommended in the table given below.

Table 2 : Repreatability of duplicate deflection test

Mean deflection ($x\ 10^{-2}$ mm)	Maximum permissible difference between the two tests ($x\ 10^{-2}$ mm)
10	2
10-30	3
31-51	4
51-100	5
100	6

ii) <u>The rebound deflection test</u> :

The rebound deflection test differs from the previous test in that the dual wheels are positioned immediately above the test points and the toe of the beam is placed on the test point between the dual wheel. The beam is adjusted in the same manner as for the transient test and when the initial reading has been noted, the lorry is deiven forward at creep speed until the wheels are far enough away to have no influence upon the deflection beam. The final dial gauge reading is recorded and the rebound deflection can be influenced by the length of time during which the loading wheels are stationary over the test point. Care must be taken over the procedure used. The rebound test is not recommended by the overseas unit of the Transport and Road Research Laboratory for the following reason :

(i) In the rebound test with the wheels located directly over the test point at the start of the deflection test, greater plastic flow will be induced in susceptible materials because of the time during which the wheels remain stationary in this position. When the lorry is driven forward the road surface rebounds but an indeterminate amount of recovery of the displaced surfacing material can occur. There is thus no clear indication from the simple rebound test when plastic flow occurs.

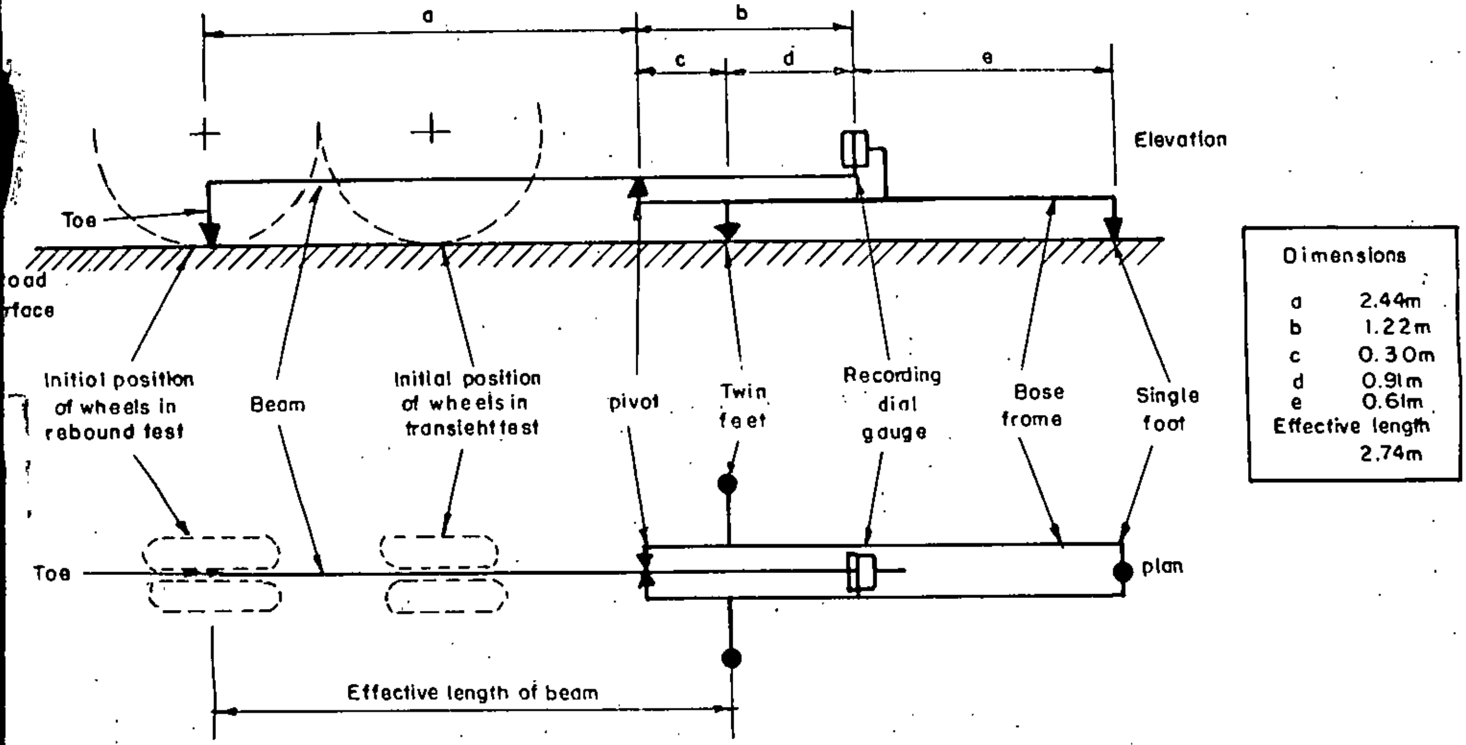
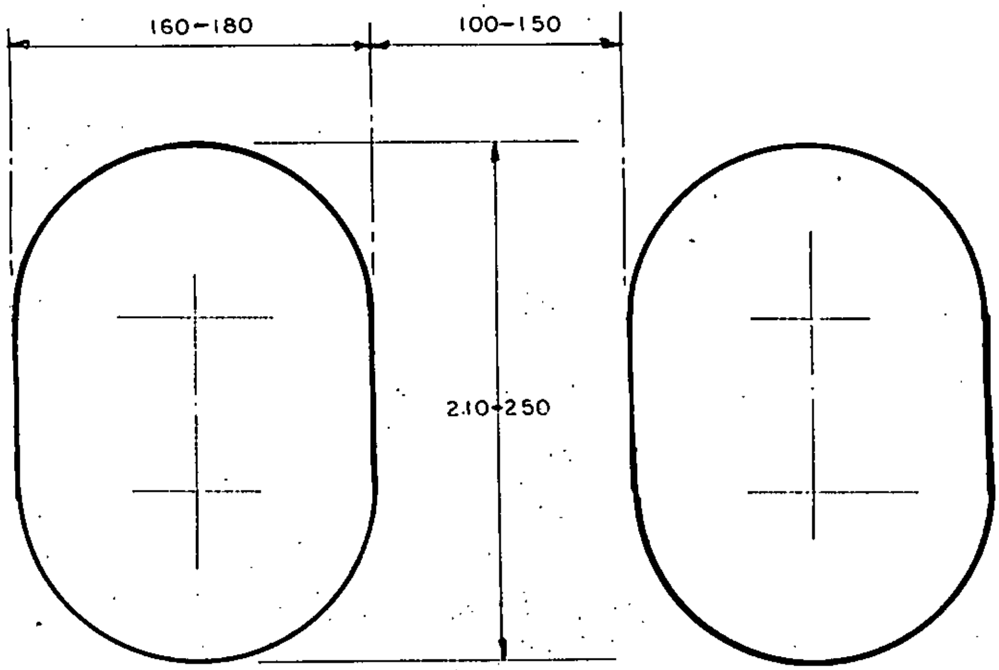


Fig. I DIAGRAMMATIC REPRESENTATION OF THE DEFLECTION BEAM



(Dimensions in millimetres)

Fig. RANGE OF DIAMENSIONS FOR THE CONTACT AREAS OF THE DEFLECTION LORRY TYRES.

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