



**Government of the People's Republic of Bangladesh  
Ministry of Communications  
Roads and Railways Division**

**Pavement Design Guide  
for  
Roads & Highways Department**

**April 2005**

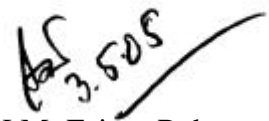
## Foreword

In order that all roads under the Roads and Highways Department are designed and built to appropriate high standards a series of RHD design guides and standards are being developed. This Pavement Design Guide, which has been prepared by RHD officers working in conjunction with the IDC3 Consultants, forms part of this series.

This Guide contains a straightforward procedure for the design of new flexible road pavements based on the cumulative number of Equivalent Standard Axles that the road will be subjected to during the required design life of the road. Standard pavement designs are included for both 3.7m and 5.5m roads whilst all other new road pavements, including the full reconstruction or widening of existing roads, should be designed in accordance with this Guide.

Where existing roads are to be partially reconstructed, or strengthened by means of an overlay, the requirement for these works will be included in the RHD Annual Roads Needs Assessment Report with typical details shown in the RHD Standard Drawings.

I wish to thank and commend all of the officers of the RHD involved in the preparation of this Guide which will go along way towards ensuring that consistent high quality road pavements are provided for an RHD roads in Bangladesh.



A.K.M. Faizur Rahman  
CHIEF ENGINEER  
Roads and Highways Department  
Sarak Bhaban, Ramna, Dhaka.

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### **APPENDIX 1: Standard Pavement Designs**

### **APPENDIX 2: Example of Pavement Design**

### **Glossary of terms and abbreviations used**

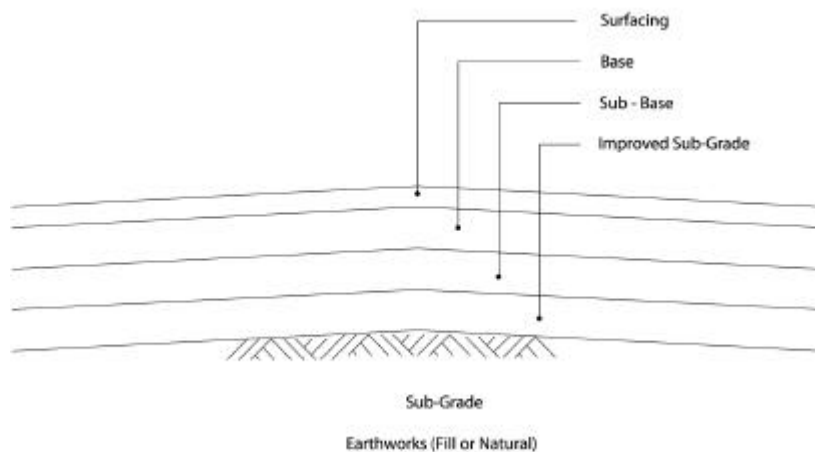
4WMV	4-Wheel Motorised Vehicle
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
BRRL	Bangladesh Road Research Laboratory
CBR	California Bearing Ratio
ESA	Equivalent Standard Axle
RHD	Roads and Highways Department
Standard Axle	8160 kg
TRL	Transport Research Laboratory
UK	United Kingdom

## 1 Introduction

The design of flexible road pavements is generally thought to be a specialist activity that can only be undertaken by consultants experienced in this type of design. Part of the reason for this may be that foreign consultants engaged on the design of road pavements in Bangladesh have tended to use design standards from their respective countries, or other international standards with which they are familiar.

This RHD Pavement Design Guide has been prepared based on two internationally recognized design standards, namely the AASHTO Pavement Design Manual and the TRL Overseas Road Note 31, with a view to making the design of road pavements as straightforward as possible and to ensure that the same standards are adopted for all RHD roads.

For roads that are intended to carry only low volumes of traffic standard pavement designs have been included, together with an easy to follow design procedure to identify the required thickness of the various pavement layers for other more heavily trafficked roads. In this respect, throughout this Guide the following descriptions have been adopted for these pavement layers:



**Surfacing** is the riding surface of the road and varies from a light bitumen spray with stone chippings (bitumen surface treatment) to one or more layers of dense bitumen surfacing.

**Base** is the main load-spreading layer of the road pavement. It must be constructed of high quality brick or stone aggregate.

**Sub-base** is the secondary load-spreading layer of the pavement. It is usually either crushed stone, broken brick aggregate (frequently mixed with sand) or locally available gravel.

**Improved Sub-grade** is imported material (e.g. fine or coarse sand) that is locally available. It is intended to act as a cushioning layer between weak sub-grades and the road pavement layers. If the sub-grade is of sufficient strength (i.e. CBR value) then an improved sub-grade may not be required.

**Sub-grade** is the soil immediately beneath the road structure. It is a layer of natural locally available material that meets the requirements of RHD Technical Specifications.

## 2 Pavement Design

### 2.1 Principles of Design

Natural ground, including earth embankments, cannot support the wheel loads of vehicles - particularly when wet. The purpose of a road pavement is to distribute and spread wheel loads through to the underlying ground (i.e. the sub-grade) via pavement layers of the required thickness and strength such that each layer can support the load transmitted from the layer immediately above it without deformation.

The strength of each layer is expressed in terms of the California Bearing Ratio (CBR) and it is essential that the materials used, and compaction obtained, for each layer achieves the required CBR for that layer. If the underlying layers do not have the required CBR then the upper layers of a road pavement will fail even if they have been correctly constructed.

The CBR requirements for the various pavement layers are contained in the RHD Specification and are summarized as follows:

Pavement Layer		CBR	RHD Specification Clause
Aggregate Base	Type I	$\geq 80\%$	3.3.2
	Type II	$\geq 50\%$	3.3.2
Sub-base		$\geq 25\%$	3.2.2
Improved Sub-grade		$\geq 8\%$	2.8.2
Sub-grade		$\geq 5\%$	2.7.2
Embankment fill/natural ground		$\geq 3\%$	2.6.2

**Table 1: Required CBR for Pavement Layers**

Reference should be made to the RHD specification for the materials, workmanship and testing procedures that should be adopted to achieve the above CBR values.

Standard pavement designs for 3.7m and 5.5m roads are shown at Appendix 1. All other road pavements require to be designed with the thickness of the various pavement layers, including the bituminous surfacing, being determined by estimating the cumulative number of Equivalent Standard Axles (ESAs) that the road will be subjected to over its design life, and then reading off the required thickness for each layer from the design chart included at Table 5. An example of a pavement design based on this method is included at Appendix 2.

### 2.2 Design Procedure

#### *Base Year Traffic Counts*

For both the geometric and pavement design of new roads, or the upgrading / widening of existing roads, traffic counts must be undertaken to establish the current Average Annual Daily Traffic (AADT) on the road. At least one whole day (24 hour) traffic count in both

directions of flow should be undertaken on a typical weekday for sections of the road having more or less the same traffic volumes.

For geometric design purposes the forecast traffic demand for the road in the design year should be estimated expressed in passenger car units (PCUs). This determines the required capacity or width of the road and details of this design procedure are contained in the RHD Geometric Design Manual.

For the design of road pavements a different approach is adopted in that an estimate must be made of the cumulative number of heavy axle loads that the road pavement will be subjected to over its design life. In this cars, rickshaws and other light traffic may be ignored with only trucks and other commercial vehicles being considered.

For single carriageway roads the average truck and commercial vehicle flow in both directions is adopted for design purposes i.e. 0.5 x the sum of both directions. For dual carriageways, where trucks may be more heavily loaded in one direction than the other, the pavement for each carriageway should be subject to a separate design based on the forecast commercial traffic for that carriageway (heaviest loaded lane).

*Design Life and Traffic Growth Rates*

For new roads and the full depth reconstruction of existing roads the following design standards are to be adopted:

	<b>Pavement Design Life</b>	<b>Traffic Growth Rate</b>
<b>National Road</b>	20 years	10% pa
<b>Regional Road</b>	20 years	7% pa

**Table 2: Pavement Design Life and Traffic Growth Rates**

Where a new or reconstructed road is likely to lead to a significant generation or diversion of traffic, detailed traffic studies should be undertaken to estimate the additional traffic that will use the road in addition to the estimated base flow.

*Determining Cumulative ESAs Over the Pavement Design Life*

For pavement design purposes all heavy commercial vehicles are expressed in terms of the equivalent number of standard axles that they represent. A Standard Axle is taken to be 8,160 kg. Based on axle load studies previously undertaken in Bangladesh, the following equivalence factors have been determined:

<b>Vehicle Category</b>	<b>Equivalence Factor</b>
Large Truck (dual axle)	4.8
Medium Truck (Single axle)	4.62
Small Truck	1.0
Large Bus	1.0
Mini Bus	0.5

**Table 3: Vehicle Equivalence Factors**

Using the recorded (or estimated) AADT for the above vehicle categories together with their equivalence factors, estimates should be made of the current daily ESAs for the road. This should then be multiplied by 365 to obtain the annual ESAs for the road.

To obtain the cumulative ESA loading over the design life of the road, the current annual ESA loading should be multiplied by one of the following factors:

Road Type	Factor
National Road	57.3
Regional Road	41.0

**Table 4: Cumulative Growth Factors**

The above factors have been derived from the following compound growth formula:

$$\text{Cumulative ESA} = \frac{(1 + r)^n - 1}{r} \quad \text{where } r = \text{annual traffic growth rate}$$

$$n = \text{design life in years}$$

(Note: For National Roads  $r = 10\%$  and  $n = 20$  years; For Regional Roads  $r = 7\%$  and  $n = 20$  years)

*Determination of Pavement Layers*

The estimated cumulative ESAs are then used to determine the various pavement layers from the following design chart:

mm Traffic ESA (mill)	Surfacing (mm)		Roadbases (mm)* (Select one type)			Sub-bases (mm)** Subgrade CBR %				
	Asphalt Wearing Course	Asphalt Base- Course	Cement- bound Granular	Granular Base Type I    Type II		5	8 - 25	> 25		
	60 - 80	↓	155	↓ Refer to BRRL for design advice	N/A	N/A	300	150	0	
40 - 60	140		↓		↓	↓	↓	↓	↓	
30 - 40	125		↓		250	300	250	↓	↓	
25 - 30	110		↓		↓	↓	↓	↓	↓	
17 - 25	105		↓		↓	↓	200	↓	↓	
15 - 17	95		↓		↓	↓	↓	↓	↓	
11 - 15	90		↓		↓	↓	↓	↓	↓	
9 - 11	80		↓		↓	↓	↓	↓	↓	
7 - 9	70		↓		↓	↓	↓	↓	↓	
6 - 7	65		↓		↓	↓	↓	↓	↓	
5 - 6	60		↓		↓	↓	↓	↓	↓	
4 - 5	55		↓		↓	↓	↓	↓	↓	
3 - 4	45		↓		↓	175	200	175	↓	↓
< 3	35		↓		↓	150	175	150	↓	↓

\* CBR of granular base type I is min. 80%      N/A. = not applicable  
\* CBR of granular base type II is min. 50%  
\*\* CBR of sub-base material is 25%

**Table 5: Thickness Design Table for Flexible Pavements**

*Determination of Improved Sub-grade Thickness*

It can be seen from the foregoing design chart that it assumes a minimum sub-grade strength of 5% CBR. In Bangladesh, apart from higher ground within the Chittagong Hill Tracts where in situ CBRs will be higher, most roads are constructed on embankments that will have a CBR of less than 5%. Under these circumstances an improved sub-grade layer should be provided as follows:

CBR Required	Compacted Thickness of additional layer to provide required CBR			
	CBR of Underlying layer			
	2%	3%	4%	5%
5%	250 mm	150 mm	100 mm	-

**Table 6: Improved Sub-grade Requirements**

In all cases, sub-grade material with a CBR of less than 2% should be removed and replaced with fill material complying with Section 2.6 of the RHD Specification

**3. Drainage Design**

*Freeboard*

Much of Bangladesh is subject to flooding on an annual basis, and occasionally this flooding is of a severity that results in parts of the road network being inundated. Understandably traffic, and in particular heavy commercial vehicles, continue to use these roads and this can result in severe damage being done to the road pavement.

Accordingly, in the design of new roads or full reconstruction of existing roads the freeboard to the lowest edge of the pavement surface, above Highest Flood Level (HFL) (50 year return period for National and Regional Highways and 20 year return period for District (Zila) Roads), shall be at least the values shown in the table below, and in any event the Formation Level (top of sub-grade level) should be at least 30 cm above HFL.

Road Type	Freeboard (m)
Dual 1 carriageway	1.0
7.3 m carriageway	1.0
6.2 m carriageway	1.0
5.5 m carriageway	0.9
3.7 m carriageway	0.9

**Table 7: Freeboard**

In view of the foregoing all RHD Divisions should determine the HFL for the 50 and 20 year return period within their Division, and record this by means of permanent marks on an outer wall of the Divisional offices or other Government building within the Division.

### *Sub-grade Drainage*

To prevent rapid deterioration of the pavement layers and to maintain the sub-grade at or above the design strength it is essential to allow all water entering the pavement layers to drain away as quickly as possible. [Standing water in the pavement layers will cause a reduction in strength and result in high pore-water pressures under traffic loading that will lead to surface disintegration.]

Where full depth pavement construction is being undertaken incorporating an improved sub-grade (i.e. a sand layer) this should be extended for the full width of the embankment such that it can act as a drainage layer.

Where only partial reconstruction is being undertaken, or only the provision of hard shoulders, sub-grade drains should be provided between the existing road pavement and the edge of the embankment as detailed in the RHD Standard Drawings.

### *Surface Water Drainage*

The road surface should be designed to shed water as quickly as possible during rain. Standing water is both a serious traffic hazard and will eventually soak through the pavement layers, weakening its structure. Key design considerations are as follows:

- A good surface drainage requires an impermeable surface. This will be achieved through meeting the RHD Specification for surfacing materials and through carrying out sufficient planned maintenance.
- The surface must be laid to the correct camber and falls and low spots should be avoided.
- Unpaved shoulders should generally have a steeper camber than the road pavement (e.g. 5%) with a small step (e.g. 25-38 mm) between pavement and shoulder.
- Rural roads in cuttings should include a side ditch a minimum of 1m deep with culverts provided through access roads to ensure the ditch is continuous.

Where existing roads pass through villages or bazaars it is frequently the case that they require full or partial reconstruction. Almost invariably the deterioration of these roads is a direct result of inadequate surface water drainage, either because such drainage was not provided in the first place or because the drainage facilities that are there are blocked due to lack of maintenance.

In any event where roads pass through villages, bazaars and other locations where there is frontage development they should be provided with positive surface water drainage with a longitudinal gradient of not less than 0.3% to an outfall. This drainage must be maintained and regularly cleaned as part of the routine maintenance of the road.

### *Cross Drainage*

Where embankments are, or have been, constructed they may obstruct the natural passage of water at ground level. In effect this means that the embankment can act as a dam and cause localized flooding.

To prevent this, in addition to the provision of bridges and culverts where embankments cross existing water courses, cross drainage structures in the form of 1m diameter pipe culverts should be provided at regular intervals. Typical details for pipe culverts are contained in the RHD Standard Drawings.

#### **4. Partial Reconstruction of Roads and Pavement Strengthening**

##### *Partial Reconstruction*

Where existing roads require partial reconstruction these will have been identified in the RHD Annual Roads Needs Assessment Report. The type of partial reconstruction that is required will differ for Zilla roads and National / Regional roads, and for the latter whether they are high or low volume traffic routes.

Typical details for the various types of partial reconstruction are contained in the RHD Standard Drawings and these should be adopted wherever partial reconstruction is to be undertaken.

##### *Pavement Strengthening*

An existing road pavement that is in otherwise good condition may require strengthening to extend or maintain its design life. Frequently this takes the form of a bituminous overlay, the thickness of which being a function of the forecast ESA loading and the condition of the existing road.

Here again the strengthening requirements will be identified in the RHD Annual Roads Needs Assessment Report and no design by the Divisions will be required.

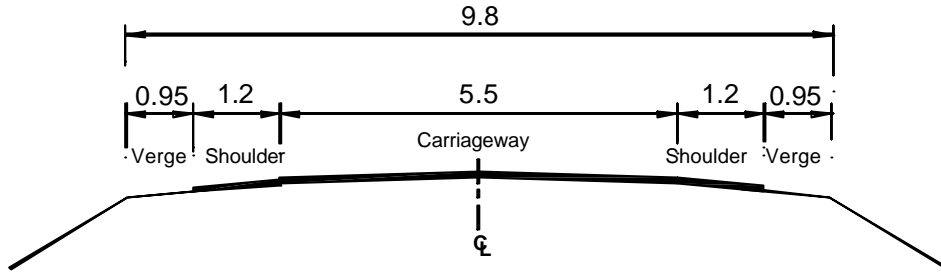
#### **5. Strategic Roads**

These design standards are a simplified version of the international standards upon which they are based. As such they will be appropriate for the design of road pavements for the majority of the roads in Bangladesh.

However, for strategic roads in the National Road network that will be subjected to very high traffic flows these Standards may only be used as a guide to the pavement design. In all such cases these roads must be designed in accordance with the AASHTO Design Manual or Overseas Road Note 31 as appropriate.

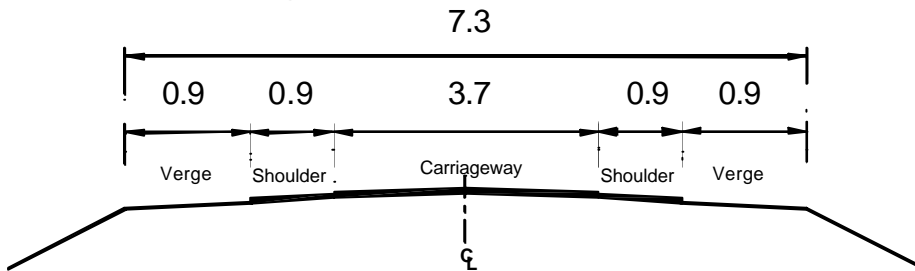
## Appendix 1: Standard Pavement Designs

### Type 5: 5.5m Carriageway



	40mm bituminous carpeting + 12mm seal coat				
	200mm base Type 1				
	200mm sub-base				
	improved sub-grade (see table for thickness)	Existing Subgrade CBR	Improved Subgrade (mm)		
		3%	300		
		4%	250		
		5%	200		

### Type 6: 3.7m Carriageway



	40mm bituminous carpeting + 7mm seal coat				
	150mm base Type 1				
	150mm sub-base				
	improved sub-grade (see table for thickness)	Existing Subgrade CBR	Improved Subgrade (mm)		
		3%	300		
		4%	250		
		5%	200		

## Appendix 2: Example of Pavement Design

**Background:** An existing 6.2m Regional Road that is located on an embankment requires full reconstruction. A check has been made and the existing road surface is 1.0m above the Highest Flood Level for a 50 year return period. Accordingly the embankment does not require to be raised.

A number of trial pits were undertaken and the CBR of the sub-grade beneath the existing road was found to be 3%.

A 24 hour classified traffic count was carried out on a typical weekday.

### Design:

Half of the two-way flow of commercial vehicles is used to determine the cumulative ESAs over the design life of the road as follows:

	Existing Flow / day (0.5x two-way flow) (a)	ESA Factor (b)	Existing ESAs / day (a) x (b)	Annual ESAs (a) x (b) x 365
Heavy truck	20	4.8	96	35,040
Medium truck	150	4.62	693	252,945
Light truck	50	1.00	50	18,250
Large bus	100	1.00	100	36,500
			<b>Total</b>	<b>342,735</b>

By reference to Table 4 and using the appropriate factor for a Regional road the cumulative ESAs over the design life for the road will be:

$$342,735 \times 41.0 = 14 \text{ million ESAs}$$

By reference to Table 6 an improved sub-grade will be required to achieve a sub-grade strength of 5% CBR and by reference to the design chart in Table 5 the required pavement layers will be:

- 130 mm DBS (40mm wearing course + 90mm base course)
- 250 mm Base Type 1
- 200 mm Sub-Base
- 300 mm Improved sub-grade