National Highways & Infrastructure Development Corporation Ltd

(Ministry of Road Transport and Highways)

PROJECT

Four Laning of NH-37 from End of Moran Bypass (km 562.525) to Bogibeel Junction near Lapetketa (km 581.700) in the state of Assam under SARDP-NE, Phase 'A' on EPC mode- Balance Work

Revision: R0

PAVEMENT DESIGN REPORT

(January 2019)

Four Laning of NH-37 from End of Moran Bypass (km 562.525) to Bogibeel Junction near Lapetkata (km 581.700) in the state of Assam under SARDP-NE, Phase 'A' on EPC mode- Balance Work

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Pavement Design Report

1. General

The Government of India has entrusted to the National Highways & Infrastructure Development Corporation Ltd (NHIDCL) for the development, maintenance and management of National Highway No. 37 (NH-37) in the State of Assam.

The Project Road is a part of National Highway NH-37 which starts at km 562.525 to km 581.700 (approximately 19.078 km) on the End of Moran Bypass (km 562.525) to Bogibeel Junction near Lapetketa (km 581.700) in the state of Assam. M/s Manaranjan has been awarded the project on Engineering, Procurement and Construction (EPC) basis through Competitive Bidding process.

This report pertains to the design of pavement structure comprising design process and design recommendations for Flexible Pavement for the Main Carriageway along with Truck Lay Bye and Bus Bays.

2. Brief Review of the EPC Agreement

This section presents a review of the Contract Agreement (CA), including its Schedules to establish contractual framework for pavement design. From the review of various articles / clauses of the CA and its schedules, the key details / provisions are summarized below:

The CA stipulates under sub-clause 5.3.1 & 5.3.2 of Schedule B (i.e. design period and strategy, & design traffic) that the pavement of the Project Highway shall be designed for 15 Years and for traffic loading of 60 million standard axles (MSA) and under Clause 5.4 the entire project road shall be reconstructed.

As per Schedule B (Clause 5.1) and Annex-I of Schedule D of CA, the pavement design shall be carried out as per the provisions of Section 5 of the Manual of Specifications and Standards for Four-Laning of Highways (IRC: SP: 84-2014). IRC: SP: 84-2014 refers to the following IRC guidelines for pavement design:

- IRC: 37- 2012 (Tentative Guidelines for the Design of Flexible Pavements)

3. Project Background

The project involves upgradation of existing two road to four-laning with paved shoulder for the section of NH-37 from end of Moran Bypass to Bogibeel Junction near Lapetketa. The present width of the carriageway varies from 5.4m to 7m and the existing pavement is flexible.

4. Objective

The objective is to select the suitable pavement type requiring minimal maintenance under the given traffic loading for the design life adopted. To achieve this objective and thereby to predict the performance of any pavement structure, it is necessary to analyse material characteristics, traffic, local environment and its impacts, modes of failure of existing pavement and technology available for construction.

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5. The Approach of Pavement Design

To have sound engineering judgment considering the local environment and past pavement performance in this region and analysis for 15 years design life, all activities related to field surveys, materials investigations have been done as per relevant good industry practice. The attempt has been made to work out the design of pavement structure as prescribed in IRC Guidelines IRC: 37-2012.

The goal of the pavement design is to optimize the road construction technically and economically on long term basis, based on the pavement investigation and given traffic loading. Hence, a few pavement options have been studied before proposing the pavement section presented in due course.

6. Effective Subgrade CBR

Reference to evaluate effective CBR is drawn from clause 5.2 of IRC: 37-2012. Soil sample for conducting CBR test is taken at every 5km interval and analysis is done. Soil sample of soil below 500mm from top of subgrade soil is collected at every 5km interval and testing is done for CBR of embankment while subgrade sample is taken for its CBR analysis. According to IRC:37-2012, 90th percentile CBR is considered for analysis and the summary is shown below:

Table 1. CBR of Embankment and Subgrade

Location	CBR of Embankment	CBR of Subgrade
1	9.7	10.33
2	9.9	10.69
3	8.2	10
4	9.7	10.8
5	9.26	10.86
6	8.37	10.69
7	9.4	10.86
8	10.3	11.04
9	9.26	11.04
10	9.99	10.33
11	9.8	10.15
12	9.9	10.3
13	9.9	10.7
14	8.37	10.69
15	9.2	10.5
16	9.08	10.68
17	8.727	9.99
18	10.15	10.57
19	9.26	10.3

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Table 2. CBR of Embankment and percentile

Location	Ascending order CBR of Embankment	Percentile
3	8.2	100
6	8.37	95
14	8.37	89
17	8.727	84
16	9.08	79
15	9.2	74
5	9.26	68
9	9.26	63
19	9.26	58
7	9.4	53
1	9.7	47
4	9.7	42
11	9.8	37
2	9.9	32
12	9.9	26
13	9.9	21
10	9.99	16
18	10.15	11
8	10.3	5

Table 2. CBR of Subgrade and percentile

Location	Ascending order CBR of Subgrade	Percentile
17	9.99	100
3	10	95
11	10.15	89
12	10.3	84
19	10.3	79
1	10.33	74
10	10.33	68
15	10.5	63
18	10.57	58
16	10.68	53
2	10.69	47
6	10.69	42
14	10.69	37
13	10.7	32
4	10.8	26
5	10.86	21
7	10.86	16
8	11.04	11
9	11.04	5

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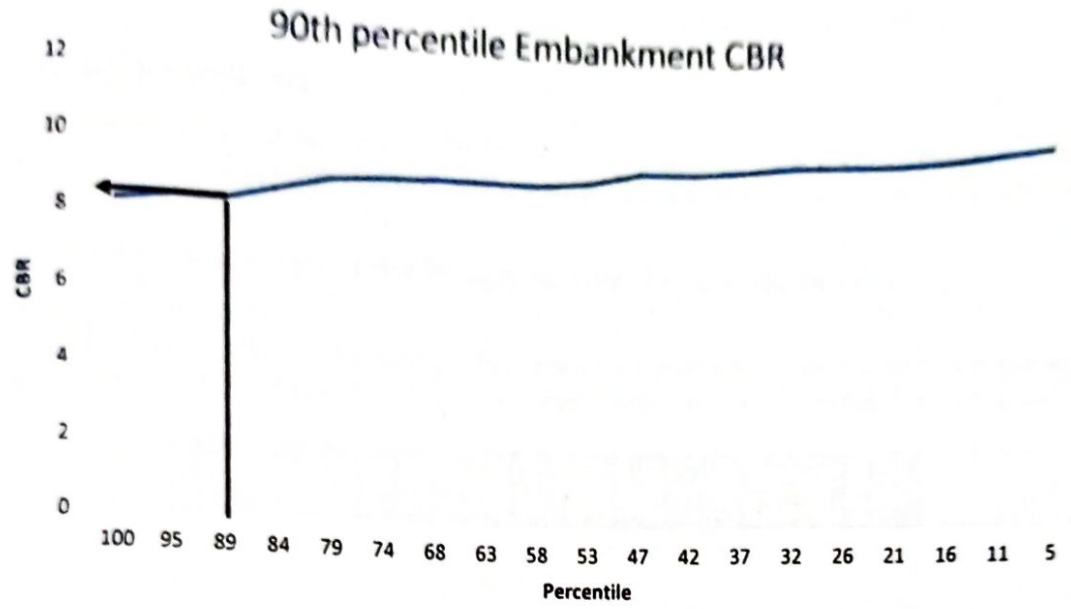
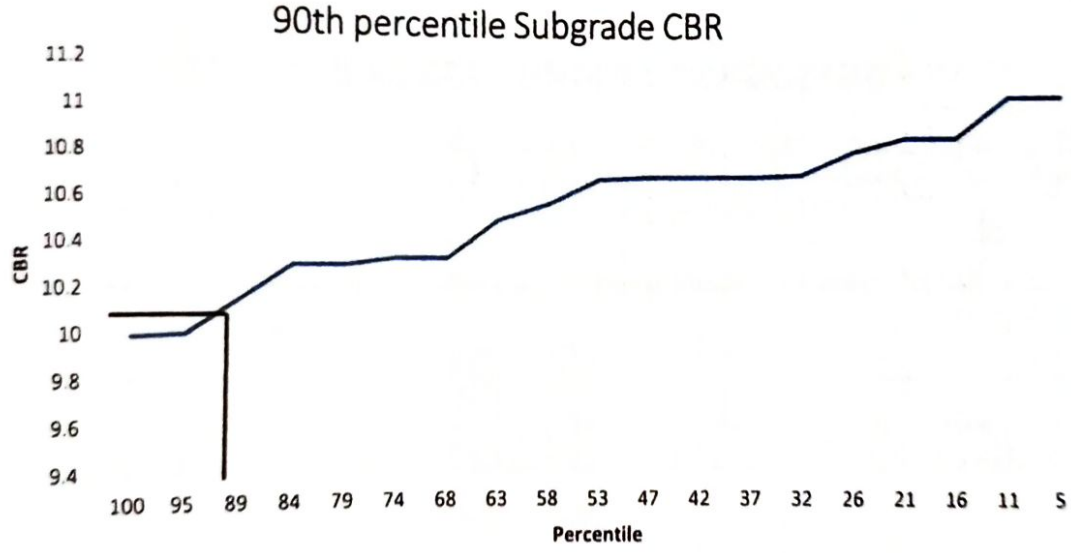




From the above tables and graphs, it is observed that 90th percentile Effective CBR is 9.25% but for pavement design purposes, an effective CBR of 9 % is adopted.

7. Pavement Thickness Design

The scope of pavement design for the project includes:

- Upgradation of existing pavement from 2-lane to 4-lane with paved shoulder
- Construction of Service Road.
- Construction of Truck Lay Bye and Bus Bays.

The new flexible pavement is designed in accordance with IRC: 37- 2012 for the main carriageway, service road, and truck lay bye and bus bays. VG-40 grade of bitumen is adopted. The Calculation and IIT PAVE results of the New Pavement have been given hereunder.

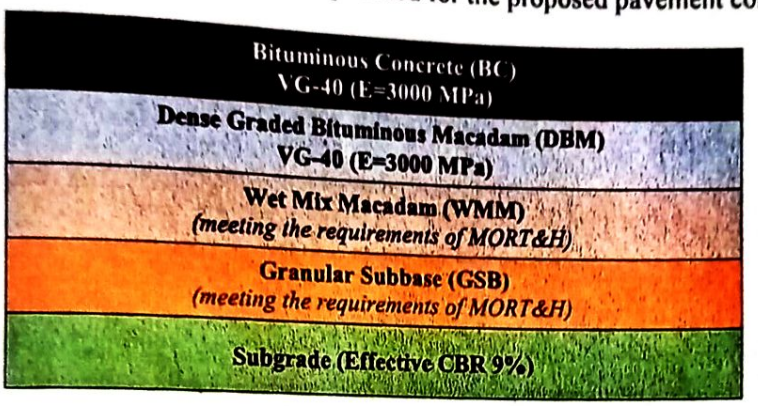
7. 1. Pavement Design Life

The EPC Agreement stipulates that the flexible pavement shall be designed in accordance with the Manual IRC: SP: 84-2014 for minimum design period of **15 years** and design traffic of **60 MSA**.

7. 2. Pavement Thickness for Main Carriageway, Truck Lay Bye and Bus Bays

Materials for Pavement

As per IRC: 37-2012, there is variation in the bituminous surfacing material with variation in the design traffic. The following materials are specified for the proposed pavement composition.



Reference is drawn to the record of temperature of the project region obtained from http://www.imdagrimet.gov.in/temperature_monthly_archive?page=4, whereby, the Annual Average Pavement Temperature (AAPT) falls well within the limit of 35°C.

Analysis of Pavement Section as per Layered Elastic Theory & IRC-37

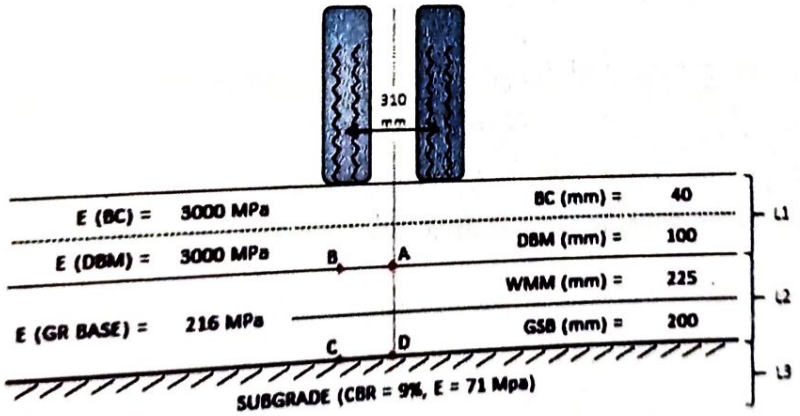


Figure 1- Proposed Pavement Composition

INPUT FOR IITPAVE SOFTWARE:

Number of layers (n)	3
Elastic Moduli (E), in MPa	3000 216 71

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Poisson's Ratio (μ)	0.35 0.35 0.35
Thickness of Layers (h), mm	140 425 700
Single Wheel Load (N), Tyre Pressure (kPa)	20000.00 0.56
Number of points to be considered	4
Co-ordinate of Point "A"	140 0.000
Co-ordinate of Point "B"	140 155.000
Co-ordinate of Point "C"	565 0.000
Co-ordinate of Point "D"	565 155.000

CHECK FOR FATIGUE CRITERIA:

Bituminous surfacing of pavements display flexural fatigue cracking if the tensile strain at the bottom of bituminous layer is beyond certain limit.

Points "A" and "B" are the critical locations for tensile strains (e_t). Maximum value of the strain is adopted for design.

As per IRC-37-2012:

$$N_F = 2.021 \times 10^{-4} \times [1/e_t]^{3.89} \times [1/E]^{0.854}$$

Where,

N_F = Fatigue life in number of standard axles

e_t = Maximum tensile strain at the bottom of Bituminous layer

E =Resilient Modulus of bituminous layer (MPa)

CHECK FOR RUTTING CRITERIA:

Points "C" and "D" are the critical locations for the vertical subgrade strains (e_z). Maximum value of the strain is adopted for design.

AS per IRC-37-2012:

$$N_R = 1.41 \times 10^{-8} \times [1/e_z]^{4.5337}$$

Where,

N_R = Number of cumulative standard axles

e_z = Vertical subgrade strain

Output of IIT Pave:-


```
No. of layers                    3
E values (MPa)                3000.00  216.00   71.00
Mu values                        0.350 350.35
thicknesses (mm)               140.00  425.00
single wheel load (N)  20000.00
tyre pressure (MPa)              0.56
Dual  Wheel
  Z        R        SigmaZ          SigmaT          SigmaR          TaoRZ           DispZ           epZ             epT             epR
140.00     0.00-0 1143E+00 0 7416E+00 0 6961E+00-0 1684E-01 0 3932E+00-0 1939E-03 0 1912E-03 0 1248E-03
140.00L    0.00-0 1143E+00-0 3723E-02-0 1433E-01-0 1684E-01 0 3932E+00-0 4990E-03 0 1912E-03 0 1249E-03
140.00   155.00-0 1010E+00 0 6421E+00 0 2976E+00-0 6120E-01 0 4041E+00-0 1433E-03 0 1911E-03 0 3609E-04
140.00L  155.00-0 1010E+00 0 4256E-02-0 2906E-01-0 6119E-01 0 4041E+00-0 4138E-03 0 1911E-03 0 3609E-04
140.00   155.00-0 1010E+00-0 4256E-02-0 2906E-01-0 6119E-01 0 4041E+00-0 1817E-03 0 1242E-03 0 1023E-03
140.00L  155.00-0 1010E+00-0 4256E-02-0 2474E-01-0 3290E-02 0 2824E+00-0 3024E-03 0 1242E-03 0 1019E-03
565.00     0.00-0 2070E-01 0 2823E-01 0 1848E-02 0 6787E-03-0 3292E-02 0 2825E+00-0 1961E-03 0 1297E-03 0 1150E-03
565.00L    0.00-0 2069E-01 0 1848E-02 0 6787E-03-0 3292E-02 0 2825E+00-0 3246E-03 0 1299E-03 0 1148E-03
565.00   155.00-0.2196E-01 0 3000E-01 0 2766E-01-0 4431E-02 0 2896E+00-0 1961E-03 0.1299E-03 0 1148E-03
565.00L  155.00-0.2196E-01 0 1933E-02 0 1143E-02-0 4813E-02 0 2896E+00-0 3246E-03 0.1299E-03 0 1148E-03
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The allowable and computed (from IIT Pave) tensile strain and vertical strain for the proposed pavement composition are given below in Table 1:

Table 1- Tensile & Vertical Strain Calculations for 60MSA traffic

Tensile Strain in Bituminous Layer (microns)		Vertical Compressive Strain on Subgrade (microns)		Remarks
Computed from IIT Pave	Allowable	Computed from IIT Pave	Allowable	
191	193	324	357	Design is Safe

The recommended pavement composition for the main carriageway, truck lay bye and bus bays designed according to IRC-37-2012 is given below:

Design traffic loading = 60 MSA
Effective CBR of Subgrade = 9%

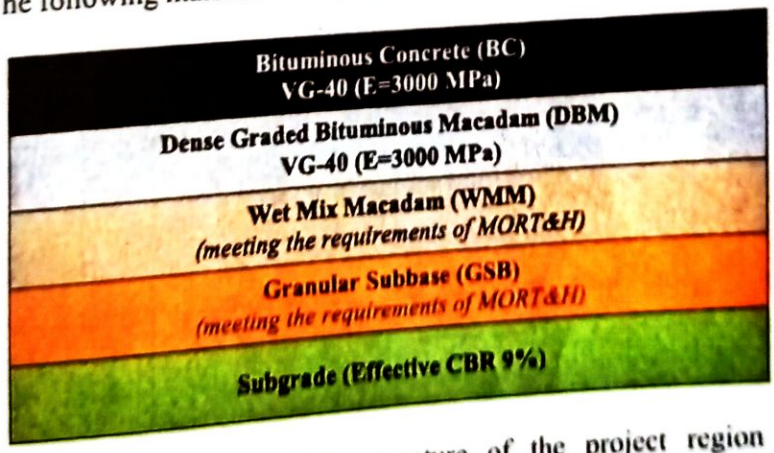
- Main Carriageway, Truck Lay Bye and Bus Bays

Bituminous Concrete (BC) - 40 mm
Dense Bituminous Macadam (DBM) - 100 mm
Wet Mix Macadam (WMM) - 225 mm
Granular Sub-Base (GSB) - 200 mm

7.3. Pavement Thickness for Service Road

Materials for Pavement

As per IRC: 37-2012, there is variation in the bituminous surfacing material with variation in the design traffic. The following materials are specified for the proposed pavement composition.



Reference is drawn to the record of temperature of the project region obtained from http://www.imdagrimet.gov.in/temperature_monthly_archive?page=4, whereby, the Annual Average Pavement Temperature (AAPT) falls well within the limit of 35°C.

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Analysis of Pavement Section as per Layered Elastic Theory & IRC-37

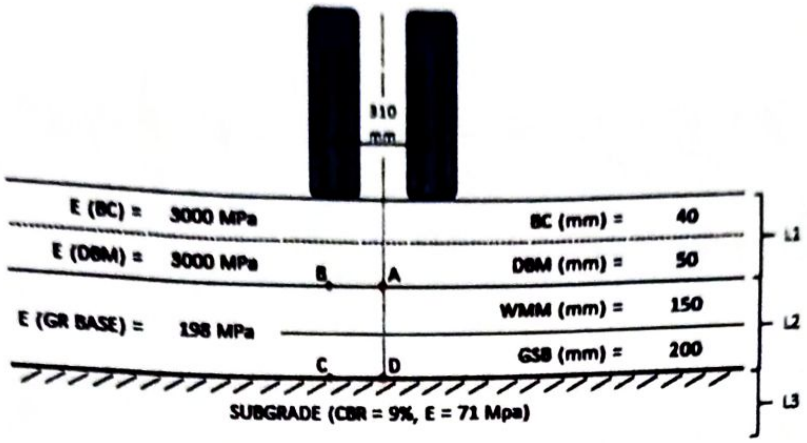

Figure 2- Proposed Pavement Composition

INPUT FOR IITPAVE SOFTWARE:

Number of layers (n)	3
Elastic Moduli (E), in MPa	3000 198 71
Poisson's Ratio (μ)	0.35 0.35 0.35
Thickness of Layers (h), mm	90 350
Single Wheel Load (N), Tyre Pressure (kPa)	20000.00 0.56
Number of points to be considered	4
Co-ordinate of Point "A"	90 0.000
Co-ordinate of Point "B"	90 155.000
Co-ordinate of Point "C"	440 0.000
Co-ordinate of Point "D"	440 155.000

CHECK FOR FATIGUE CRITERIA:

Bituminous surfacing of pavements display flexural fatigue cracking if the tensile strain at the bottom of bituminous layer is beyond certain limit.
Points "A" and "B" are the critical locations for tensile strains (e_t). Maximum value of the strain is adopted for design.

As per IRC-37-2012:

$$N_F = 2.21 \times 10^{-4} \times [1/e_t]^{3.89} \times [1/E]^{0.854}$$

Where,

N_F = Fatigue life in number of standard axles
e_t = Maximum tensile strain at the bottom of Bituminous layer
E =Resilient Modulus of bituminous layer (MPa)

CHECK FOR RUTTING CRITERIA:

Points "C" and "D" are the critical locations for the vertical subgrade strains (e_z). Maximum value of the strain is adopted for design.

AS per IRC-37-2012:

$$N_R = 4.1656 \times 10^{-8} \times [1/e_z]^{4.5337}$$

Where,

N_R = Number of cumulative standard axles

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e_z = Vertical subgrade strain

Output of IIT Pave:-


```
No. of layers                3
E values (MPa)          3000.00  198.00   71.00
Mu values                  0.350.350.35
thicknesses (mm)          90.00  350.00
single wheel load (N) 20000.00
tyre pressure (MPa)        0.56
Dual  Wheel
  Z        R       SigmaZ        SigmaT        SigmaR        TaoRZ        DispZ      epZ          epT          epR
 90.00     0.00-0.1877E+00 0.1119E+01 0.9042E+00-0.1991E-01 0.5242E+00-0.2986E-03 0.2894E-03 0.1928E-03
 90.00L    0.00-0.1877E+00-0.2057E-01-0.3474E-01-0.1991E-01 0.5242E+00-0.8504E-03 0.2894E-03 0.1928E-03
 90.00   155.00-0.1426E+00 0.8094E+00 0.1105E+00-0.8456E-01 0.5336E+00-0.1548E-03 0.2735E-03-0.4095E-04
 90.00L  155.00-0.1426E+00-0.1827E-01-0.6440E-01-0.8456E-01 0.5336E+00-0.5738E-03 0.2735E-03-0.4095E-04
440.00     0.00-0.3401E-01 0.4150E-01 0.3333E-01-0.6300E-02 0.3656E+00-0.3041E-03 0.2108E-03 0.1551E-03
440.00L    0.00-0.3401E-01 0.3134E-02 0.2038E-03-0.6300E-02 0.3656E+00-0.4956E-03 0.2108E-03 0.1551E-03
440.00   155.00-0.3712E-01 0.4521E-01 0.3876E-01-0.9671E-02 0.3798E+00-0.3359E-03 0.2254E-03 0.1814E-03
440.00L  155.00-0.3712E-01 0.3388E-02 0.1070E-02-0.9676E-02 0.3798E+00-0.5448E-03 0.2254E-03 0.1814E-03
```

The allowable and computed (from IIT Pave) tensile strain and vertical strain for the proposed pavement composition are given below in Table 2:

Table 2- Tensile & Vertical Strain Calculations for 10MSA traffic

Tensile Strain in Bituminous Layer (microns)		Vertical Compressive Strain on Subgrade (microns)		Remarks
Computed from IIT Pave	Allowable	Computed from IIT Pave	Allowable	
289	314	545	673	Design is Safe

The recommended pavement composition for the service road designed according to IRC-37-2012 is given below:

Design traffic loading = 10 MSA
Effective CBR of Subgrade = 9%

- Service Road

Bituminous Concrete (BC) - 40 mm
Dense Bituminous Macadam (DBM) - 50 mm
Wet Mix Macadam (WMM) - 150 mm
Granular Sub-Base (GSB) - 200 mm

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