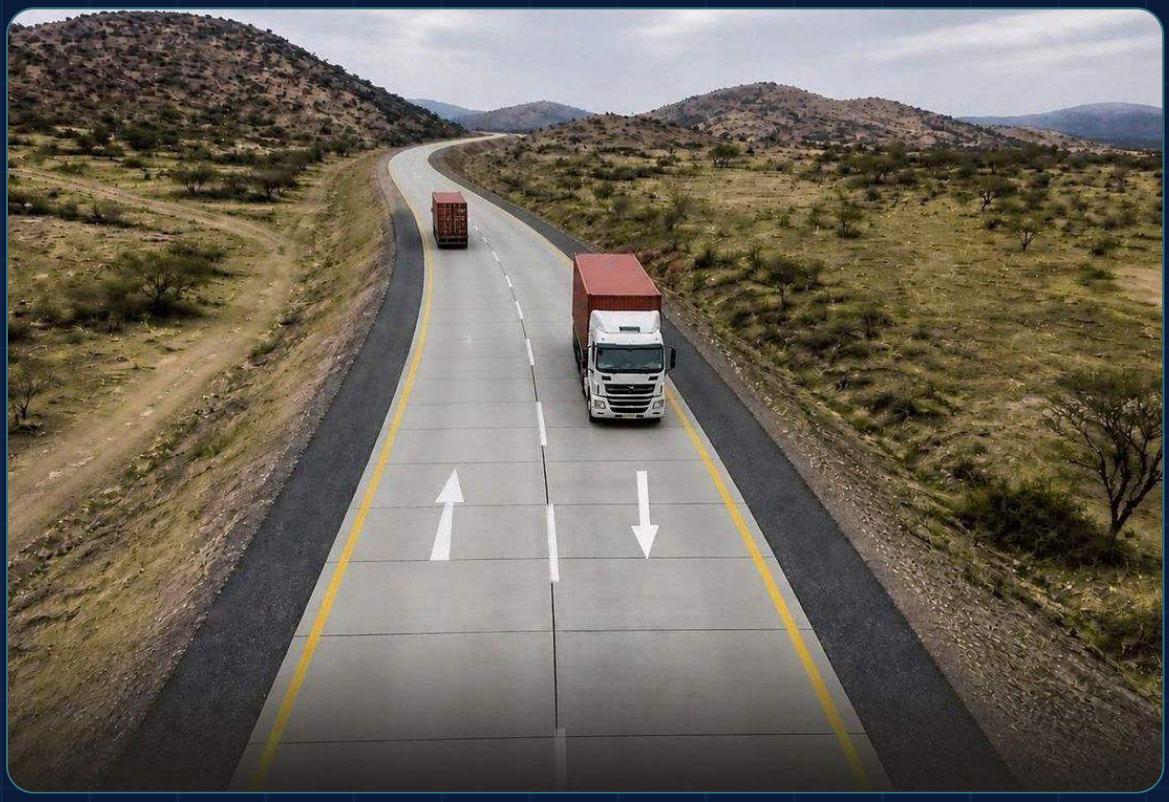
ENGINEERING REPORT

Rigid Pavement Design Report

Based on AASHTO Guide for Design of Pavement Structures, 1993



Sample Road

Client: Highway Authority

PREPARED & SUBMITTED BY

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ISSUE

November 2026

Sample report: illustrative data, not for design use

DOCUMENTS CONTROL SHEET

Report Name	Rigid Pavement Design Report
Project Name	Sample Road
Project Number	
Report for	Highway Authority

Originators Record

Date / Prepared by / Reviewed by / Approved for Issue by — to be completed per your organization's document control procedure.

Distribution

Organization / Contact / Hard copies / Soft copies — to be completed before issue.

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EXECUTIVE SUMMARY

The proposed project road will form an important regional transport link within and around the project area. The road traverses predominantly rural and sparsely developed areas, providing connectivity between local communities and supporting the movement of people, goods and commercial traffic. The project corridor forms part of the wider regional road network that connects inland areas with the national highway system and with important trade and economic centres.

The development of the project road is expected to improve regional accessibility, reduce travel times and vehicle operating costs, and enhance the movement of goods and passengers, contributing to the socio-economic development of the surrounding areas. The project also forms part of the wider improvement of road infrastructure, supporting connectivity with major routes and access to markets, services and other economic centres.

The proposed road generally follows the existing transport corridor, with improvements and realignments introduced where required to meet the applicable highway standards, improve road geometry, enhance safety and provide an appropriate level of service for the anticipated traffic. The road is expected to carry a significant share of heavy commercial vehicles, many of them loaded close to or above the legal axle load limits, so the axle loads of the heavy vehicles govern the pavement design.

The pavement design has been developed in accordance with the AASHTO Guide for Design of Pavement Structures, 1993, considering the projected traffic and its axle loads, the strength and moisture condition of the subgrade, the locally available construction materials, the climate and drainage of the project area, and the construction and maintenance capability expected for the project. The objective is a pavement that carries the design traffic over its design period with an acceptable level of serviceability, at the lowest whole-of-life cost.

Design basis. The pavement has been designed with the AASHTO Guide for Design of Pavement Structures, 1993, an empirical method based on the performance of the pavements of the AASHO Road Test. The design traffic is the cumulative number of 80 kN equivalent single axle loads (W_{18}); with the design reliability (Z_R, S_0), the allowable loss of serviceability (ΔPSI), the concrete modulus of rupture (S_c) and elastic modulus (E_c), the composite modulus of subgrade reaction (k), the load transfer coefficient (J) and the drainage coefficient (C_d), the design equation gives the required concrete slab thickness (D).

Based on the traffic and subgrade parameters set out in this report, the following pavement structure is recommended:

Pavement Layer	Thickness (cm)
PCC Slab	41.00
Lean Concrete Subbase	15.00
Granular Subbase	15.00

Provided slab thickness = **41.00 cm**, against a required slab thickness of **40.29 cm** — status: **ADEQUATE margin +0.71 cm**.

The key plan and location map are included as Annexure A, the pavement design calculations by AASHTO 1993 in Annexure B, proposed typical cross sections in Annexure C, and soil investigation results of CBR in Annexure D of this report.

1. INTRODUCTION

1.1 General

The proposed project road will form an important regional transport link within and around the project area. The road traverses predominantly rural and sparsely developed areas, providing connectivity between local communities and supporting the movement of people, goods and commercial traffic. The project corridor forms part of the wider regional road network that connects inland areas with the national highway system and with important trade and economic centres.

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The key plan and location map of the project road are provided as Annexure A.

2. ASSESSMENT OF ESALS

The traffic loading for pavement design is expressed as the cumulative number of Equivalent Standard Axle Loads (ESALs) over the design period. ESALs are calculated in accordance with the AASHTO Guide for Design of Pavement Structures, 1993, by applying Load Equivalency Factors (LEFs) derived from Appendix D (Tables D.10–D.18 for rigid pavements) to each vehicle type and axle group in the traffic fleet, using the axle configuration, loads, and Adopted design factors set out in the ESAL Calculator.

2.1 Input Data

Traffic & Project Parameters	
Project	**Sample Road**
Traffic count year (base year)	2026
Construction completion year	2029
Projected year for pavement design	2049
Design life	20 years (after opening to traffic)
Pre-construction period	3 years
Total analysis period (n)	**23 years**
Annual traffic growth rate (g)	3% per year
AASHTO LEF Interpolation Parameters	
Slab thickness (D) assumed for LEF lookup	14 in
Terminal Serviceability Index (P_t) for LEF lookup	2.5
Growth Factor	
Growth Factor formula	$GF = [(1 + g/100)^n - 1] / (g/100)$
Growth Factor, GF	**26.87**

2.2 Equivalent Axle Load Factors (EALFs)

Load Equivalency Factors (LEFs) for each axle group are obtained from AASHTO 1993 Appendix D by bilinear interpolation on axle load (kips) and slab thickness D (in = **14**), with linear interpolation on the Terminal Serviceability Index (P_t = **2.5**). Table references: D.10–D.12 for p_t=2.0, D.13–D.15 for p_t=2.5, D.16–D.18 for p_t=3.0 (Single/Tandem/Triple axles respectively). The composite LEF for each truck type is the sum of its individual axle LEFs (Total column below). Where the composite LEF has been increased to allow for unchecked overloading, the Adopted value governs that truck type's Daily ESALs.

Truck Type		Front Axle	Mid. Axle	Rear1 Axle	Rear2 Axle	Total	Adopted	AADT	Daily ESAL
Truck Type 1 (Composite)	Axle Type	Single	Tandem	Triple	—				
	Load Kips	12.00	42.00	74.00	—	**128.00**			
	LEF (AASHTO)	0.17	4.96	17.10	—	**22.23**	**22.23**	150	**3,335**
Truck Type 2	Axle Type	Single	Tandem	Tandem	—		**18.09**	125	**2,262**
	Load Kips	13.00	48.00	48.00	—	**109.00**			
								Total Daily ESAL	**5,783**

Truck Type		Front Axle	Mid. Axle	Rear1 Axle	Rear2 Axle	Total	Adopted	AADT	Daily ESAL
	LEF (AASHTO)	0.25	8.92	8.92	—	**18.09**			
Truck Type 3	Axle Type	Single	Tandem	Tandem	—				
	Load Kips	13.00	26.00	26.00	—	**65.00**			
	LEF (AASHTO)	0.25	0.62	0.62	—	**1.49**	**1.49**	125	**186**
								Total Daily ESAL	**5,783**

2. ASSESSMENT OF ESALS (CONTINUED)

2.3 Cumulative ESALs (AASHTO Method)

The Total Daily ESAL of the fleet (both directions, previous page) is annualised (×365 days) and grown at 3% a year from the traffic count year 2026 to the opening year 2029, $(1+g)^p = 1.093$. It is then accumulated over the 20-year design life with the growth factor $GF = [(1+g)^n - 1]/g$ and multiplied by the directional distribution factor DDF = 1 and the lane distribution factor LDF = 1 (AASHTO 1993, Part II, 2.1.3) to give the design-lane ESALs, W_{18}: W_{18} = annual ESAL × $(1+g)^p$ × GF × DDF × LDF. Traffic during construction is not design traffic.

Total Daily ESAL	5,783
Total Annual ESAL	2,110,822
Growth to the opening year, $(1+g)^p$	1.093
Growth Factor over the design life, GF	26.87
Design lane factor, DDF × LDF	1 × 1 = 1.00
Design-lane ESALs over the design life, W_{18}	**61,977,932 (61.98 million)**

For the project road, a design ESAL, W_{18}, of **61.98 million** has been adopted, corresponding to $\log_{10}(W_{18})$ = **7.7922**, matching the value used in the design equation below.

2.4 Axle Loads and Their Effect on the Pavement

The axle loads of the truck fleet are compared below with the legal axle load limits of the National Highway Authority (NHA, NHSO 2000 regime: front single axle 5.5 t, single axle 12 t, tandem 22 t, tridem 31 t). The last two columns give the AASHTO load equivalency factor (LEF) of each axle with the load as entered and, estimated, with the load capped at the legal limit.

Truck	Axle	Load (kips)	Load (t)	Legal limit (t)	Load / limit	Status	LEF as entered	LEF at the legal limit (est.)
Truck Type 1 (Composite)	front single axle	12.00	5.4	5.5	99%	within	0.17	0.17
Truck Type 1 (Composite)	tandem axle	42.00	19.1	22.0	87%	within	4.96	4.96
Truck Type 1 (Composite)	tridem (triple) axle	74.00	33.6	31.0	108%	over by 8%	17.10	12.44
Truck Type 2	front single axle	13.00	5.9	5.5	107%	over by 7%	0.25	0.19
Truck Type 2	tandem axle	48.00	21.8	22.0	99%	within	8.92	8.92
Truck Type 2	tandem axle	48.00	21.8	22.0	99%	within	8.92	8.92
Truck Type 3	front single axle	13.00	5.9	5.5	107%	over by 7%	0.25	0.19
Truck Type 3	tandem axle	26.00	11.8	22.0	54%	within	0.62	0.62
Truck Type 3	tandem axle	26.00	11.8	22.0	54%	within	0.62	0.62

The heaviest axle is the tridem (triple) axle of the Truck Type 1 (Composite) at **33.6 t**, 8% above the legal limit of 31.0 t. **33% of the axle passes are above the legal limits.**

In the AASHTO method the load equivalency factors (Appendix D, rigid pavement tables, depending on the slab thickness D and the terminal serviceability p_t) rise with roughly the fourth power of the axle load, as observed in the AASHO Road Test: an axle 10% over the limit does about 1.46 times the damage of a legal one, and 20% over about 2.07 times. With the loads as entered the fleet gives **5,783 ESALs per day**, against an estimated 5,069 ESALs per day if every axle carried no more than its legal limit: **overloading increases the design ESALs by about 14%**.

Share of the ESALs by truck: Truck Type 1 (Composite) 58%, Truck Type 2 39%, Truck Type 3 3%.

Axle load survey data should be used where available, and enforcement of the legal limits protects the pavement.

3. PAVEMENT DESIGN PARAMETERS

The AASHTO Design Guide for Pavement Structures, 1993, has been used for the purpose of the rigid pavement design.

3.1 Reliability (R)

Design Reliability (R) represents the degree of confidence that the pavement structure will perform satisfactorily throughout the selected design period under the anticipated traffic and environmental conditions. The appropriate reliability level is selected based on the functional classification of the roadway, traffic importance, and whether the facility is located in an urban or rural area.

A design reliability level of **95 %** has been adopted. The corresponding standard normal deviate (Z_R) of **-1.645** is used directly in the AASHTO 1993 design equation for the selected reliability level.

Functional Classification	Reliability — Urban (%)	Reliability — Rural (%)
Interstate and other Freeways	85–99.9	80–99.9
Principal Arterial	80–99	75–95
Collectors	80–95	75–95
Local	50–80	50–80

3.2 Standard Deviation (So)

The overall standard deviation (S_0) accounts for the inherent variability and uncertainty associated with pavement design and performance — the combined effects of variations in material properties, construction quality, traffic estimation, and actual pavement performance relative to the predicted design conditions.

An overall standard deviation of **S_0 = 0.37** has been adopted for the pavement design of the project road, used in conjunction with the adopted reliability level of **95 %**.

3.3 Standard Normal Deviate (ZR)

The recommended values of standard normal deviation (Z_R) by the AASHTO Guide 1993 are given below. The value corresponding to the adopted reliability of **95 %** is **-1.645**, which has been adopted in the design of the project road.

Reliability R (%)	Standard Normal Deviate (ZR)
50	0.000
60	-0.253
70	-0.524

Reliability R (%)	Standard Normal Deviate (ZR)
75	-0.674
80	-0.841
85	-1.037
90	-1.282
91	-1.340
92	-1.405
93	-1.476
94	-1.555
95	-1.645
96	-1.751
97	-1.881
98	-2.054
99	-2.327
99.9	-3.090
99.99	-3.750

3.4 Performance Criteria

Pavement serviceability represents the ability of the pavement to provide a safe, comfortable and satisfactory level of service to the traffic using the facility. Pavement performance is assessed in terms of the Present Serviceability Index (PSI), representing the overall condition and functional performance of the pavement as perceived by road users.

The AASHTO design procedure uses two principal serviceability parameters: the Initial Serviceability Index (P_0) and the Terminal Serviceability Index (P_t). The difference between these two values, expressed as the allowable loss of serviceability ($\Delta PSI = P_0 - P_t$), is incorporated into the pavement design equation. An Initial Serviceability Index of **P_o = 4.50** and a Terminal Serviceability Index of **P_t = 2.50** have been adopted, giving an allowable serviceability loss of **ΔPSI = 2.00**. A soaked subgrade CBR of **20.00%** has been adopted.

3.5 Concrete Strength, Elastic Modulus & Modulus of Rupture

A 28-day concrete compressive strength (f'c) of **5000 psi** has been adopted. The adopted elastic modulus of concrete, E_c = **4,030,509 psi**, and flexural strength, S_c = **530 psi** (entered measured values take precedence over the estimates), have been used in the AASHTO 1993 rigid pavement design equation.

3.6 Modulus of Subgrade Reaction (k)

The modulus of subgrade reaction has been determined with the procedure of the AASHTO Guide 1993 (Part II, Section 3.2.1). The roadbed soil resilient modulus has been estimated from the adopted subgrade CBR of **20.00%** as $M_R = 2555 \times CBR^{0.64}$ = **17,380 psi**, the same correlation as used for flexible pavements. Without a subbase, the guide relates the k-value to the roadbed modulus as $k = M_R/19.4$ = **896 pci**.

No credit has been taken for the subbase in the k-value (the composite k-value of Figure 3.3 has not been used), which is conservative. The k-value has been reduced for the potential loss of support from subbase erosion and differential soil movements with a loss of support factor LS = **0.5** (Table 2.7 of the guide: Cement aggregate mixture / lean concrete (LS 0.0-1.0)) using Figure 3.6, giving a design modulus of subgrade reaction of k = **485 pci**, adopted in the design equation.

Two steps of the procedure of the guide have not been applied, and the following assumptions are made: (1) the depth to a rigid foundation (bedrock) is greater than 10 ft, so the correction for a rigid foundation near the surface (Figure 3.4) does not apply; and (2) a single design value of the roadbed soil resilient modulus represents the whole year, so the seasonal relative damage of Figure 3.5 is not used to derive an effective k-value from monthly or seasonal moduli. Where bedrock lies within 10 ft of the subgrade surface, or the roadbed modulus varies markedly with the seasons (for example frost or wet seasons), the k-value should be determined with Figures 3.4 and 3.5 of the guide and entered as the measured effective k.

3.7 Load Transfer Coefficient (J)

The load transfer coefficient (J) accounts for the ability of the pavement structure to transfer load across discontinuities such as joints or cracks, reflecting the presence or absence of load transfer devices (dowels) at the joints and whether the pavement is provided with a tied concrete shoulder or an asphalt shoulder / edge support.

A load transfer coefficient of J = **3.60** has been adopted. For jointed concrete pavements, AASHTO 1993 Table 2.6 gives this value for a tied concrete shoulder without load transfer devices, J = 3.6–4.2.

A load transfer coefficient has been selected in accordance with AASHTO 1993 Table 2.6, which ranges from about 2.5–3.1 for jointed plain or jointed reinforced concrete pavement with dowelled joints and a tied concrete shoulder, rising to about 3.6–4.4 where joints are undowelled or the shoulder is asphalt rather than tied concrete. The value adopted for this project reflects the joint and shoulder detailing shown on the project drawings.

3.8 Drainage Coefficient (Cd)

The drainage coefficient (C_d) is used to account for the effect of drainage conditions on the structural performance of the pavement, reflecting the quality of drainage and the length of time the pavement structure is exposed to moisture conditions approaching saturation. The AASHTO Guide for Design of Pavement Structures, 1993, classifies drainage quality according to the approximate time required for water to be removed from the pavement structure, ranging from Excellent (water removed within approximately 2 hours) to Very Poor (water does not drain effectively). The appropriate drainage coefficient is then selected based on the drainage quality and the percentage of time the pavement structure is expected to be exposed to moisture levels approaching saturation.

A drainage coefficient of C_d = **1.00** has been adopted, reflecting the quality of drainage and the percentage of time the pavement structure is expected to be exposed to moisture levels approaching saturation.

A drainage coefficient has been selected in accordance with AASHTO 1993 Table 2.5, which ranges from about 1.10–1.25 for excellent drainage quality down to about 0.70–0.90 for poor drainage, depending on the percentage of time the pavement structure is exposed to moisture levels approaching saturation. The value adopted for this project reflects the subsurface drainage provisions and the regional rainfall and water-table conditions expected at the site.

4. COMPUTATION OF REQUIRED SLAB THICKNESS

The AASHTO 1993 empirical equation for rigid pavement design is used to determine the required PCC slab thickness, D, based on the design parameters adopted above.

4.1 AASHTO 1993 Rigid Pavement Equation

The design slab thickness is solved iteratively so that the left-hand side ($\log_{10}$ W18) and right-hand side of the AASHTO 1993 rigid pavement equation are in balance, using the adopted Z_R, S0, ΔPSI, S_c, C_d, J, E_c and composite k.

Design ESAL, W18	61.98 million
Left-hand side, $\log_{10}$(W18)	7.792
Trial design thickness, D	40.30 cm

Right-hand side, at trial D	7.793
Check	MATCH (Δ 0.001)
Solved required thickness, D	40.29 cm

4.2 Slab Thickness Check

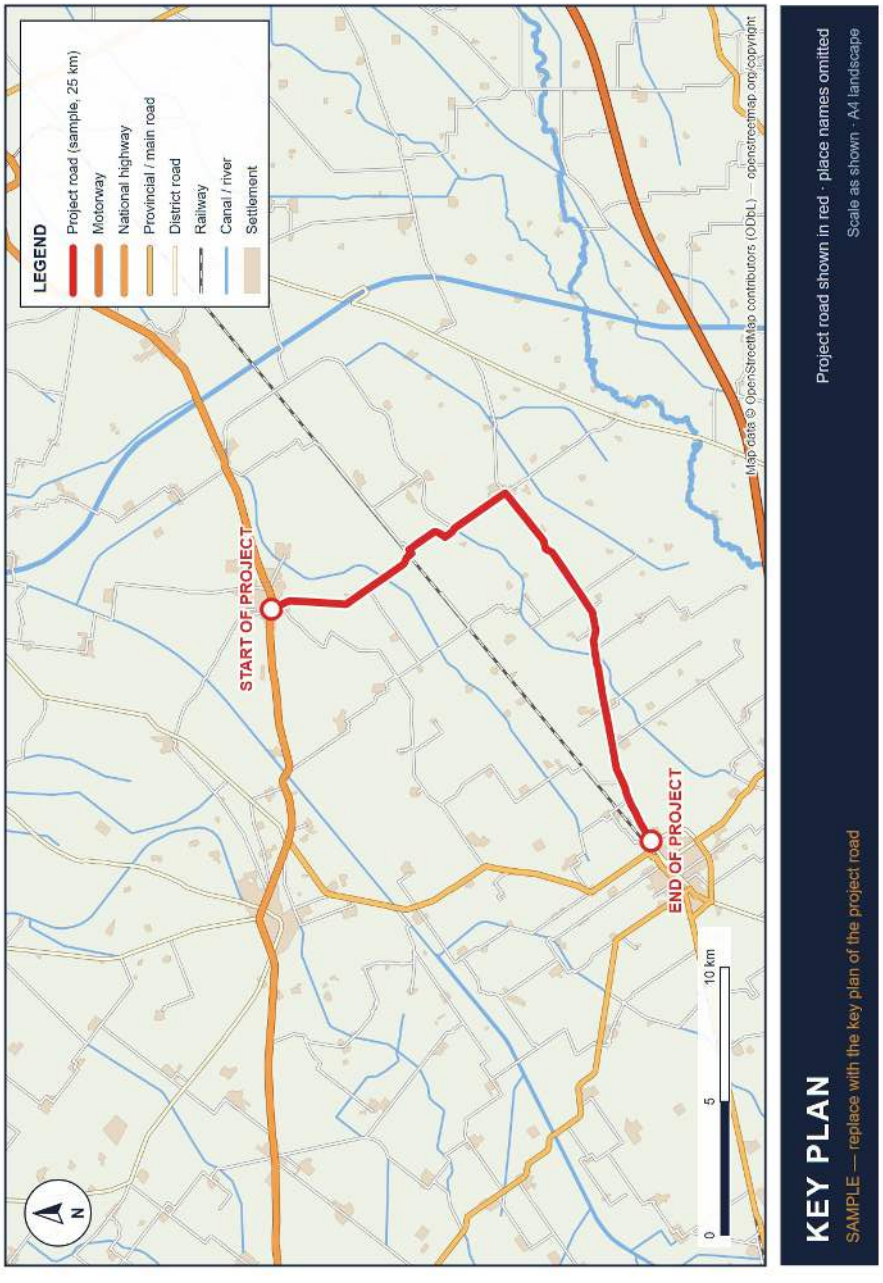
The provided PCC slab thickness is checked against the required thickness solved above.

Layer	Thickness (cm)
PCC Slab (provided)	41.00
PCC Slab (required)	40.29
Lean Concrete Subbase	15.00
Granular Subbase	15.00

Provided slab thickness = **41.00 cm**, against required slab thickness = **40.29 cm** — status: **ADEQUATE margin +0.71 cm**.

Note: this calculator produces a single pavement structure. If the project requires separate designs for multiple road sections, repeat this calculation for each section and present the results as separate subsections.

ANNEXURE – A (KEY PLAN AND LOCATION MAP)



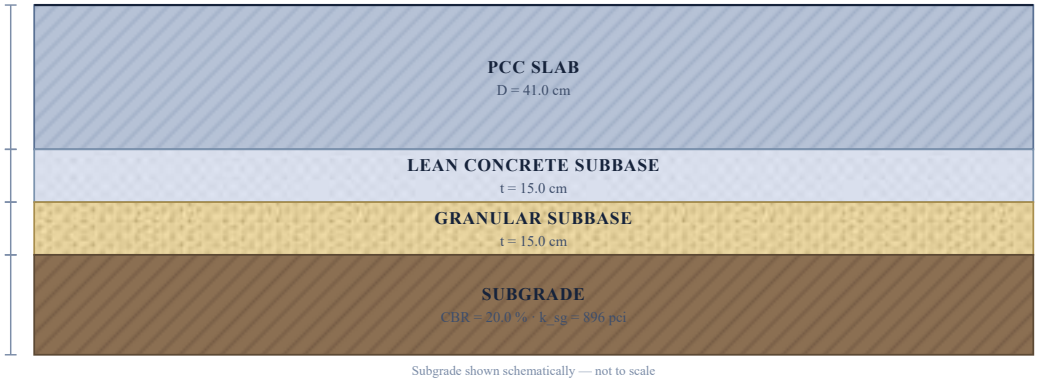
Sample key plan — insert the actual key plan and location map of the project road to replace this sample (upload it in the Generate Report form under Annexure A; use + Add plan for more). Map data © OpenStreetMap contributors (ODbL).

ANNEXURE – B (DESIGN CALCULATIONS BY AASHTO 1993)

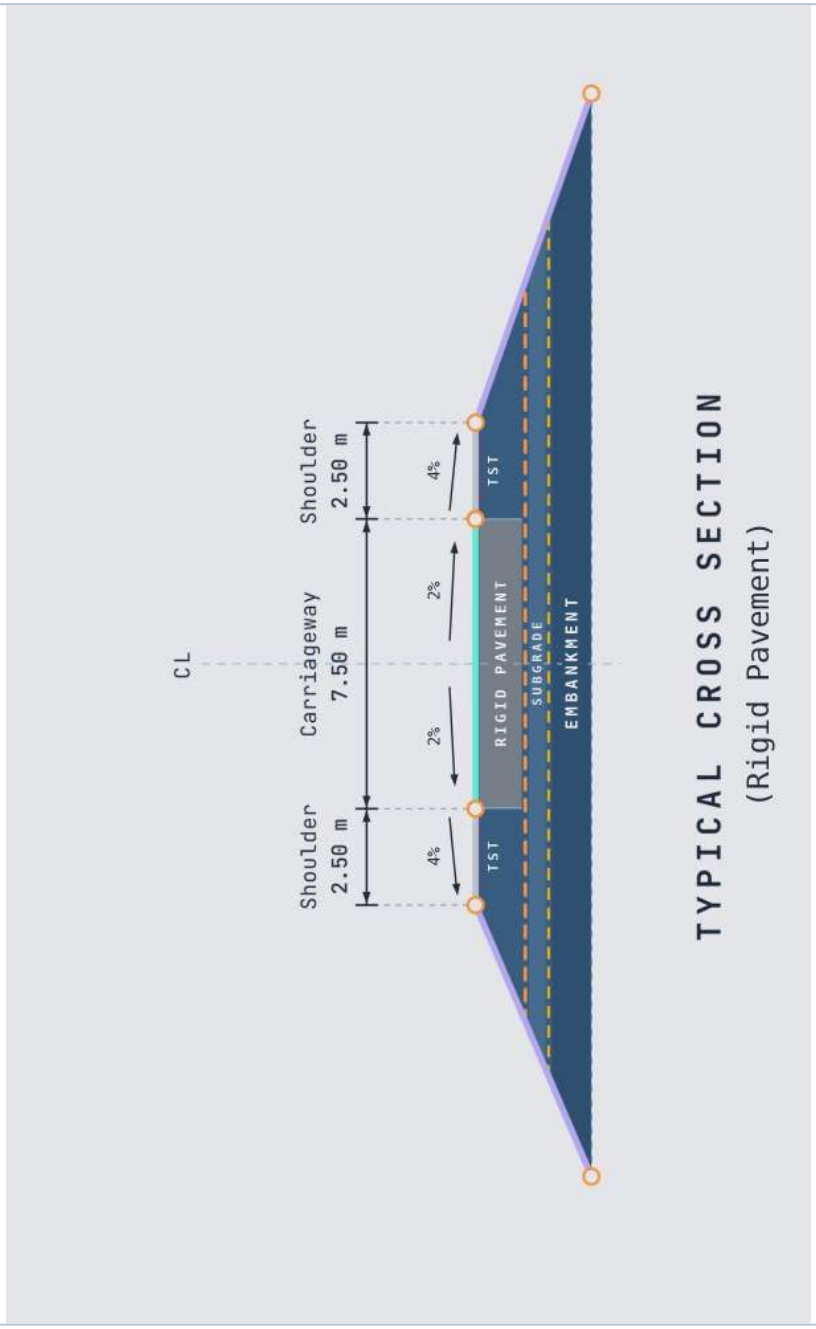
Full printout of the rigid pavement design calculator, corresponding to the design summarized above.

Reliability, R	95 %
Standard normal deviate, ZR	-1.645
Overall standard deviation, S0	0.37
Initial / Terminal serviceability	P0=4.50 / Pt=2.50
Subgrade CBR	20.00%
Drainage coefficient, Cd	1.00
Concrete strength, f'c	5000 psi
Ec / Sc	4,030,509 / 530 psi
k (M_R/19.4 / design, after LS)	896 / 485 pci
Load transfer coefficient, J	3.60
Design ESAL, W18	61.98 million
Required / Provided slab thickness	40.29 / 41.00 cm
Status	ADEQUATE margin +0.71 cm

Pavement Layers Sketch



ANNEXURE – C (TYPICAL CROSS SECTIONS)



Sample drawing — insert the actual project cross section to replace this sample (upload it in the Generate Report form under Annexure C; use + Add cross section for more sections).

ANNEXURE – D (SOIL INVESTIGATION RESULTS OF CBR)

A design CBR of **20.00%** has been adopted for the subgrade in this design.

Full soil and material investigation report, borehole logs and laboratory CBR test results to be attached separately by the design engineer.