ENGINEERING REPORT

Rigid Pavement Design Report

Based on Road Note 31 (5th Edition): A Guide to the Structural Design of Surfaced Roads in Tropical and Sub-Tropical Regions



Sample Project

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EXECUTIVE SUMMARY

The proposed Sample Project (Road 1) 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 pavement has been designed in accordance with Road Note 31 (5th Edition): A Guide to the Structural Design of Surfaced Roads in Tropical and Sub-Tropical Regions. The design of the pavement structure includes selecting materials of adequate strength and placing them at the proper thickness, so that the pavement carries the anticipated traffic loading over its design period without structural distress.

Design basis. Road Note 31 (5th Edition) does not have a structural design method of its own for concrete pavements. For jointed unreinforced (JUCP), jointed reinforced (JRCP) and continuously reinforced (CRCP) concrete pavements, Chapter 10 adopts the rigid pavement design method of the Austroads Guide to Pavement Technology Part 2 (2019): a mechanistic-empirical method based on the Portland Cement Association (PCA) procedure, in which the slab thickness is the least thickness for which concrete fatigue and sub-base erosion stay within their limits over the design period. Road Note 31 also gives a design catalogue (Table 10-7), based on MESA, for an assumed traffic mix and 4.5 MPa concrete; both are compared in this report.

Not covered by Road Note 31, and therefore taken from the Austroads Guide:

- the design traffic in heavy vehicle axle groups (HVAG) with its load spectrum — Road Note 31 refers to Section 7 of the Austroads Guide for this calculation;
- the coefficients of the fatigue and erosion equations — Road Note 31 reproduces the Austroads tables with misprints (one equation constant, an erosion column and two coefficients), so the Austroads values have been used; they are listed in Annexure B.

Limits of Road Note 31 for concrete pavements: its thickness designs are for design traffic greater than 1 million HVAG, and steel fibre reinforced concrete is not one of its pavement types, so it is not designed in this report.

For the design traffic of 12,860,549 heavy vehicle axle groups (45.06 MESA) and a subgrade design CBR of 20%, Road Note 31 offers the following concrete pavement options — read from the Table 10-7 catalogue (A) or designed by fatigue and erosion (B):

- **Option 1 — A catalogue**: Table 10-7 catalogue: undowelled JUCP / JRCP, 230 mm slab, 530 mm total.
- **Option 2 — A catalogue**: Table 10-7 catalogue: dowelled JUCP / JRCP / CRCP, 220 mm slab, 520 mm total.
- **Option 3 — B designed**: Jointed unreinforced concrete pavement, undowelled (JUCP), 265 mm slab, 565 mm total.
- **Option 4 — B designed**: Jointed unreinforced concrete pavement, dowelled (JUCP), 200 mm slab, 500 mm total.
- **Option 5 — B designed**: Jointed reinforced concrete pavement (JRCP), 190 mm slab, 490 mm total, ranked first.
- **Option 6 — B designed**: Continuously reinforced concrete pavement (CRCP), 190 mm slab, 490 mm total, ranked first.

The preferred option is set out below; part 4 of this report compares the options in detail.

Based on the design traffic and subgrade parameters set out in this report, the following concrete pavement (Option 5 — Jointed reinforced concrete pavement (JRCP)) is recommended:

Pavement layer	Thickness (mm)
Concrete slab (PCC)	190
Lean mix concrete sub-base (LCS)	150
Unbound granular / selected material (Section 10.5.4.2)	150
Total	**490**

Design traffic 12,860,549 heavy vehicle axle groups (HVAG), 45.06 MESA; subgrade design CBR 20% (effective CBR 75.0% on the sub-base, Figure 10-2); concrete flexural strength 4.5 MPa; reliability 95% (load safety factor 1.2). Fatigue 0% and erosion 90% at the design thickness (erosion governs).

The key plan and location map are included as Annexure A, the design calculations by Road Note 31 (5th Edition) in Annexure B, typical cross sections in Annexure C and the soil investigation results of CBR in Annexure D of this report.

1. INTRODUCTION

1.1 General

The proposed Sample Project (Road 1) 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 Sample Project 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 Road Note 31 (5th Edition): A Guide to the Structural Design of Surfaced Roads in Tropical and Sub-Tropical Regions, 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.

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

1.2 Design Philosophy

The concrete pavement has been designed in accordance with Chapter 10 of Road Note 31 (5th Edition). For jointed unreinforced (JUCP), jointed reinforced (JRCP) and continuously reinforced (CRCP) concrete pavements, Road Note 31 adopts the **Austroads rigid pavement design philosophy**: its thickness designs are taken from the Austroads Guide to Pavement Technology Part 2: Pavement Structural Design (2019). The Austroads method is based on the USA Portland Cement Association (PCA) method (Packard 1984), revised to suit Australian tropical and sub-tropical conditions, and assumes that the concrete base and sub-base are not bonded.

The base thickness is the least thickness for which two distress modes stay within their limits over the design period (typically 30–40 years):

• **flexural fatigue** cracking at the base of the concrete; and

• **erosion** of the sub-base or subgrade from the repeated deflections at joints and planned cracks.

Rigid pavements are sensitive to axle load magnitudes but relatively insensitive to the number of load repetitions, so they must be designed for the axle loads they will actually carry; where overloading is a problem a stronger pavement type such as CRCP may be prudent. In line with the Austroads method, the design traffic is the cumulative number of heavy vehicle axle groups (HVAG) with their load spectrum. Each load is multiplied by the load safety factor of the chosen reliability (Table 10-5); the allowable repetitions in fatigue and erosion are found for every axle group type and load, and the damage is summed over the spectrum; both totals must not exceed 100% (Table 10-4). The support is the effective subgrade CBR on a bound or lean-mix concrete sub-base (Figure 10-2), with a minimum sub-base (Table 10-3) and a minimum slab thickness (Table 10-6).

As an alternative, Road Note 31 gives a design catalogue based on MESA (Table 10-7), built for an assumed traffic mix and 4.5 MPa concrete. Both the catalogue options (A) and the designed options (B) are compared in part 4 of this report. Where Road Note 31 reproduces Austroads coefficients with misprints, the Austroads values have been used; they are listed in Annexure B.

2. DESIGN TRAFFIC

The traffic loading is expressed as the cumulative number of heavy vehicle axle groups (HVAG) in the design lane over the design period with their axle loads, following the Austroads method adopted by Road Note 31.

2.1 Traffic Data

#	Vehicle	Dir. 1 / day	Dir. 2 / day	Axle groups: load → ESA	ESA / vehicle
1	Semi-trailer (6 axles) AASHTO Truck Type 1 (Composite), counted 2026	150	150	SAST 5.4 t (53.3 kN) → 0.715 TADT 19.1 t (186.8 kN) → 3.663 TRDT 33.6 t (329.1 kN) → 10.694	15.072
2	Semi-trailer (5 axles) AASHTO Truck Type 2, counted 2026	125	125	SAST 5.9 t (57.8 kN) → 0.989 TADT 21.8 t (213.4 kN) → 6.247 TADT 21.8 t (213.4 kN) → 6.247	13.484
3	Semi-trailer (5 axles) AASHTO Truck Type 3, counted 2026	125	125	SAST 5.9 t (57.8 kN) → 0.989 TADT 11.8 t (115.6 kN) → 0.537 TADT 11.8 t (115.6 kN) → 0.537	2.064

ESA of an axle group = (load / Table 10-2 standard load)^4; the MESA is used only to enter the Table 10-7 catalogue. The designed slabs use the axle groups and their loads.

Parameter	Value
Growth periods	20 years at 3%
Years from traffic count to opening	3
Seasonal factor	1

2.2 Direction and Lane Distribution

Carriageway: Single carriageway, 6 m or wider — Total ESAs in the heaviest loaded direction.

The traffic of each direction has been counted separately, and the design traffic follows the cross-section rule of Table 2-5 for the carriageway type.

The lane distribution follows Table 2-5 of Road Note 31 for the carriageway type and width (Single carriageway, 6 m or wider).

2.3 Design Traffic

Quantity	Value
Design traffic, HVAG	**12,860,549**
Design traffic, MESA (for the Table 10-7 catalogue)	45.06
ESA per HVAG	3.50
Cumulative days of traffic (Equation 2-6, growth included)	10,717

2.4 Axle Loads and Their Effect on the Concrete Pavement

The axle group loads of the heavy vehicles 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).

Vehicle	Axle group	Load (t)	Legal limit (t)	Load / limit	Status
Semi-trailer (6 axles) (AASHTO Truck Type 1 (Composite), counted 2026)	SAST — single axle, single tyres	5.4	5.5	99%	within
Semi-trailer (6 axles) (AASHTO Truck Type 1 (Composite), counted 2026)	TADT — tandem axle, dual tyres	19.1	22.0	87%	within
Semi-trailer (6 axles) (AASHTO Truck Type 1 (Composite), counted 2026)	TRDT — triaxle, dual tyres	33.6	31.0	108%	over by 8%
Semi-trailer (5 axles) (AASHTO Truck Type 2, counted 2026)	SAST — single axle, single tyres	5.9	5.5	107%	over by 7%
Semi-trailer (5 axles) (AASHTO Truck Type 2, counted 2026)	TADT — tandem axle, dual tyres	21.8	22.0	99%	within
Semi-trailer (5 axles) (AASHTO Truck Type 2, counted 2026)	TADT — tandem axle, dual tyres	21.8	22.0	99%	within
Semi-trailer (5 axles) (AASHTO Truck Type 3, counted 2026)	SAST — single axle, single tyres	5.9	5.5	107%	over by 7%
Semi-trailer (5 axles) (AASHTO Truck Type 3, counted 2026)	TADT — tandem axle, dual tyres	11.8	22.0	54%	within
Semi-trailer (5 axles) (AASHTO Truck Type 3, counted 2026)	TADT — tandem axle, dual tyres	11.8	22.0	54%	within

The heaviest axle group is the TRDT of the Semi-trailer (6 axles) at **33.6 t (329 kN)**, 8% above the legal limit of 31.0 t. **33% of the axle group passes are above the legal limits**, so the design reflects the actual (overloaded) traffic, not the legal loads.

Road Note 31 notes that rigid pavements are sensitive to axle load magnitudes but relatively insensitive to the number of load repetitions, so concrete pavements must be designed for the maximum axle loads they are likely to carry; where overloading is a problem a stronger pavement type such as CRCP may be prudent. In the design every axle load is multiplied by the load safety factor of the chosen reliability (Table 10-5: 1.2 for Jointed reinforced concrete pavement (JRCP)), so the 329 kN group is checked at 395 kN. Axle load survey data should be used where available, and enforcement of the legal limits protects the pavement.

Contribution of each axle group type to the damage of Jointed reinforced concrete pavement (JRCP) at its design slab thickness of 190 mm:

Axle group type	Fatigue damage	Erosion damage
TADT — tandem axle, dual tyres	0.0%	48.8%
TRDT — triaxle, dual tyres	0.0%	40.7%
Total	**0.0%**	**89.5%**

The slab thickness is governed by erosion; both totals are within 100%.

3. PAVEMENT DESIGN PARAMETERS

The design parameters adopted for the concrete pavement are presented in the following sub-sections.

3.1 Subgrade and Sub-base

A subgrade design CBR of **20%** (class S5) has been adopted on a sub-base of **150 mm lean-mix concrete (LCS)**, giving an effective subgrade CBR of **75.0%** (Figure 10-2). The soil investigation results are given in Annexure D.

3.2 Concrete

A 28-day characteristic flexural strength of **4.5 MPa** has been adopted; Road Note 31 sets 4.5 MPa as the minimum.

3.3 Reliability and Load Safety Factor

A project reliability of **95%** has been adopted; the load safety factors of Table 10-5 are 1.3 for undowelled and 1.2 for dowelled pavements.

3.4 Shoulders

Concrete shoulders are provided (edge factor F2 = 0.94).

4. COMPUTATION OF SLAB THICKNESS

The slab thickness is determined with the design parameters of parts 2 and 3 of this report. The detailed calculations are given in Annexure B.

4.1 Fatigue and Erosion Analysis

Jointed reinforced concrete pavement (JRCP): least thickness with fatigue and erosion ≤ 100% = **190 mm**; minimum slab thickness (Table 10-6) 180 mm; design slab thickness **190 mm** — fatigue 0.0%, erosion 89.5% (erosion governs).

4.2 Comparison of Options

Option A is read from the Table 10-7 catalogue; options B are designed by fatigue and erosion. The rank is a screening; the choice also considers construction, ride quality and maintenance.

Option	Slab (mm)	LSF	Layers (mm)	Total (mm)	Cost / km	Rank
Option 1 — A catalogue Table 10-7 catalogue: undowelled JUCP / JRCP	230	1.3	PCC 230 / LMC 150 / GRAN 150	530	–	5
Option 2 — A catalogue Table 10-7 catalogue: dowelled JUCP / JRCP / CRCP	220	1.2	PCC 220 / LMC 150 / GRAN 150	520	–	4
Option 3 — B designed Jointed unreinforced concrete pavement, undowelled (JUCP)	265	1.3	PCC 265 / LCS 150 / GRAN 150	565	–	6
Option 4 — B designed Jointed unreinforced concrete pavement, dowelled (JUCP)	200	1.2	PCC 200 / LCS 150 / GRAN 150	500	–	3
Option 5 — B designed Jointed reinforced concrete pavement (JRCP)	190	1.2	PCC 190 / LCS 150 / GRAN 150	490	–	★ 1
Option 6 — B designed Continuously reinforced concrete pavement (CRCP)	190	1.2	PCC 190 / LCS 150 / GRAN 150	490	–	★ 1

4.3 Recommended Pavement

Based on the design traffic and subgrade parameters set out in this report, the following concrete pavement (Option 5 — Jointed reinforced concrete pavement (JRCP)) is recommended:

Pavement layer	Thickness (mm)
Concrete slab (PCC)	190
Lean mix concrete sub-base (LCS)	150
Unbound granular / selected material (Section 10.5.4.2)	150
Total	**490**

Design traffic 12,860,549 heavy vehicle axle groups (HVAG), 45.06 MESA; subgrade design CBR 20% (effective CBR 75.0% on the sub-base, Figure 10-2); concrete flexural strength 4.5 MPa; reliability 95% (load safety factor 1.2). Fatigue 0% and erosion 90% at the design thickness (erosion governs).

The pavement layers are drawn to scale in Annexure C (Typical Cross Sections), and the detailed design calculations are given in Annexure B.

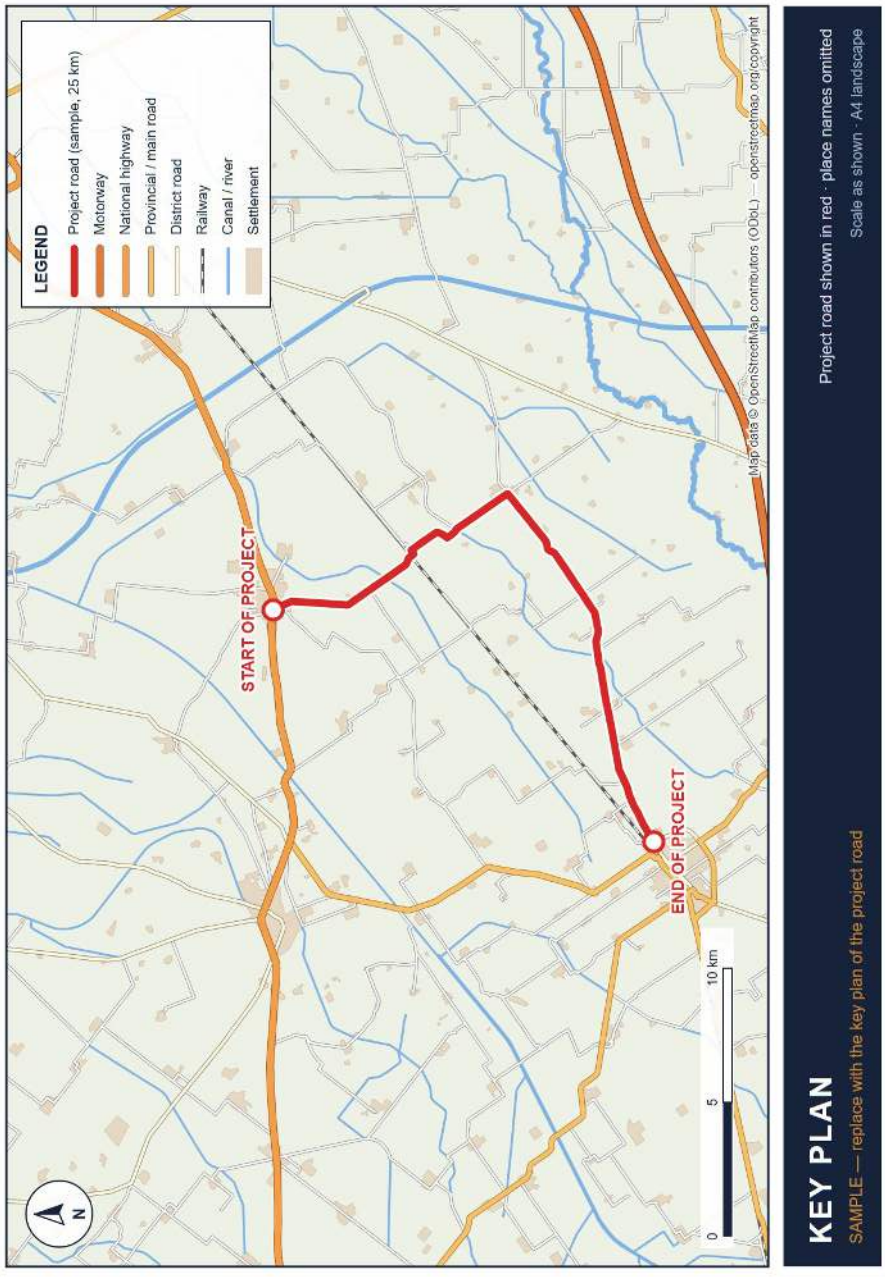
4.4 Construction Layers

Layer	Thickness (mm)	Construction	Road Note 31 rule	Check
Concrete slab	190	one layer	concrete slab: placed in one layer (no layer limit in Road Note 31)	–
LCS	150	one layer	lean-mix concrete: placed in one layer (no layer limit in Road Note 31)	–
GRAN	150	one layer	granular: compaction layers of at most 200 mm (as Section 4.4.1 for crushed stone; follow your specification)	specification

Each layer is built in the compaction layers shown, so that it can be compacted to the specified density.

ANNEXURE – A (KEY PLAN AND LOCATION MAP)

Referred to in: Executive Summary, 1.1 General.



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

ANNEXURE – B (DESIGN CALCULATIONS BY ROAD NOTE 31 (5TH EDITION))

Referred to in: Executive Summary, 1.2 Design Philosophy, 4. Computation of Slab Thickness, 4.3 Recommended Pavement.

Full printout of the Road Note 31 Rigid Pavement Design tool, corresponding to the design summarised above.

1. Design traffic (HVAG)

Traffic input	Vehicle mix and axle loads; 20 years at 3%; 3 years to opening; seasonal factor 1; Single carriageway, 6 m or wider (Total ESAs in the heaviest loaded direction)
Design inputs	Concrete shoulder: yes; f_{cf} 4.5 MPa; reliability 95%; sub-base 150 mm lean-mix concrete (LCS)

#	Vehicle	Description	Dir. 1 / day	Dir. 2 / day	Axle groups (t)
1	Semi-trailer (6 axles)	AASHTO Truck Type 1 (Composite), counted 2026	150	150	SAST 5.44, TADT 19.05, TRDT 33.57
2	Semi-trailer (5 axles)	AASHTO Truck Type 2, counted 2026	125	125	SAST 5.9, TADT 21.77, TADT 21.77
3	Semi-trailer (5 axles)	AASHTO Truck Type 3, counted 2026	125	125	SAST 5.9, TADT 11.79, TADT 11.79

ESA/day dir. 1 (n = 4) **4,204**

ESA/day dir. 2 (n = 4) **4,204**

Design lane a, ESA/day **4,204**

Design traffic, HVAG **12.86 M**

Design traffic, MESA **45.06**

ESA per HVAG **3.50**

Growth factor (days) **10,717**

Table 2-5: Single carriageway, 6 m or wider → Total ESAs in the heaviest loaded direction a = 1 × 4,204 (direction 1, the heavier loaded) = 4,204 ESA/day; axle groups 1,200 HVAG/day in the design lane Equation 2-6 (growth 20 years at 3%; 3 years from count to opening): cumulative days = 10,717 Design traffic, HVAG = 1,200.0 × 10,717 = 12,860,549 axle groups <- design traffic of the concrete pavement Design traffic, MESA = 4,204.2 × 10,717 / 10^6 = 45.06 MESA (Table 10-2 standard loads, n = 4; used for the Table 10-7 catalogue)

Load spectrum by axle group (Table 10-4 step 8)

Axle group	Loads	Heaviest (kN)	Repetitions	Share of HVAG	Standard load (Table 10-2)
SAST Single axle, single tyres	2	57.8	4.29 M	33.3%	58 kN
TADT Tandem axle, dual tyres	3	213.4	6.97 M	54.2%	135 kN
TRDT Triaxle, dual tyres	1	329.1	1.61 M	12.5%	182 kN

Design period 20 years: RN31 / Austroads use 30–40 years for rigid pavements (Section 10.5.2).

2. Subgrade

Subgrade design CBR **20%**

Subgrade class **S5**

3. Design inputs and sub-base

Effective subgrade CBR	LSF undowelled / dowelled	Edge factor F2
75.0%	**1.3 / 1.2**	**0.94**

Table 10-3 minimum for 12.86 M HVAG: 150 mm LCS (under CRCP a heavily bound sub-base with an asphalt surfacing is also acceptable) — the selected sub-base meets it.

Figure 10-2 covers design CBR 2–15%; the value at 15% is used.

Figure 10-2 — effective subgrade strength

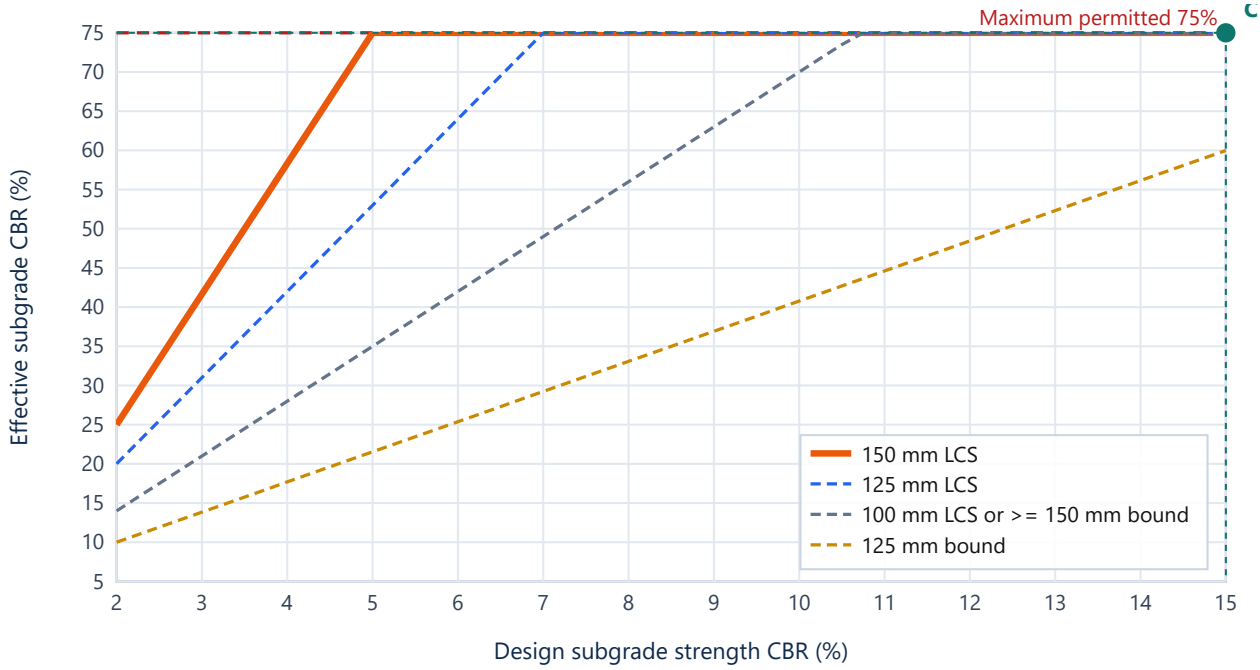


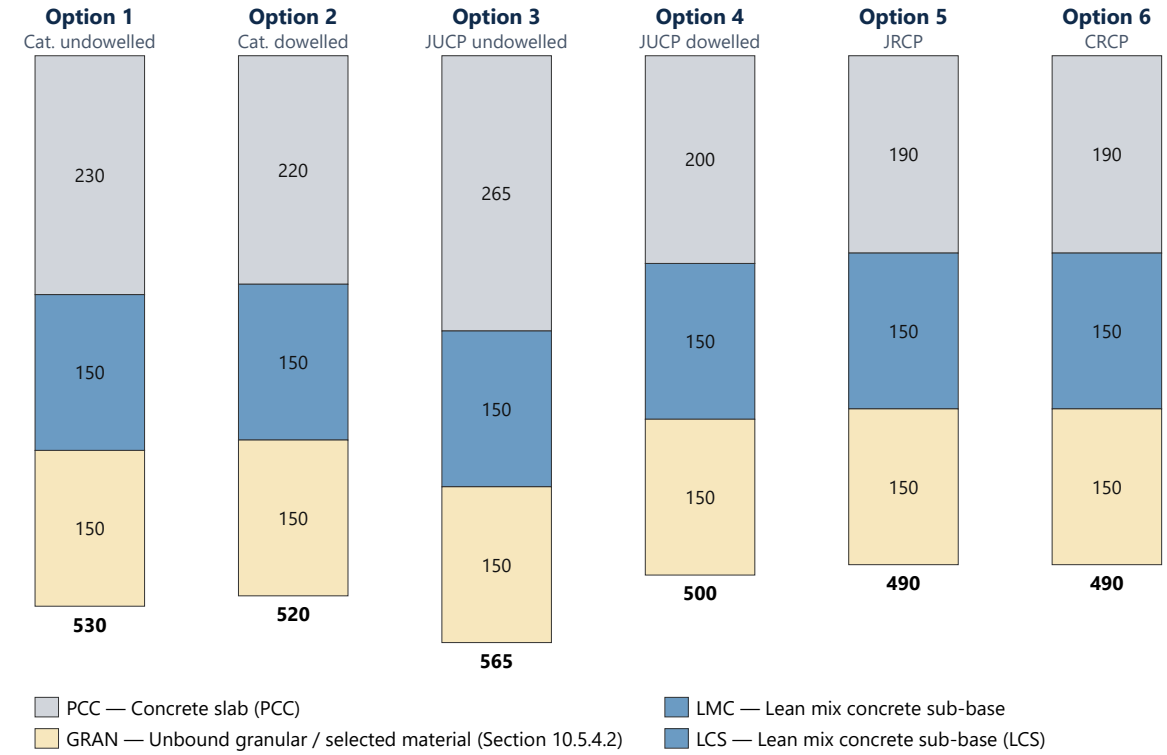
Figure 10-2 redrawn from Road Note 31 (lines read from the figure); the thick line is your sub-base. Below CBR 2 use 150 mm LCS and 5%.

4. Concrete pavement options

Pavement types: ***JUCP*** *= jointed unreinforced concrete pavement (plain slabs, no steel mesh);* ***JRCP*** *= jointed reinforced concrete pavement (longer slabs with steel mesh);* ***CRCP*** *= continuously reinforced concrete pavement (no transverse joints, continuous longitudinal steel).* ***Dowelled*** *= steel dowel bars across the transverse joints transfer load between slabs;* ***undowelled*** *= no dowels, load passes by aggregate interlock.*

Rank	Option	Slab (mm)	LSF	Layers top → bottom (mm)	Total (mm)	Steel (t/km)	Cost / km (PKR)	
5	**Option 1** A : catalogue Table 10-7 catalogue: undowelled JUCP / JRCP Table 10-7 column 30-80 MESA (your traffic 45.06 MESA), foundation F3	**230**	1.3	PCC 230 / LMC 150 / GRAN 150	**530**	0.7	rates missing	
4	**Option 2** A : catalogue Table 10-7 catalogue: dowelled JUCP / JRCP / CRCP Table 10-7 column 30-80 MESA (your traffic 45.06 MESA), foundation F3	**220**	1.2	PCC 220 / LMC 150 / GRAN 150	**520**	15.8	rates missing	
6	**Option 3** B : designed Jointed unreinforced concrete pavement, undowelled (JUCP) Designed for your traffic: 45.06 MESA, 12,860,549 HVAG · Table 10-1 suits: Low traffic routes such as rural roads erosion governs; fatigue 0%, erosion 94%	**265**	1.3	PCC 265 / LCS 150 / GRAN 150	**565**	0.7	rates missing	
3	**Option 4** B : designed Jointed unreinforced concrete pavement, dowelled (JUCP) Designed for your traffic: 45.06 MESA, 12,860,549 HVAG · Table 10-1 suits: Low / medium / high Table 10-6 minimum governs; fatigue 0%, erosion 42%	**200**	1.2	PCC 200 / LCS 150 / GRAN 150	**500**	12.3	rates missing	
★ 1	**Option 5** B : designed Jointed reinforced concrete pavement (JRCP) Designed for your traffic: 45.06 MESA, 12,860,549 HVAG · Table 10-1 suits: Medium / high / very high erosion governs; fatigue 0%, erosion 90%	**190**	1.2	PCC 190 / LCS 150 / GRAN 150	**490**	23.4	rates missing	
★ 1	**Option 6** B : designed Continuously reinforced concrete pavement (CRCP) Designed for your traffic: 45.06 MESA, 12,860,549 HVAG · Table 10-1 suits: Medium / high / very high erosion governs; fatigue 0%, erosion 90%	**190**	1.2	PCC 190 / LCS 150 / GRAN 150	**490**	85.2	rates missing	

All 6 are concrete pavement options of RN31 Chapter 10 for this traffic and subgrade: the catalogue (A) assumes its own traffic mix and 4.5 MPa concrete; the designed slabs (B) use your load spectrum and Step 3 inputs. Choose on cost, plant, ride quality and maintenance (Section 10.4). Rank (★ = best) is by total thickness (fill every rate to rank by cost).



Options side by side, same scale (mm). Hover a layer for its name.

Life-cycle cost of the options (Chapter 12)

Option	Construction (PKR)	Periodic treatments	Treatments, PV (PKR)	Routine, PV (PKR)	Residual value, PV (PKR)	Life-cycle cost, PV (PKR)
Option 1 — A catalogue JUCP undowelled 230 mm slab, 530 mm total	–	missing: construction rates, JUCP undowelled periodic maintenance	–	0	0	**–**
Option 2 — A catalogue JUCP dowelled 220 mm slab, 520 mm total	–	missing: construction rates, JUCP dowelled periodic maintenance	–	0	0	**–**
Option 3 — B designed JUCP undowelled 265 mm slab, 565 mm total	–	missing: construction rates, JUCP undowelled periodic maintenance	–	0	0	**–**
Option 4 — B designed JUCP dowelled 200 mm slab, 500 mm total	–	missing: construction rates, JUCP dowelled periodic maintenance	–	0	0	**–**
Option 5 — B designed JRCP 190 mm slab, 490 mm total	–	missing: construction rates, JRCP periodic maintenance	–	0	0	**–**
Option 6 — B designed CRCP 190 mm slab, 490 mm total	–	missing: construction rates, CRCP periodic maintenance	–	0	0	**–**

Present value over 40 years at 6% (Equation 12-1, PV = FV / (1 + r)^n); treatments due in the final year are not counted; residual value is a negative cost discounted from the end of the period (Section 12.2.5). Costs per km of carriageway at your rates. Not included: land, design fees, road user costs, environmental mitigation, contingencies and taxes / conversion to economic prices (Sections 12.2.1–12.2.3) — add them where they differ between options.

Choosing between the options (Road Note 31 Section 10.4 and Chapter 12)

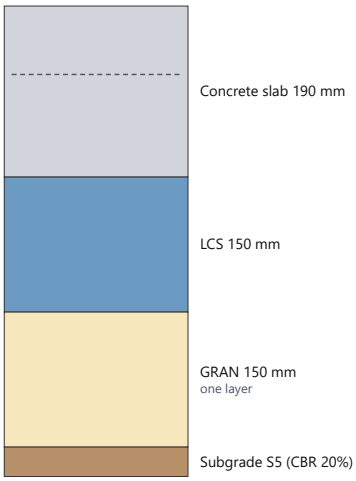
Every option listed is a valid Chapter 10 concrete pavement for this traffic and subgrade. The ranking is a screening by life-cycle cost, construction cost or thickness — not a recommendation on its own. Section 10.4.1 lists what the choice depends on:

1. **Budget and life-cycle cost**: construction plus joint and slab maintenance over the analysis period (Chapter 12; for analysis periods over 20 years concrete often has a lower life-cycle cost than asphalt but a higher initial cost, Section 12.2.1).
2. **Traffic level**: suitability of each type in Table 10-1 (undowelled JUCP for low-traffic routes; dowelled JUCP, JRCP and CRCP for medium to very high traffic).
3. **Ride quality**: paver-laid CRCP usually rides well; joints are the main weakness of jointed slabs.
4. **Plant available**: CRCP normally needs a concrete paver; slip-form or fixed-form paving and steel fixing capability for JRCP / CRCP.
5. **New build or rehabilitation**, and the **local labour** available, which may favour labour-intensive options.
6. **Environment**: e.g. CRCP is beneficial where differential settlement is likely; jointed slabs suit less well where temperature ranges are high.
7. **Other criteria**: safety, embodied carbon (Chapter 13) and community preferences — score them with a multi-criteria analysis where they cannot be priced (Section 12.5).

5. Selected design

Selected	Concrete slab	Total thickness
Option 5	**190 mm**	**490 mm**

Jointed reinforced concrete pavement (JRCP). *Square joints at 8 to 12 m with dowels in all transverse joints; reinforcement stopped at contraction and expansion joints; usually every third joint an expansion joint (Sections 10.6.1.2, 10.6.3.2).*



Total 490 mm; dashed line = reinforcement

Layer	Thickness (mm)	Depth to bottom (mm)
Concrete slab (PCC)	**190**	190
Lean mix concrete sub-base (LCS)	**150**	340
Unbound granular / selected material (Section 10.5.4.2)	**150**	490
Subgrade S5, design CBR 20%		490

Construction layers and aggregate size

Layer	Thickness (mm)	Construction	Road Note 31 rule	Check
Concrete slab	190	one layer	concrete slab: placed in one layer (no layer limit in Road Note 31)	–
LCS	150	one layer	lean-mix concrete: placed in one layer (no layer limit in Road Note 31)	–
GRAN	150	one layer	granular: compaction layers of at most 200 mm (as Section 4.4.1 for crushed stone; follow your specification)	specification

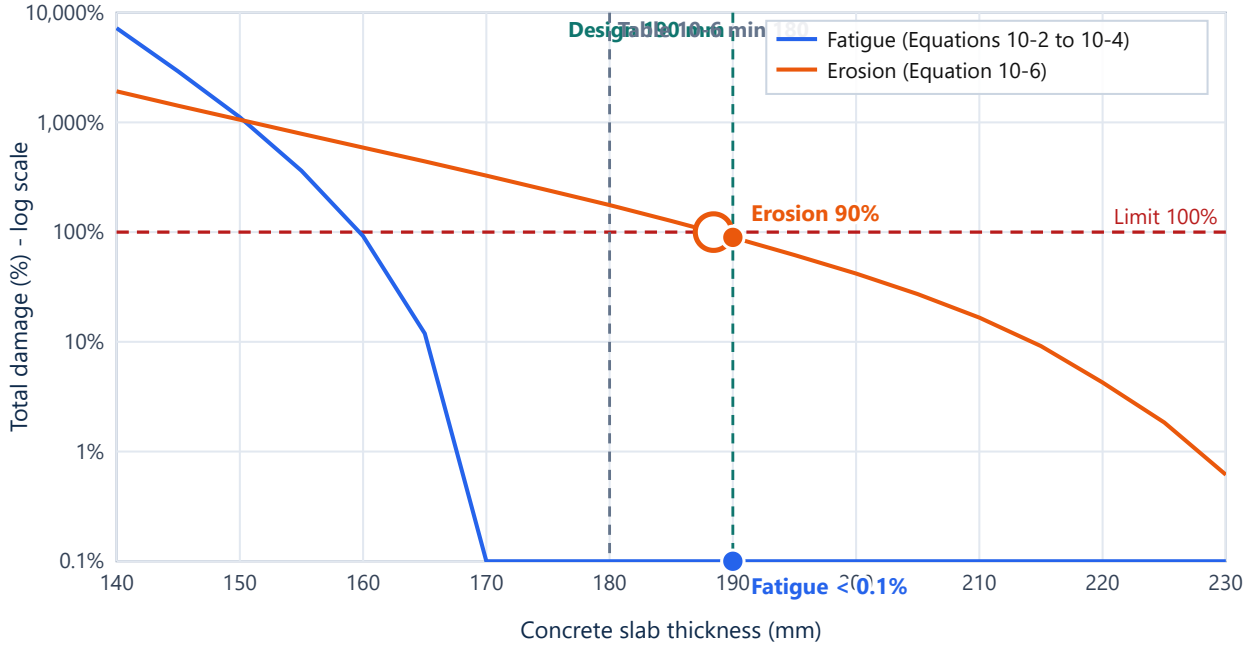
Each layer is built in the compaction layers shown, so that it can be compacted to the specified density.

Quantities and cost per km

Item	Thickness (mm)	Quantity / km	Unit	Rate	Amount (PKR)
Concrete slab (PCC)	190	1,387	m^3	–	–
Lean mix concrete sub-base (LCS)	150	1,095	m^3	–	–
Unbound granular / selected material (Section 10.5.4.2)	150	1,095	m^3	–	–
Steel (dowels, ties, reinforcement)	–	23.38	t	–	–
Total per km, 7.3 m wide	490				rates missing

Steel: Tie bars 12 mm x 750 mm at longitudinal joints (1 joint, 1,000 mm c/c) — 0.67 t/km; Dowels 28 mm x 450 mm at 300 mm, joints every 10 m — 5.22 t/km; JRCP mesh: 224 mm^2/m longitudinal + 82 mm^2/m transverse — 17.50 t/km.

Fatigue and erosion against slab thickness



The design thickness is the least multiple of 5 mm where both curves are at or below 100% (Table 10-4 step 17), and not less than Table 10-6. Here erosion governs.

Slab thickness (mm)	Total fatigue (%)	Total erosion (%)	Result
165	11.9	440.1	NOT OK
170	0.0	326.9	NOT OK
175	0.0	241.1	NOT OK
180	0.0	176.0	NOT OK
185	0.0	126.7	NOT OK
190	**0.0**	**89.5**	OK
195	0.0	61.9	OK
200	0.0	41.8	OK
205	0.0	27.2	OK

Damage by axle group at 190 mm (Table 10-4 steps 8–16)

Effective CBR 75.0%, f_{cf} 4.5 MPa, LSF 1.2, dowelled / CRCP erosion factors (Table 10-10), with concrete shoulder. Calculated thickness 190 mm, Table 10-6 minimum 180 mm.

▼ SAST — Single axle, single tyres: equivalent stress 0.868, erosion factor 1.760 — fatigue 0.00%, erosion 0.00%

Group load (kN)	Design load × LSF (kN)	Expected repetitions	Allowable (fatigue)	Fatigue (%)	Allowable (erosion)	Erosion (%)
57.8	69.4	2,679,281	Unlimited	0.00	Unlimited	0.00
53.3	64.0	1,607,569	Unlimited	0.00	Unlimited	0.00
Total				**0.00**		**0.00**

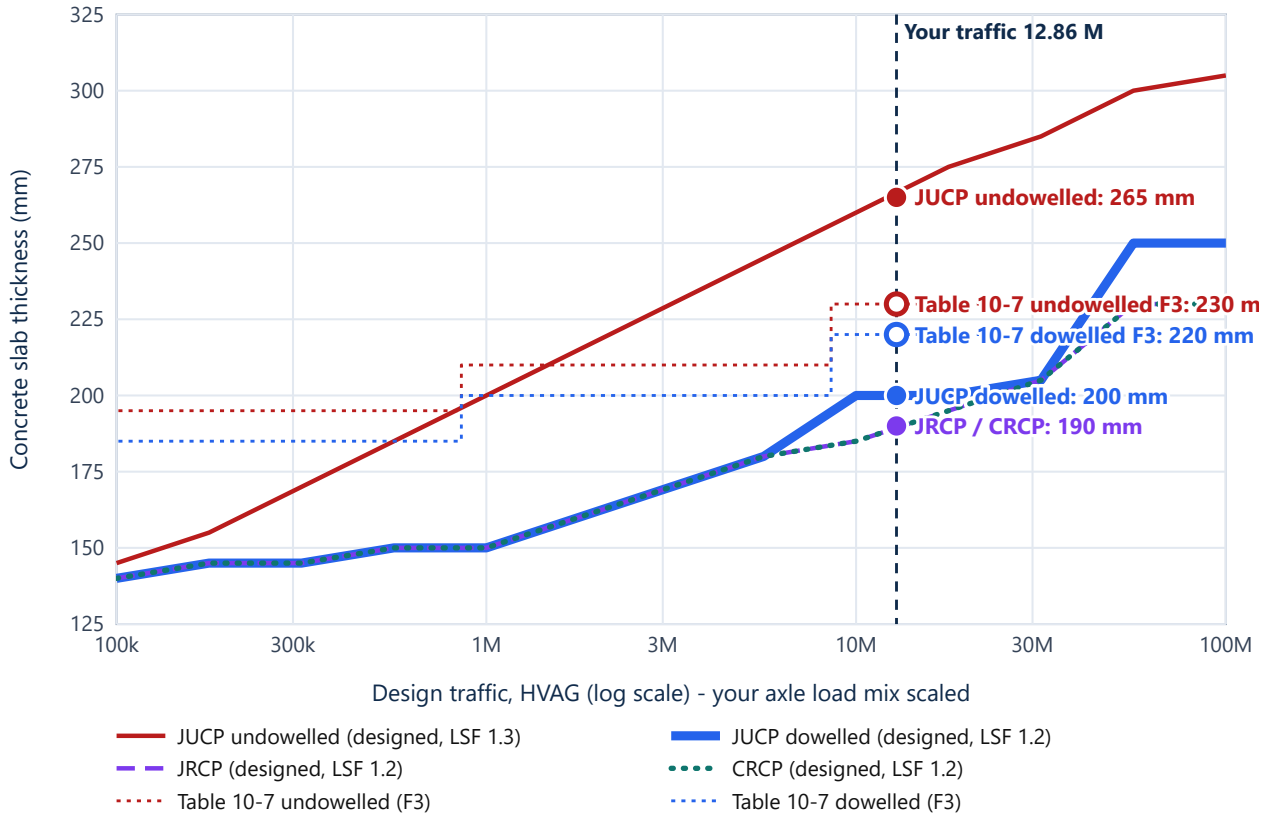
▼ TADT — Tandem axle, dual tyres: equivalent stress 1.021, erosion factor 2.319 — fatigue 0.00%, erosion 48.85%

Group load (kN)	Design load × LSF (kN)	Expected repetitions	Allowable (fatigue)	Fatigue (%)	Allowable (erosion)	Erosion (%)
213.4	256.1	2,679,281	Unlimited	0.00	5.74 M	46.71
186.8	224.1	1,607,569	Unlimited	0.00	75.40 M	2.13
115.6	138.7	2,679,281	Unlimited	0.00	Unlimited	0.00
Total				**0.00**		**48.85**

▼ TRDT — Triaxle, dual tyres: equivalent stress 0.856, erosion factor 2.323 — fatigue 0.00%, erosion 40.67%

Group load (kN)	Design load × LSF (kN)	Expected repetitions	Allowable (fatigue)	Fatigue (%)	Allowable (erosion)	Erosion (%)
329.1	394.9	1,607,569	Unlimited	0.00	3.95 M	40.67
Total				**0.00**		**40.67**

Design chart — slab thickness against traffic



Drawn by the tool with Table 10-4 for your axle load mix scaled to each traffic level, effective CBR 75.0%, 4.5 MPa, 95% reliability, with concrete shoulder (not a Road Note 31 figure). Dotted steps: the Table 10-7 catalogue for foundation F3, its MESA ranges converted at your 3.50 ESA per HVAG. Dowelled JUCP, JRCP and CRCP use the same design factors, so their calculated thickness is the same: they are drawn thick solid (JUCP dowelled), dashed (JRCP) and dotted (CRCP) so all three stay visible where they coincide; they part only where the Table 10-6 minimums differ (steps at 10 and 50 million HVAG). Circles: the thickness of each line at your traffic (filled = designed, hollow = Table 10-7 catalogue).

6. Reinforcement, dowels, tie bars and joints

Slab	190 mm, JRCP
JRCP mesh (Equation 10-7)	Longitudinal 224 mm^2/m (L = 10 m joint spacing); transverse 82 mm^2/m (L = 3.65 m to the free edge); μ 1.5, f_s = 0.6 × 500 MPa. Place at 1/4 to 1/3 of the depth; stop 40–80 mm from slab edges and joints (Section 10.5.5.2).
Dowel bars (Table 10-14)	28 mm diameter, 450 mm long, at 300 mm, at every transverse joint; smooth, corrosion-coated, on cradles; capped at expansion joints (25 mm + 10 mm gap).
Tie bars	12 mm deformed bars, 750–1000 mm long, at mid-depth, 100 mm centre coated: longitudinal joints at 1,000 mm c/c by Equation 10-7 (82 mm^2/m, L = 3.65 m); transverse construction joints at 300–500 mm (Sections 10.6.1.3, 10.6.2.2).
Concrete cover (Table 10-11)	Mesh: top 60 mm, bottom 90 mm; tie bars: top 70 mm, bottom 80 mm (row for slabs up to 200 mm).
Joints (Section 10.6.3)	Square joints at 8–12 m (input 10 m); every third joint usually an expansion joint. Slab widths 3.7–4.3 m; longitudinal joints tied, up to about 16 m tied width for JUC and 30 m for JRC / CRCP; joint grooves 1/4 to 1/3 of the depth, sealed.
Concrete	Flexural strength 4.5 MPa (minimum 4.5); compressive strength at least 32 MPa; f_{cf} = 1.37 f_{cs} from splitting tests (Equation 10-12); coarse aggregate up to 25 mm; separation membrane (125 μm polythene) under jointed slabs (Section 10.5.4.3).

7. Method, references and Road Note 31 misprints

- **Traffic.** Each axle group of each vehicle row is one load in the spectrum; repetitions = daily number in the design lane (Table 2-5 rule; for "heaviest direction" rules the direction with more axle groups) × seasonal factor × growth summed year by year (Equation 2-6). The MESA shown (for the Table 10-7 catalogue) uses the Table 10-2 standard loads with n = 4.
- **Thickness design (Table 10-4).** Effective subgrade CBR from Figure 10-2 (straight lines read from the figure, maximum 75%; below CBR 2 use 150 mm LCS and 5%). Equivalent stress S_e and erosion factor F_3 from Equation 10-5 with the coefficients of Tables 10-8 to 10-10 (CRCP and JRCP use the dowelled erosion table). Fatigue: Equations 10-2 to 10-4 (unlimited below S_r = 0.45); erosion: Equation 10-6 (F_2 = 0.94 with, 0.06 without concrete shoulder; unlimited when the bracket is zero). The thickness is the least multiple of 5 mm with total fatigue and erosion damage ≤ 100%, and not less than Table 10-6.
- **Verification.** The engine reproduces the Austroads AGPT02-26 Appendix M worked example (40 million HVAG, CBR_E 75%, 4.5 MPa, LSF 1.3, undowelled with shoulders): equivalent stresses and erosion factors of all five groups to 3 decimals, total fatigue 125% / erosion 119% at 210 mm and 66% / 93% at 215 mm, design thickness 215 mm.
- **Catalogue.** Table 10-7 gives slab and sub-base by MESA and foundation class (F1–F4 from the subgrade class and the capping of RN31 Key 3).
- **Below the sub-base** RN31 asks for at least 150 mm of unbound granular or selected subgrade material (Section 10.5.4.2); it is added to every option unless capping already provides it.
- **Steel.** JRCP mesh and transverse / tie steel by subgrade drag (Equation 10-7, $f_s = 0.6\ f_{sy}$, ρ = 2400 kg/m^3); CRCP longitudinal steel by Equations 10-8 and 10-10 with the 0.67% minimum; cover Table 10-11; dowels Table 10-14 (450 mm long at 300 mm).
- **Costs.** Construction quantities per km over the carriageway width at your rates; joint sealing, formwork and curing are not priced.
- **Not covered:** RCC and CRCB thickness (RN31 gives none), steel fibre concrete, roundabouts (LSF + 0.3), mix design (Section 10.5.6).

Road Note 31 misprints found against the Austroads source:

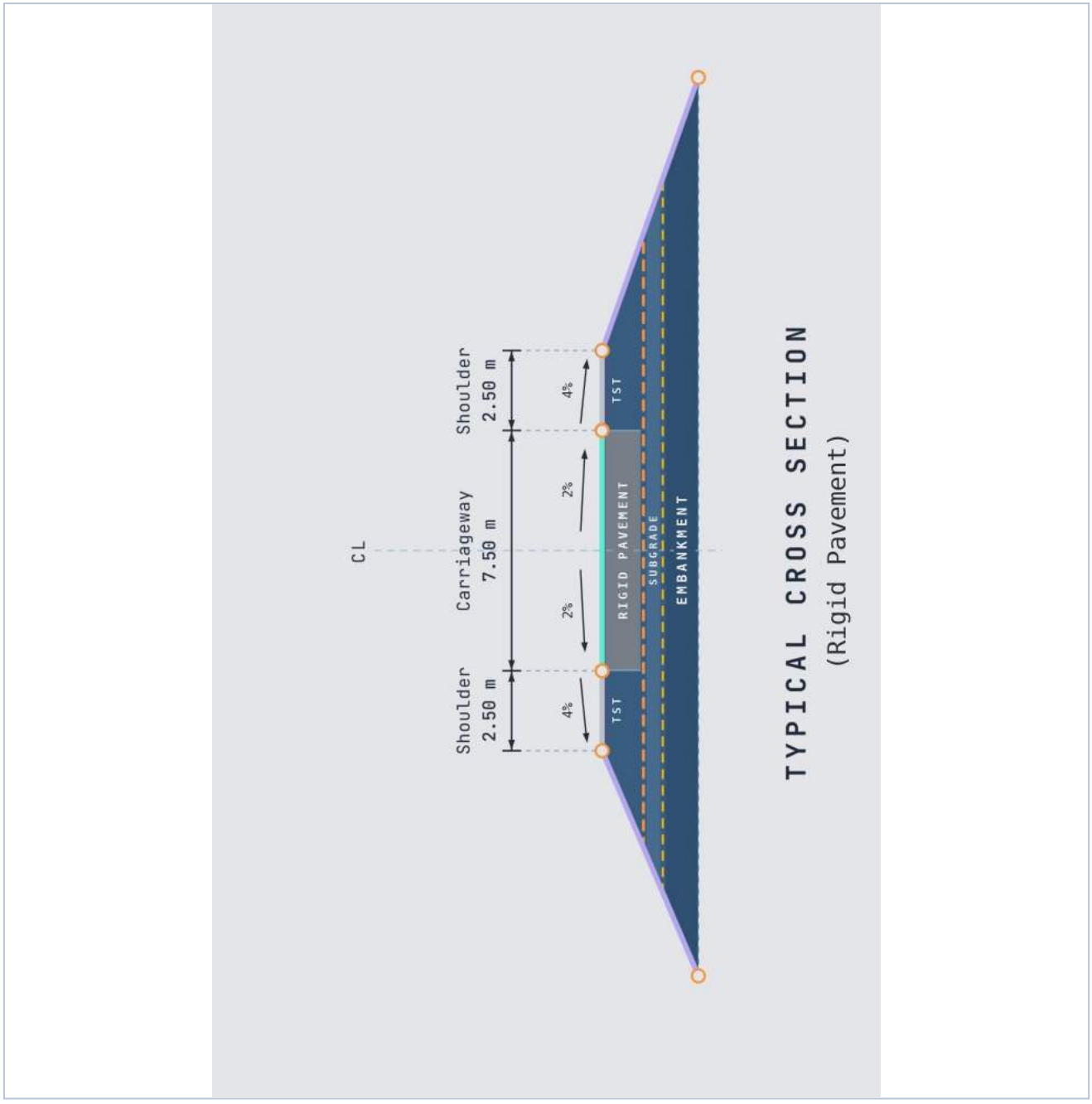
- Equation 10-3 is printed as N = (4.258 / (Sr - 0.0828))^3.268; the Austroads source (AGPT02 Equation 59) has (Sr - 0.4325), which is continuous with Equation 10-2 at Sr = 0.55. The tool uses 0.4325.
- Tables 10-9 and 10-10 head the first erosion column "SAST & TAST"; in the Austroads source (Tables 9.5 and 9.6) TAST is grouped with TADT, as the Appendix M worked example shows. The tool uses the Austroads grouping.
- Table 10-9 (undowelled, no shoulder): RN31 prints j = -1,387 for SAST and i = -1.0741 for TADT; the Austroads source has -1,384 and +1.0741. The tool uses the Austroads values.
- Table 10-7 labels its traffic ranges T1-T4 (0.1-3), T5-T7 (3-30) and T8-T10 (30-80), but Key 1 puts T8 at 17-30 MESA. The tool uses the printed MESA ranges.
- Equation 10-4 says the flexural strength is at least 4.5 MPa, while Table 10-4 step 5 allows 4 MPa where no strength data exist; the tool warns below 4.5 MPa.
- Equation 10-6 uses F4 = 72 for quad axles (QADT); the current Austroads guide (AGPT02-26) gives 54. This is a difference between the methods, not a misprint: the tool follows RN31.
- Equation 10-10 (CRCP minimum steel for crack-width control) prints the denominator as f_ct - m f_ct; the steel-yield derivation, and Austroads Equation 65, have f_sy - 7.5 f_ct. The tool uses f_sy - 7.5 f_ct.
- Interpretations are recorded here with the equation or table they concern; they follow the Austroads source where RN31 Chapter 10 is borrowed from it (the November 2024 RN31 revision still has the Equation 10-3 and Table 10-9 differences). Have each one reviewed by the responsible pavement engineer before the tool is relied on as validated design software.

- **References:** Road Note 31, 5th edition, TRL 2023 (FCDO / ReCAP), Chapter 10; Austroads AGPT02-26 *Guide to Pavement Technology Part 2: Pavement Structural Design*, Chapter 9 and Appendix M. Check every design against your road agency's requirements.

Generated with the free Road Note 31 Rigid Pavement Design tool at shahidpervaiz.net. Results must be checked by a qualified pavement engineer.

ANNEXURE – C (TYPICAL CROSS SECTIONS)

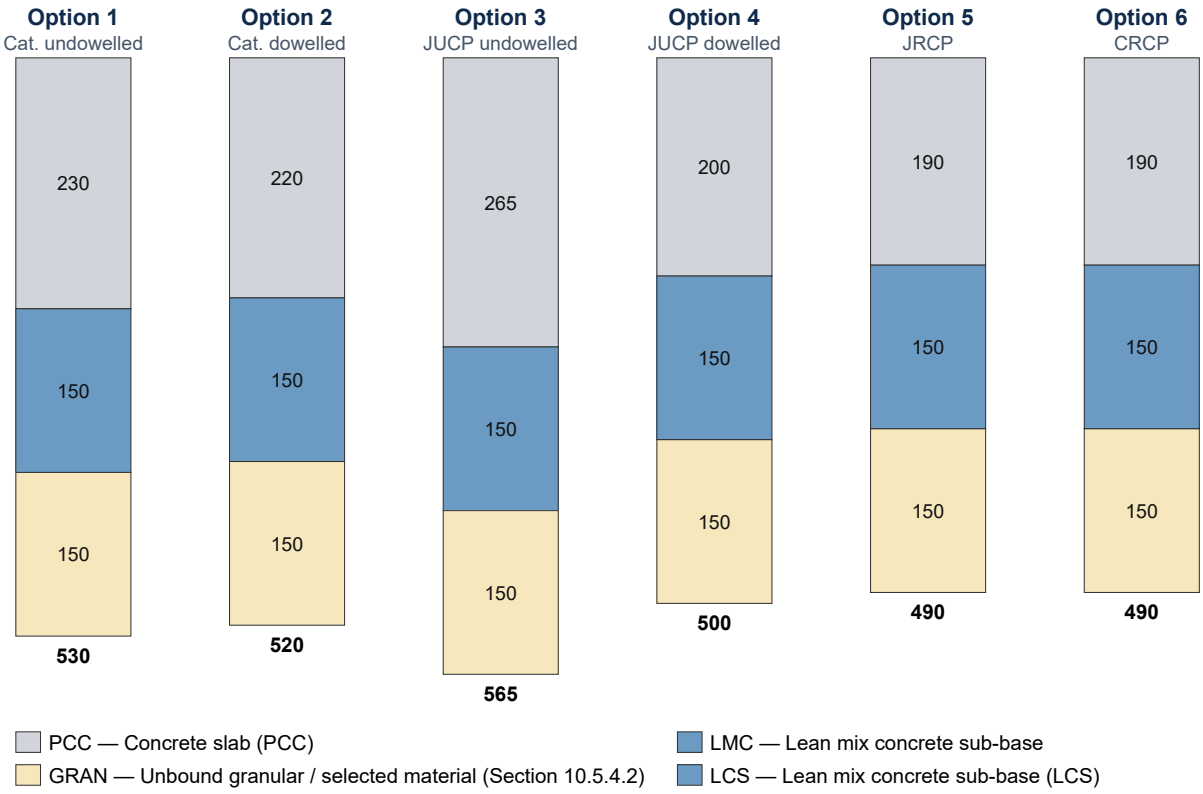
Referred to in: Executive Summary, 4.3 Recommended Pavement.



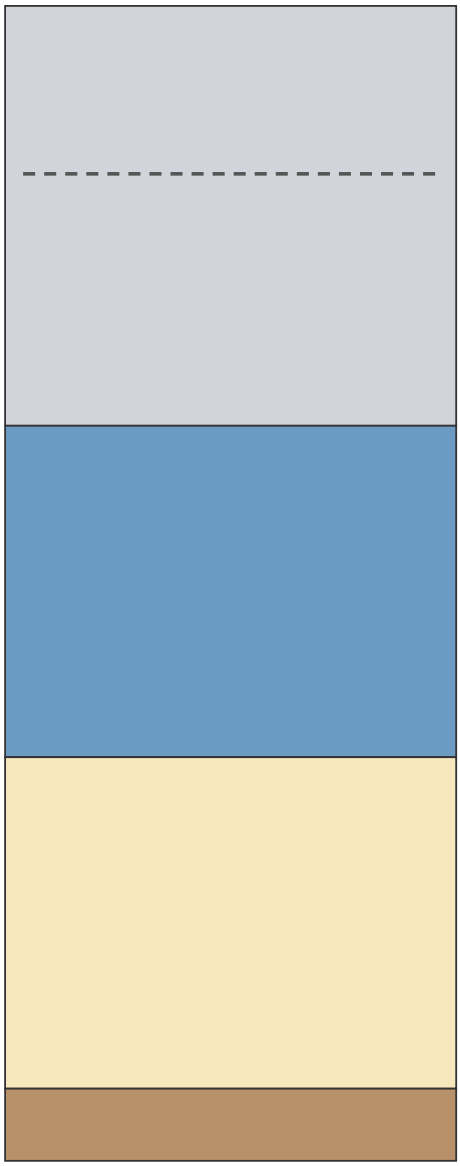
Sample drawing — insert the actual project cross section to replace this sample (upload it in the report form under Annexure C; use + Add cross section for more sections).

Pavement layers (to scale)

Pavement options drawn to scale by the tool (thicknesses in mm).



Recommended pavement



Concrete slab 190 mm

LCS 150 mm

GRAN 150 mm
one layer

Subgrade S5 (CBR 20%)

Total 490 mm; dashed line = reinforcement

ANNEXURE – D (SOIL INVESTIGATION RESULTS OF CBR)

Referred to in: Executive Summary, 3.1 Subgrade and Sub-base.

A subgrade design CBR of **20%** has been adopted in this design (see part 3.1 of this report).

Full soil and material investigation report, borehole logs and laboratory CBR test results to be attached separately by the design engineer (upload images or PDFs in the report form; + Add report / page for more).

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