JABATAN KERJA RAYA MALAYSIA

Cawangan Kerja Keselamatan · Pasukan Projek Khas 2

CADANGAN PEMBINAAN KEM 2 SKN RAJD, OYA, SIBU, SARAWAK (REKA & BINA)

No. Kontrak: JKR/IP/CKUB/225/2020

RIGID PAVEMENT DESIGN REPORT

FOR PROPOSED REINFORCED CONCRETE INTERNAL ROADS

Prepared in reference to Construction Drawing DPI/C/KEM2Sibu/C/RD/201

Implementing Agency	Design & Build Contractor	C&S Engineering Consultant
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ENDORSEMENT & CERTIFICATION

Cadangan Pembinaan Kem 2 SKN RAJD, Oya, Sibu, Sarawak (Reka & Bina)
Contract No. JKR/IP/CKUB/225/2020
Rigid Pavement Design Report — Reinforced Concrete Internal Roads

I, the undersigned, hereby certify that this pavement design report and the supporting calculations in Appendix B have been prepared in accordance with sound engineering practice and the governing standards — JKR ATJ 5/85 (Pindaan 2013), REAM GL 7/2004, the Odemark method of equivalent thickness, JKR/SPJ/2008 and MS 144. The reinforced concrete internal road pavement shown on PEPC-endorsed Construction Drawing DPI/C/KEM2Sibu/C/RD/201 has been assessed as structurally adequate for the internal camp traffic over the stated 10-year design life, together with the operational provisions in this report. The information is accurate to the best of my professional knowledge.

Name : IR. HILMI BIN OMAR
Designation : Managing Director
Company : DPI Konsult Sdn. Bhd.
PEPC No. : C17478 (Civil)

PE stamp & signature — Date: _______________

Compliance Statement & Professional Disclaimer

The data, design assumptions and derivations in this document are based on the contract documents, the PEPC-endorsed construction drawing `DPI/C/KEM2Sibu/C/RD/201`, and the standards named above. Liability is not assumed for unforeseen ground conditions, construction that departs from the endorsed drawings and specifications, third-party modifications, traffic loading in excess of the basis in Section 3, or misinterpretation of this report. The construction material test records are a separate submission to be read with this report. Any modification to the design basis requires formal review by DPI Konsult Sdn. Bhd.

Sign-off

Prepared by	Reviewed by
Abdul Rahman bin Hilmi **Design Engineer** **DPI Konsult Sdn. Bhd.**	Ir. Mohd Rawawi bin Awang Ngah Associate Director DPI Konsult Sdn. Bhd.

DOCUMENT CONTROL & DESIGN BASIS

1. Purpose and standing of this report

1. This is the **rigid pavement design report and design calculations** for the reinforced concrete internal roads at Kem 2 SKN RAJD, Oya, Sibu, prepared by DPI Konsult Sdn. Bhd. as the Civil & Structural Engineering Consultant for the project.
2. It provides the design basis and supporting calculations for the reinforced concrete internal road pavement shown on PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201` (Sheets 1 and 2, marked "Construction"), adopted for the bound surfacing in place of the contract flexible bituminous pavement.
3. The report addresses three aspects of the pavement design: (i) slab thickness and concrete grade; (ii) reinforcement type; (iii) load-bearing capacity. The transverse and construction joint details are provided separately on the PEPC-endorsed joint detail drawing (Deliverable R-1).
4. The report demonstrates that the pavement section (100 mm G30 slab, Road Type A; 125 mm G30 slab, Road Type C; both with two layers of BRC A7 fabric on the **identical** 50 mm sand bedding and 300–350 mm crusher-run foundation) is a sound engineering design for the internal camp traffic (Traffic Category T1) over a 10-year structural design life, and provides greater durability, hydrocarbon resistance and lower whole-life maintenance than the contract bituminous surfacing.

2. Scope of professional responsibility

Party	Responsibility
Design engineer	Design basis, traffic derivation, structural calculations (Appendix B), and operational provisions
Reviewing engineer	Verification of inputs, methodology and arithmetic
Endorsing PEPC	Professional endorsement that the design basis, calculations and conclusions represent sound engineering practice for the stated scope; personal check of Appendix B

3. Basis documents

1. PEPC-endorsed construction drawing `DPI/C/KEM2Sibu/C/RD/201`, Sheets 1 and 2, Contract Vol. 3 of 8 (Civil Works — Road Works).
2. JKR Arahan Teknik (Jalan) 5/85 (Pindaan 2013) and REAM GL 7/2004.
3. Contract Civil Works Design Brief and its supporting Design Calculation (Road Works), Vol. 3 of 8 (Civil Works) — including Design Calculation Sheet 2, Section 3.0, which fixes the subgrade design category (SG2).

4. Declaration

1. Traffic demand is derived from the logical internal camp-generated movements set out in Section 3.2. It is **not** based on the Sibu–Bintulu trunk-road traffic count, which is a regional through-road flow and not representative of a 6 m internal camp street.
2. The subgrade design parameter (Category SG2, CBR not less than 12.1 %) is that fixed by the Contract Civil Works Design Brief and its supporting Design Calculation (Road Works), Sheet 2 Section 3.0, and is adopted unchanged in this design. Compliance of the Grade 30 concrete is to be verified during construction by 28-day cube testing to JKR/SPJ/2008 Section 9; those records, together with the in-situ formation CBR and compaction records, form part of the separate construction verification package (see Deliverable R-2).
3. The operational provisions in Section 6 form part of the design and are to be implemented as described.

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY

This section states the pavement design, the aspects addressed, how the design has been verified, and what the design shows. Sections 2 to 8 give the full basis, calculations and supporting material.

1.1 Project Background & Context

1. The project **"Cadangan Pembinaan Kem 2 SKN RAJD, Oya, Sibu, Sarawak (Reka & Bina)"**, Contract No. **JKR/IP/CKUB/225/2020**, is the design-and-build of a Royal Army Engineers Regiment (RAJD) cantonment off the Sibu–Bintulu Road, Sibu Division, Sarawak.
2. DPI Konsult Sdn. Bhd. is the **Civil & Structural Engineering Consultant**; Wekajaya Sdn. Bhd. is the Design-and-Build contractor.
3. The Contract Civil Works Design Brief (Vol. 3 of 8, Section B3 Road Works, April 2021) specified the internal road network as a **flexible bituminous pavement with a 10-year design life**, to Arahan Teknik (Jalan) 5/85 and REAM guidelines:

- **Road Type A** (general internal roads — admin, quarters, utility): 100 mm bituminous surfacing (40 mm ACW + 60 mm ACB) on 50 mm sand bedding and 300 mm crusher-run road base.
- **Road Type C** (Main Entrance to *Trup Loji*, the heavy plant route): 110 mm bituminous surfacing (50 mm ACW + 60 mm ACB) on 50 mm sand bedding and 350 mm crusher-run road base. This route carries plant with an *unloader weight up to 42 MT* transported on a low-loader.

4. The internal road pavement is designed as **jointed reinforced concrete (Grade 30, two layers of BRC A7 fabric)** on the **identical granular foundation** — the sand bedding and crusher-run road base are unchanged from the contract flexible design (PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201`, marked "Construction"):

Layer Component	Road Type A	Road Type C
Bound surfacing	**100 mm** G30 concrete, 2 layers BRC A7 *(was 100 mm bituminous)*	**125 mm** G30 concrete, 2 layers BRC A7 *(was 110 mm bituminous)*
Sand bedding	50 mm *(unchanged)*	50 mm *(unchanged)*
Crusher run road base	300 mm *(unchanged)*	350 mm *(unchanged)*
Subgrade	compacted existing earth, design Category SG2 (CBR ≥ 12.1 %) — contract design basis, unchanged	same

5. The bound surfacing was changed from bituminous to reinforced concrete for resistance to fuel and oil spillage, freedom from shoving and rutting under slow-moving heavy plant, and lower whole-life maintenance — the grounds on which reinforced concrete was adopted for the internal roads (Section 5.2).

1.2 Basis of the Design Change

1. The Contract Civil Works Design Brief specified the internal road network as a flexible bituminous pavement with a 10-year design life. The bound surfacing was subsequently changed to jointed reinforced concrete — at no additional cost and with no extension of time — and is recorded on PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201` (Sheets 1 and 2, marked "Construction").
2. This report provides the design basis and supporting calculations for that change, covering **(i)** slab thickness and concrete grade; **(ii)** reinforcement type; and **(iii)** load-bearing capacity.
3. The transverse contraction, construction and isolation joint details are provided separately on the PEPC-endorsed joint detail drawing (Deliverable R-1). The construction-quality and material-testing records — method statement, inspection records, 28-day cube and formation test results, construction photographs and site-supervision diary — form a separate construction verification package.

1.3 Scope of This Design Report

1. The report sets out the **design basis** for the reinforced concrete pavement section: it characterises the section and foundation, establishes the internal traffic demand, and verifies structural adequacy through the equivalent-thickness comparison against the JKR ATJ 5/85 (Pindaan 2013) pavement catalogue.
2. Because the sand bedding and crusher-run road base are **identical** in the contract flexible section and the reinforced concrete section, and the road-base thickness is unchanged, the structural comparison is confined to the change in the **bound surfacing layer** — from bituminous surfacing to a Grade 30 reinforced concrete slab.
3. The internal traffic demand is **derived from logical internal camp movements** (Section 3.2). The 28,342 veh/day figure on the earlier design calculation sheet is a Sibu–Bintulu **trunk-road** count ("both directions, 24 hour") and does not represent a 6 m internal camp street.

1.4 Summary of Findings

1.4.1 Traffic classification

Road	Derived 10-year design ESAL	ATJ 5/85 category	Design life
Type A branches	≈ 0.06×10^6	**T1** (low-volume)	10 years
Type C spine (incl. controlled 42 MT low-loader)	≈ 0.24×10^6	**T1** (low-volume)	10 years

A sensitivity check tripling every traffic assumption yields ≈ 0.72×10^6 ESAL — still within Category T1. The classification is robust.

1.4.2 Structural adequacy — equivalent-thickness comparison

Check	Type A (100 mm slab)	Type C (125 mm slab)
Equivalent thickness of the concrete pavement section (Odemark, referred to the SG2 subgrade) vs the ATJ 5/85 catalogue requirement for Category T1 (≈ 515 mm)	≈ 688 mm even with the slab taken as fully cracked (≈ 920 mm uncracked) → **exceeds the T1 requirement**, adequacy ratio ≈ 1.34	≈ 819 mm cracked (≈ 1,109 mm uncracked) → **exceeds the T1 requirement**, adequacy ratio ≈ 1.59
Surfacing layer only — replacing the bituminous surfacing with G30 concrete on the same foundation	+69 mm equivalent thickness	+116 mm equivalent thickness
Crack control (BRC A7 to MS 144)	2 layers BRC A7, reinforcement ratio ≈ 0.28 % — above the minimum for crack-width control	2 layers BRC A7, reinforcement ratio ≈ 0.23 % — above the minimum for crack-width control

1.4.3 Reverse-capacity check (foundation basis)

Reading the design section equivalent thickness back against the ATJ 5/85 catalogue (Section 4.4) shows the section can sustain **≈ 27–33 times** the imposed 10-year design traffic before the equivalent-thickness ratio falls to 1.0. The foundation is not the limiting element of the design.

1.4.4 Role of the BRC A7 reinforcement

1. Two layers of BRC A7 (284 mm²/m total) provide **crack-width control** (reinforcement ratio 0.23–0.28 %, above the minimum for crack-controlled slabs on ground). They hold shrinkage and thermal cracks tight, preserving aggregate interlock and shear transfer across panels and preventing moisture ingress, spalling and subgrade pumping.
2. The reinforcement is provided for crack-width control, not as a load-capacity multiplier, consistent with MS 144 and JKR/SPJ/2008.

1.4.5 Design conclusion

The reinforced concrete internal road pavement is **structurally adequate as Traffic Category T1 low-volume camp roads for a 10-year structural design life**, on the basis that:

1. the internal camp traffic classifies robustly as Category T1 under ATJ 5/85;
2. on the equivalent-thickness comparison the concrete pavement section — even with the slab taken as fully cracked — exceeds the ATJ 5/85 catalogue requirement for Category T1 by a factor of 1.34 (Type A) to 1.59 (Type C), on the **same** 50 mm sand and 300–350 mm crusher-run foundation as the contract flexible design;
3. replacing the bituminous surfacing with a G30 concrete slab of the same order of thickness **increases** the load-spreading capacity of the section, not reduces it;
4. two layers of BRC A7 keep any crack tight and benign, and the operational provisions in Section 6 keep heavy plant within the design basis.

1.4.6 Design verification summary

Design aspect	Status in this report
(i) Slab thickness & concrete grade	Addressed. Grade 30 concrete to JKR/SPJ/2008 Section 9 (compliance to be verified by 28-day cube testing during construction) with 100 mm / 125 mm slab thickness, assessed as structurally adequate for Category T1 on the equivalent-thickness comparison against ATJ 5/85 and REAM GL 7/2004.
(ii) Reinforcement type	Addressed. Two layers of BRC A7 welded steel fabric to MS 144 / JKR/SPJ/2008, reinforcement ratio 0.23–0.28 %, above the minimum for crack-width control.
(iii) Load-bearing capacity	Addressed. Verified by the equivalent-thickness comparison against the ATJ 5/85 catalogue: the concrete pavement section exceeds the Category T1 requirement with an adequacy ratio of 1.34 (Type A) to 1.59 (Type C), and a reverse-capacity margin of 27–33×.

2.0 DESIGN BASIS, GOVERNING STANDARDS & METHODOLOGY

2.1 Governing Standards

1. JKR publishes one primary pavement design manual — **Arahan Teknik (Jalan) 5/85 (Pindaan 2013): Manual for the Structural Design of Flexible Pavement** — which establishes the traffic spectrum, load-equivalence factors, subgrade classification, design life and the pavement catalogue. For concrete pavements the national guideline is **REAM GL 7/2004**.
2. The design uses the following standards and method, and no others:

Standard / Method	Role in this design
JKR ATJ 5/85 (Pindaan 2013)	Traffic classification (Table 2.5), load-equivalence factors (Table 2.1), subgrade category (Table 2.6), 10-year design life for low-volume roads (Cl. 2.7), and the pavement catalogue used as the structural benchmark (Table 4.1 / Fig. 3.1).
REAM GL 7/2004 — *Guidelines to the Design of Plain Concrete Pavement*	Malaysian concrete-pavement guideline; referenced for the jointed-concrete-pavement design basis.
Odemark method of equivalent thickness	Transforms the layered pavement section into an equivalent thickness of subgrade-quality material, so the concrete pavement section can be compared directly against the ATJ 5/85 catalogue.
JKR/SPJ/2008 — Standard Specification for Road Works, Sections 4 & 9	Workmanship and material requirements for the crushed-aggregate road base (Section 4) and the Grade 30 concrete pavement (Section 9).
MS 144	Specification for the BRC A7 welded steel wire fabric (reinforcement).

2.2 Design Verification Method

The verification proceeds in four steps:

```
STEP 1  Characterise the pavement section and the foundation
        100 / 125 mm G30 slab + 2x BRC A7 ; 50 mm sand bedding ;
        300 / 350 mm crusher run ; subgrade Category SG2 (CBR >= 12.1%)
                                |
                                v
STEP 2  Establish the internal traffic demand
        Logical cantonment movements (NOT the Sibu-Bintulu trunk-road count)
        -> cumulative 10-year ESAL -> Traffic Category (ATJ 5/85)
                                |
                                v
STEP 3  Verify structural adequacy - equivalent-thickness comparison
        Odemark equivalent thickness of the concrete pavement section
        vs the ATJ 5/85 SG2 catalogue requirement for the design category
        -> adequacy ratio >= 1.0
                                |
                                v
STEP 4  Set out the operational provisions
        Heavy-vehicle routing and movement logging (Section 6)
```

The equivalent-thickness comparison isolates the engineering change. The sand bedding and crusher-run road base are identical in the contract flexible section and the reinforced concrete section, and the road-base thickness is unchanged, so the comparison reduces to the contribution of the **bound surfacing layer** — bituminous surfacing replaced by a Grade 30 reinforced concrete slab. Because concrete has a much higher stiffness than a bituminous layer of the same order of thickness, the substitution **increases** the load-spreading capacity of the section (Section 5.1).

2.3 Key Design Assumptions & Material Parameters

1. The parameters adopted for the equivalent-thickness calculation:

Parameter	Symbol	Road Type A	Road Type C	Basis
Concrete slab thickness	D	100 mm	125 mm	Drawing `DPI/C/KEM2Sibu/C/RD/201`
Concrete grade (28-day cube)	f_{cu}	30 MPa	30 MPa	JKR/SPJ/2008 Section 9
Assumed concrete stiffness — uncracked	E	20,000 MPa	20,000 MPa	Conservative design assumption for G30
Assumed concrete stiffness — fully cracked (lower bound)	E	3,000 MPa	3,000 MPa	Conservative lower bound with the slab held by dual-layer BRC A7
Crack-control steel fabric	—	2 layers BRC A7 (284 mm²/m total)	same	Drawing; MS 144
Sand bedding	h_{sand}	50 mm ($E \approx 80$ MPa)	50 mm	Drawing layer stack
Crusher-run road base	h_{cr}	300 mm ($E \approx 350$ MPa)	350 mm	Drawing layer stack; JKR/SPJ/2008 Section 4
Subgrade strength	CBR	≥ 12.1 % ($E_{sg} = 120$ MPa)	≥ 12.1 %	Category SG2 — contract Design Calculation Sheet 2 §3.0; ATJ 5/85 Table 2.6

2. The concrete stiffness is treated as a range. The **fully cracked lower bound** (3,000 MPa) is used as the governing case for the equivalent-thickness comparison, so the section is shown to be adequate even if the slab is assumed to have cracked throughout its area — a deliberately conservative basis. The uncracked value is reported alongside for context only.

2.4 Design Life & Serviceability Criteria

1. **Design life.** Arahan Teknik (Jalan) 5/85 (Pindaan 2013) Clause 2.7 states that, for low-volume and other rural roads (Traffic Categories T1 and T2), a design life of 10 years may be adequate. The structural design life for the internal cantonment road network is therefore **10 years**, matching the contract brief, which set a 10-year design life for the (flexible) internal pavement.
2. **Serviceability — foundation.** No structural rutting; subgrade vertical strain within the ATJ 5/85 catalogue envelope for Category T1; no subgrade pumping or road-base erosion.
3. **Serviceability — slab.** Shrinkage, thermal and any load-induced cracks restrained by the dual-layer BRC A7 to tight, non-progressing cracks; no joint faulting or corner spalling that would impair the running surface.

3.0 SITE PARAMETERS, TRAFFIC & MATERIAL PROPERTIES

This section establishes the engineering inputs: the subgrade foundation, the internal cantonment traffic demand, the Grade 30 concrete, and the dual-layer BRC A7 steel fabric. Values are taken from the contract Civil Works Design Brief and its supporting design calculation, JKR ATJ 5/85 (Pindaan 2013), and the contract material specifications.

3.1 Subgrade Strength & Foundation Parameters

1. The subgrade design basis is **Subgrade Category SG2** (design CBR taken at the SG2 threshold, ≥ 12.1 %; design resilient modulus $E_{sg} = 120$ MPa under JKR ATJ 5/85 (Pindaan 2013) Table 2.6). This is the value fixed by the Contract Civil Works Design Brief and its supporting **Design Calculation (Road Works), Design Calculation Sheet 2, Section 3.0 *"Sub Grade Strength / Sub Grade Category"*** (DPI Konsult Sdn. Bhd., 15 April 2020), forming part of Contract `JKR/IP/CKUB/225/2020`, Volume 3 of 8 (Civil Works).
2. For a Traffic Category T1 low-volume cantonment road network, an SG2 subgrade is a competent foundation.
3. The **same SG2 subgrade underlies the contract flexible pavement design**; it is adopted unchanged in this design, so the surfacing-only comparison in Section 5 is independent of the subgrade value. The pavement is founded on compacted existing earth in accordance with the standard road formation specification; in-situ CBR and compaction records for the formation form part of the separate construction verification package.

3.2 Traffic Loading Spectrum

3.2.1 Basis of the traffic derivation

1. The internal road network of Kem 2 SKN RAJD serves cantonment operations — administrative complexes, residential quarters, workshop facilities, and the heavy plant depot (*Trup Loji*).
2. The 28,342 veh/day figure on the earlier design calculation sheet is a through-traffic count on the external Sibu–Bintulu Federal trunk road, annotated "*24 hour per day – both directions*". A flow of that size is a regional trunk-road volume and is not a meaningful design input for the 6.0 m internal cantonment carriageway shown on the PEPC-endorsed construction drawing `DPI/C/KEM2Sibu/C/RD/201` (two 3.0 m lanes). The internal traffic demand is therefore derived from the cantonment-generated movements below.
3. Traffic is classified according to **JKR ATJ 5/85 (Pindaan 2013) Table 2.5**:

Traffic Category	10-Year Design Traffic ($\times 10^6$ ESAL)	Description
T1	≤ 1.0	Low volume (rural / access / minor facilities)
T2	$1.1 - 2.0$	Low to medium volume
T3	$2.1 - 10.0$	Medium volume
T4	$10.1 - 30.0$	Heavy commercial
T5	> 30.0	Very heavy trunk / expressway

4. Standard Malaysian **Load Equivalence Factors (LEF)** from **ATJ 5/85 Table 2.1**:

Vehicle Class	Description	LEF
Cars, 4WD, pickups, motorcycles	Light private and utility transport	≈ 0
CV1	Small lorries & vans (2 axles, < 3 MT)	0.1
CV2	Medium / large lorries (2–4 axles)	4.0
CV3	Articulated / prime movers (3+ axles)	4.4
CV4	Buses (2–3 axles)	1.8

3.2.2 Cantonment operational movements & design ESAL

The anticipated daily commercial-vehicle movements across the internal network:

Vehicle Class / Movement	Road Type A Branches (CV/day)	Road Type C Heavy Spine (CV/day)
CV1 — light delivery / maintenance vans	6 – 10	15 – 25
CV2 — supply, water, fuel & refuse lorries	1 – 3	5 – 10
CV3 — prime movers & low-loader tractors	≈ 0	1 – 3
CV4 — regimental transport buses	1 – 3	3 – 6
42 MT low-loader (plant to/from *Trup Loji*)	—	≤ 2 trips/week (≈ 100 trips/year)
Light vehicles (cars, 4WD, motorcycles)	frequent (non-damaging, LEF ≈ 0)	frequent (non-damaging, LEF ≈ 0)

Applying JKR ATJ 5/85 Equation (2) for the base-year equivalent standard axles on the governing Road Type C heavy corridor (upper bound: 20 CV1 + 8 CV2 + 2 CV3 + 5 CV4; lane distribution $L = 1.0$, terrain factor $T = 1.1$):

$$\mathrm{ESAL}_{\mathrm{Y1}} = [20(0.1) + 8(4.0) + 2(4.4) + 5(1.8)] \times 365 \times 1.0 \times 1.1 \approx 20,800 \ \mathrm{ESAL} / \mathrm{year}$$

For a 10-year design life at a growth rate of 3 % per annum (traffic growth factor $\mathrm{TGF} = 11.46$, ATJ 5/85 Table 2.4):

$$\mathrm{ESAL}_{\mathrm{DES}} = 20,800 \times 11.46 \approx 0.24 \times 10^{6} \ \mathrm{ESAL}$$

Road Classification	Cumulative 10-Year Design ESAL	Governing ATJ 5/85 Category
Road Type A (Branch Access)	$\approx 0.06 \times 10^{6}$ ESAL	**Category T1**
Road Type C (Main Spine Corridor)	$\approx 0.24 \times 10^{6}$ ESAL	**Category T1**
Type C sensitivity check ($\times 3$ traffic)	$\approx 0.72 \times 10^{6}$ ESAL	**Category T1 (upper bound)**

Both internal road alignments classify as **Traffic Category T1** ($\leq 1.0 \times 10^{6}$ ESAL).

3.2.3 42 MT low-loader

The heaviest operational vehicle on Road Type C is a multi-axle low-loader transporting heavy plant, with an unloader gross combination mass up to 42 MT. The heaviest single axle is of the order of 9 t. Movements are limited to about two trips per week (approximately 100 per year) and are included in the ESAL count above; their contribution to the 10-year cumulative total is small. The low-loader is managed by the operational provisions summarised in Section 6.3 and set out in full in the companion *Cantonment Traffic & Operational Provisions Guide* (routing to Road Type C, movement logging).

3.3 Concrete Material Properties (Grade 30)

1. Concrete for the rigid pavement is **Grade 30** (characteristic 28-day cube compressive strength $f_{cu} = 30$ MPa) conforming to **JKR/SPJ/2008 Section 9**:

Material Parameter	Symbol	Design Value	Source
28-day cube strength	f_{cu}	30.0 MPa	JKR/SPJ/2008 Section 9
Concrete density	γ_c	24.0 kN/m^3	Reinforced concrete
Assumed stiffness for equivalent-thickness comparison	E	3,000 MPa (cracked, governing) – 20,000 MPa (uncracked)	Conservative design assumption (Section 2.3)

2. Compliance of the Grade 30 concrete is to be verified during construction by 28-day cube testing at the sampling and acceptance frequency of JKR/SPJ/2008 Section 9. The cube test records form part of the separate construction verification package and are to be read with this design report.

3.4 Steel Fabric Specification (Dual-Layer BRC A7)

1. The concrete slabs are reinforced with **two layers of BRC A7** welded steel wire fabric conforming to **MS 144**, positioned near the top and near the bottom of the slab with 30 mm nominal cover.

Reinforcement Parameter	Specification / Value	Reference
Steel fabric type	**BRC A7** (7 mm wire at 200 mm pitch both ways)	MS 144
Cross-sectional area per layer	$A_s = 142 \text{ mm}^2/\text{m}$	MS 144
Total steel area (2 layers)	$A_{s,\text{total}} = 284 \text{ mm}^2/\text{m}$	Drawing `DPI/C/KEM2Sibu/C/RD/201`
Characteristic yield strength	$f_y = 500$ MPa	MS 144, Grade 500
Reinforcement ratio	**0.28 %** (Type A, 100 mm slab); **0.23 %** (Type C, 125 mm slab)	Above the 0.15 % minimum for crack-width control

2. The reinforcement ratio (0.23–0.28 %) exceeds the minimum area for crack-width control in a slab on ground (0.15 %), keeping shrinkage, thermal and any load-induced cracks tight and non-progressing.

4.0 STRUCTURAL ADEQUACY — EQUIVALENT-THICKNESS VERIFICATION

Structural adequacy is verified by transforming the pavement section into an equivalent thickness of subgrade-quality material by the **Odemark method of equivalent thickness**, and comparing that equivalent thickness against the JKR ATJ 5/85 (Pindaan 2013) pavement catalogue requirement for the design Traffic Category (T1, Section 3.2) on an SG2 subgrade.

The Odemark transformation is:

$$h_e = 0.9 \sum_{i=1}^{m} h_i \left(\frac{E_i}{E_{sg}}\right)^{1/3}, \qquad E_{sg} = 120 \text{ MPa}$$

The concrete slab stiffness is taken at its **fully cracked lower bound** ($E = 3,000$ MPa) as the governing case; the uncracked value ($E = 20,000$ MPa) is reported alongside for context.

4.1 Road Type A (100 mm G30 Slab on 300 mm Crusher Run)

Layer Component	Thickness h_i (mm)	Modulus E_i (MPa)	Equivalent Contribution $h_{e,i}$ (mm)
G30 concrete slab — fully cracked (governing)	100	3,000	263
G30 concrete slab — uncracked (context)	100	20,000	495
Sand bedding	50	80	39
Crushed-aggregate road base	300	350	386

$$h_{e,\text{cracked}} = 263 + 39 + 386 \approx 688 \text{ mm} \qquad h_{e,\text{uncracked}} \approx 920 \text{ mm}$$

Comparison against the JKR ATJ 5/85 (Pindaan 2013) SG2 catalogue, transformed the same way:

ATJ 5/85 catalogue baseline (SG2)	Equivalent thickness $h_{e,\text{req}}$ (mm)	Corresponding traffic
T1 / SG2 (design demand)	**515**	$\leq 1.0 \times 10^6$ ESAL
T2 / SG2	690	$1.1 - 2.0 \times 10^6$ ESAL
T3 / SG2	865	$2.1 - 10.0 \times 10^6$ ESAL
T4 / SG2	910	$10.1 - 30.0 \times 10^6$ ESAL

$$\text{Adequacy ratio (cracked slab)} = \frac{688}{515} \approx 1.34 \quad (\geq 1.0,\ \text{adequate})$$

Even with the slab assumed fully cracked, the Type A section is equivalent to a Category T2 flexible pavement and exceeds the Category T1 design requirement. Subgrade vertical strains remain within the catalogue envelope, so there is no rutting or subgrade-pumping mechanism.

4.2 Road Type C (125 mm G30 Slab on 350 mm Crusher Run)

Layer Component	Thickness h_i (mm)	Modulus E_i (MPa)	Equivalent Contribution $h_{e,i}$ (mm)
G30 concrete slab — fully cracked (governing)	125	3,000	329
G30 concrete slab — uncracked (context)	125	20,000	619
Sand bedding	50	80	39
Crushed-aggregate road base	350	350	451

$$h_{e,\,\text{cracked}} = 329 + 39 + 451 \approx 819\ \text{mm} \qquad h_{e,\,\text{uncracked}} \approx 1,109\ \text{mm}$$

$$\text{Adequacy ratio (cracked slab)} = \frac{819}{515} \approx 1.59 \quad (\geq 1.0,\ \text{adequate})$$

The cracked-slab equivalent thickness (≈ 819 mm) is equivalent to a Category T3 flexible pavement — a 59 % reserve over the Category T1 requirement. The slow-moving 42 MT low-loader load is spread by the stiff section over the 350 mm crushed-aggregate base, keeping subgrade contact pressure low and uniform.

4.3 Summary of Structural Adequacy

Evaluation Parameter	Road Type A (100 mm slab)	Road Type C (125 mm slab)
Equivalent thickness — cracked slab (governing)	≈ 688 mm	≈ 819 mm
Equivalent thickness — uncracked slab (context)	≈ 920 mm	≈ 1,109 mm
ATJ 5/85 catalogue requirement, Category T1 / SG2	515 mm	515 mm
Adequacy ratio (cracked slab)	**1.34 — adequate**	**1.59 — adequate**
Equivalent ATJ 5/85 category of the concrete pavement section	T2 (cracked) – T4 (uncracked)	T3 (cracked) – > T4 (uncracked)
Subgrade rutting / pumping risk	eliminated by the equivalent-thickness margin	eliminated by the equivalent-thickness margin
Crack-width control	2 layers BRC A7, $\rho = 0.28\%$	2 layers BRC A7, $\rho = 0.23\%$
Overall	**adequate for Category T1, 10-year design life**	**adequate for Category T1, 10-year design life**

4.4 Reverse-Capacity Assessment

Reading the cracked-slab equivalent thickness of the design section back against the ATJ 5/85 SG2 catalogue ceilings (T1: 515 mm / 1.0×10^6 ESAL; T2: 690 mm / 2.0×10^6; T3: 865 mm / 10.0×10^6):

Road Section	Cracked h_e (mm)	Equivalent traffic capacity	Imposed 10-year demand	Reserve factor
Road Type A	688	$\approx 2.0 \times 10^6$ ESAL	0.06×10^6 ESAL	$\approx 33\times$
Road Type C	819	$\approx 6.6 \times 10^6$ ESAL	0.24×10^6 ESAL	$\approx 27\times$

The equivalent-thickness capacity of the concrete pavement section exceeds the 10-year cumulative cantonment traffic demand by **27 to 33 times**. The foundation is not the limiting element of the design over the service life of the pavement.

5.0 COMPARISON OF THE FLEXIBLE AND RIGID DESIGNS

5.1 The Engineering Change — Bound Surfacing Only

5.1.1 What changed and what did not

The contract flexible design and the reinforced concrete design share the **same granular foundation**. The sand bedding and the crushed-aggregate road base are identical in material and in thickness; only the **bound surfacing layer** was changed, from bituminous surfacing to a Grade 30 reinforced concrete slab.

Layer Component	Contract Flexible — Type A	Reinforced Concrete — Type A	Contract Flexible — Type C	Reinforced Concrete — Type C
Bound surfacing	100 mm bituminous (40 ACW + 60 ACB)	**100 mm G30 concrete + 2× BRC A7**	110 mm bituminous (50 ACW + 60 ACB)	**125 mm G30 concrete + 2× BRC A7**
Sand bedding	50 mm	**50 mm — unchanged**	50 mm	**50 mm — unchanged**
Crushed-aggregate road base	300 mm	**300 mm — unchanged**	350 mm	**350 mm — unchanged**
Subgrade formation	compacted earth, Category SG2 (CBR ≥ 12.1 %)	same	same	same
Design life	10 years	10 years	10 years	10 years

The road-base thickness is unchanged. On Road Type A the surfacing thickness is also unchanged (100 mm bituminous replaced by 100 mm concrete); on Road Type C the concrete surfacing is 15 mm thicker than the bituminous surfacing it replaced.

5.1.2 Effect of the surfacing change on load-spreading

Because the foundation is identical, the structural effect of the change is fully captured by the equivalent thickness of the **surfacing layer alone** (Odemark transformation, referred to the SG2 subgrade, $E_{sg} = 120$ MPa):

Surfacing option	Thickness	Assumed stiffness E	Equivalent thickness of the surfacing $h_{e,\,\mathrm{surf}}$
Bituminous surfacing — Type A	100 mm	$\approx 1,200$ MPa	≈ 194 mm
G30 concrete — Type A, fully cracked (governing)	100 mm	3,000 MPa	≈ 263 mm
G30 concrete — Type A, uncracked	100 mm	20,000 MPa	≈ 495 mm
Bituminous surfacing — Type C	110 mm	$\approx 1,200$ MPa	≈ 213 mm
G30 concrete — Type C, fully cracked (governing)	125 mm	3,000 MPa	≈ 329 mm
G30 concrete — Type C, uncracked	125 mm	20,000 MPa	≈ 619 mm

On the identical foundation, replacing the bituminous surfacing with the Grade 30 concrete slab therefore **increases** the equivalent thickness of the section:

Road	Change in surfacing $h_{e,\,\mathrm{surf}}$ (concrete, fully cracked, vs bituminous)
Road Type A	**+69 mm**
Road Type C	**+116 mm**

Even on the conservative assumption that the concrete slab has cracked throughout its area, the concrete surfacing spreads load better than the bituminous surfacing it replaced. The complete section still exceeds the ATJ 5/85 catalogue requirement for Category T1 (Section 4). The change is a structural upgrade of the surfacing, on an unchanged foundation.

5.2 Why the Surfacing Was Changed to Concrete

The substitution of bituminous surfacing with Grade 30 reinforced concrete was made for the operational conditions of a military engineering cantonment:

Operational attribute	Bituminous surfacing	Reinforced concrete (Grade 30)
Fuel, oil & chemical resistance	Diesel, engine oil and hydraulic fluid dissolve the bitumen binder, causing ravelling, softening and potholing in workshop yards and vehicle staging areas.	Concrete is inert to hydrocarbons and resists fuel spills, solvents and lubricants in the *Trup Loji* plant yards and workshop aprons.
Slow-moving & stationary heavy plant	Bitumen deforms under stationary plant, heavy low-loaders and tight turning — shoving and rutting.	Concrete does not creep under sustained or slow load; no rutting or shoving under stationary plant or multi-axle low-loaders.
Tropical climate	High pavement temperatures soften the binder, accelerating rutting and aggregate loss; monsoon rain worsens it.	Concrete keeps its stiffness regardless of pavement temperature or surface water.
Maintenance	Periodic crack sealing, pothole patching and structural mill-and-overlay every 5 to 7 years.	Joint cleaning and resealing at roughly 8 to 10 year intervals; no structural resurfacing while within serviceability limits.

5.2.1 Whole-life maintenance profile

```
BITUMINOUS SURFACING
Year 0        Year 5        Year 10       Year 15       Year 20
Construction  Patch & seal  Mill & overlay Patch & seal  Mill & overlay
------+------------+-------------+-------------+-------------+-------->
      (recurrent surface disruption and fuel/oil damage repairs in plant yards)

G30 REINFORCED CONCRETE + DUAL BRC A7
Year 0                                    Year ~8-10    Year ~15-20
Construction                              Joint reseal  Condition audit
------+-----------------------------------------+-------------+-------->
      (durable running surface; no intermediate structural resurfacing)
```

The concrete surfacing removes the recurring 5 to 7 year bituminous resurfacing cycle and the fuel- and oil-damage repairs, at lower whole-life cost to the Government and with less disruption to cantonment operations — the durability grounds on which reinforced concrete was adopted for the internal roads.

6.0 DESIGN CONCLUSION, PROVISIONS & RECOMMENDATIONS

6.1 Design Conclusion

1. The jointed reinforced concrete internal road pavement at Kem 2 SKN RAJD, Oya, Sibu (Road Type A: 100 mm G30 slab + 2× BRC A7 on 300 mm crusher run; Road Type C: 125 mm G30 slab + 2× BRC A7 on 350 mm crusher run), shown on PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201`, has been assessed on the design basis set out in this report.
2. **Principal conclusion.** The reinforced concrete internal road pavement is **structurally adequate as a Traffic Category T1 low-volume cantonment road network for a 10-year structural design life**, together with the operational provisions in Section 6.3.
3. The conclusion rests on three findings:

Finding 1 — Traffic demand is low-volume (Category T1). Cantonment-generated traffic gives 10-year cumulative design values of ≈ 0.06×10^6 ESAL (Type A) and ≈ 0.24×10^6 ESAL (Type C), within the Category T1 threshold (≤ 1.0×10^6 ESAL). A 10-year design life complies with JKR ATJ 5/85 (Pindaan 2013) Clause 2.7.

Finding 2 — The section exceeds the ATJ 5/85 catalogue requirement for Category T1. On the Odemark equivalent-thickness comparison — even with the concrete slab taken as fully cracked — the pavement section gives an equivalent thickness of ≈ 688 mm (Type A) and ≈ 819 mm (Type C) against the Category T1 / SG2 requirement of ≈ 515 mm, an adequacy ratio of **1.34 to 1.59**, on the **same** 50 mm sand and 300–350 mm crusher-run foundation as the contract flexible design. The reverse-capacity margin is 27–33×.

Finding 3 — The BRC A7 controls crack width. Two layers of BRC A7 (284 mm^2/m total, reinforcement ratio 0.23–0.28 %, above the 0.15 % minimum for crack-width control) keep shrinkage, thermal and any load-induced cracks tight and non-progressing, preserving load transfer across panels and keeping water out of the foundation.

6.2 Design Verification Summary

Design aspect	Technical finding	Status
(i) Slab thickness & concrete grade	Grade 30 concrete ($f_{cu} = 30$ MPa) to JKR/SPJ/2008 Section 9, compliance to be verified by 28-day cube testing during construction; slab thickness 100 mm (Type A) and 125 mm (Type C), assessed as structurally adequate for Category T1 on the equivalent-thickness comparison against ATJ 5/85 and REAM GL 7/2004.	**Structurally adequate**
(ii) Reinforcement type	Two layers of BRC A7 welded steel fabric (284 mm^2/m total) to MS 144 and JKR/SPJ/2008, reinforcement ratio 0.23–0.28 %, above the minimum for crack-width control.	**Compliant**
(iii) Load-bearing capacity	Verified by the equivalent-thickness comparison against the ATJ 5/85 catalogue: the concrete pavement section exceeds the Category T1 requirement with an adequacy ratio of 1.34 (Type A) to 1.59 (Type C), and a reverse-capacity margin of 27–33×.	**Structurally adequate**

The transverse contraction, construction and isolation joint details are provided separately on the PEPC-endorsed joint detail drawing (Deliverable R-1); they are not covered in the body of this report.

6.3 Operational Provisions

To keep the pavement within its design basis over the 10-year design life, operational provisions covering heavy-vehicle routing, lane discipline, low-loader logging and drainage housekeeping **form part of the design** and are to be implemented as described. These provisions, and the accompanying Cantonment Vehicle Operational Guide, are set out in full in the companion document *Kem 2 SKN RAJD, Oya — Cantonment Traffic & Operational Provisions Guide*, issued alongside this report. The structural adequacy findings in Section 6.1–6.2 assume those provisions are implemented as written in that guide.

6.4 Recommendation & Deliverable Register

Ref	Action item	Responsible party	Milestone
R-1	Finalise, site-verify and PEPC-endorse the joint, dowel bar, tie bar and cover **detail drawing**.	DPI Konsult / Wekajaya	Formal submission
R-2	Include the 28-day concrete cube test records and the in-situ formation CBR / compaction records in the construction verification package.	Wekajaya / DPI Konsult	Formal submission
R-3	Implement the Cantonment Traffic & Operational Provisions Guide (companion document) and the low-loader logbook with the regimental transport officers.	DPI Konsult / Camp Command	On handover
R-4	Carry out annual walk-through condition surveys (joint sealant, drainage outfalls, surface tightness).	Camp Maintenance / JKR	Annual
R-5	Assemble the construction verification package (method statements, inspection checklists, QA/QC photographs, supervision diary, record drawings).	Wekajaya	Formal submission

6.5 Certification & Submission

This rigid pavement design report and the design calculations in Appendix B set out the design basis for the reinforced concrete internal road pavement shown on PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201`. Professional engineering endorsement is certified on the Endorsement & Certification page of this document.

7.0 APPENDICES

APPENDIX A — Construction Drawings Register & Layer Stacks

Drawing Number	Sheet	Drawing Title	Status / Endorsement
`DPI/C/KEM2Sibu/C/RD/201`	1 of 2	Road Layout Plan — cantonment alignment, ingress/egress off Sibu–Bintulu Road, Wisma Bintara / Wisma Perwira, Road Type A / Type C extents	PE stamp Ir. Hilmi bin Omar C17478; marked "Construction"
`DPI/C/KEM2Sibu/C/RD/201`	2 of 2	Detail of Reinforced Concrete Road for Road Type A and Road Type C — layer stack and structural dimensions	PE stamp Ir. Hilmi bin Omar C17478; marked "Construction"
`C-RD201.dwg`, `C-RD202.dwg`	CAD	Digital CAD alignment, cross-sections, and drainage layouts	Technical archive
Joint & Detailing Drawing	—	Detail of transverse contraction joints, construction joints, isolation joints, dowels, tie bars, and BRC A7 cover	Final submission deliverable (R-1)

Structural cross-sections from PEPC-endorsed Construction Drawing `DPI/C/KEM2Sibu/C/RD/201` Sheet 2 of 2:

```
ROAD TYPE A (Branch Roads)             ROAD TYPE C (Heavy Corridor)
100 mm  G30 Concrete, 2 layers BRC A7      125 mm  G30 Concrete, 2 layers BRC A7
 50 mm  Sand Bedding                        50 mm  Sand Bedding
300 mm  Crushed Aggregate Road Base        350 mm  Crushed Aggregate Road Base
        Compacted Formation (SG2, CBR >= 12.1%)    Compacted Formation (SG2, CBR >= 12.1%)
```

The sand bedding and crushed-aggregate road base are identical to the contract flexible section (Section 5.1).

APPENDIX B — Design Calculation Sheets

B.1 Summary of engineering inputs

Parameter	Symbol	Road Type A	Road Type C	Unit	Source
Concrete slab thickness	D	100	125	mm	Drawing `DPI/C/KEM2Sibu/C/RD/201`
Concrete 28-day cube strength	f_{cu}	30	30	MPa	JKR/SPJ/2008 Section 9
Assumed concrete stiffness — cracked (governing)	E	3,000	3,000	MPa	Conservative design assumption
Assumed concrete stiffness — uncracked (context)	E	20,000	20,000	MPa	Conservative design assumption
Subgrade resilient modulus (SG2)	E_{sg}	120	120	MPa	JKR ATJ 5/85 Table 2.6; Category SG2 per contract Design Calculation Sheet 2 §3.0
Crushed-aggregate base modulus	E_{cr}	350	350	MPa	JKR ATJ 5/85 / JKR/SPJ/2008
Sand bedding modulus	E_{sand}	80	80	MPa	Pavement standard
Steel fabric area (2 layers BRC A7)	$A_{s,\text{total}}$	284	284	mm^2/m	MS 144

B.2 Traffic spectrum & design ESAL (JKR ATJ 5/85 Pindaan 2013)

$$\mathrm{ESAL}_{\mathrm{Y1}} = \left[\sum_{i=1}^{k} \mathrm{CV}_i \cdot \mathrm{LEF}_i\right] \times 365 \times L \times T$$

$$\mathrm{ESAL}_{\mathrm{DES}} = \mathrm{ESAL}_{\mathrm{Y1}} \times \mathrm{TGF}(r = 3\%,\ n = 10) = \mathrm{ESAL}_{\mathrm{Y1}} \times 11.46$$

Operational parameter	Road Type A	Road Type C	Type C sensitivity ($\times 3$)
Daily commercial spectrum (CV1 / CV2 / CV3 / CV4)	6 / 2 / 0 / 2	20 / 8 / 2 / 5	60 / 24 / 6 / 15
Daily equivalent factor $\sum \mathrm{CV}_i \cdot \mathrm{LEF}_i$	4.2 ESAL/day	51.8 ESAL/day	155.4 ESAL/day
Lane & terrain factors (L, T)	1.0, 1.1	1.0, 1.1	1.0, 1.1
Base-year traffic ($\mathrm{ESAL}_{\mathrm{Y1}}$)	$\approx 4,900$ ESAL/yr	$\approx 20,800$ ESAL/yr	$\approx 62,400$ ESAL/yr
Traffic growth factor ($\mathrm{TGF}_{10\ \mathrm{yr},\ 3\%}$)	11.46	11.46	11.46
Cumulative 10-year traffic ($\mathrm{ESAL}_{\mathrm{DES}}$)	$\approx 0.056 \times 10^6$	$\approx 0.24 \times 10^6$	$\approx 0.72 \times 10^6$
Governing ATJ 5/85 category	**T1**	**T1**	**T1**

B.3 Equivalent thickness — Odemark method

$$h_e = 0.9 \sum_{i=1}^{m} h_i \left(\frac{E_i}{E_{sg}}\right)^{1/3}, \qquad E_{sg} = 120 \text{ MPa}$$

Layer component	Thickness h_i (mm)	Modulus E_i (MPa)	Contribution $h_{e,i}$ (mm)
Sand bedding	50	80	39
Crushed-aggregate base — Type A	300	350	386
Crushed-aggregate base — Type C	350	350	451
G30 concrete slab — cracked (governing), 100 / 125 mm	100 / 125	3,000	263 / 329
G30 concrete slab — uncracked (context), 100 / 125 mm	100 / 125	20,000	495 / 619

- **Type A:** $h_{e,\,\mathrm{cracked}} \approx 688$ mm (adequacy ratio $688 / 515 = 1.34$ — adequate); $h_{e,\,\mathrm{uncracked}} \approx 920$ mm.
- **Type C:** $h_{e,\,\mathrm{cracked}} \approx 819$ mm (adequacy ratio $819 / 515 = 1.59$ — adequate); $h_{e,\,\mathrm{uncracked}} \approx 1,109$ mm.
- **ATJ 5/85 catalogue requirement, Category T1 / SG2:** ≈ 515 mm.

B.4 Reverse-capacity assessment

Calibrating h_e against the ATJ 5/85 SG2 catalogue ceilings (T1: 515 mm / 1.0×10^6; T2: 690 mm / 2.0×10^6; T3: 865 mm / 10.0×10^6 ESAL):

Road section	Cracked h_e (mm)	Equivalent capacity	Imposed 10-year demand	Reserve factor
Road Type A	688	$\approx 2.0 \times 10^6$ ESAL	0.056×10^6 ESAL	$\approx 33 \times$
Road Type C	819	$\approx 6.6 \times 10^6$ ESAL	0.24×10^6 ESAL	$\approx 27 \times$