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Mine Road Geometric Feasibility Study Pt Mahakam Sumber Jaya Uses Manual Method Of Road Pavement Design (Mdpl)

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Abstract – The operational road section of PT Mahakam Sumber Jaya is a supporting tool for coal production operational activities located in Separi, Kutai Kartanegara. This study plans the geometric design and thickness of the road pavement. It attempts to review the geometric planning referring to the Bina Marga standards and re-planning using Auto CAD Civil 3D software, which is commonly used in geometric road planning, while the thickness planning of the pavement usually employs component analysis methods; however, I am re-planning using the Manual Pavement Design Method of 2024. The geometric planning of the road includes horizontal and vertical alignments, while the pavement thickness planning includes the detailed planning of rigid pavement structures. From the geometric planning results with a road length of 4.539 km, a pavement width of 2 x 3.5 m, a total of 7 curves, and a thickness of 300 mm concrete with a concrete quality of Fs 4.5 MPa, layers Foundation thickness 150 mm, LPA class A 200 mm, and selected coarse granular embankment 200 mm.

Keywords: Geometric planning, rigid pavement thickness, public works method, pavement design manual

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1. Introduction

The basis of geometric design is the nature of movement, the size of the vehicle (dimensions and weight), the nature of the driver, and the characteristics of the traffic flow (speed, density, and volume) [1]. In geometric planning, there are three important elements: horizontal alignment (road trace), with a special emphasis on road axis design; vertical alignment (road's extended cross-section); and the road's transverse cross-section. The effective design of horizontal alignment, including the selection of curve radii, is crucial to ensuring smooth and safe operations, especially on mine haul roads [2]

Generally, road pavement construction is divided into two types: flexible pavement and rigid pavement. There are several methods for planning pavement thickness. This research uses the method outlined in the 2024 Road Pavement Design Manual, which is the most recent

guideline available. The scope of the planning is at PT. MAHAKAM SUMBER JAYA, Separi Site, Kutai Kartanegara. Due to the opening of an Open Pit Mining area (the primary location in the open mining method), a new road was constructed to support the smooth production of coal, with a length of 4.5 km and a width of 7 m.

The design of pavement for a coal mine haul road in Indonesia often relies on subgrade soil characteristics such as the California Bearing Ratio (CBR), which is a key parameter in determining the thickness of pavement layers [3]. Therefore, a thorough geometric and pavement design is essential to ensure that this haul road can function optimally in supporting the operational activities of the coal mining company.

2. Research Objectives

1. Know the right geometric design according to the N0 rule. 13 /P/ BM / Year 2021 Directorate General of Highways.
2. Knowing the thickness of the pavement using the guidelines of the Road Pavement Design Manual No. 03 / M / BM / 2024 of the Directorate General of Highways.
3. Identify existing problems, plan improvements, compare existing.

3. Method

3.1 Data Collection

The data collection process begins by conducting literature studies related to research obtained from related agencies (company data), libraries (literature). Furthermore, the field orientation was carried out by conducting a field review to make direct observations of the conditions of the research area and mining activities at the location.

Figure 1. Research Design

Data Analysis Techniques

After obtaining the necessary data, an analysis can be carried out for the geometric planning of the road:

a. Topographic maps are obtained from data downloads from the survey team which are then processed to obtain contour maps.
b. Road Geometric Planning is guided by Road Geometric Design No. 13 of 2021 Directorate General of Highways.
c. Road Pavement Planning uses the guidelines of the Road Pavement Design Manual No. 03 / M / BM / 2024 of the Directorate General of Highways.

4. Analysis

The analysis data used for the calculation is data taken from the observation results, the data taken is LHR data, DCP data, which is needed to determine the calculation of the pavement. The following are the results of daily LHR data on PT. MAHAKAM SUMBER JAYA.

4.1. Geometric Calculations

The geometric calculations involve determining the length of the road trace and the azimuth for each segment, as well as detailed planning for each curve.

a. Coordinate Data (x, y)

The following 9 coordinate points are used in the calculations:
A: (2783.501, 3719.042)
B: (2920.877, 3581.102)
C: (3332.968, 3592.405)
D: (3649.986, 4600.302)
E: (4149.451, 4880.818)
F: (4793.341, 4905.798)
G: (5149.930, 5300.071)
H: (5362.223, 6292.815)
I: (5492.728, 6411.504)

b. Determining the Trase Length (D)

The length of each segment is calculated using the Euclidean distance formula,

$$\mathbf{D = (xa-xb)^2 + (ya-yb)^2} \quad (1)$$

Table 1. Euclidean distance formula

Symbol	*Description*
DD	Distance or length between two points (in units such as meters)
xa,xbx_a, x_b	X-coordinates of the first point (a) and second point (b)
ya,yby_a, y_b	Y-coordinates of the first point (a) and second point (b)
\sqrt{}	Square root of the sum of the squared differences in coordinates

DAB : 194.68 m
DBC : 412.25 m
DCD : 1056.58 m
DDE : 572.85 m
DEF : 644.37 m
DFG : 531.61 m
DGH : 1015.19 m
DHI : 176.40 m

C. Determining the Azimuth (J)

The azimuth for each road segment is calculated using the formula:

$$\mathbf{J = 90 - arctan\ (xa-xbya-yb)} \quad (2)$$

Table 2. Azimuth formula

Symbol	*Description*
JJ	Azimuth angle (in degrees)
xa,xbx_a, x_b	X-coordinates of point A and point B
ya,yby_a, y_b	Y-coordinates of point A and point B
arctan\arctan	Inverse tangent function (returns angle in degrees or radians, depending on calculator settings)

J1 (A-B): 135.12°
J2 (B-C): 88.43°
J3 (C-D): 17.46°

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J4 (D-E): 60.68°
J5 (E-F): 87.78°
J6 (F-G): 42.13°
J7 (G-H): 12.07°
J8 (H-I): 47.71°

D. Determining the Angle (Δ)

The turning angle at each point is calculated as the difference in azimuth between consecutive segments.

Δ1 (at B): 46.69°
Δ2 (at C): 70.97°
Δ3 (at D): 43.22°
Δ4 (at E): 27.10°
Δ5 (at F): 45.65°
Δ6 (at G): 30.06°
Δ7 (at H): 35.64°
Δ8 (at I): 7.13°

E. Calculating Turns

The calculations were performed for 7 turns with a design speed (Vr) of 60 km/h. The design parameters used include:

Planned Speed (Vr): 60 km/h
Minimum Radius (Rmin): 130.03 m
Curve Type: Spiral-Circle-Spiral (S-C-S) Bend

Each turn has a different set of planning details, such as the circular radius (Rc), spiral length (Ls), and total length of the curve (Total L).

Turn 1 (Trase A-B-C): Rc = 180 m, Ls = 60 m, Total L = 206.60 m, Ts = 73.80 m.
Turn 2 (Trase B-C-D): Rc = 239 m, Ls = 50 m, Total L = 345.88 m, Ts = 160.25 m.
Turn 3 (Trase C-D-E): Rc = 180 m, Ls = 60 m, Total L = 195.71 m, Ts = 68.33 m.
Turn 4 (Trase D-E-F): Rc = 180 m, Ls = 60 m, Total L = 145.09 m, Ts = 42.89 m.
Turn 5 (Trase E-F-G): Rc = 205 m, Ls = 60 m, Total L = 223.25 m, Ts = 85.71 m.
Turn 6 (Trase F-G-H): Rc = 205 m, Ls = 60 m, Total L = 167.48 m, Ts = 57.71 m.
Turn 7 (Trase G-H-I): Rc = 287 m, Ls = 50 m, Total L = 228.45 m, Ts = 103.52 m.

F. Pavement Calculation

Calculation of Rigid Pavement for Pavement Design Manual (MDP) Traffic 2024.

Table 3. Pavement Design Manual (MDP) Traffic 2024.

1. Plan age (UR)	: 40 years old
2. Early Year Data	: 2024
3. Opening of traffic in the year	: 2025
4. Traffic growth rate per year (i)	: 3.5
5. Number of Columns	: 2
6. Tensile strength, Fcf	: 4.5
7. Type of Pavement	: JPCP
8. Load safety factor, Lsf	: 1.2
9. Road shoulder material type	:Concrete

The average daily traffic data is converted to the Number of Commercial Vehicle Axis Groups (JSKN) Vehicle Axis configuration table so that it is obtained as shown in the table below.

Table 5. Number of Commercial Vehicle Axis Groups (JSKN)

Goal. Own.	LHR	WHERE	STRT	CTRL	STdRT	STdRG	STrRG	SQrRG
1	2	3	4	5	6	7	8	9
Goal. 5A	241	482	241	241	0	0	0	0
Goal. 6A	0	0	0	0	0	0	0	0
Goal. 6B	815	1630	815	815	0	0	0	0
Goal. 7A1	0	0	0	0	0	0	0	0
Goal. 7A2	0	0	0	0	0	0	0	0
Goal. 7A3	22444	44888	0	0	22444	22444	0	0
Goal. 7B1	0	0	0	0	0	0	0	0
Goal. 7B2	0	0	0	0	0	0	0	0
Goal. 7B3	0	0	0	0	0	0	0	0
Goal. 7C1	0	0	0	0	0	0	0	0
Goal. 7C2A	0	0	0	0	0	0	0	0
Goal. 7C2B	0	0	0	0	0	0	0	0
Goal. 7C3	0	0	0	0	0	0	0	0
Goal. 7C4	0	0	0	0	0	0	0	0
Total	23500	47000	1056	1056	22444	22444	0	0
R	84,550							
Proportion of Vehicle Type (%)		100	2,25	2,25	47,75	47,75	0,00	0

To calculate the daily average number of heavy vehicles on the design path cumulatively using the equation

JSKN= (∑LHR jk x JSKN jk)* 365*DD*DL*R (3)

= 580184005.9

Tabel 6. California bearing ratio (CBR)

Segmen	From	Wed	CBRsegmen	CBR design	FK (%)
1	0+000	4+250	18.18	4.92	0.54

Table 7. CBR table of basic soil equivalent design

No	Material	Dharat Dukug CBR (%)	Thick
1	LFA Class A	9000%	0,2
2	Coarse-grained selection stack	3000%	0,2
3	Groundland	4,92%	200,0

CBR Ekuivalen

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CBR Ekuivalen = **(∑i.hi.CBRi033/∑i.hi)^3 (4)**

= 4,877478395 %

Bottom Foundation Thickness

Value of Number of Commercial Vehicle Axis Group (JSKN) 580184005.9

Based on Table 7 The minimum bottom foundation thickness for cement concrete pavement is obtained as a type of lower foundation layer in the form of

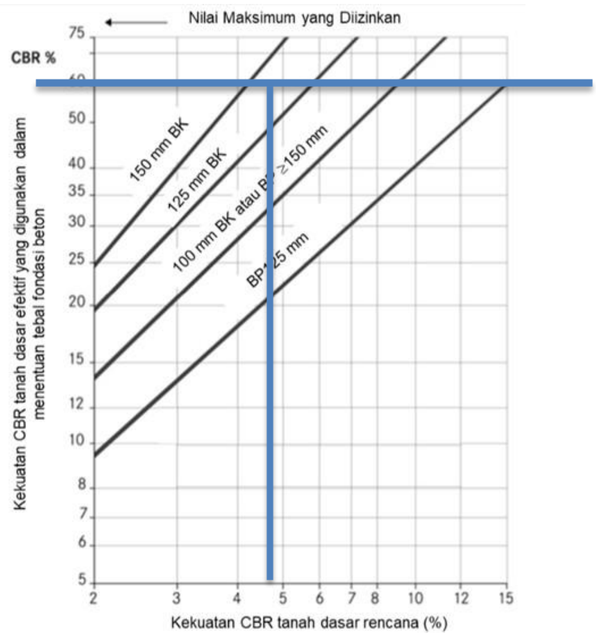

Figure 2. Thick Concrete Rigid Pavement Plan

From the relationship between the value of the number of commercial vehicle axis groups (JSKN) and the table

G. Minimum concrete thickness

Minimum Rigid Pavement Thickness Determination

The determination of the minimum rigid pavement concrete thickness aims to ensure that the mine road structure is capable of withstanding heavy vehicle loads throughout its design life without experiencing significant structural failure due to:

- Fatigue (concrete deterioration) from repeated loading
- Erosion of the slab base caused by traffic pressure and water infiltration

This study adopts a calculation approach based on the number of commercial vehicle axles (JSKN) and the manual design method issued by the Indonesian Ministry of Public Works and Housing (PUPR).
In addition to the national manual, international research supports the importance of considering both structural fatigue and base erosion in determining the optimal pavement thickness. Ceylan et al. (2013) demonstrated through mechanistic-empirical simulations that insufficient slab thickness significantly increases the risk of bottom-up cracking under high-repetition loading. Furthermore, Li & Liu **(2010)** emphasize that rigid pavement in high-load environments like mining haul roads should be designed with higher thickness to reduce deflections, as even minor joint deflection can initiate pumping and progressive erosion. These findings reinforce the need for conservative design in mine roads, recommending a minimum feasible thickness of 243 mm and an optimal thickness of 300 mm, particularly when subgrade strength and drainage conditions are uncertain.

H. Concrete Thickness Simulation

Simulation was conducted using two concrete thickness scenarios to evaluate the pavement structure's performance against fatigue and erosion:

1. Tested Concrete Thickness:
   - Case 1: Actual thickness = 243 mm (below initial minimum of 250 mm)
   - Case 2: Thickness = 300 mm (above standard minimum as a conservative design option)

I. Pavement Performance Evaluation

Two key parameters were analyzed:

1. Fatigue Damage
   - Based on heavy traffic loading and load repetitions in relation to concrete's modulus of elasticity and flexural strength

Result:

- Fatigue Damage for both cases = 0.000%
- < 100% → Safe

2. Erosion Damage

Refers to the loss of base support due to water infiltration and dynamic pressure from heavy vehicle wheels.

Table 8. CBR table of basic soil equivalent design

Concrete Thickness (mm)	*Fatigue Damage (%)*	*Erosion Damage (%)*	*Remarks*
243	0.000	76.06	Safe, acceptable
300	0.000	0.010	Very safe, conservative

5. Results and Discussion

Although 243 mm is technically within safety limits—as both fatigue and erosion damages are calculated to be under 100% threshold—it poses a higher long-term risk, especially if subgrade conditions deteriorate over time or traffic intensity increases. Such minimal thickness can lead to early-stage failures such as corner cracking, loss of support due to pumping, and increased deflection under dynamic loading.

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- In contrast, a 300 mm concrete thickness provides a greater structural capacity, better load transfer, and improved resistance to both fatigue and erosion-related distresses. This is particularly important for mine haul roads subjected to:
- High traffic repetition and heavy-duty operations
- Extreme axle loads, such as those from large mining trucks (e.g., CAT 793, Komatsu 830E)
- Variable subgrade strengths, which may degrade seasonally due to moisture fluctuation or consolidation

According to Baek & Cho (2017), increased slab thickness directly correlates with enhanced fatigue life and load-bearing capacity, especially in mine haul road systems. Their findings emphasize that thinner slabs, while structurally acceptable under ideal conditions, offer very little margin for operational variability.

Moreover, Alegre et al. (2019) stress that Jointed Plain Concrete Pavement (JPCP) is essential in such environments to control shrinkage cracking and thermal stresses, which are often magnified in large, open-surface haul roads exposed to daily temperature fluctuations. The inclusion of contraction joints at appropriate spacing improves ride quality, minimizes joint faulting, and reduces maintenance frequency.

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a. Typical Rigid Pavement Layer Structure

Table 9. Typical Rigid Pavement

Layer	*Material*	*Function*	*Thickness (mm)*
Surface	Cement concrete (fs = 4.5 MPa)	Load bearing, vehicle surface	243–300
Base Layer	Lean Concrete (thin concrete)	Distributes load to subbase	150
Subbase	LFA Class A (CBR ≥ 90%)	Additional load distribution layer	200
Subgrade	Selected soil (CBR 30%)	Immediate pavement foundation	200
Natural Ground	In-situ soil (CBR ≈ 17.99%)	Existing soil, stability evaluation	-

b. Joint Design Details

Table 10 . Joint Design Details

Parameter	Specification
Slab Size	2 m × 3.5 m
Parameter	Specification
Slab Length	5 m
Shrinkage Joint	Every 5 m
Dowel Bar	Ø38 mm @ 300 mm, 450 mm length
Tie Bar	D16 @ 300 mm, 700 mm length

c. Technical Conclusion

- The 243 mm thickness technically meets the design criteria for fatigue and erosion, but is not ideal for long-term performance under heavy traffic.

- The 300 mm thickness is strongly recommended in areas with high traffic intensity and long service life expectations, and provides better tolerance for variations in soil support and environmental conditions.

Table 11 . Material Thickness

Material	Thickness (mm)
Beton Semen = Fs 4.5 MPa	300
Bottom Foundation Layer, Thin Concrete	150
LFA Class A = CBR 90%	200
Coarse-grained option stack = 30% CBR	200
Groundland = CBR 17.99%	

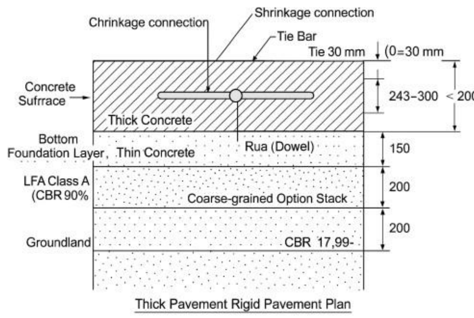

Figure 3. Typical Rigid Pavement Structure

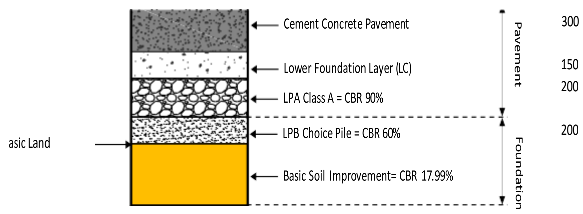

Figure 4. Top View

The rigid pavement in figure 4 structure consists of five key layers:

1. Cement Concrete Pavement (300 mm) – Serves as the main structural layer to resist high axle loads and fatigue.

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2. Lower Foundation Layer (LC, 150 mm) – Provides support and reduces stress transfer to lower layers.
3. LPA Class A (CBR ≥ 90%) – High-strength granular base layer.
4. LPB Choice Fill (CBR ≥ 80%) – Granular subbase with good drainage and intermediate strength.
5. Improved Subgrade (CBR ≥ 17.99%) – Treated or compacted soil to provide uniform support and reduce settlement.

This multi-layer configuration improves load distribution, prevents pumping and erosion, and extends the pavement service life, particularly for mine haul roads with extreme loading.

Rigid pavement
The number of axis groups of each type of vehicle is required for the purpose of cement concrete pavement design. The plan life of 40 years and traffic load are calculated based on the number of axial groups of heavy vehicles as follows:

Table 12 . Cumulative hheavy vehicle

Vehicle Type	Number of Axis Groups	LHR 2024	Axis Group 2024	Number of Axis Groups 2024
1	2	3	4	5
5B	2	2045	4090	86513732,09
6B	2	0	0	0
7A1	2	847	1694	35832337,94
7A2	2	0	0	0
7C1	2	22498	44996	951777968
7C2A	3	0	0	0
7C2B	3	0	0	0
7C3	3	0	0	0
Cumulative heavy vehicle axle group 2024				1074124038

Rn = r (1 + r) n − 1 (5)
R40 = (1+0.01*3.5)^40-1/0.01*3.5
= 6.59816895-1/0.0483
= 5.59816895/0.0483
= 115.90412

Table 12. Cement concrete pavement for cumulative heavy vehicle axle groups of design 1074124038 structures for traffic with the number of heavy vehicle axial groups are:
Cement concrete pavement with seamless joints
Plan life = 40 years
Thick concrete slab = 305 mm
Thin concrete layer (LMC) = 100 mm
Drainage layer (LFA kls A) = 150 mm
Connection = Dowel
Pavement Foundation Structure From the calculation of the axial group of heavy vehicles and the california bearing ration (CBR) data, the following values were obtained:
HVAG = 1074124038
CBR = 4.92 %

The relationship of CESA and CBR is shown with a cut of orange line in the chart table of section 2 of the Minimal Road Foundation Design

Bagan Desain - 2: Desain Fondasi Jalan Minimum [1]

CBR Tanah dasar (%)	Kelas Kekuatan Tanah Dasar	Uraian Struktur Fondasi	Perkerasan Lentur: Beban lalu lintas pada lajur rencana dengan umur rencana 40 tahun (juta ESA5)			Perkerasan Kaku
			< 2	2 - 4	> 4	Stabilisasi Semen [6]
			Tebal minimum perbaikan tanah dasar			
≥ 6	SG6	Perbaikan tanah dasar dapat berupa stabilassi semen atau material timbunan pilihan (sesuai persyaratan Spesifikasi Umum, Devisi 3 – Pekerjaan Tanah) (pemadatan lapisan ≤ 200 mm tebal gembur)	Tidak diperlukan perbaikan			300
5	SG5		-	-	100	
4	SG4		100	150	200	
3	SG3		150	200	300	
2,5	SG2.5		175	250	350	
Tanah ekspansif (potensi pemuaian > 5%)			400	500	600	Berlaku ketentuan yang sama dengan fondasi jalan perkerasan lentur
Perkerasan di atas tanah lunak [2]	SG1 [3]	Lapis penopang [4][5]	1000	1100	1200	
		-atau- lapis penopang dan geogrid [4][5]	650	750	850	
Tanah gambut dengan HRS atau DBST untuk perkerasan untuk jalan raya minor (nilai minimum – ketentuan lain berlaku)		Lapis penopang berbutir [4][5]	1000	1250	1500	

(1) Desain harus mempertimbangkan semua hal yang kritikal; syarat tambahan mungkin berlaku.
(2) Ditandai dengan kepadatan dan CBR lapangan yang rendah.
(3) Menggunakan nilai CBR insitu, karena nilai CBR rendaman tidak relevan.
(4) Permukaan lapis penopang di atas tanah SG1 dan gambut diasumsikan mempunyai daya dukung setara nilai CBR 2.5%, dengan demikian ketentuan perbaikan tanah SG2.5 berlaku. Contoh: untuk lalu lintas rencana > 4 jt ESA, tanah SG1 memerlukan lapis penopang setebal 1200 mm untuk mencapai daya dukung setara SG2.5 dan selanjutnya perlu ditambah lagi setebal 350 mm untuk meningkatkan menjadi setara SG6.
(5) Tebal lapis penopang dapat dikurangi 300 mm jika tanah asal dipadatkan pada kondisi kering.

(6) Untuk perkerasan kaku, material perbaikan tanah dasar berbutir halus (klasifikasi A4 sampai dengan A6) harus berupa stabilisasi semen.

6. Conclusion

From the results of this study, conclusions were obtained, namely:

1. Due to the opening of Open Pit Mining (The main location in the open mining method) because the road body has not yet been formed, a new road was made using the highway standard, this road is used to support the smooth production of coal in road planning.
2. Using the AutoCad Civil 3D & Road Pavement Design Manual 2024 assistance program, this road geometric planning is made for comfort and safety for road users. This road is planned for the operation of PT. Mahakam Sumber Jaya has a road length of 4,539 km, a pavement width of 7 m and a shoulder of the road with a width of 1 m with a slope of 4%. In the horizontal alignment planning, 7 horizontal curves are obtained consisting of spiral circle spiral (SCS) curves. From the analysis that has been carried out, the pavement uses rigid pavement using the Highway Road Pavement Design Manual Method (MDP 2024) Using JPCP (Jointed Plain Concrete Pavement) CBR 4.92% calculation using a thickness, Cement Concrete 300 mm, Lower Foundation Layer (Lc) 150 mm, LPA Class A, 200 mm, 200 mm selected pile layer. For the thickness comparison using a thickness of 243 mm, erosion damage is 75.98%, not included in the provisions because the minimum thickness is 250 mm. So the thickness we use is 300 mm.
3. According to MDPL 2024, the selection of the type of road pavement at the research location uses rigid pavement because concrete has better resistance to heavy loads, high traffic, and concrete is more resistant to deformation due to changes in temperature and traffic load

7. Suggestion

1) Evaluate the durability of the pavement against heavy loads vehicle.

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2) Evaluation of the effectiveness of the patchwork method compared to Overlay on damaged roads.
3) Perform road maintenance for safety and comfort user road.

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