Journal of Applied Engineering and Technological Science
Vol 4(1) 2022 : 251-262

DAMAGE ANALYSIS OF LAHAT ROADS–FENCE NATURAL FROM ENDIKAT BRIDGE TO GO TO DEPATI H. DUAJI LINTAS STREET PAGARALAM–LAHAT

Sartika Nisumanti[1*], Andy Kurniawan[2], Khodijah Al Qubroh[3]
Indo Global Mandiri University[123]
sartika.nisumanti@uigm.ac.id

Received : 20 September 2022, Revised: 13 October 2022, Accepted : 14 October 2022
**Corresponding Author*

ABSTRACT
Roads have a very important role in human life. For the present and the future, in the era of industrialization, trade and public transportation, transportation of goods and services. This study aims to determine the type of damage that occurs on the pavement surface, pavement conditions and the necessary actions on the pavement conditions of the Lahat-Pagaralam section of the bridge from Endikat to the Depati H. Duaji road of Pagaralam-Lahat by using the Pavement Condition Index method (PCI). There are 10 types of damage to the Lahat - Pagaralam crossing from the Endikat bridge to the Depati H. Duaji Lintas Pagaralam road, namely crocodile cracks by 20.39%, obesity by 3.95%, basins by 0.66%, curl by 0.66 %, edge cracks of 3.29%, longitudinal/transverse cracks of 5.26%, fillings of 55.92%, aggregate wear of 1.32, holes of 7.24% and grooves of 1.32%. The average pavement condition index (PCI) for the Lahat - Pagaralam section from the Endikat bridge to the Depati H. Duaji Pagaralam road section is 82.63% which is included in the Very Good category. The repair methods that can be carried out are the P2 (Local Asphalt Laburan) repair method, the P5 repair method (Hole filling) and the P6 repair method (Alignment).
***Keywords**: Pavement Condition Index, Type of road damage, Road, Damage Analysis*

1. Introduction

Initial research on the condition of the road surface is by conducting a visual survey which means by seeing and analyzing the damage based on the type and level of damage to be used as a basis for carrying out maintenance and repair activities(Ale et al., 2018). The purpose of this study was to conduct an assessment to identify and classify the types and levels of damage to road pavements. Assessment of the condition of the road pavement is an important aspect in determining road maintenance and repair activities(Isradi et al., 2020; Isradi et al., 2019). To assess the condition of the pavement, it is necessary to determine the type of damage, the cause, and the level of damage that occurred. Many Regency/City road pavements in Indonesia have been damaged due to the repetition of traffic loads, along with increasing economic growth in the regions, including one in the Pagaralam City area, South Sumatra Province(Ahmad et al., 2018; Fotiadi et al., 2020).

From the results of field monitoring, it can be seen that there is a traffic load that exceeds the planned capacity. It is even possible that with the current traffic conditions, the pavement structure will be damaged more quickly(Li et al., 2021). To determine whether in the near future or in the future, the road is still in good condition, the surface condition, structural capability and geometry need to be evaluated. If judgment is made to determine or select the required repair, then the most economical repair can be designed and implemented(Bhandari et al., 2022; Taher, 2020).

In connection with this, it is necessary to study the level and type of road damage in the Pagaralam city area. From the results of this study, it will be known the level and type of damage that is dominant, as well as the priority order of roads that must be handled immediately based on the results of the value of the damage conditions on each road segment. For this reason, researchers are interested in conducting research with the title "Analysis of Damage to the Lahat-Pagarlam Cross Road from the Endikat Bridge to the Depati H.duaji Road Crossing Pagaralam-lahat.

2. Literature Review

Definition of Feeling

Road pavement is a system consisting of several layers of material placed on the subgrade. The main purpose of constructing a pavement is to provide a flat surface with a certain roughness, with a fairly long service life, and minimum maintenance(Pandey et al., 2021).

Pavement Types

In Indonesia, there are two types of road pavements that are commonly used in the field, namely:

1. Flexible Pavement Construction

According to Tenriajeng (2000: 9) in his book that the road pavement receives vehicle loads through wheel contact in the form of a load that is evenly distributed P0 for example in Figure 1, the surface layer receives the load and is then distributed to the subgrade which then becomes a P1 load, namely the carrying capacity. subgrade is greater than the free.

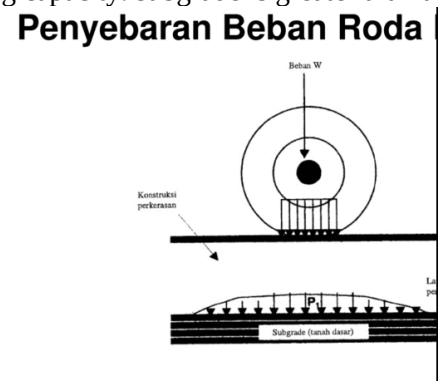

Fig 1. Distribution of Wheel Loads through the Pavement Layer (Tenriajeng, 2000: 9)

Surface layer
Top foundation layer
Sub foundation layer
Subsoil layer

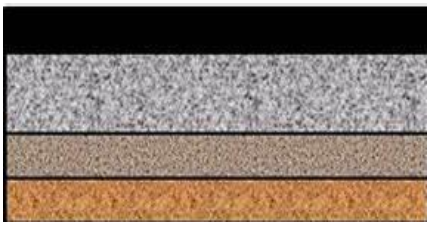

Fig 2. Stacking Layers of Flexible Pavement Construction

Flexible pavement construction consists of layers located above the compacted subgrade. These layers function to receive the traffic load and distribute it to the lower layers(Kermani et al., 2019; Arab et al., 2020).

Roads are land transportation infrastructure which includes all parts of the road, including complementary buildings and equipment intended for traffic, which are on the ground surface, above the ground surface, below the ground and/or water surface, and above the water surface, except roads. railways, lorries and cable roads(Ratnaningsih et al., 2021).

Causes of Road Damage According to Alam (2020), damage to road pavement construction can be caused by:

1. Traffic, which results from an increase in the load (vehicle axle) that exceeds the design load, or also the retifiation of the load (vehicle volume) that exceeds the planned volume so that the design life of the road is not achieved.
2. Water, which comes from rainwater, poor road drainage system, rising water due to capillary nature
3. Pavement material. This can be caused by the nature of the material itself or also caused by a poor material processing system.
4. Climate, air temperature and high rainfall can damage the road pavement.

5. The condition of the subgrade is unstable, because of its bad nature or because of the poor implementation system.

Types of Damage

Damage that occurs on roads can be grouped into two, namely structural damage and functional damage. Structural damage is damage that includes damage or failure to the road structure which causes a reduction in the carrying capacity of the road against the load of passing vehicles so that repairs are needed to restore the structural function of the pavement so that it can serve traffic well. Functional damage is damage in the form of comfort and safety of passing motorists so that motorists feel disturbed which is generally caused by overloaded vehicles that pass continuously and cause damage(Avci et al., 2021). Road damage can be seen and classified as follows:

1. Crocodile Cracks (Alligator Cracks)

The crack is a network of small polygons resembling crocodile skin, with a slit width greater than or equal to 3 mm. These cracks are caused by fatigue from repeated traffic loads(Taufikurrahman et al., 2022).

Possible causes:

a. Pavement material or material quality that is not good enough to cause weak pavement or brittle asphalt layers.
b. Asphalt weathering
c. Less use of asphalt.
d. High ground water on the road pavement.
e. The undercoat is less stable.

Levels :

L = Longitudinal crack with a thin line that is not interconnected.
M = Further development of light quality cracks.
H = The cracks will be interconnected to form fragments.

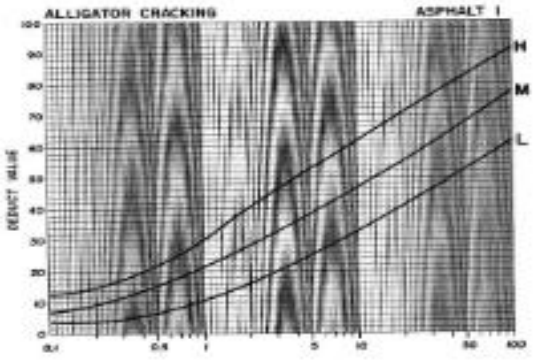

Fig 3. Crocodile Skin Crack Deduct Value

Obesity (Bleeding)

This surface defect is the occurrence of asphalt concentration in a certain place on the road surface. The physical form of this damage can be recognized by the appearance of a thin layer of asphalt (without aggregate) on the surface of the pavement and if in conditions of high pavement surface temperature (hot sun) or in heavy traffic, traces of 'tire flowers' will be seen from vehicles passing through it. This will also endanger traffic safety because the road will become slippery(Setiawan & Winayati, 2021).

Main possible causes:

a. Uneven or excessive use of asphalt.
b. Not using a suitable binder (asphalt).
c. As a result of the release of asphalt from the bottom layer which has excess asphalt.

Levels :

L = Asphalt melts with a low melting rate with an indication of not sticking to the shoes.
M = The melt is getting wider with an indication of asphalt sticking to the shoe.

H = The melt is getting more widespread and worrying

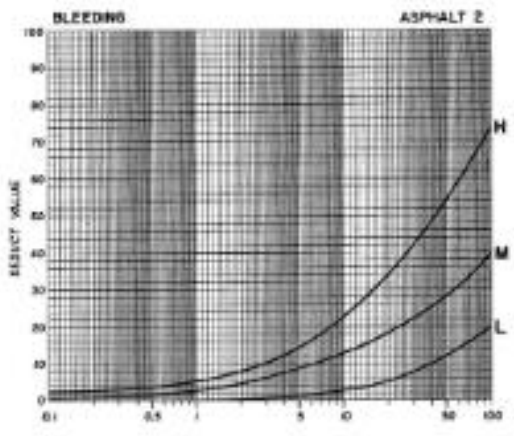

Fig. 4 Obesity Deduct Value

Road Repair Method

Road repair methods according to the 1995 Director General of Highways Standards are:

1. Repair Method P1

Damage type:

Locations of asphalt fat, especially on bends and inclines.

Handling steps:

a. Mobilize equipment, workers and materials to the site
b. Mark the road to be repaired
c. Clean the area with air compressor
d. Spread coarse sand or fine aggregate >10 mm thick over the damaged surface
e. Compaction with light compactor (weight 1-2 tons) until a flat surface is obtained and has an optimal density of 95%.

2. Repair Method P2

Damage type:

a. Damage to the edge of the paved road
b. 2mm smaller alligator crack
c. Crack line width is less than 2 mm
d. peeled off

Handling steps:

a. Mobilize equipment, workers and materials to the site
b. Mark the road to be repaired
c. Clean the area with air compressor
d. Spread coarse sand or fine aggregate with a thickness of 5 mm over the damaged surface until smooth.
e. Compaction with a pneumatic machine until a flat surface is obtained and has an optimal density of up to 95%.

3. P3 Repair Method

Damage type:

Locations of one-way cracks with a crack width of less than 2 mm.

Handling steps:

a. Mobilize equipment, workers and materials to the site
b. Mark the road to be repaired
c. Clean the area with air compressor

d. Spray tack coat (0.2 lt/m2) on the area to be repaired.
e. Spread and flatten the asphalt-concrete mixture over the damaged surface until smooth.
f. Perform light compaction (1-2 tons) until a flat surface is obtained and has an optimal density of up to 95%.

4. Repair Method P4
Damage type:
Locations of one-way cracks with crack widths greater than 2 mm
Handling steps:
a. Mobilize equipment, workers and materials to the site
b. Mark the road to be repaired
c. Clean the area with air compressor
d. Filling cracks with 2lt/m2 cut back asphalt using asphalt sprayer
e. Spread coarse sand or fine aggregate >10 mm thick over the damaged surface.
f. Compacting with a baby roller at least 3 passes.

5. P5 Repair Method (Hole Patching)
Damage type:
a. Hole >50 mm . depth
b. Crocodile crack larger 2 mm
c. Curly depth >30 mm
d. Groove depth >30 mm
e. Subside with depth >50 mm
f. Jembul with depth >50 mm
g. Road pavement edge damage

Handling steps:
a. Mobilize equipment, workers and materials to the site.
b. Mark the road to be repaired
c. Excavate the material until it reaches the layer below it.
d. Cleaning the repaired area by manpower.
e. Spraying prime coat absorbent layer at a rate of 0.5 lt/m2
f. Spread the asphalt mixture over the damaged surface until smooth.
g. Compacting with a baby roller minimum of 5 passes.
6. P6 Repair Method (Alignment)

Damage type:
a. Hole with depth < 30 mm
b. Curl with depth <30 mm
c. Grooves with depth < 30 mm
d. Drop location with depth < 50 mm
e. Jebulum with a depth of <50 mm
f. Road pavement edge damage

Handling steps:
a. Mobilize equipment, workers and materials to the site.
b. Mark the road to be repaired
c. Cleaning the repaired area by manpower.
d. Spraying the tack coat absorbent layer at a rate of 0.5 lt/m2
e. Spread the asphalt mixture over the damaged surface until smooth.
f. Compacting with a baby roller minimum of 5 passes.

3. Research Methods

In the Pavement Contidion Index (PCI) research which examines the level of pavement surface conditions where the study aims to determine the level of surface damage on the Lahat - Pagaralam road section from the Endikat bridge to the Depati H. Duaji road, Pagaralam - Lahat. The research was conducted to analyze the damage to the pavement structure by making visual observations.

Research Stage

1. Preparation
   a. Check equipment and preparation
   b. Check the completeness of the survey form
2. The order of execution of the service includes
   a. Fill in the survey form
   b. Make observations of road damage at the location of pavement damage and fill in the survey form every 500 meters.
   c. Take photos of the road damage observed during the survey.

Primary Data

The primary data used to complete the data in this final project research is by means of surveys and direct observations in the field according to the research location. Steps to obtain primary data from the field include:

1. Measurement of the type of damage
2. Dimensions of road damage
3. Field survey data
4. Recording the location of the damage

Secondary Data

Secondary data obtained from the relevant agencies in this study, the Department of Public Works Pagaralam City which is the data in this study. These data include:

1. Geometric data of road segments
2. Existing pavement structure data
3. Type of road

Data Analysis Method

The road damage analysis method used is the pavement condition index (PCI) method. In the PCI method, the calculation results from a survey of road conditions visually identified from the type of damage, severity, and quantity.

Data Analysis Procedure

There are several stages in this method, such as:

1. Damage Level (Severity Level)
   Severity level is the level of damage for each type of damage. The level of damage used in the PCI calculation is low severity level (L), medium severity level (M), and high severity level (H).
2. Finding the Density (Damage Level)
   Finding density is the percentage of the total area or length of one type of damage to the area or total length of the measured road section. It can be in m or in square meters. Density can be expressed by equation 3.1 or 3.2:
   Density = ...(3.1)
   Or
   Density = ...(3.2)
   Information:
   Ad: Total area of damage type for each level of damage (m)
   Ld: Total length of damage type for each level of damage (m)

As: Total area of segment unit (m^2)

Research Flowchart

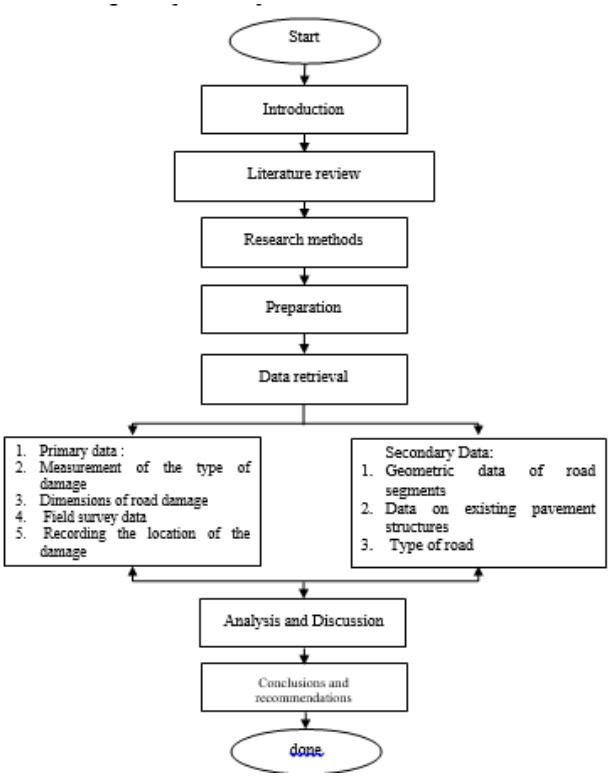

Fig 5. Research Flowchart

4. Results and Discussions

Lahat-Pagaralam Cross Road Data

The data on the Lahat-Pagaralam cross road from the Endikat bridge to the Depati H. Duaji Cross Pagaralam road is as follows:

1. Road Length : 19,400 m (19.4 KM)
2. Pavement Type : Flexible pavement
3. Line Separator: Dotted line headquarters
4. Road Shoulder Width : 5 m

Road Damage Analysis

Using Pavement Condition Index (PCI) Method

As for the example of calculating the PCI value, the data taken from KM 3+000 to 3+500 can be seen in

Table 1 - Pavement Condition At KM 3+000 to 3+50

AIRFIELD ASHPALY PAVEMENT
SKETCH : CONDITION SURVEY
DATA SHEET FOR SAMPLE UNIT

SKETCH : 100 M

1. Retak Buaya (m²)	9. Pinggir Jalan Turun Vertikal (m)	17. Patah Slip (m²)
2. Kegemukan (m²)	10. Retak Memanjang/Melintang (m)	18. Mengembang Jembul (m²)
3. Retak Kotak-Kota (m²)	11. Tambalan (m)	19. Pelepasan Butir (m)
4. Cekungan (m²)	12. Pengausan Agregat (m)	
5. Keriting (m²)	13. Lubang (m²)	
6. Amblas (m²)	14. Perpotongan Rel (m²)	
7. Retak Pinggir (m)	15. Alur (m)	
8. Retak Sambung (m)	16. Sungkur (m²)	

STA	Distress Severity	Quantity										Total	Density (%)	Deduct Value
3+000 - 3+500	12L	0,51										0,51	0,06	0
	15L	28										28	3,11	18
	11L	2,94										2,94	0,33	0
	1L	5,4										5,4	0,6	7

a. Calculating Density Value (Density)
The calculation of the density value can be seen in table 4.2.
Ad : Total area of damage for each level of damage (m2)
Ld : Total length of damage type for each level of damage (m)
As : Total area of segment unit (m2)

Table 2 - Calculation of Density

Damage Type	Level Damage	1	2	3
		Ad	As	Ad/As*100%
Aggregate Wear	L	0,51	900	0,06
Plot	L	28,00	900	3,11
Patches	L	2,94	900	0,33
Crocodile Crack	L	5,40	900	0,60

b. Deduct Value (DV)

Finding the deduct value (DV) in the form of a graph of the types of damage by entering the density percentage into the graph of each type of damage then drawing a vertical line to cut the level of damage (low, medium, high). Next draw a horizontal line and the DV can be found. Find the deduct value (DV) in KM 3+000 to 3+500.

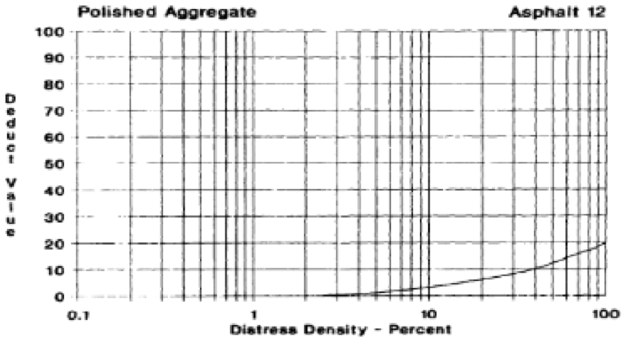

Fig 6. Graph of Aggregate Wear Deduct Value

2) Flow

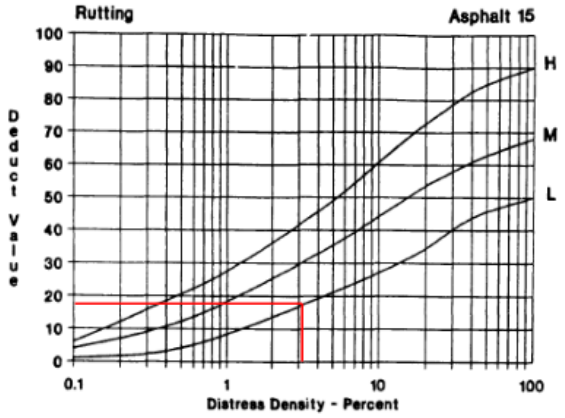

Fig 7. Graph of Deduct Value Flow

Pavement Condition Index (PCI) Method Analysis

Analysis of the calculation of the PCI value is carried out to determine the PCI value per segment. PCI analysis can be seen in table 2

Table 2 – PCI Analysis

No	KM	CDV Max	100-CDV	PCI
1	3+000 - 3+500	18	82	Satisfying
2	3+500 - 4+000	21	79	Satisfying
3	4+000 - 4+500	43	57	Well
4	4+500 - 5+000	47	53	currently

The average PCI value per km on the Lahat - Pagaralam cross road section from the Endikat bridge to the Depati H. Duaji Cross Pagaralam road is:

1. 0+000 - 5+000 Km = 795/10 = 79.50%
2. 5+000 - 10+000 Km = 825/10 = 82.50%
3. 10+000 - 15+000 Km = 823/10 = 82.30%
4. 15+000 - 20+000 Km = 862/10 = 86.20%

The average PCI value for each segment on the Lahat - Pagaralam cross road from Endikat bridge to Depati H. Duaji Cross Pagaralam road is:

PCItotal = / Number of Segments

PCItotal = 330.54 = 82.63% (Very Good) So it can be concluded that the pavement value on the Lahat - Pagaralam cross road from Endikat bridge to Depati H. Duaji Cross Pagaralam road is very good.

Classification of Pavement Quality The PCI value of each research unit can determine the quality of the segment unit pavement layer based on certain conditions, namely perfect (excellent), satisfactory (satisfactory), good (good), moderate (fair), poor (poor), and failed (failed).

Proposed Handling

1. P2 Repair Method (Local Asphalt Laburan)

a. Damage Type

1) Transverse cracks, diagonal cracks, and longitudinal cracks with crack width < 2 mm.

b. Handling Step

1) Prepare workers, equipment, and materials at the site of damage.
2) Marking on the road before repair.
3) Use air compressor to clean the area.
4) On the surface of the damaged road, fine aggregate and coarse sand with a thickness of 5 mm are spread.

5) Smoothing to optimal density (95%) using a pneumatic machine.
6) At the work site, the safety equipment and remaining materials are cleaned.
7) Demobility.

2. P5 Repair Method (Hole Patching)
a. Damage Type
1) Hole with depth > 50 mm.
2) Crocodile skin cracks > 3 mm.
3) Grooves with depth > 30 mm.
4) Damage to the edge of the road pavement.
b. Handling Step
1) Prepare workers, equipment, and materials at the site of damage.
2) Marking on the road before repair.
3) Excavation of material with depths ranging up to 150 – 200 mm or reaching the material below.
4) Use air compressor to clean the area.
5) Inspection of optimum moisture content in road works, if the moisture content is dry, add water to optimum condition and dig up material if any is wet and then allow to dry.
6) Compact the bottom of the excavation with hand compactor.
7) Adding class A or class B aggregate with a maximum thickness of 15 cm into the excavation, after that compacting the aggregate in a state of optimum water content until the maximum density is obtained.
8) The addition of prime coat (binder) type RS with a dose of 0.5 lt/$m2$. For the cut back type MC-30, emulsion asphalt is used at a rate of 0.8 lt/m2.
9) Using a concrete mixer to mix the cold mixed aggregate with the ratio of coarse and fine aggregate 1.5 : 1. Asphalt mixer with a maximum capacity of approximately 0.1 3. Before the asphalt is treated, to cool the mixture by adding all 0.1 m3 of aggregate. Then add asphalt and stir for 4 minutes. After that the cold asphalt mixture is prepared sufficiently for the entire work.
10) Spreading cold asphalt mixture with a maximum thickness of 40 mm and compaction until a flat surface is obtained.
11) Compaction using a baby roller at least 3 passes.
12) At the work site, the safety equipment and remaining materials are cleaned.

3. P6 Repair Method (Alignment)
a. Damage Type
1) Holes with a depth of < 50 mm.
2) Grooves with a depth of < 30 mm.
3) Damage to the edge of the road pavement.

b. Handling steps
1) Prepare workers, equipment, and materials at the site of damage.
2) Marking on the road before repair.
3) Use air compressor to clean the area.
4) In the damaged area, 0.5 lt/$m2$ of RC type tack coat is sprayed, for emulsion asphalt it is 0.2 lt/m2, while for cutback using asphalt ketlle with holes.
5) Using a concrete mixer to mix the cold mixed aggregate with a ratio of coarse and fine aggregate 1.5: 1. Asphalt mixer with a maximum capacity of approximately 0.1 m3. Before the asphalt is treated, to cool the mixture by adding all 0.1 3 aggregate.
6) Asphalt material is added and stirred for 4 minutes, after which it prepares asphalt concrete mix, cold asphalt mixture class A, class C, or class E until the job is finished.
7) Add cold asphalt mixture on the surface to a thickness of 10 mm above the surface.
8) Compaction using a baby roller at least 5 passes until the maximum density is obtained.

9) At the work site, the safety equipment and remaining materials are cleaned.

5. Conclusion

Based on the analysis and discussion that has been described, the following conclusions can be drawn: There are 10 types of damage to the Lahat - Pagaralam cross road from Endikat bridge to Depati H. Duaji Lintas Pagaralam road, namely crocodile cracks by 20.39%, obesity by 3.95%, basins by 0.66%, curl by 0 0.66%, edge cracks 3.29%, longitudinal/transverse cracks 5.26%, fillings 55.92%, aggregate wear 1.32, holes 7.24% and grooves 1.32%. The average pavement condition index (PCI) for the Lahat - Pagaralam section from the Endikat bridge to the Depati H. Duaji Pagaralam road is 82.63% which is included in the Very Good category. The repair methods that can be carried out are the P2 (Local Asphalt Laburan) repair method, the P5 repair method (Hole filling) and the P6 repair method (Alignment).

References

Ahmad, S. N., Harianto, T., Samang, L., & Hustim, M. (2018). Level vulnerability damage of pavement using Pavement Condition Index method. In *MATEC Web of Conferences* (Vol. 181, p. 11003). EDP Sciences.

Alam, M. J., Karim, M. E., & Hoque, M. S. (2020). Causes of damage of rural road in coastal areas of Bangladesh. *Geotechnical Engineering Journal of the SEAGS & AGSSEA, 51*(4), 146-155.

Ale, L., Zhang, N., & Li, L. (2018, December). Road damage detection using RetinaNet. In *2018 IEEE International Conference on Big Data (Big Data)* (pp. 5197-5200). IEEE.

Arab, M. G., Alzara, M., Zeiada, W., Omar, M., & Azam, A. (2020). Combined effect of compaction level and matric suction conditions on flexible pavement performance using construction and demolition waste. *Construction and Building Materials, 261*, 119792.

Avci, O., Abdeljaber, O., Kiranyaz, S., Hussein, M., Gabbouj, M., & Inman, D. J. (2021). A review of vibration-based damage detection in civil structures: From traditional methods to Machine Learning and Deep Learning applications. *Mechanical systems and signal processing, 147*, 107077.

Bhandari, S., Luo, X., & Wang, F. (2022). Understanding the effects of structural factors and traffic loading on flexible pavement performance. *International Journal of Transportation Science and Technology*.

Fotiadi, A. A., Gnezdilova, S. A., & Strekha, I. S. (2020, October). Remote method for predicting damage to cement concrete pavements. In *International Scientific Conference on Innovations and Technologies in Construction* (pp. 333-339). Springer, Cham.

Isradi, M., Subhan, A., & Prasetijo, J. (2020). Evaluation of the road pavement damage with bina marga method and pavement condition index method. In *Proceedings of the International Conference on Industrial Engineering and Operations Management*, August (pp. 3608-3614).

Isradi, M., Arifin, Z., & Sudrajat, A. (2019). Analysis of the Damage of Rigid Pavement Road by Using Pavement Condition Index (PCI). *Journal of Applied Science, Engineering, Technology, and Education, 1*(2), 193-202.

Kermani, B., Xiao, M., Stoffels, S. M., & Qiu, T. (2019). Measuring the migration of subgrade fine particles into subbase using scaled accelerated flexible pavement testing–a laboratory study. *Road Materials and Pavement Design, 20*(1), 36-57.

Li, N., Zhan, H., Yu, X., Tang, W., Yu, H., & Dong, F. (2021). Research on the high temperature performance of asphalt pavement based on field cores with different rutting development levels. *Materials and Structures, 54*(2), 1-12.

Pandey, P., Hossain, M. S., & Ahmed, A. (2021). Performance evaluation of modified moisture barrier in mitigating expansive soil associated pavement distresses. *Transportation Geotechnics, 31*, 100667.

Ratnaningsih, D., Wahiddin, W., Subagyo, U., & Sasongko, R. (2021, February). Analysis of the needs road facilities in Jalan Soekarno Hatta Malang City. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1073, No. 1, p. 012017). IOP Publishing.

Setiawan, T., & Winayati, W. (2021). Identifikasi Jenis-Jenis Kerusakan Jalan (Perkerasan Lentur) Studi Kasus Jalan Lintas Taluk Kuantan–Batas Provinsi Sumatera Barat. *Racic: Rab Construction Research*, *6*(1), 69-77.

Taher, S. A., Alyousify, S., & Hassan, H. J. A. (2020). Comparative Study of Using Flexible and Rigid Pavements for Roads: a Review Study. *Journal of Duhok University*, *23*(2), 222-234.

Taufikurrahman, T., Karyawan, I. D. M. A., & Yasa, I. W. (2022). Study of Road Surface Damage due to Rainwater Puddles using the Pavement Condition Index. *Path of Science*, *8*(8), 3014.

Tenriajeng, A. (2000). *Rekayasan Jalan Raya II*. Gunadarma. Jakarta.