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Calculation Thickness of the Added Flexural Layer on Composite Layer using a Light Weight Deflectometer (LWD) Pusjatan

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ABSTRACT

Calculating the thickness of the flexible overlay needs to consider several factors, such as traffic load, soil characteristics, existing pavement conditions, and planned changes to the road design. This procedure generally uses recognized pavement design methods, such as the AASHTO 1993 method (Guide for Design of Pavement Structures). This research aims to determine the thickness of the added layer using an asphalt layer on composite roads in accordance with the 1993 AASHTO standards. It is hoped that this method can produce an effective overlay design, extend the life of the pavement, and increase the comfort and safety of road users. The data used in this research includes primary and secondary data. The results of this analysis are to calculate the STA 0 segment, for other STAs use the same method. From the Light Weight Deflectometer (LWD) deflection data, the Subgrade Reaction Modulus (k) value was 473 psi/in, the Concrete Elasticity Modulus (Ec) value was 4,843,105 psi and the Rupture Modulus (Sc') value was 699 psi. The traffic load used is 25.000.000, so the result of calculating the plate thickness to serve future traffic (Df) is 10.79 inches or 27.40 cm and the effective plate thickness value (Deff) is 9.13 inches or 23.30 cm, then the result is the added layer thickness (Dol) is 3.30 inches or 8.39 cm.

Keywords: *Overlay; Composite Pavement; LWD.*

INTRODUCTION

A road is a pathway that facilitates the movement of people and goods from one location to another with the main purpose of providing safety, convenience and efficiency [1], [2], [3]. Roads serve as connectors between regions that facilitate social and economic interaction. In Indonesia, many roads suffer from various damages due to high traffic volumes, lack of regular maintenance, extreme weather, and unstable soil conditions [4], [5], [6]. Common damages such as cracks, potholes, and uneven surfaces interfere with road function and jeopardize user safety. In addition to human factors, natural disasters such as earthquakes and floods also worsen the condition of already fragile roads [7], [8]. [9].

To address these issues, regular repairs and maintenance are key to ensuring the safety and reliability of the road network [10], [11], [12]. This involves not only physical repairs but also careful planning to deal with environmental challenges that could potentially damage roads. The use of modern technology in road construction can also improve the durability and service

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life of road infrastructure. One of the appropriate solutions to repair functional or structural defects in road pavements is to add an overlay. However, one of the constraints in designing the thickness of overlays on composite roads in Indonesia is the absence of appropriate design standards [13], [14]. [15].

In designing the thickness of the additional layer of pavement, several crucial factors must be considered to ensure the reliability and sustainability of the structure. First, the traffic load that the road is expected to experience, which includes the type of vehicle, its volume and frequency of traffic. These loads affect the need for additional layer thickness. The characteristics of the soil beneath the pavement are also an important factor, especially if the soil is unstable or has a low bearing capacity. Evaluation of the condition of the existing pavement is also necessary to understand the damage that has occurred and its effect on the design plan. Future planned changes to the road design should also be considered as these changes may affect the loads borne by the road and require adjustments to the existing pavement [16].

Overlay calculation procedures typically use technically recognized pavement design methods, such as those documented in the "AASHTO 1993 (Guide for Design of Pavement Structures)" manual. This method provides a proven framework for evaluating the various factors that influence the need for additional layers of pavement, thereby ensuring that the road infrastructure built can function optimally and safely for its users.

Ummati *et al* (2024) in his research used Light Weight Deflectometer (LWD) to assess the elastic modulus and quality of pavement structure. The results showed that the coefficient of variance (CV) of the LWD measurements was 47%, while the Back Calculation (BB) method recorded a CV of 32.8%. This study highlights the reliability of the LWD method in providing elastic modulus estimates even with significant variations between measurement methods.

Yudhistira *et al* (2024) studied the use of LWD on dirt roads to test soil strength and compared it with the Dynamic Cone Penetrometer (DCP) tool. The results showed a strong correlation between LWD and DCP measurements with a confidence level of 85%. This correlation is adequate in highway engineering practice, demonstrating the potential of LWD as a reliable tool for soil strength evaluation in the field. Conducted research on the method of determining the type of road maintenance using the Bina Marga Method, focusing on the minimum modulus value produced by LWD for various pavement layers.

The results showed that sand 1, sand 2, and sand 3 layers had elastic moduli of 19.0 MPa, 41.7 MPa, and 21.6 MPa, respectively. The study also revealed that the sand layer had the highest coefficient of variation, reaching 55.8%, which emphasizes the importance of careful analysis in determining the appropriate type of maintenance to maintain long-term road reliability.

Overall, studies using LWD have demonstrated the tool's ability to provide the data needed for road structural analysis and soil strength evaluation. However, the variation of results between methods and field conditions emphasizes the importance of using appropriate methods and comprehensive analysis to support accurate decision-making in road infrastructure management.

This research aims to calculate the thickness of the added layer of flexure on the composite layer using the Light Weight Deflectometer (LWD) Pusjatan. This research is expected to provide innovation in the method of designing the thickness of the added layer on composite pavements in Indonesia, as well as providing appropriate design standards to improve the quality and reliability of road infrastructure in Indonesia.

METHOD

This research aims to calculate the thickness of the added layer of flexure on the composite layer using the Light Weight Deflectometer (LWD) Pusjatan. This research is expected to provide innovation in the method of designing the thickness of the added layer on composite pavements in Indonesia, as well as providing appropriate design standards to improve the quality and reliability of road infrastructure in Indonesia.

This research uses a quantitative method by collecting primary data directly from the field. The data collected included the existing condition of the composite pavement and deflection testing data using the Pusjatan LWD. The research process began with the preparation of tools and locations, including calibration of the Pusjatan LWD tool and initial surveys at the research site. After that, data collection was carried out by measuring the existing condition of the pavement and conducting deflection testing using the Pusjatan LWD at several predetermined points.

The data obtained were then processed using the Microsoft Excel program in tabular and graphical form, with unit conversions according to the "1993 AASHTO manual". Data analysis begins with analyzing input data, namely pavement data and LWD deflections to obtain variables and calculation parameters according to the 1993 AASHTO guidelines. The variables and parameters obtained are used to calculate the thickness of the slab capable of serving the traffic load (Of), the effective slab thickness (Deff), and the thickness of the added layer (Doi) based on the equations established by AASHTO 1993. The results of these calculations are then analyzed and used to design the thickness of the added layer with an asphalt layer on the composite road according to the 1993 AASHTO standard.

This study used samples from several points on the Al Fathu Canal - Ciputih Road (Lkr. Baru) Soreang, Bandung Regency, which were selected based on an initial survey to obtain a representation of the existing condition of the composite pavement. The tool used was Pusjatan's Light Weight Deflectometer (LWD), which was chosen for its ability to provide accurate and relevant data for pavement analysis. The test was conducted by operating the Pusjatan LWD at several predetermined points in the research location.

The deflection data obtained were recorded and processed using Microsoft Excel for further analysis. The data processing involved unit conversion as per AASHTO 1993 guidelines and analysis of input data to obtain the required variables and parameters. References supporting this method include the "Guide for Design of Pavement Structures" by AASHTO (1993) as well as research by Putranto (2017) and Siegfried (2017) on the use of LWD in pavement evaluation.

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RESULTS AND DISCUSSION

Primary Data Collection

Primary data obtained from the research was used to calculate the design of the thickness of the added layer with asphalt on the composite road. The data includes pavement data with the following details: road classification is arterial road, asphalt thickness is 8 cm, concrete slab thickness is 24 cm, cumulative ESAL is 25,000,000, asphalt modulus is 1100 MPa, and road shoulder type is aggregate. In addition, deflection data from the Pusjatan Light Weight Deflectometer (LWD) was also obtained from the field location, with testing conducted on Sunday, March 10, 2024.

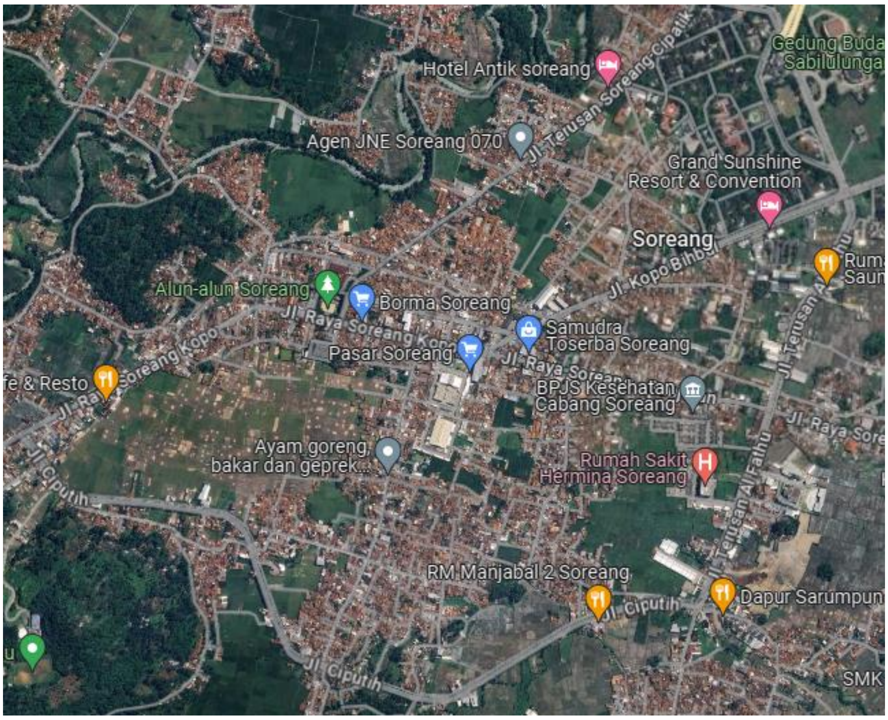

Figure 1. Research Location

Data Analysis

Data analysis was conducted to identify calculation parameters based on the "1993 AASHTO standard". The data analyzed included pavement data and deflection data from the Pusjatan Light Weight Deflectometer (LWD).

Pavement data included classification as an arterial road used to determine Reliability (R) and Standard Normal Deviation (ZR) values, 8 cm asphalt thickness converted to 3.15 inches, 24 cm concrete slab thickness converted to 9.45 inches, cumulative ESAL of 25,000,000 to determine traffic load, 1100 MPa asphalt elastic modulus converted to 159,542 psi, and aggregate shoulder type used to determine Load Transfer coefficient (J). LWD deflection data was obtained from field testing conducted on March 10, 2024 and analyzed to calculate the added layer thickness parameters.

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Tabel 1. LWD Data

StationID	Force	D0	D1	D2	D3
	kg	µm	µm	µm	µm
0	3094	36.80	29.70	23.70	22.30
1	3094	34.20	29.70	25.30	21.50
2	3094	39.10	35.00	29.60	20.40
3	3094	35.20	29.00	24.00	36.70
4	3094	46.80	34.10	24.10	16.80
5	3094	41.80	23.80	19.90	16.00
6	3094	35.70	25.10	23.00	19.10
7	3094	39.90	33.10	29.20	26.40
8	3094	44.18	37.80	33.30	28.60
9	3094	46.50	34.80	22.00	16.90
10	3094	46.60	33.50	22.40	17.60

Calculation Parameters

The collected pavement data were used to determine the calculation variables in the design of the thick asphalt overlay on the composite road in accordance with the "1993 AASHTO standard."

Table 2. Reliability Determination

Road Classification	Recommended Reliability Leve	
	Urban	Rural
Expressway	85-99,9	80-99,9
Main Arterial	80-99	75-95
Collector	80-95	75-95
Local	50-80	50-80

Table 3. Determination of Final Service Index

Final service index	Percentage of people who said it was unacceptable
3,0	12
2,5	55
2,0	85

Table 4. Determination of Overall Standard Deviation (S0)

S0 value range according to the existing pavement	
0,30-0,40	Rigid Pavement
0,40-0,50	Flexural Pavement

Parameter determinations included a reliability value of 90% for main arterial roads, a standard normal deviation of -1.282, and a final service index with loss of serviceability (ΔPSI) of 2.0. The overall standard deviation value was set at 0.35 according to the composite pavement type which refers to rigid pavement.

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Parameter Determination of LWD Deflection Data

To determine the values of Subgrade Reaction (k), Modulus of Elasticity of Concrete (Ec), and Modulus of Rupture (Sc'), data from deflection testing with a Light Weight Deflectometer (LWD) was used. This calculation was carried out through several stages, including calculating the AREA value from the deflection data, the relative radius of stiffness (ℓk), and the subgrade reaction modulus (k).

Table 4. Analyzed LWD Deflection Data

STA	P	d0	d12	d24	d36
	lbs	mils	mils	mils	mils
0	6821	1,45	1,17	0,93	0,88
1	6821	1,35	1,17	1,00	0,85
2	6821	1,54	1,38	1,17	0,80
3	6821	1,39	1,14	0,94	0,83
4	6821	1,84	1,34	0,95	0,66
5	6821	1,65	0,94	0,78	0,63
6	6821	1,41	0,99	0,91	0,75
7	6821	1,57	1,30	1,15	1,04
8	6821	1,74	1,49	1,31	1,13
9	6821	1,83	1,37	0,87	0,67
10	6821	1,83	1,32	0,88	0,69

From the calculation results, the dynamic k value is then converted to the effective static k value (keff) which is used to calculate the concrete slab thickness (Df). The Modulus of Elasticity of Concrete (Ec) is calculated using the concrete relative stiffness radius (ℓk) and subgrade reaction modulus (k), while the Modulus of Rupture (Sc') is calculated based on the Ec value obtained. The final result of this calculation is used to determine the thickness of the concrete slab that is suitable for the future traffic load.

Determination of Concrete Slab Thickness for Future Traffic (Df)

To determine the future concrete slab thickness of the composite pavement to be overlaid, parameters of the existing slab such as modulus of elasticity, modulus of rupture, and load transfer are required. Other parameters required are:

1. Load Transfer Coefficient (J): This indicates the ability of the concrete pavement to distribute the load across the joint or crack region. The J coefficient depends on the type of load transfer and the road shoulder. Assuming JRCP pavement and aggregate shoulders, the load transfer coefficient is 3.8.
2. Loss of Support (LS): For overlay design assuming the slab is fully supported, LS is set = 0.
3. Drainage Coefficient (Cd): Determined based on the drainage quality and the annual percentage of time the pavement structure is exposed to moisture. With excellent drainage quality and water removed in 4 hours, and the percentage of time exposed to water is 1%, the drainage coefficient (Cd) is set = 1.15.
4. Calculation of Concrete Slab Thickness (Df): The slab thickness can be calculated using nomograms from AASHTO or by trial and error method using equations involving parameters such as elastic modulus, modulus of rupture, drainage coefficient, and load transfer coefficient. After calculations with Goal Seek in Microsoft Excel, the slab thickness required to serve the future traffic load is 27.40 cm.

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Determination of Effective Plate Thickness (Deff)

The determination of the effective plate thickness (Deff) of the composite pavement is done by calculating using a formula that considers the thickness of the concrete slab (Dpcc), the thickness of the asphalt surface (Dac), and several adjustment factors, namely the Joint and Crack Correction Factor (Fjc), the Durability Adjustment Factor (Fdur), and the Asphalt Concrete Quality Adjustment Factor (Fac). In this case, the known values are Dpcc of 9.45 inches, Dac of 3.15 inches, with Fjc of 0.80, Fdur of 1, and Fac of 1.

Based on the calculations, the effective concrete slab thickness (Deff) was found to be 9.13 inches or equivalent to 23.20 cm. In addition, if an overlay is required for structural purposes, the asphalt overlay thickness is calculated by taking into account the slab thickness for future traffic (Df) and the previously calculated Deff. In this example, Df is known to be 10.79 inches, and based on the calculation, the thickness conversion factor (A) is 2. Thus, the required asphalt overlay thickness is calculated to be 3.30 inches or 8.39 cm, in accordance with the 1993 AASHTO standard.

Recapitulation of Calculation of Add Layer Thickness

The results of the calculation of the thickness of the asphalt overlay on the composite road, based on the 1993 AASHTO standard, have been recapitulated from the Light Weight Deflectometer (LWD) test data calculated for each stationing point.

Table 5. Recapitulation of Calculations from LWD Deflection Data

STA	P	d0	d12	d24	d36	AREA	d0pcc	AREApcc	relstiff	Kdyn	Keff	Slab Ec	Sc'
	lbs	mils	mils	mils	mils	in	mils	in	in	pci	psi/in	psi	psi
0	6821	1,45	1,17	0,93	0,88	27,05	1,45	27,07	24,63	946	473	4.843.105	699
1	6821	1,35	1,17	1,00	0,85	29,07	1,35	29,09	30,31	677	339	7.949.601	834
2	6821	1,54	1,38	1,17	0,80	28,96	1,54	28,98	29,91	608	304	6.768.362	783
3	6821	1,39	1,14	0,94	0,83	27,68	1,38	27,70	26,17	879	439	5.728.065	738
4	6821	1,84	1,34	0,95	0,66	23,08	1,84	23,09	17,97	1373	686	1.991.087	575
5	6821	1,65	0,94	0,78	0,63	20,84	1,64	20,85	15,56	2027	1013	1.652.467	560
6	6821	1,41	0,99	0,91	0,75	25,38	1,40	25,40	21,33	1292	646	3.717.017	650
7	6821	1,57	1,30	1,15	1,04	28,71	1,57	28,73	29,09	629	315	6.268.726	761
8	6821	1,74	1,49	1,31	1,13	29,20	1,74	29,21	30,73	510	255	6.328.055	764
9	6821	1,83	1,37	0,87	0,67	22,84	1,83	22,85	17,68	1426	713	1.937.562	573
10	6821	1,83	1,32	0,88	0,69	22,66	1,83	22,67	17,47	1456	728	1.885.940	571

This study aims to calculate the thickness of the added layer of flexure on composite pavement using data from the Pusjatan Light Weight Deflectometer (LWD) tool. The data used in this calculation include pavement data and the results of deflection testing with LWD, which was conducted on March 10, 2024. Calculation of the thickness of the added layer is carried out in accordance with the guidelines of the 1993 AASHTO standard.

The pavement data used in this study shows that the road under study is an arterial road with an asphalt thickness of 8 cm and a concrete slab thickness of 24 cm. With a cumulative ESAL of 25,000,000 and an asphalt modulus of 1100 MPa, the calculation of the added layer thickness was performed considering various parameters, including Reliability (R), Standard Normal Deviation (ZR), final service index (ΔPSI), and overall standard deviation.

Analysis of the LWD deflection data yielded important values such as Subgrade Reaction (k), Modulus of Elasticity of Concrete (Ec), and Modulus of Rupture (Sc'), which were then used to determine the concrete slab thickness required to withstand future traffic loads. Using the

AASHTO approach, parameters such as Load Transfer Coefficient (J), Loss of Support (LS), and Drainage Coefficient (Cd) are also taken into account to ensure the reliability of the pavement structure.

The final results show that the thickness of the concrete slab to withstand future traffic loads is 27.40 cm. In addition, the effective slab thickness (Deff) calculation shows that the existing concrete slab thickness is 9.13 inches or 23.20 cm. The required asphalt overlay thickness for this composite pavement, according to the 1993 AASHTO standard, is 3.30 inches or 8.39 cm.

A recapitulation of the calculations shows that the results are in accordance with the applied standards and provide clear guidance in the design and rehabilitation of composite roads. This research makes an important contribution in the application of LWD technology for pavement analysis, as well as in the determination of the optimal thickness of the added layer based on real field conditions.

CONCLUSION

Research on the calculation of the thickness of the added layer of flexure in the composite layer using the Light Weight Deflectometer (LWD) Pusjatan shows that the analysis of pavement data produces important parameters such as Reliability (R), initial and final serviceability indices (po and pt), Overall Standard Deviation (S0), and Load Transfer coefficient (J). Deflection data from the LWD influences the design of pavement thickness, with analysis performed at each station point (STA). The calculation results for STA 0 showed that the value of the Subgrade Reaction Modulus (k) was 473 psi/in, the Modulus of Elasticity of Concrete (Ec) was 4,843,105 psi, and the Modulus of Rupture (Sc') was 699 psi.

With a traffic load of 25,000,000 ESAL, the slab thickness to serve future traffic (Df) was determined to be 27.40 cm, while the effective slab thickness (Deff) was 23.20 cm. Based on these results, the required added layer thickness (Dol) is 8.39 cm. These findings emphasize the importance of using the Light Weight Deflectometer in the design of composite overlays to ensure road strength and durability. It is recommended that this method be routinely applied in road maintenance planning to improve the accuracy of pavement thickness calculation and optimize road service life.

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