Analysis of the Impact of Overloading Goods Transportation on the Design Life of Flexible Pavemnet

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Abstract. Overloading goods often pass through the Pekanbaru Taluk Kuantan Crossroad, which is a national road, causing damage to the road surface. Based on these problems, this study aimed to determine the damage capacity of vehicles and their impact on decreasing the design life of the road pavement. The data used for overloading goods transportation are primary data obtained by directly observing the results of weighing goods transportation at the Motor Vehicle Weighing Implementation Unit for 7 days and calculating the LHR as well as technical drawing data for pavement maintenance for the Pekanbaru-Taluk Kuantan Crossroad obtained from B2PJN Riau Province. The damaging power of vehicles and the decrease in design life were analysed using the AASHTO method. The result of this study indicated that the cumulative damaging power of vehicles on the road section under normal loading conditions is 1,064,232.81 ESAL so the number of repetitions of traffic loads is 6,640,034.55 ESAL at the end of the design life. For the condition of overloading, the cumulative damage value of the vehicle increases to 3,527,541.81 ESAL, resulting in the number of repetitions of the vehicle traffic load of 22,009,281.42 ESAL at the end of the design life. The impact of overloading goods transportation on the life road pavement decreased by 64.6%. This indicates that before the road's 5-year design age, the road will no longer be able to serve the load of passing vehicles.

Keywords: Design life · Flexible pavemnet · Overloading

1 Introduction

Coyle states "transportation users buy a package of services at a certain price that must be paid" [1], from the statement the author assures that customers who buy a package of services are expecting a package of good and reliable facilities or services. These factors must be a serious concern because transportation is not just moving people, goods, and or animals through public spaces, but good transportation is connecting areas effectively and influencing economic improvement significantly [2]. To maintain the smooth movement of transportation, the conditions of the road structure must be protected from factors that cause road damage [3]. One of the factors causing road damage is a vehicle that has a load that exceeds the capacity limit [4]. According to The Minister of Transportation

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of the Republic of Indonesia stated that the violation of Over Dimension-Over Loading (ODOL) has caused huge losses for the country. The state suffered a loss of IDR 43 trillion in one year, even though the budget for road repairs was only IDR 26 trillion in the same year [5].

The Pekanbaru-Taluk Kuantan crossroad is a national road network that falls under the category of primary collector roads connecting Pekanbaru City and Taluk Kuantan Regency with a length of 160 km. This road segment is traversed by heavy vehicles necessary for transportation of coal, Crude Palm Oil (CPO), and other goods. Based on data from the Motor Vehicle Weighing Service Unit (UPPKB), freight transportation that crosses the causeway tends to be overloaded, and this crossroad has an index value of road damage conditions measured at 90.95% according to the Asphalt Institute method, so routine maintenance is needed [6]. Heavy overloading vehicles often pass through the Pekanbaru-Taluk Kuantan-Border of West Sumatera Province which cause damage to the road surface. The level of damage to this road section is in a slightly damaged condition with an average Surface Distress Index (SDI) value of 100–150 so it is necessary to carry out road rehabilitation [7]. With the rigid pavement on the Lago-Sorek road at Km 77–78, there is a decrease in service life due to vehicle overloading [8].

Based on the phenomena mentioned, it is crucial to find out to what extent the relationship between overloaded vehicles and the design life is carried out. Hence, a study of the impact of overloading goods transportation on the road pavement design life was conducted.

2 Research Methods

The methodology used in this research was by describing the factors which affected the road damage. Those factors, traffic load, stress on the surface layer caused by excessive wheel pressure, pavement materials, pavement layer thickness, roadbed or subgrade soil, and environment were then analyzed by using analysis of sensitivity. In addition to this, calculation using the Vehicle Damage factor (VDF) was also used to measure the influence of the number of truck axles and compare normal conditions between overloading conditions to the road pavement design life [9].

3 Result and Discussion

Based on the Detailed Engineering Design (DED) data obtained from Ministry of Public Works, the details can be seen in Table 1 attached.

However, after conducting a direct survey by counting the number of vehicles, data on the overloading of vehicles that passed through the road with the value of Vehicle Damage Factor (VDF) in normal conditions and overloading conditions can be seen in Table 2.

It can be seen from Table 2 that vehicle type 6 and 7 in overloading conditions increased 3 times from the conditions that should be where these vehicles transport a lot of goods from oil palm plantations and coal with an increase in the value of VDF. This can

Table 1. Road segment data

Segment name	South causeway
Road classification	The national road, Primary collector, Class I
Load class	Wide ≤ 2.500 mm, Long ≤ 18.000 mm, Tall ≤ 4.200 mm, MST ≤ 10 ton
Pavement type	Flexible Pavement
Recent overlay history	Early 2021
Overlay design life	10 years
Traffic growth factor (i)	4,83%

Table 2. VDF Cumulative Vehicle in Overloading State

Vehicle Class	VDF Normal	VDF *Overloading*	LHRT	VDF Cumulative Normal (ESAL)	Amount of Overloading Goods Transport	VDF Cumulative Overloading (ESAL)
2	0,001022	0,001022	121.622	124,30	0	124,30
3	0,001022	0,004148	480.747	491,32	15.073	538,45
4	0,019222	0,116211	232.092	4.461,27	5.673	5.011,51
5a	0,187111	0,187111	437	81,82	0	81,82
5b	1,838933	1,838933	5.630	10.353,41	0	10.353,41
6a	0,215971	1,652766	7.598	1.640,93	24.834	37.322,15
6b	2,315133	29,677576	183.717	425.328,95	21.372	1.010.108,59
7a	2,694000	23,644448	150.592	405.694,95	87.934	2.247.945,66
7b	3,883373	3,883373	164	636,81	0	636,81
7c	3,200000	3,200000	67.397	215.419,11	0	215.419,11
	TOTAL			1.064.232,81		3.527.541,81

reduce the life of the road planned where with a decrease of almost 3 times this can give premature damage before the service life of 5 years [10]. The value 1,064,232.81 ESAL is the cumulative value of VDF under normal conditions and the value of 3,527,541.81 ESAL in Table 2 is the cumulative damage power (cumulative VDF) of vehicles in a state of overload on the road section Pekanbaru-Taluk Kuantan cross in 2022. Then from the results of the destructive power value, the number of load repetitions (W18) of Vehicle Traffic can be found using the following formula.

$$w_{18} = CumulativeVDF \text{ x } \mathrm{D_D x D_L x}\left[\frac{(1+i)^n - 1}{i}\right] \quad (1)$$

Table 3. Number of load repetitions (W18) vehicle

Year	W_{18} (ESAL) Normal condition	W_{18} (ESAL) Overloading condition
1	532.116,41	1.763.770,90
2	1.089.934,03	3.612.731,94
3	1.674.694,26	5.550.997,80
4	2.287.698,39	7.582.881,89
5	2.930.310,63	9.712.905,99
6	3.603.961,04	11.945.810,26
7	4.310.148,77	14.286.563,80
8	5.050.445,36	16.740.375,73
9	5.826.498,28	19.312.706,78
10	6.640.034,55	22.009.281,42

where DD represents 2-way distribution factor (0,5), DL is strip distribution value in ideal condition (100%), n means Design life value, and i states the traffic growth factor. After calculating the cumulative VDF through the formula, it can be found that the number of load repetitions of vehicles is under normal conditions and overloading conditions during the design life can be calculated as can be seen in Table 3.

This load repetition value (W18) was used to analyze the percentage decrease in the design life of pavement due to overloading vehicles using the following formula:

$$\mathrm{RI} = 100\,[1-[\frac{N_P}{N_{1,5}}]] \qquad (2)$$

where RI represents percentage reduction in design life. Np is the repetition value of the traffic load in year-n and N1,5 is the repetition value of the traffic load at the design life of the road. By using this equation, the percentage value of the decline in the design life of the road can be calculated, which can be seen in Table 4:

From Table 4, it can be seen that the percentage decrease in the condition of the road design life in overloading conditions is the largest at 73.44%. The percentage is close to 80% where this overload is a substantial factor in reducing the service life of the road. This result is line with the previous studies that mention the actual traffic load is presented in the form of distribution for each type of load [11–13]. Five-axle trucks with semi-trailer type contribute to pavement distress to the greatest extent, contribution of this vehicles in pavement failure ranges from 58% to 84% [14].

The decrease in the design life due to the condition of the vehicle overloading between the 3rd and 4th years, the percentage 0% which indicates that in the 3rd year the road is no longer able to serve the burden of passing vehicles and a decrease in the pavement design life is obtained by 64.6% of the life road. This shows that the decrease in the design life that occurs is more than 50% so the road is no longer able to withstand vehicle loads in the third year. Similar studies have also been carried out that overloading heavy vehicles reduces the design life of the road by almost 50%, making the service life of the

Table 4. Percentage of reduction flexible pavement design life

Year	RI Normal condition	RI Overloading condition
1	91,99	73,44
2	83,59	45,59
3	74,78	16,40
4	65,55	−14,20
5	55,87	−46,28
6	45,72	−79,91
7	35,09	−115,16
8	23,94	−152,11
9	12,25	−190,85
10	0	−231,46

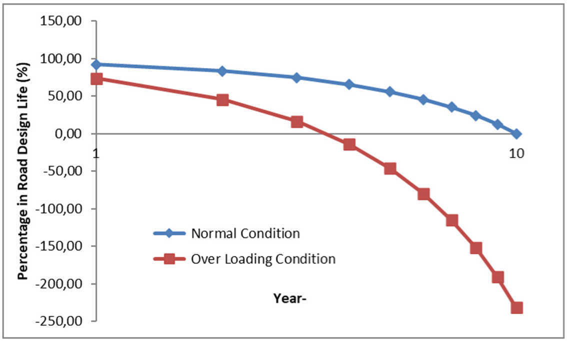

Fig. 1. Road service decline

road only 3–4 years from the planned life of the road at the beginning of planning [15]. With a decrease in the life of this plan, it will result in an increase in vehicle operating costs following the research, namely there is a linear relationship between the percentage of overload and an increase in vehicle operating costs due to overloading [16]. From the results of this study, it was found that the decrease in road service life has decreased 3 times because the number of overloading vehicles for vehicle types 6 and 7 increased 3 times so the decrease in road service life was reduced 3 times as well. Before the age of the road of five years, the road is no longer able to serve the load of traffic vehicles [10]. Therefore, the road pavement no longer has the service capability expected at the time of planning and routine maintenance needs to be carried out. The decrease in road serviceability can be drawn in normal conditions and overloading conditions can be seen in Fig. 1.

4 Conclusion

Based on the results of the analysis and discussions that have been described, it can be concluded that the cumulative damage capacity of the vehicles on the Pekanbaru-Taluk Kuantan crossroad with a design life of 10 years is 6,640,034.55 ESAL and the overloading condition is 22,009,281.42 ESAL at the end of life before 10 years and decrease in design life by 64.6%. This indicates that before the road's 5-year design age, the road will no longer be able to serve the load of passing vehicles.

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