VOL. 11, NO. 24, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

THE EFFECT OF OVERLOADED HEAVY VEHICLES ON THE VALUES OF AXLE LOAD DISTRIBUTION, TIRE PRESSURE AND EQUIVALENT AXLE LOAD (CASE STUDY: JENU – TUBAN ATERIAL ROAD, EAST JAVA, INDONESIA)

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ABSTRACT

Premature deterioration on highway pavement is still considered as one of the main issues in Indonesian related to the road problems. Premature deterioration of pavements not only occurs on relatively new roads but also prevails on roads that have just been repaired. The premature damage on roads is allegedly caused by the overloaded heavy trucks. This paper will discuss the condition of overloading of heavy trucks on an important highway in East Java, Indonesia, by means of weighing the trucks carrying construction materials in the weighbridge and measure their tire pressures. The data obtained are the total weights of trucks, the weights of each axle, and tire pressures. By calculating the EAL value for each axle and simple statistical analysis, the value of the vehicle axle load distribution and a tire pressure will be obtained. It was found that the effect of overloaded heavy vehicle are: a) higher axle-load distribution for the rear wheels than those of standard of Bina Marga (Indonesian Directorate General of Highways, 1987); b) higher average EAL value per type of truck than those of average EAL based on Bina Marga (1987), which is from 2.2 to 8.3 times higher; and 3) higher tire pressures for heavy trucks, ranging from the lowest of 130 psi to as high as 185 psi, very much higher than the recommenced tire pressures of 80 to 100 psi.

Keywords: equivalent axle load, overloaded, axle load distribution, tire pressure.

INTRODUCTION

In the flexible pavement construction design for highways, one of the data required is the value of Equivalent Axle Load (EAL). In Indonesia, the guidelines used to calculate the value of EAL refers to the method of Bina Marga (1987, 2005) [1], [2]. In the method of Bina Marga, the standard of the total load of the vehicle and the estimation value of axle load distribution are described. The method of Bina Marga is a guideline used to design construction of road pavement in Indonesia by the Directorate General of Highways, Ministry of Public Work and Housing People.

The American Association of State Highway and Transportation Officials, AASHTO [3], [4] has defined the standard axle load as 18000 kip or 8.16 tons for single axle double wheel and the recommended value of tire pressure as 80 psi. AASHTO also specified the EAL values of all vehicles

The EAL values are mostly for normal to slightly overloaded vehicles and normal tire pressures. However, in terms of the characteristics of heavy vehicles in the field, most of the heavy vehicles are suspected to be heavily overloaded. Sutikno and Mochtar [5] in his research on several roads in East Java mentioned that 48.98 % of single axles of heavy trucks exceed 10.5-ton load and 34.70 % of the single axles exceed the 16.5-ton load. In other observation of trucks carrying construction materials in the weighbridge of Jenu – Tuban arterial road, Prastyanto [6] found that almost all of the trucks transporting cargo exceeded the standards load by Bina Marga.

In this paper, the information to be presented is the effect of overloading the heavy trucks on the values of axle load distribution and tire pressures, and their impacts on the values of Equivalent Axle Load (EAL).

METHODOLOGY

The equipment used to obtain the data about distribution of the load on each axle of the vehicle was the weighbridge currently available on the field. The types of vehicles studied are heavy vehicles (heavy trucks) that were suspected to be heavily overloaded. The vehicle consisted of 2-axle trucks, 3-axle trucks, trailer trucks, and semi-trailer trucks transporting construction materials. Weighing method was as shown in Figure-1.

The weighing methods of the trucks consisted of a total load weighing of the vehicle and weighing of each axle of the vehicle. For example in Figure-1.a, the first weighing was for the front axle, the second for the total load of the vehicle, and the final weighing is for the rear axle. The methods were similarly applied to other types of vehicles (Figure 1.b to 1.d)

Heavy vehicle tire pressure measurements were carried out directly (randomly) in the field and also through interviews with the drivers of heavy trucks. The equipment used was the air pressure test as shown in Figure-2

Based on the vehicle axle loads data, the next step was to calculate the total weight of the vehicle and estimate the EAL values in accordance with the method of Bina Marga (2005) [2]. The results obtained were the average values of the total weights of the vehicles and the average EAL values for each axle of the vehicles. Based

VOL. 11, NO. 24, DECEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

on the results of these calculations, the percentage distribution of the load on each axle vehicle could be calculated.

DISCUSSION

Axle load distribution

The equation to be used to calculate the EAL value is based on Bina Marga (2005) [2]. The equation is as follows:

- Single Axle Single Wheel (SASW),

$$EAL = \left(\frac{Axle\ Load}{5{,}40}\right)^4 \quad (1)$$

- Single Axle Dual Wheel (SADW),

$$EAL = \left(\frac{Axle\ Load}{8{,}16}\right)^4 \quad (2)$$

- Tandem Axle Dual Wheel (TADW),

$$EAL = \left(\frac{Axle\ Load}{13{,}76}\right)^4 \quad (3)$$

- Triple Axle Dual Wheel (TrADW),

$$EAL = \left(\frac{Axle\ Load}{18{,}45}\right)^4 \quad (4)$$

EAL calculation results can be seen in Table-1 to Table-4. In those table there are some data obtained like the average of total vehicle weight, the average EAL value and the percentage of load distribution to each axle vehicles.

Based on Table-1 to Table-4 there are differences in the value of axle load distribution between the results of research and standards of Bina Marga (1987) [1]. Value distribution to the rear axle load of research results has a value greater than that of the standard value of Bina Marga (1987) [1] and vice versa for the front axle load distribution value.

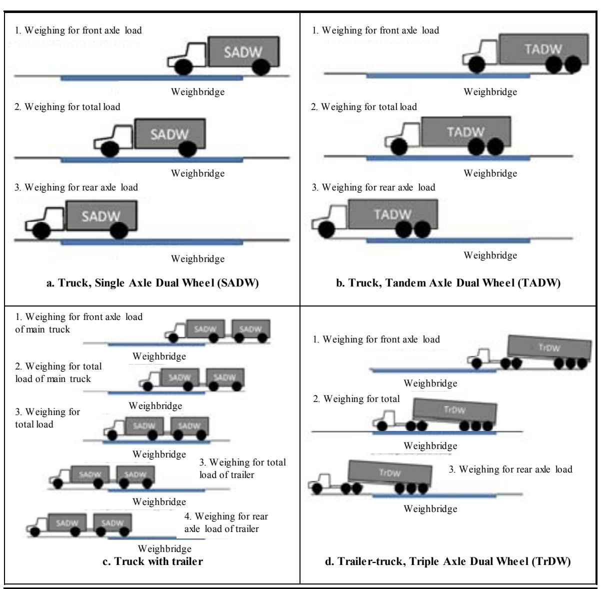

Figure-1. The vehicle weighing method in weighbridge.

Figure-2. Tire pressure tool.

Further analysis is to see the influence of the value of the vehicle axle load distribution of research results to the EAL value based Bina Marga (1987, 2005) [1], [2]. EAL equation based on Bina Marga (1987) [1] are:

- Single axle , $EAL = \left(\frac{Axle\ Load}{8{,}16}\right)^4$ (5)
- Tandem axle, $EAL = 0{,}086\left(\frac{Axle\ Load_{tandem}}{8{,}16}\right)^4$ (6)

Based on the total weight of the vehicle in Table 1 to 5 and EAL equation above, EAL value for each type of vehicle is as follows:

1. Truck tandem axle dual wheel (T 1.22)

	Axle load dist.		Average total load (ton)	EAL value		
	Front axle	Rear axle		Front axle	Rear axle	Total EAL
Research (*)	19.00%	81.00%	39.790	0.737	20.931	21.668
Bina Marga (1987)	25.00%	75.00%	25.000	0.344	2.397	2.742
Research (**)	19.00%	81.00%	39.790	3.842	30.100	33.942
Bina Marga (2005), (***)	25.00%	75.00%	25.000	1.795	3.448	5.242

Note :
(*) = EAL calculation based on Bina Marga (1987)
(**) = EAL calculation based on Bina Marga (2005)
(***) = Total load data for EAL calcultaion based on Bina Marga (1987)

From the EAL calculated above, there is a fairly significant difference between the results of research and Bina Marga. The average total load of vehicles from the results of research is 1.6 times of that of the Bina Marga (1987, 2005) [1], [2]. While average the results of research shows EAL value of 7.9 times of that of the Bina Marga (1987) [1] and 6.9 times of that of Bina Marga (2005) [2]. It is concluded that the difference in the value of the distribution and average total load affect the value of EAL.

2. Truck with trailer (T 1.2 + 2.2)

	Axle load distribution of main truck (%)		Axle load distribution of trailer (%)		Average total load (ton)	EAL value of main truck		EAL value of trailer		Total EAL
	Front axle	Rear axle	Front axle	Rear axle		Front axle	Rear axle	Front axle	Rear axle	
Research (*)	12.00%	35.00%	24.00%	29.00%	46.747	0.223	16.163	3.573	7.618	27.577
Bina Marga (1987)	18.00%	28.00%	27.00%	27.00%	31.400	0.230	1.348	1.165	1.165	3.908
Research (**)	12.00%	35.00%	24.00%	29.00%	46.747	1.165	16.163	3.573	7.618	28.519
Bina Marga (2005), (***)	18.00%	28.00%	27.00%	27.00%	31.400	1.200	0.167	6.076	0.144	7.587

Note :
(*) = EAL calculation based on Bina Marga (1987)
(**) = EAL calculation based on Bina Marga 2005)
(***) = Total load data for EAL calcultaion based on Bina Marga (1987)

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From the EAL calculated above, there is a fairly significant difference between the results of research and Bina Marga. The average total load of vehicles from the results of research is 1.5 times of that of the Bina Marga (1987, 2005) [1], [2]. While average the results of research shows EAL value of 7.1 times of that of the Bina Marga (1987) [1] and 3.8 times of that of Bina Marga (2005) [2]. It is concluded that the difference in the value of the distribution and average total load affect the value of EAL.

3. Trailer truck (T 1.2 – 22)

	Axle load dist. (%)			Average	EAL value			
	Front axle	Middle axle	Rear axle	total load (ton)	Front axle	Middle axle	Rear axle	Total EAL
Research (*)	12.86%	31.76%	55.38%	49.913	0.383	14.248	11.321	25.952
Bina Marga (1987)	18.00%	28.00%	54.00%	42.000	0.737	4.314	5.132	10.183
Research (**)	12.86%	31.76%	55.38%	49.913	1.997	14.248	16.280	32.525
Bina Marga (2005), (***)	18.00%	28.00%	54.00%	42.000	3.842	4.314	7.381	15.536

Note :
(*) = EAL calculation based on Bina Marga (1987)
(**) = EAL calculation based on Bina Marga (2005)
(***) = Total load data for EAL calcultaion based on Bina Marga (1987)

From the EAL calculated above, there is a fairly significant difference between the results of research and Bina Marga. The average total load of vehicles from the results of research is 1.2 times of that of the Bina Marga (1987, 2005) [1], [2]. While average the results of research shows EAL value of 2.5 times of that of the Bina Marga (1987) [1] and 2.1 times of that of Bina Marga (2005) [2]. It is concluded that the difference in the value of the distribution and average total load affect the value of EAL.

4. Trailer truck (T 1.2 – 222)

	Axle load dist. (%)			Average	EAL value			
	Front axle	Middle axle	Rear axle	total load (ton)	Front axle	Middle axle	Rear axle	Total EAL
Research (*)	9.00%	32.00%	59.00%	68.835	0.332	53.098	-----	-----
Bina Marga (1987)	18.00%	28.00%	54.00%	42.000	0.737	4.314	-----	-----
Research (**)	9.00%	32.00%	59.00%	68.835	1.732	53.098	23.478	78.308
Bina Marga (2005), (***)	18.00%	28.00%	54.00%	42.000	3.842	4.314	2.283	10.439

Note :
(*) = EAL calculation based on Bina Marga (1987)
(**) = EAL calculation based on Bina Marga (2005)
(***) = Total load data for EAL calcultaion based on Bina Marga (1987)

Specially for trailer-truck with triple axle dual wheel (T 1.2-222), this type is not listed in the standard of Bina Marga (1987, 2005) [1], [2], so that the total weight of vehicle is assumed to trailer-truck type T 1.2 - 22. EAL calculation for the three axes (Triple Axle Dual Wheel, TrDW) will use equation from Bina Marga (2005) [2] due to that type is not listed on the Bina Marga (1987) [1].

From the EAL calculated above, there is a fairly significant difference between the results of research and Bina Marga. The average total load of vehicles from the results of research is 1.6 times of that of the Bina Marga (2005) [2]. While average the results of research shows EAL value of 7.5 times of that of the Bina Marga (2005) [2]. It is concluded that the difference in the value of the distribution and average total load affect the value of EAL.

Table-1. Axle load distribution and EAL value for truck with trailer, single axle (T 1.2 + 2.2).

No.	Truck with trailer (T 1.2 + 2.2)							EAL value (Bina Marga, 2005)				
	Axle load distribution of main truck (kg)			Axle load distribution of trailer (kg)			Total load	EAL of main truck		EAL of trailer		Total EAL
	Front axle	Rear axle	Total load	Front axle	Rear axle	Total load		Front axle	Rear axle	Front axle	Rear axle	
1	5560	16920	22480	10300	13980	24280	46760	1.1239	18.4859	2.5386	8.6153	30.7636
2	4380	14980	19360	9525	11355	20880	40240	0.4328	11.3576	1.8565	3.7496	17.3966
3	4940	17200	22140	10320	13640	23960	46100	0.7004	19.7403	2.5583	7.8072	30.8062
4	5880	15840	21720	10700	12940	23640	45360	1.4058	14.1991	2.9565	6.3238	24.8852
5	6040	15580	21620	9880	13880	23760	45380	1.5652	13.2895	2.1492	8.3714	25.3753
6	5440	15940	21380	11440	12300	23740	45120	1.0300	14.5610	3.8632	5.1625	24.6167
7	6240	15540	21780	10420	13380	23800	45580	1.7830	13.1536	2.6590	7.2288	24.8243
8	6100	16680	22780	11900	12820	24720	47500	1.6283	17.4592	4.5230	6.0924	29.7030
9	4440	17760	22200	10260	13620	23880	46080	0.4570	22.4394	2.4994	7.7615	33.1573
10	6080	15880	21960	10540	13680	24220	46180	1.6071	14.3430	2.7836	7.8992	26.6329
11	5600	17400	23000	11500	13040	24540	47540	1.1566	20.6746	3.9449	6.5215	32.2975
12	7000	18280	25280	15840	18000	33840	59120	2.8237	25.1851	14.1991	23.6771	65.8850
Average							46746.67	1.3095	17.0740	3.8776	8.2675	30.5286
Axle load based on average EAL above (kg)								5776.56	16587.24	11450.66	13836.75	47651.21
Axle load distribution								12.12%	34.81%	24.03%	29.04%	100.00%
Axle load distribution (rounded value)								12.00%	35.00%	24.00%	29.00%	100.00%
Axle load distribution (Bina Marga, 1987)								18.00%	28.00%	27.00%	27.00%	100.00%

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Table-2. Axle load distribution and EAL value for trailer truck, tandem axle (T 1.2 – 22).

No.	Trailer truck (T 1.2 - 22)				EAL Value			
	Axle Load Distribution (kg)				Bina Marga (2005)			
	Front axle	Middle axle	Rear axle	Total load	Fron axle	Middle axle	Rear axle	Total EAL
1	7380	14760	24080	46221	3.4886	10.7050	9.3789	23.5725
2	7720	14480	24080	46282	4.1773	9.9155	9.3789	23.4717
3	6820	14220	37860	58900	2.5443	9.2223	57.3124	69.0789
4	5780	18220	28680	52680	1.3126	24.8561	18.8731	45.0418
5	5060	19560	20860	45480	0.7710	33.0153	5.2818	39.0680
Average				49912.60	2.4587	17.5428	20.0450	40.0466
Axle load based on average EAL above (kg)					6761.95	16699.94	29115.22	52577.11
Axle load distribution					12.86%	31.76%	55.38%	100.00%
Axle load distribution (rounded value)					13.00%	32.00%	55.00%	100.00%
Axle load distribution (Bina Marga, 1987)					18.00%	28.00%	54.00%	100.00%

Table-3. Axle load distribution and EAL value for trailer truck, triple axle (T 1.2 – 222).

No.	Trailer truck (T 1.2 - 222)				EAL Value			
	Axle Load Distribution (kg)				Bina Marga (2005)			
	Front axle	Middle axle	Rear axle	Total load	Fron axle	Middle axle	Rear axle	Total EAL
1	3820	19600	47480	70900	0.2504	33.2862	43.8589	77.3954
2	7080	17200	44020	68300	2.9550	19.7403	32.4052	55.1005
3	7380	19540	43040	69960	3.4886	32.8804	29.6144	65.9835
4	4960	27280	36700	68940	0.7118	124.9156	15.6559	141.2834
5	4620	28660	38400	71680	0.5358	152.1753	18.7646	171.4757
6	7380	18900	43040	69320	3.4886	28.7797	29.6144	61.8828
7	6970	12030	44520	63520	2.7756	4.7239	33.9028	41.4023
8	4980	25840	37240	68060	0.7233	100.5563	16.5979	117.8776
Average				68835.00	1.8661	62.1322	27.5518	91.5501
Axle load based on average EAL above (kg)					6311.46	22909.70	42270.15	71491.30
Axle load distribution					8.83%	32.05%	59.13%	100.00%
Axle load distribution (rounded value)					9.00%	32.00%	59.00%	100.00%
Axle load distribution (Bina Marga, 1987) *					18.00%	28.00%	54.00%	100.00%

(*) : the result based on trailer-truck type T 1.2-22, due to trailer-truck type T 1.2-222 is not listed in Bina Marga (1987)

Table-4. Axle load distribution and EAL value for trailer truck, triple axle (T 1.22 – 222).

No.	Trailer truck (T 1.22 - 222)				EAL Value			
	Axle Load Distribution (kg)				Bina Marga (2005)			
	Front axle	Middle axle	Rear axle	Total load	Fron axle	Middle axle	Rear axle	Total EAL
1	6140	23440	32500	62080	1.6715	8.4209	9.6283	19.7206
2	7300	27060	44880	79240	3.3398	14.9568	35.0127	53.3093
3	5640	23160	34800	63600	1.1900	8.0257	12.6570	21.8727
4	7460	26760	45600	79820	3.6423	14.3044	37.3142	55.2610
5	6180	21880	36640	64700	1.7155	6.3932	15.5538	23.6624
6	6400	29280	42240	77920	1.9731	20.5027	27.4733	49.9490
7	5340	22220	35360	62920	0.9563	6.7999	13.4916	21.2478
8	5120	28240	44220	77580	0.8082	17.7413	32.9981	51.5476
9	5870	29430	41720	77020	1.3963	20.9261	26.1452	48.4675
10	5120	25240	46480	76840	0.8082	11.3210	40.2790	52.4082
11	5040	26740	42640	74420	0.7588	14.2617	28.5288	43.5493
12	5280	30120	41480	76880	0.9140	22.9586	25.5487	49.4214
Average				72751.67	1.5978	13.8843	25.3859	40.8681
Axle load based on average EAL above (kg)					6071.22	26561.33	41413.74	74046.29
Axle load distribution					8.20%	35.87%	55.93%	100.00%
Axle load distribution (rounded value)					8.00%	36.00%	56.00%	100.00%
Axle load distribution (Bina Marga, 1987) *					18.00%	28.00%	54.00%	100.00%

(*) : the result based on trailer-truck type T 1.2-22, due to trailer-truck type T 1.22-222 is not listed in Bina Marga (1987)

5. Trailer truck (T 1.22 – 222)

	Axle load dist. (%)			Average total load (ton)	EAL value			
	Front axle	Middle axle	Rear axle		Front axle	Middle axle	Rear axle	Total EAL
Research (*)	8.00%	36.00%	56.00%	72.752	0.259	9.127	-----	-----
Bina Marga (1987)	18.00%	28.00%	54.00%	42.000	0.737	0.371	-----	-----
Research (**)	8.00%	36.00%	56.00%	72.752	1.349	13.125	23.776	38.251
Bina Marga (2005), (***)	18.00%	28.00%	54.00%	42.000	3.842	0.534	2.283	6.659

Note :

(*) = EAL calculation based on Bina Marga (1987)

(**) = EAL calculation based on Bina Marga 2005)

(***) = Total load data for EAL calcultaion based on Bina Marga (1987)

Regarding the trailer truck type T 1.2 – 222, this type is not listed in the standard of Bina Marga (1987, 2005) [1], [2], so that the total weight of vehicle is assumed similar with that of the trailer-truck type T 1.2 - 22. For EAL calculation for the three axes (Triple Axle Dual Wheel, TrDW), equation from Bina Marga (2005) [2] is used.

From the EAL calculated above, there is a fairly significant difference between the results of research and Bina Marga. The average total load of vehicles from the results of research is 1.7 times of that of the Bina Marga (2005) [2]. While average the results of research shows EAL value of 5.7 times of that of the Bina Marga (2005) [2]. It is concluded that the difference in the value of the distribution and average total load affect the value of EAL.

Tire pressure of heavy vehicle

Tire pressure measurement directly in the field was not as easy as when weighing the vehicle axle loads. Most of drivers refused the request to measure their tire pressures if the method of tire pressure measurements were conducted directly at the air-pumping hole of the tires. Some of the drivers argued that the method could be very dangerous to the vehicle that was carrying fairly heavy load. Therefore, the tire pressure measurement could be carried out only on vehicles with permission from the drivers. Despite the difficulties, results of some measurement can be seen as data in Table-5 to Table-7.

In Table-5 to Table-7, the tire pressure values for different types of vehicles with different axle type are presented. For the tandem axle truck (T 1.22), front wheel tire pressure average is 137.143 psi (ranging from 130-150 psi) and the rear wheel average of 174.286 psi (ranging from 160-185 psi). Trailer truck with triple axle (T 1.2-222 and T 1.22-222), front wheel tire pressure average is 132 psi (ranging from 130-150 psi), the average middle wheel 175.625 psi (ranging from 160-185 psi) and average rear wheel 174 psi (ranging from 160-185 psi). Truck with trailer (T 1.2 + 2.2), front wheel average was 130 psi and the rear wheel average of 143.333 psi (ranging from 140-150 psi).

Simplified, the value of tire pressure for single axle single wheel (SASW), tandem and triple axle dual wheel (TADW and TrDW), and single axle dual wheel (SADW) are 130-140 psi, 160-185 psi and 140-150 psi.

As mentioned before, AASHTO [3], [4], have determined that the standard tire pressure value for single axle dual wheel (SADW) is 80 psi. The results showed that the pressure of tires for heavy vehicles that are being overloaded are much greater than 80 psi. Although the available data is not too many, it can be concluded that the tendency to use higher tire pressures is the impact of heavy vehicles that are being overloaded.

Table-5. Tire pressure for tandem truck.

No.	Type of truck	Weight (ton)			Tire pressure (psi)		
		Veh.	Mat.	Total	Front	Rear	
1	1.22	10	32	42	150	180	180
2	1.22	10	32	42	130	185	160
3	1.22	10	32	42	130	170	170
4	1.22	10	32	42	140	170	180
5	1.22	10	25	35	130	170	170
6	1.22	10	25	35	140	185	180
7	1.22	13	29	42	140	170	170
				Average	**137.143**	**174.286**	

Table-6. Tire pressure for trailer-truck.

No.	Type of truck	Weight (ton)			Tire pressure (psi)					
		Veh.	Mat.	Total	Front	Midle		Rear		
1	1.2-222	13	55	68	130	175		170	180	160
2	1.2-222	13	55	68	130	175		180	180	160
3	1.22-222	18	60	78	140	185	180	180	180	180
4	1.22-222	17	60	77	130	175	185	180	170	175
5	1.22-222	17	37.3	54.3	130	160	170	160	170	185
				Average	**132.000**	**175.625**		**174.000**		

Table-7. Tire pressure for truck with trailer.

No.	Type of truck	Weight of main truck (ton)			Weight of trailer (ton)			Tire pressure of main truck (psi)		Tire pressure of trailer (psi)	
		Veh.	Mat.	Total	Veh.	Mat.	Total	Front	Rear	Front	Rear
1	1.2+2.2	6.4	15	21.4	4.5	20	24.5	130	140	140	140
2	1.2+2.2	6.2	15	21.2	4	20	24	130	150	150	140
3	1.2+2.2	6.4	15	21.4	4.3	20	24.3	130	150	140	140
							Average	**130.000**	**143.333**		

The effect of applying high tire pressure is to increase the value of strain and stress that occur in flexible pavement structure, Huang [7]. In the case of road damage due to overloaded heavy vehicle, such as permanent deformation, the vertical strain is one factor that needs to be concerned. The value of vertical strain caused by heavy vehicle can be calculated with the following equation:

$$\varepsilon_z = \frac{(1+\mu)q}{E}\left[1 - 2\mu + \frac{2\mu z}{(a^2+z^2)^{0.5}} - \frac{z^3}{(a^2+z^2)^{1.5}}\right] \quad (7)$$

On the surface of the half-space theory, z = 0, hence:

$$\varepsilon_z = \frac{(1+\mu)q}{E}[1 - 2\mu] \quad (8)$$

Where :
q : uniform pressure (≈tire pressure, psi)
ε_z : vertical strain
μ : poisson ratio
E : elastic modulus (psi)
a : contact radius
: $\sqrt{\frac{P}{q\,\pi}}$
p : concentrated load (lb)
z : thickness of pavement considered as homogeneous half-space (in)

In the calculation of the elastic modulus, Boussinesq Theory (1885), the pavement structure is assumed as a homogeneous layer, having isotropic properties and elastic, therefore the value of the elastic modulus (E) can be calculated by the following equation :

$$d = \frac{(1+\mu)qa}{E}\left\{\frac{a}{(a^2+z^2)^{0.5}} + \frac{1+2\mu}{a}\left[(a^2+z^2)^{0.5} - z\right]\right\} \quad (9)$$

On the surface of the half-space theory, z = 0, hence:

$$d = \frac{2(1-\mu^2)qa}{E} \quad (10)$$

$$E = \frac{2(1-\mu^2)qa}{d} \quad (11)$$

where :
d : vertical deflection (in)

Based on the formula above, it was clear that the value of the tire pressure has an effect on the value of the vertical strain. The higher the tire pressure, the higher the strain value of vertical and vice versa.

Asphalt pavement strength is often indicated by the value of Marshall Stability (MS). In Indonesia, MS value for flexible pavement minimum is 800 kg, according to Bina Marga (2005) [2]. For MS value on highways that passed heavy vehicles with high tire pressure, Mochtar [8] suggested that the minimum value of the MS can be calculated by the following equation (see Table-8):

Marshall stability (kg) ≥ 10 p_o (psi) (12)
where :
p_o = tire pressure (psi = 0,07 kg/cm^2).

Based on Table-8 and the maximum value of tire pressure of 185 psi, the minimum Marshall Stability requirements needed is 1850 kg. This value is greater than the minimum standards required of Bina Marga is 800 kg.

So it can be concluded that the use of high-pressure tires which will increase the value of the vertical strain that occurs in the structure of flexible pavements. As consequence, the minimum Marshal Stability value required for the pavement is also high.

Table-8. The correlation between tire pressure with minimum of Marshall Stability for flexible pavement.

Tire pressure (psi)	Minimum value of Marshall Stability for flexible pavement (kg)*
80	800
90	900
100	1000
110	1100
120	1200
130	1300
140	1400
150	1500
160	1600
170	1700
180	1800
190	1900
200	2000

(*) = from equation (12)

CONCLUSIONS

Based on the discussion above, it can be concluded as follows:

- Heavy vehicles are overloaded lead to changes in the axle load distribution of vehicles. The results showed that the axle load distribution for the rear wheel is greater than the standard of Bina Marga (1987) [1].
- The results showed that the EAL value of research results greater than EAL based on Bina Marga (1987, 2005) [1], [2] which is 2.2 to 8.3 times.
- The value of tire pressure for single axle single wheel (SASW), tandem and triple axle dual wheel (TADW and TrDW), and single axle duwal wheel (SADW) are 130-140 psi, 160-185 psi and 140-150 psi.

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