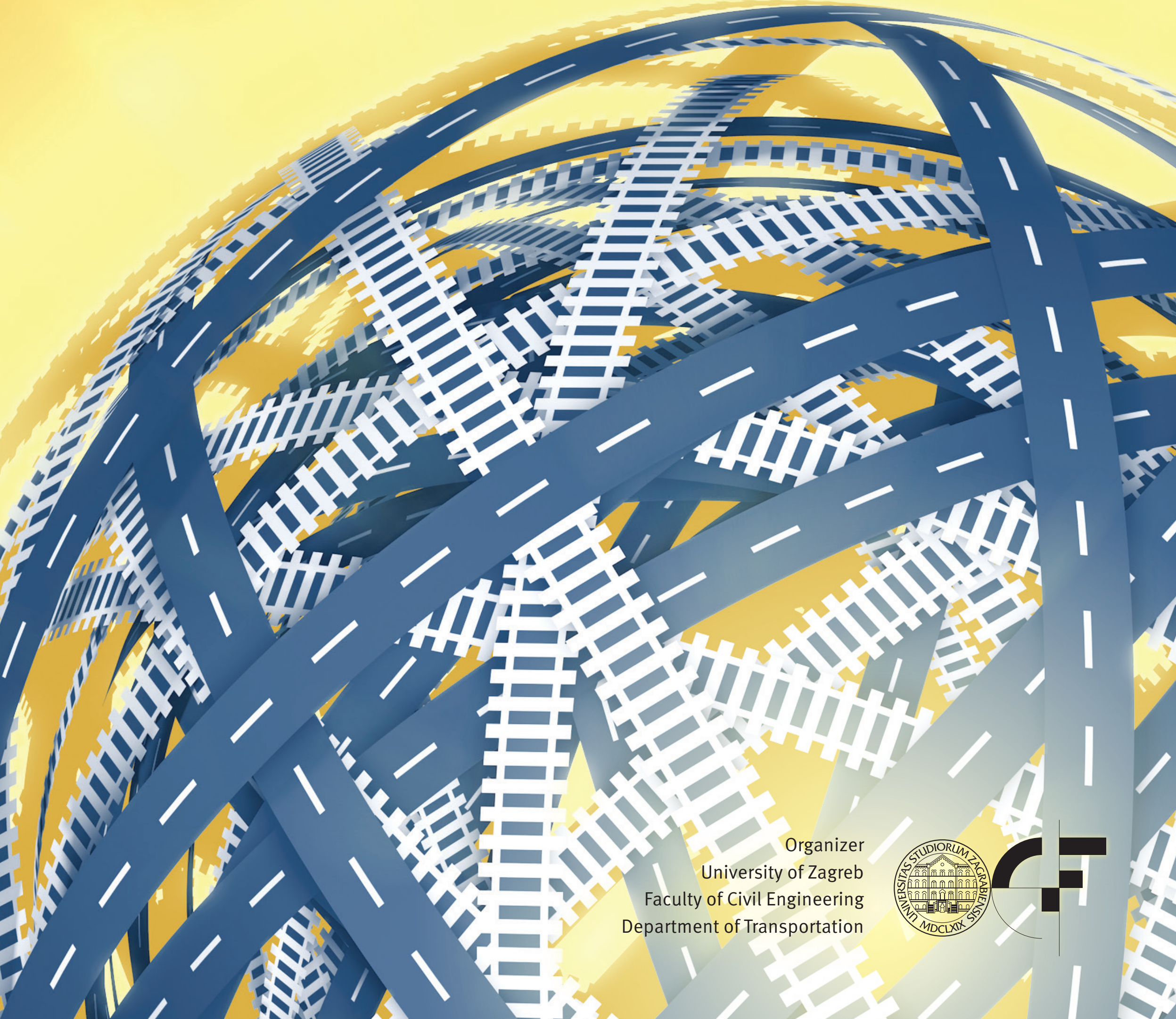
CETRA 2016

4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
Department of Transportation

CETRA[2016]
4th International Conference on Road and Rail Infrastructure
23–25 May 2016, Šibenik, Croatia

TITLE
Road and Rail Infrastructure IV, Proceedings of the Conference CETRA 2016

EDITED BY
Stjepan Lakušić

ISSN
1848-9850

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY
“Tiskara Zelina”, May 2016

COPIES
400

Zagreb, May 2016.

Proceedings of the
4th International Conference on Road and Rail Infrastructures – CETRA 2016
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

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IMPACT ASSESSMENT IN THE PAVEMENT LIFE CYCLE DUE TO THE OVERWEIGHT IN THE AXLE LOAD OF COMMERCIAL VEHICLES

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Abstract

Commercial vehicles may have different wheel and axle set ups, usually presenting single or dual wheels, and single-axle or dual or triple tandem-axles. In pavement design, requests caused by these various set ups of wheels and axles are converted into the request of the standard axle, loading 8.17 ton-force, which together make up the Number "N". Due to mechanical manufacture of axles and wheels, and to ensure that the pavements will not receive excessive point loads that might lead to its rupture, there are set weight limits for axle set ups. In Brazil, the legislation on dimensions and weights of vehicles is Resolution n.º 12, dated February 6, 1998, CONTRAN – National Traffic Council. Despite being established by laws, not all roads are properly invigilated to assure these limits are being respected, such as free access roads, roads with insufficient weighing scales for proper control or urban roads. Although overweight axles may cause damage to vehicles, as well as high operation and maintenance costs, depending on the profile of the conductors, it may be more common to disrespect these limits, which shortens the life cycle of pavements.
This article aims to analyse and compare the effect on the life cycle of the pavement when requested by single axle with single wheels, and single-axles, dual and triple tandem-axles with dual wheels, when the axles have 20%, 35%, 50% and 70% overload Brazilian legal values, according to the equivalences axles for AASHTO and USACE methods.

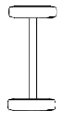
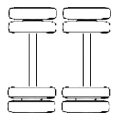
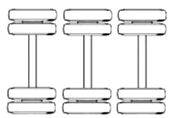
Keywords: Flexible pavement, axle load, overweight

1 Introduction

One of the most important parameters for the design of the structure of a pavement is the vehicle traffic that uses the pavement. The traffic on a highway is composed of various types of vehicles with different weights and axle configurations. The maximum weight for axles of vehicles are determined by several factors, such as the strength of the mechanical components and tires used in the vehicles. Other important factor is the limits defined in the design methods of the structures. By respecting the maximum weight, it is unlikely that the pavement structure is requested by a concentrated load, higher than the pavement resistance, and able to cause its rupture.
To ensure a safe maximum weight, the weight limits of vehicle axles are stipulated by law and supervised by competent government agencies. In Brazil, the law establishing these limits is the 12th Resolution, dated February 6th, 1998, from the National Traffic Council – CONTRAN [1]. The supervision occurs in balances for commercial vehicles, usually located in the region next the major highways. Table 1 shows the weight limits for each axle configuration, according to Brazilian regulations.

However, in developing countries such as Brazil, it is common to find vehicles with overweight axles due to the large number of self-employed drivers, whose behavioral profile differs significantly from logistics companies. For the self-employed drivers the short-term costs – such as tolls and fuel – are more significant, and costs in the long-term – such as vehicle maintenance – are less relevant because they have no immediate effect on the drivers' budget, encouraging the overloading of the vehicle, for example.

Table 1 Maximum legal load according to axles configuration, as 12th Resolution (CONTRAN, 1988)

Axle Type	Configuration	Legal Maximum Load [kN]
Single Wheel Single-Axle (SWSA)		58.84
Dual Wheel Single-Axle (DWSA)		98.07
Dual Wheel Dual Tandem-Axle (DWDT)		166.71
Dual Wheel Triple Tandem-Axle (DWTT)		250.07

Another cause of the overload axles can be irregular distribution of the load on the vehicle, accumulating it on only one axle, rather than distributing it. In these cases, in the checkpoints, the driver is instructed to distribute the transported material, and the axles are checked again, and the vehicle released only when the weights for each axle are within the allowed limits. Overloading axles, besides bringing damage to vehicles and tires, will have an effect on the pavement higher than the limits established in the design, which will accelerate the deterioration of the pavement. If the overload is not sufficient to cause the pavement's immediate rupture, it is expected that the overweight accelerates the fatigue process, reducing the pavement's life cycle and therefore the number of requests supported by it.

2 Vehicle traffic

The vehicle traffic that the structure must support is quantified by the effect that various vehicles with different axle configurations that use the stretch of the roadway cause in the pavement. To enable the quantification, a fixed pattern vehicle is established. In the case of road pavements, this is taken as the standard 80kN (or 18 kips) dual wheel single-axle.
Axles with different weights and configurations to the standard one have its effect on the pavement expressed as a number of repetitions of the reference axle, these are called equivalent wheel load factors – EWLF [2]. In other words, the effects of the axles are recorded as a number of the standard axles passes.
The sum of the equivalent wheel load factors in the axles of each vehicle multiplied by its frequency in traffic flow within a certain period of time results in the number of requests that

the pavement's structure must support within the stipulated period. This value is called the "Number N" and because that direct relationship with the amount of traffic that go on the pavement in a period of time. It is also used as a measure of the life cycle of the structure.
In general, heavier axles represent a higher number of passages of the standard axles than lighter axles, therefore the more vehicles with higher axle loads using the pavement structure; the shorter it is expected to be the life cycle of the structure.

3 Equivalent Wheel Load Factors – EWLF

The equivalent wheel load factors (EWLF) usually refer to the effect of the vertical tension on the bottom layer of the pavement, to the traction on the bottom fiber of the asphalt layer or on its deflection; since these are the requests suffered by the pavement, which are closely related to the fatigue of the structure. The most common factors are established by the pavement design methods of the American Association of State Highway and Transportation Officials – AASHTO and the U.S. Army Corp of Engineers – USACE.
The Traffic Studies Manual [3] from the National Department of Transport Infrastructure – DNIT, the Brazilian Federal highway agency, presents equations to obtain the equivalent wheel load factors from the methods cited.
For the USACE method, the general equation has the format shown in equation (1). The constants "A" and "B" vary according to the load and type of the analysed axle, as shown in Table 2. "P" is the axle load in ton-force.

$$FC = A \times P^B \tag{1}$$

For the AASHTO method, the general equation has the format shown in equation (2). The constants "A" and "B" vary according to the type of the axle analysed, such as in Table 3. "P" is the axle load in ton-force.

$$FC = \left(\frac{P}{A}\right)^B \tag{2}$$

Table 2 Constants used to obtain the equivalent wheel load factors for the USACE method

Axle Type	Axle Load [kN]	Constants	
		A	B
Single or Dual Wheel Single-Axle (SWSA or DWSA)	0 – 80	2.0782×10^{-4}	4.0175
	≥ 80	1.8320×10^{-6}	6.2542
Dual Wheel Dual Tandem-Axle (DWDT)	0 – 108	1.5920×10^{-4}	3.4720
	≥ 108	1.5280×10^{-6}	5.4840
Dual Wheel Triple Tandem-Axle (DWTT)	0 – 176	8.0359×10^{-5}	3.3549
	≥ 176	1.3229×10^{-7}	5.5789

Table 3 Constants used to obtain the equivalent wheel load factors for the AASHTO method

Axle Type	Constants	
	A	B
Single Wheel Single-Axle (SWSA)	7.77	4.32
Dual Wheel Single-Axle (DWSA)	8.17	4.32
Dual Wheel Dual Tandem-Axle (DWDT)	15.08	4.14
Dual Wheel Triple Tandem-Axle (DWTT)	22.95	4.22

4 Overload axles

In this study, the adopted overloads were 20%, 35%, 50% and 70% of the Brazilian legal load of single and tandem axles. Using equations (2) and (3), according to the axle load adopted, the equivalent wheel load factors shown in Tables 4 to 7 were calculated.
Tables 4 to 7 show the absolute load on the overloaded axle and the proportion of the factors according to those relating to statutory burden, which represent the growth of the factors in relation to the overload of the analysed axles. The equivalent factors represent the number of repetitions of the pattern of 80 kN axle in accordance with the method, type and load of the axle. Figures 1 and 2 present the results in a graphical form.

Table 4 Equivalent wheel load factors in overload axles – Single Wheel Single-Axle

Single Wheel Single-Axle (SWSA)	Load [kN]	Equivalent Factors		Proportion	
		USACE	AASHTO	USACE	AASHTO
Legal load	58.84	0.2779	0.3273	100.0%	100.0%
20% overload	70.61	0.5781	0.7195	208.0%	219.8%
35% overload	79.43	0.8806	1.1968	316.9%	365.6%
50% overload	88.26	1.7020	1.8867	612.4%	576.4%
70% overload	100.03	3.7232	3.2399	1339.7%	989.8%

Table 5 Equivalent wheel load factors in overload axles – Dual Wheel Single-Axle

Dual Wheel Single-Axle (DWSA)	Load [kN]	Equivalent Factors		Proportion	
		USACE	AASHTO	USACE	AASHTO
Legal load	98.07	3.2895	2.3944	100.0%	100.0%
20% overload	117.68	10.2882	5.2634	312.8%	219.8%
35% overload	132.39	21.4911	8.7547	653.3%	365.6%
50% overload	147.10	41.5370	13.8011	1262.7%	576.4%
70% overload	166.71	90.8655	23.6995	2762.3%	989.8%

Table 6 Equivalent wheel load factors in overload axles – Dual Wheel Dual Tandem-Axle

Dual Wheel Dual Tandem-Axle (DWDT)	Load [kN]	Equivalent Factors		Proportion	
		USACE	AASHTO	USACE	AASHTO
Legal load	166.71	8.5488	1.6424	100.0%	100.0%
20% overload	200.06	23.2346	3.4937	271.8%	212.7%
35% overload	225.06	44.3257	5.6893	518.5%	346.4%
50% overload	250.07	78.9932	8.8002	924.0%	535.8%
70% overload	283.41	156.9232	14.7753	1835.6%	899.6%

Table 7 Equivalent wheel load factors in overload axles – Dual Wheel Triple Tandem-Axle

Dual Wheel Triple Tandem-Axle (DWTT)	Load [kN]	Equivalent Factors		Proportion	
		USACE	AASHTO	USACE	AASHTO
Legal load	250.07	9.2998	1.5599	100.0%	100.0%
20% overload	300.08	25.7169	3.3670	276.5%	215.8%
35% overload	337.64	49.6127	5.5348	533.5%	354.8%
50% overload	375.10	89.3037	8.6338	960.3%	553.5%
70% overload	425.12	179.5252	14.6417	1930.4%	938.6%

5 Comparison and analysis

The increase in equivalent wheel load factors studied for both design methods grows exponentially, as shown in Figure 1, increasing with axle overload, as expected. The equivalent wheel load factors to AASHTO method represent a smaller number of repetitions of the pattern axle when compared to USACE method. In AASHTO method, the growth of its factors increasing overload is similar in all the different axles compositions: by submitting an overload of 20% the factors are 2.1-2.2 times higher than the factor of the legal load and, analogously, overloading 35% makes the factors 3.4-3.7 times higher, as 50% overload 5.3-5.8 times, and finally, overloads 70% 8.9-9.9 times higher factors. That is, an overload of 70% of an axle in any road configuration discussed represents the passage of nearly 10 times the axle passage in its legal load, in the AASHTO method.
The equivalent wheel load factors to USACE method have similar values to those found for the AASHTO method for simple wheels single axle (SWSA), as shown in Figure 2, which differs from other axle configurations, particularly with the increased axle overload. The factors for the USACE method are quite sensitive to the increased axle overload for the dual wheels axle configurations.

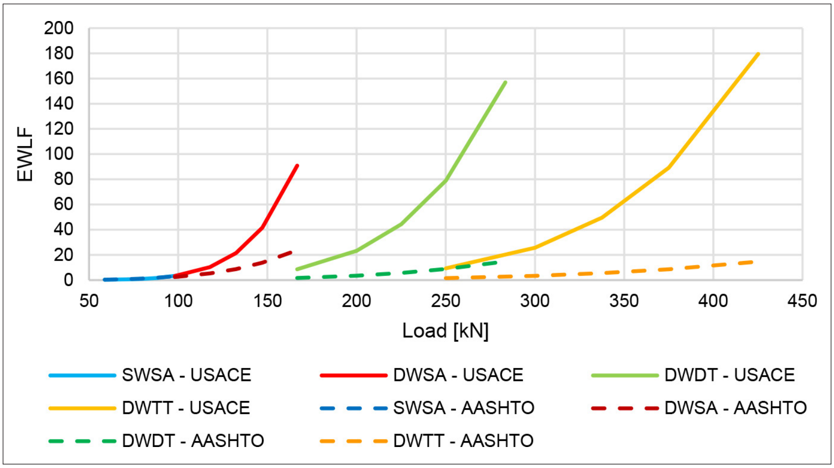


Figure 1 Equivalent wheel load factors in overload axles

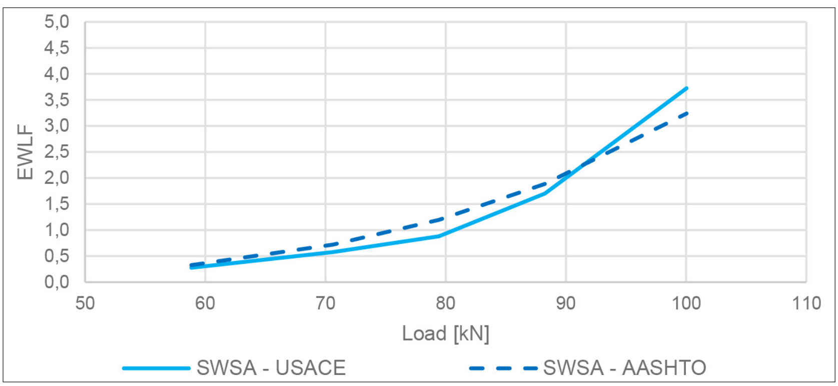


Figure 2 Equivalent wheel load factors in overload axles – Single Wheel Single-Axle

The axles in tandem type configurations, dual and triple tandem-axle, show growth of its factors, in comparison to legal loads, in line with the growth of overload similarly. When the overload is 20%, the factor is 2.7 times the legal load factor, while for 35%, 5.2-5.3; 50%, 9.2-9.6; and with 70% overload, it is 18.3-19.3 times the factor of the legal load.
Although they present smaller USACE equivalent wheel load factors than tandem-axles, the dual wheel single-axles (DWSA) for the USACE method presents the critical equivalent factor growth with the axle overload. With 20% overload the wheel load factor at 3.1 times the one for legal load, and when raised to 35% this multiplier rises to 6.5; when raised to 50% it reaches 12.6 times and finally when it is raised to 70% overload, the factor is 27.6 times the factor for the legal load.

6 Conclusion

This study concluded that axles overloading – once they present much larger equivalent wheel load factors than its maximum legal load – will result in a traffic with a "Number N" as higher as the frequency and overload of the axle. Consequently, the number of requests experienced by the pavement can quickly approach the 'Number N' established when the structure was designed, which will lead to its early fatigue and, therefore, reduce the life cycle of the pavement.

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