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ASSESSMENT OF ROAD OVERLOAD IN TOGO AND OPTIMIZATION OF LOAD CHOICES FOR PAVEMENT SIZING

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ABSTRACT
Road pavements in Togo, under the effect of the overload phenomenon, accelerates their degradation process. The annual maintenance budget fails to keep up with the process. As a result, the causeways quickly fall into disrepair. The weighing data at the Djéréhouyé substation between 2017 and 2019 made it possible to characterize the circulating loads and to optimize the aggressiveness of the traffic by choosing a rational reference load for the dimensioning of the pavements. For a traffic aggressiveness of 1, the optimal load of 15 tonnes on the axle is judicious as a reference load for the dimensioning of pavements in Togo.

KEYWORDS: overlord, aggressiveness, degradation, road.

1. INTRODUCTION
The purpose of the structure of a roadway is to support the traffic loads. The latter must be considered in terms of volume and punching or aggressiveness load. In Togo and in the West African Economic and Monetary Union (UEMOA) states in general, the axle load of 13 tonnes at the axle is considered as a reference for the dimensioning of pavements in accordance with the NF standard. P98-086 [1]. These pavements are essentially flexible or bituminous structures and the NF P98-086 standard establishes the coefficient of aggressiveness corresponding to 1. The UEMOA Commission, in order to protect the pavements, has imposed loads on the axle. 11.5 tonnes for their operation [2]

The flow of traffic circulating on the road network reveals a dispersed configuration of the type of truck and its axle load. There are many types of trucks with varying axle configurations ranging from two axles in single trucks to more than six axles with articulated assemblies. Also the axle load on the roadway varies from less than 3 tons to more than 23 tons. There then arises a problem of overload and aggressiveness in relation to the design load. In this study, we evaluate the overload in order to optimize the aggressiveness for a better consideration of the traffic in the dimensioning of the pavements.

2. MATERIALS AND METHODS
The pavement sizing methods make use of the concept of equivalent traffic which makes it possible to express the effect of several different loads from a reference load. They thus define an equivalence factor which allows their conversion [3]. We based ourselves on traffic analysis reports on two homogeneous sections of the Lomé-Cinkassé community road (CU9), approximately 675 km long. The first section is taken at the exit of Lomé (the capital of Togo) and the second section at the entrance of the town of Cinkassé (border with Burkina-Faso). The traffic volume is taken from existing study reports for the CU9 and brought back to the year 2020 from the growth rates defined in these reports, the average of which is 5.5%. If AADT0 is the annual average daily traffic in heavy goods vehicles estimated in the year of the study (A0) and "i" the growth rate of goods transport vehicles, we define the average daily annual traffic for the year 2020 (AADT2020) from equation:

$$AADT_{2020} = AADT_0\,[1+ ((2020-A_0) -1)i] \qquad (i)$$

The different truck configurations on the network have therefore been identified. The assessment of the aggressiveness of each type of truck was based on the axle loads actually in circulation, of which data for 2017, 2018 and 2019 are available for the Djéréhouyé weighing station on the CU9, and of the reference load for the dimensioning of the pavements. The axle load levels were evaluated for each type of vehicle differentiated by the number of axles. Axle loads are distributed by class. It is therefore discussed the representativeness of the axle load of 13 tons used for the dimensioning of the pavements and the calculation of equivalence of heavy goods vehicle traffic.

The various axle loads in circulation are used to calculate the coefficients of aggressiveness (CA) for the various truck configurations based on the reference loads considered. The calculation of the aggressiveness coefficient of each heavy-duty truck (CA_{PL}) is carried out step by step. The coefficient of aggressiveness of each axle (i) of the axle group consisting of the considered heavy vehicle (PL) is first calculated. The sum of the aggressiveness of the axles (i) gives the aggressiveness coefficient of the type of heavy vehicle (PL). Thus we have for single axles, calculated the coefficient of aggressiveness from the following power function [4]:

$$\mathrm{CAi} = \left(\frac{\mathrm{Paxlei}}{\mathrm{Pref}}\right)^{-1/\mathrm{b}} \qquad \text{(ii).}$$

In this equation, Pref is the reference load used for the sizing and the conversion into equivalence of the axle load; -1/b is a coefficient linked to the materials used for the constitution of the pavement layers, therefore linked to the pavement structure used for the road considered; b characterizes the slope of the fatigue line of the material considered.

The CEBTP guide [5] recommends values of 4 for the coefficient -1 / b for flexible pavements. With the evolution of traffic and road materials, new values are proposed for this coefficient in the catalog of pavement structures of Senegal [6]. The Senegal catalog gives values of 5 for this coefficient for flexible structures (flexible and bituminous). For tandem and tridem axles, the aggressiveness coefficients are multiplied by "k" respectively to take into account the axle configuration. With "k", a coefficient whose values are recorded in table 1.

$$CA_{tandem} = 2 \times K \left(\frac{P_{ref}}{P_{axle\,élem}}\right)^{1/b} \qquad \text{(iii)}$$

$$CA_{tridem} = 3 \times K \left(\frac{P_{ref}}{P_{axle\,élem}}\right)^{1/b} \qquad \text{(iv)}$$

Table 1: Coefficient "k" for tandems and tridems

New pavement	Flexible and bituminous structures
Single axles	1,00
Tandem axle	0,75
Tridem axle	1,10

The limitation of axle weights is regulated in Togo by Regulation No. 14/2005 / CM /WAEMU [2] which limits axle loads to 6 tonnes for a single front axle, 12 tonnes for a single axle rear, 20 tonnes for a type 4 tandem and 25 tonnes for a type 2 tridem. The total authorized laden weight in the WAEMU space is given for each type of heavy vehicle in figure 1.

Figure 1: Total Weight allowed in charge (TWAC) [2]

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For a typical heavy vehicle, the aggressiveness coefficient is therefore determined by the equation:
$CA_{PL} = \sum_i CA_{axle\ group_i}$ (v)

Knowing the aggressiveness of each "nPli" effective truck configuration made it possible to subsequently calculate the average aggressiveness coefficient (AAC) on the CU9 for the two sections considered. The latter is defined as the coefficient which would make it possible to convert all the evaluated heavy goods vehicle traffic of all types, into a standard traffic volume equivalent to the reference load considered (Figure 2).

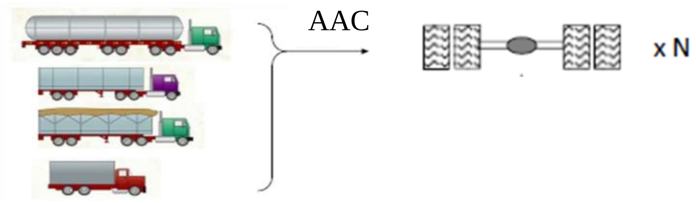

Figure 2: Characterization of the average aggressiveness coefficient

Ultimately, the average coefficient of aggressiveness of the traffic on a section of road is calculated by the following equation.

$$AAC = \frac{\sum (n_{PL_i} \times CA_{PL_i})}{\sum n_{PL_i}} \quad \text{(vi)}$$

3. RESULTS AND DISCUSSION

Observation of the heavy goods vehicles in circulation shows that several types of axles circulate on this road. They consist of standard twin wheels and traditional suspensions. The composition of heavy goods vehicle traffic considered by direction, for the two homogeneous sections, is presented in table 2.

Table 2: Traffic by direction for the two sections

Truck type	Section 1		Section 2	
	Volume	Percentage	Volume	Percentage
2-axle trucks	765	51,65%	209	23,80%
3-axle trucks	341	23,02%	169	19,25%
4-axle trucks	225	15,19%	300	34,17%
5-axle trucks	56	3,78%	75	8,54%
6-axle trucks +	94	6,35%	125	14,24%
Total	1481	100,00%	878	100,00%

The weighing statistics for the three (03) years available at the Djéréhouyé station on the CU9 give the frequency distribution of the various loads in circulation on this road (Figure 3).

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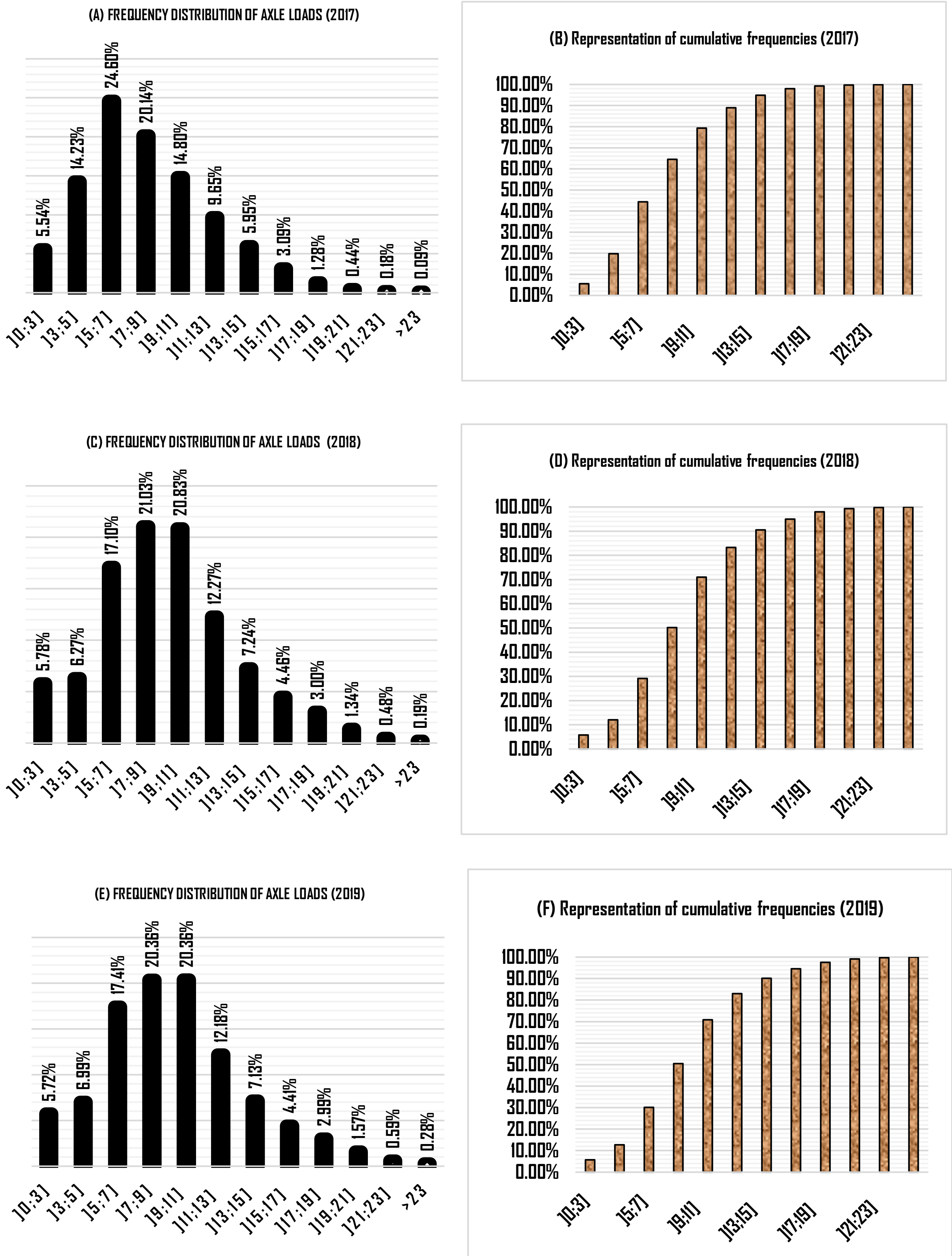

Figure 3: Axle load frequencies for the years 2017, 2018 and 2019

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The distribution of axle loads shows that:

- for the year 2017; 79.32% of running axles have loads less than or equal to 11 tonnes; 88.96% for 13 tonnes; 94.91% for 15 tons and 98% for 17 tons ;
- for the year 2018; 71.01% of the axles traveling on this section of road have loads less than or equal to 11 tonnes; 83.28% for 13 tons; 90.53% for 15 tons and 94.99% for 17 tons ;
- for the year 2019; 70.84% of the axles traveling on this section of road have loads less than or equal to 11 tonnes; 83.02% for 13 tonnes; 90.15% for 15 tons and 94.56% for 17 tons.

The analysis of the weighing data allows to say the traffic overloads on the CU9, considering the design load of 13 tons, represent 11.04%; 16.72% and 16.98% respectively in 2017, 2018 and 2019. Based on the UEMOA's 11.5 tonnes circulating load [2], the surcharges represent 20.68%; 28.99% and 29.16% respectively in 2017, 2018 and 2019 (Figure 4).

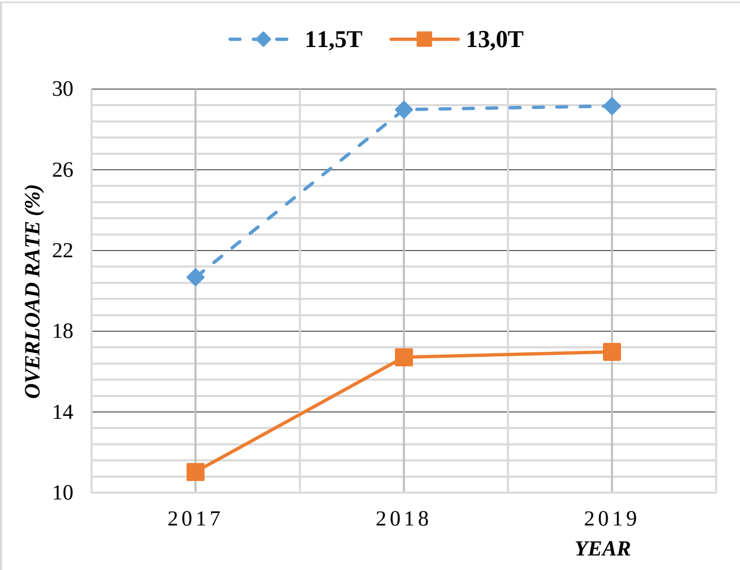

Figure 4: Evolution of surcharges from 2017 to 2019

The efforts to suppress the phenomenon of overloading undertaken by UEMOA since 2005, despite the large allocated budgets, are therefore not satisfactory. Pavements are increasingly subject to the aggressiveness of overloading. And the phenomenon tends to stabilize around 30% and 17% of overload respectively for references of 11.5 tonnes and 13 tonnes. These different overload rates give average aggressiveness coefficients in 2019 of 1.8 and 2.1 respectively for the first and second section, considering the reference load of 13 tonnes; for a reference load of 11.5 tonnes, the aggressiveness is, in the same order of road sections, 3.3 and 3.8.

Optimizing the design load can reduce the damaging effects of aggressive overloaded trucks on the roadway. Thus, we consider the rates of overloaded trucks of 10% and 5%, representing loads of 15 tonnes and 17 tonnes respectively. We consider the conditions of 2019 for the calculation of aggressiveness. Thus, the first section, with heavy traffic, presents average aggressiveness coefficients varying from 3.3 for 11.5 tonnes to 0.5 for 17 tonnes (Table 3) and for the last section of CU9, the aggressiveness coefficient mean (AAC) varies between 3.8 and 0.6 depending on the reference load (Table 4).

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Traffic characteristics		Workforce	UEMOA overload rate (%)	UEMOA overloaded trucks (%)	CA Reference axles 11,5 T	CA Reference axles 13 T	CA Reference axles 15 T	CA Reference axles 17 T
Traffic PL	2-axle trucks	765	25	63	2,72	1,47	0,72	0,38
	3-axle trucks	341	33	63	3,19	1,72	0,85	0,45
	4-axle trucks	225	22	63	3,92	2,13	1,04	0,55
	5-axle trucks	94	28	63	5,12	2,78	1,36	0,73
	6-axle trucks +	56	35	63	4,75	2,58	1,26	0,67
Average aggressiveness coefficient (AAC)					**3,3**	**1,8**	**0,9**	**0,5**

Table Error! No text of specified style in document.: Coefficient d'agressivité sur la deuxième section du CU9

Traffic characteristics		Workforce	UEMOA overload rate (%)	UEMOA overloaded trucks (%)	CA Reference axles 11,5 T	CA Reference axles 13 T	CA Reference axles 15 T	CA Reference axles 17 T
Trafic PL	2-axle trucks	209	25	63	2,72	1,47	0,72	0,38
	3-axle trucks	169	33	63	3,19	1,72	0,85	0,45
	4-axle trucks	300	22	63	3,92	2,13	1,04	0,55
	5-axle trucks	125	28	63	5,12	2,78	1,36	0,73
	6-axle trucks +	75	35	63	4,75	2,58	1,26	0,67
Average aggressiveness coefficient (AAC)					**3,8**	**2,1**	**1,0**	**0,6**

The detailed analysis of axle loads at the Djéréhouyé weighing station in 2019 shows that overload rates vary depending on the type of truck. We have the average overload rates of 25%, 33%, 22%, 34% and 35% respectively for two-axle (2E), three-axle (3E), four-axle (4E), five-axle (5E) trucks including three tractor axles and two trailer axles, five axles (5E) including two tractor axles and three trailer axles and more (6E +).

The information bulletin on Regulation 14 of UEMOA [7] gives 63% as the average overload rate on the Lomé-Cincassé corridor in December 2019. By varying the design reference load from 11.5 T to 17T, we find that the aggressiveness (CA) with the number of axles of trucks up to five axles and decreases for trucks with six axles. In addition, the aggressiveness decreases for all types of trucks when the reference load considered for sizing increases (Figure 5).

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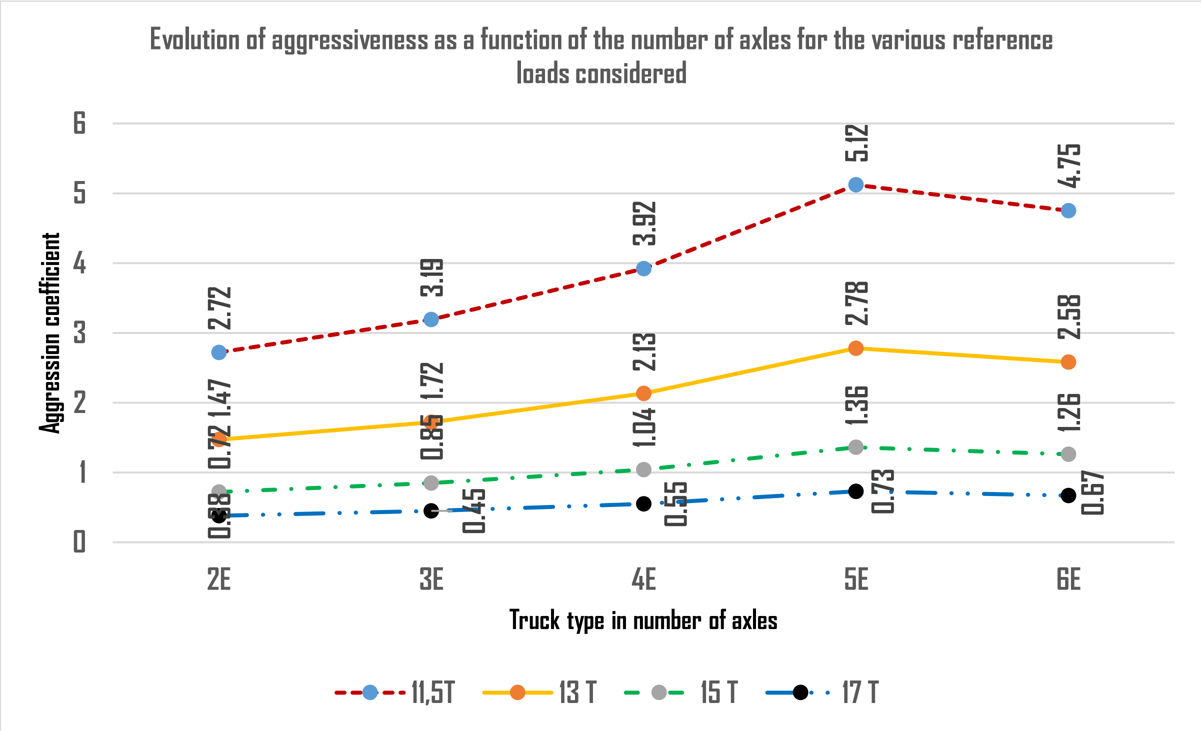

Figure 5: Agressiveness of différent types of trucks

The reduction in Agressiveness for trucks with more than six axles is due to a better distribution or the load on the axle. The average Agressiveness coefficient also changes in the same order with the reference loads considérés (figure 6).

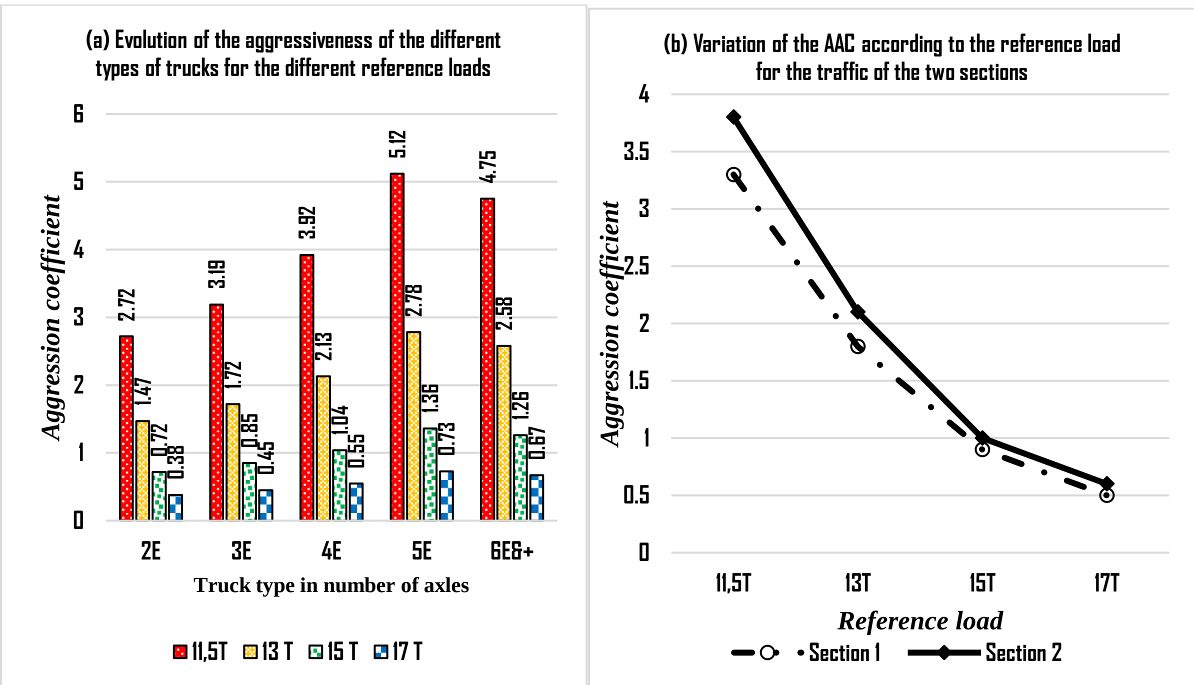

Figure 6: Aggressiveness of groups of trucks (a) and average aggressiveness (b)

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When the reference load considered for the dimensioning of the pavement structures increases, the average aggressiveness coefficients converge towards a limit value on the two road sections. In accordance with standard NF P98-086, to establish an aggressiveness coefficient of 1, the reference load to be chosen must be the 15 tonnes standard axle load. This load makes it possible to have an average aggressiveness coefficient of 0.9 and 1 respectively for sections 1 and 2. This consideration makes it possible to greatly reduce the initiation and evolution of pavement degradation, thus making investment in infrastructure profitable road.

4. CONCLUSION

The phenomenon of truck axles overloading tends to become systemic. Analysis of the weighing data at the Djéréhouyé substation shows that despite the measures taken to reduce this phenomenon, the situation worsened between 2017 and 2019. The constraints are felt at the level of road maintenance funds which have been unable to finance maintenance needs. Taking into account the actual distribution of the axle loads on the CU9 and the objective of balancing aggressiveness by setting the unit, a reference load of 15 tonnes on the axle is obtained proves judicious for the sizing of pavements in Togo. This has the advantage of reducing the pressure on the fight against overloading and rationalizing the planning and programming of road maintenance.

5. ACKNOWLEDGEMENTS

Sonnou TIEM, Senanou GBAFA, Kodjo ATTIPOU

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