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THE INFLUENCE OF UPWARD ROAD TRAFFIC ON THE REINFORCED CONCRETE SLABS OF MULTI - GIRDER BRIDGES ACCORDING TO EUROCODE 1

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Abstract

The global motorway network is currently experiencing substantial growth, leading to a constant expansion of engineering structures, with bridges being a particular focus. Due to the enormous investments made, it is crucial that we not only preserve their value but also enhance them to meet future requirements. The growth of road traffic has become a major concern due to the increasing number of vehicles and the tonnage carried per axle. Future needs are also expected to follow the same trend. This surge in tonnage will escalate and may have serious repercussions on the stability of road bridges. Given that the computations for pre-existing bridges were conducted in agreement with the national regulations in force before their building, it is crucial to scrutinise the safety response of these bridges with regard to the amplified loads of heavy goods vehicles in circulation. The article aims to compare the various distortions that occur in the concrete multiple girder bridge slabs under the current regulations and the growing weight of lorries presently operating by taking Algeria as a case study.

Keywords: Frame Bridge, Reinforced Concrete, traffic, truck, Modelling, Simulation, Eurocode.

INTRODUCTION

The world highway network has a very large number of engineering structures, for example the Algerian park alone has more than 10,000 engineering structures which the investments for their achievements are enormous. Since the beginning of the national roads network construction, the road traffic has known a permanent and accelerated growth which is characterized by a significant increase in the number of vehicles, on one hand, and by the tonnage transported per axle on the other hand. The future needs in terms of goods transport experiences a huge increase and consequently, the increase in the tonnage of the trucks must follow this trend. It is very important, in this case, to study the impact of this increase in tonnage on the road bridges safety in Algeria.

Knowing that the calculations of the existing bridges and especially those built before 2000 were calculated according to the Algerian regulation which is the CPC booklet 61 title II [1], it is necessary to check the response of these bridges from the safety point of

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view with respect of the increase in the load of the heavy goods vehicles actually circulating. So, it is required to establish a traffic load model superior to those described by the regulation of calculation taking Eurocode 1 [2] as a reference.

2. PURPOSE AND PRINCIPLE OF EVALUATION

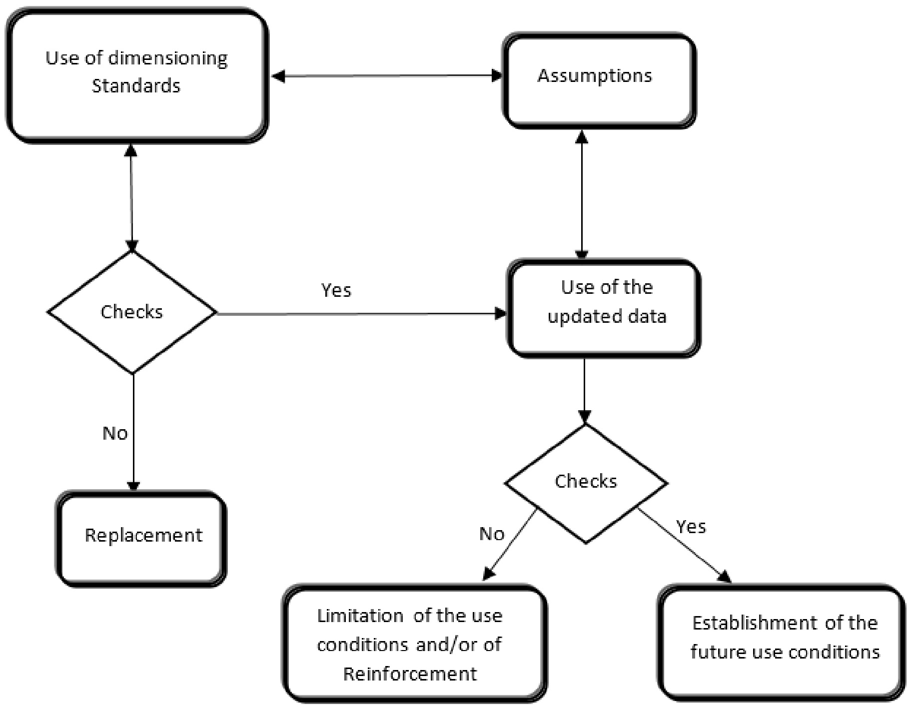

Fig 1: Evaluation principal flow chart. Source: Own elaboration

Fig. 1 shows schematically the principle of the evaluation that begins by using in force the sizing standards which are identical to those used for the sizing of new structures.

In addition, this approach has in general the advantage of making it possible to identify relatively and quickly the construction elements or the determining sections. Updated data regarding the loads and the actions as well as the strength and the structure behaviour should be defined on the usage requirements basis agreed with the owner.

Concerning the evaluation of an existing bridge, the updated data are the new load model, the updated load factors for self-weight and permanent loads, and the dynamic impact coefficient. It should be noted that the numerical calculations carried out must be completed by either establishing the conditions related to future use or by proposals related to reinforcement or replacement. The long-term goal of this research is to establish a road traffic load model superior to the standards currently used and at least equivalent to the limit proposed by European standards namely 40 tonnes, but in this article the main aim is to compare the effect of load models of 28 t and 36 t with the regulatory loads model applied in Algeria. The essential basis for establishing the 28 t and 36 t load model is the recent measurements carried out and the future traffic

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characteristics (traffic composition, axle weights, vehicle geometry and distance between vehicles). The results found in the slabs of multi-beam bridges due to this future traffic were calculated with the Robot structural analysis professional 2022 program [3], then compared with those of the regulatory load model of 30 t used in the Algerian regulation. This comparison provides the correction factors establishment which make it possible to easily determine the loads under upstream traffic to evaluate the slabs of the existing multi beam bridges.

3. TRAFFIC MODELLING

On Algerian roads and according to the statistics of the national office dated 12/31/2019 [4], the distribution of vehicles taken from Table 1 is as follows:

- 64.55% of passenger vehicles;
- 27.37% of heavy goods vehicles (simple trucks, semi-trailer and trailer trucks);
- 08.09% other types (motorcycles, agricultural vehicles, etc.).

Table 1: Distribution of the national automobile fleet. Source: ONS [4].

Type of vehicle	Number	%
Tourism vehicle	4 245 307	64,55
Truck	424 822	6,46
Van	1 219 476	18,54
Coach-bus	88 707	1,35
Road tractor	88 242	1,34
Agricultural Tractor	165 968	2,52
Special vehicle	7 420	0,11
Trailer	155 788	2,37
Motorcycle	181 458	2,76
Total	6 577 188	100

A significant increase in the number of heavy goods vehicles has been registered in these recent years (Table 2) and this increase keeps going, in fact according to the trend line in Fig. 2 it is expected that in 2030 the number of heavy goods trucks will be 497,911, an increase of 17% to the current number.

Table 2: Distribution of heavy goods vehicles by type and payload of the vehicles.

Payload (in tonnes)	Truck	Van	Trailer	Total	%
0 to 0.99	-	856 179	-	856 179	47,56
1 to 1.79	-	206 764	-	206 764	11,49
1.8 to 2.99	-	118 335	125 541	243 876	13,55
3. to 4.5	76 742	38 198	10 776	125 716	6,98
4.6 to 6.5	74 080	-	7 266	81 346	4,52
6.6 to 8.9	70 153	-	8 461	78 614	4,37
9 to 12.9	71 644	-	3 744	75 388	4,19
13 to 16.9	63 164	-	-	63 164	3,51
17 and more	69 039	-	-	69 039	3,84
Total	424 822	1 219 476	155 788	1 800 086	100

Source: ONS [4].

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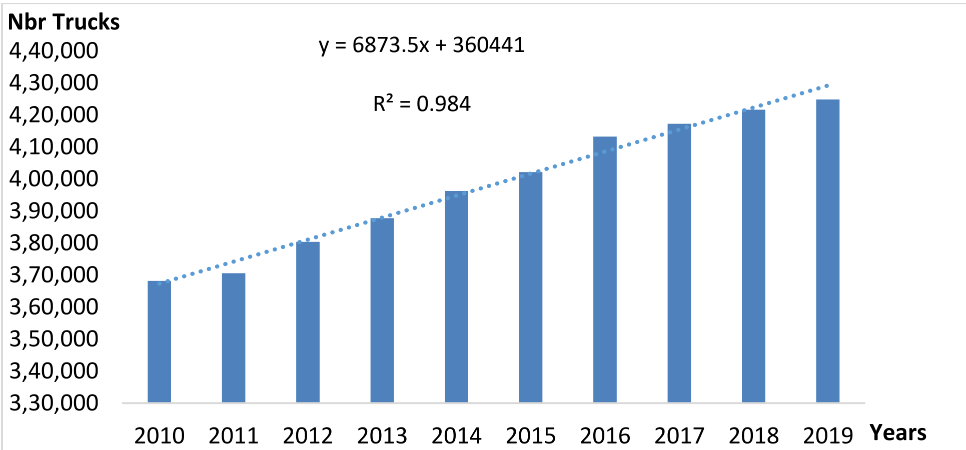

Fig 2: Increase in the number of heavy goods vehicles. Source: Own elaboration.

Since the effects of passenger cars (total weight <3.5t) are very low, it is not necessary to classify them into different classes. However, this is not the case for heavy goods vehicles because the number and the arrangement of axles can be very different from one type of truck to another. A classification is required to allow the geometry of the truck to be included and the loads on the different axles according to Eurocode 1 [2] as shown in Fig. 3.

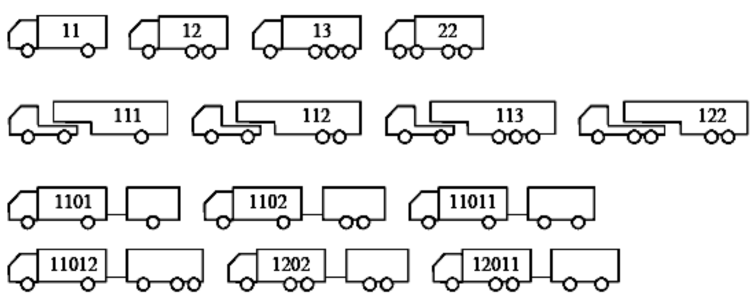

Fig 3: Classification of heavy goods vehicles. Source: EN 1991[2]

The part of total weight transmitted on the most heavily loaded axle is defined in Eurocode 1 (actions on structures - part 2: actions on bridges, due to traffic) [2]. The geometry of the vehicles considered is based on traffic measurements carried out in Brohltalbrücke (Germany) in 1984 [5], however, the distance between the different axles of each type of heavy goods vehicle is represented by a beta distribution. This type of distribution in fact responds to the modelling of a wide variety of forms of probability densities having lower and upper bounds.

The distribution describing the distance between vehicles as well as the variation of the parameters as a function of the speeds or the volume of traffic have been studied on several times by Hou et al [6], Bez [7] and Koshini [8], which make the characterization of the traffic as being saturated or fluid possible. This distribution was taken into account during the calculation.

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4. MODELLING OF MULTI-BEAM BRIDGE SLABS

Existing concrete bridges have characteristics related to their location, size, geometry and static system. In order to isolate certain typical structures, a series of selected characteristics is analysed.

The analysis of bridges is carried out basing on information taken from a database of public works departments of several wilayas in western Algeria. The sample corresponds to bridges, mainly those in reinforced and prestressed concrete, distributed over different categories of roads (highways, main roads). The bridges found in the database constitute a particular sample of the western Algeria bridges, they are structures with a size that is considered of a medium importance. Small bridges, generally with a single span (5 - 15 m), such as underpasses, are under-represented despite their large number, because these bridges are not systematically tested upon receipt.

The retained elements to characterize the Algerian bridges are as follows:

- The static system;
- The span and slenderness of the main beams;
- The type of cross sections;
- The deck width of the bridge;
- The number and position of the main beams;
- The thickness of the slabs;
- The diaphragms and secondary elements.

In this study, only single-span bridges and multi-beam multi-span bridges were studied and represented in fig. 4.

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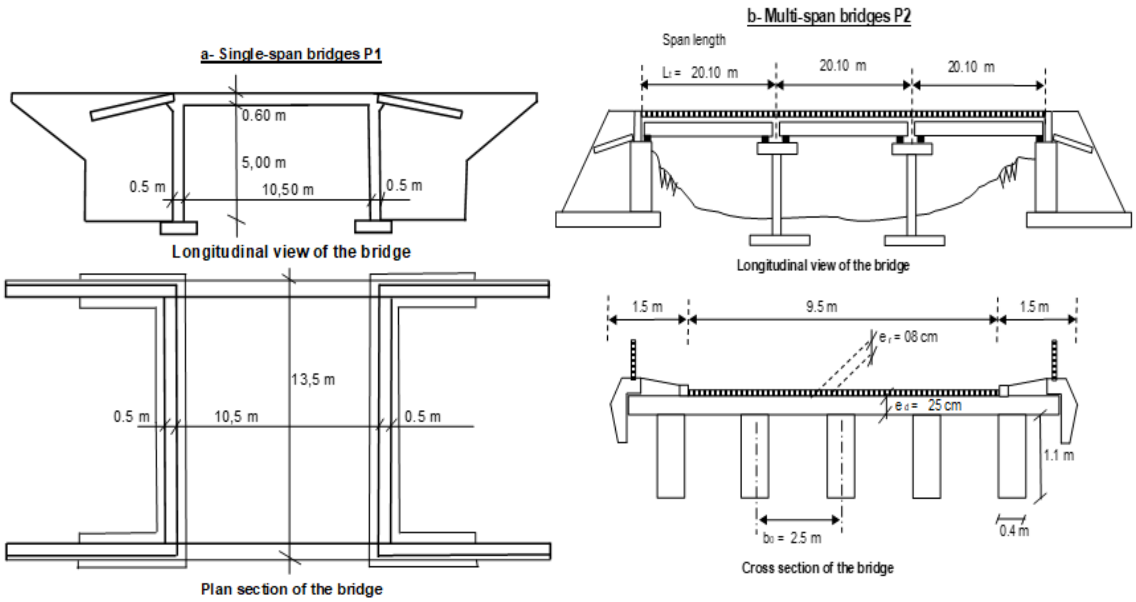

Fig 4: Classification type of bridges with chosen beams. Source: Own elaboration.

5. SIMULATION OF FORCES

The calculation was carried out with the program Robot structural analysis professional 2022 [3]. Also, the results found in the different bridges types over future traffic are compared to the model of charges regulated by the Algerian regulation of 30 t. The first step consists in establishing the stresses due to road traffic, these are then compared with the efforts due to the loads of 30 t given by the Algerian regulation.

It should be noted that the reflections made in this article concern only the static effect of road traffic, the dynamic effects being introduced by the use of the dynamic coefficient according to CPC booklet 61 title II [1] and Eurocode1 [2]. First of all, the calculations were made under the effect of regulatory loads with the value of 30 t, and then under upstream traffic of 28 t and 36 t, the results of which are given in Table 3 making it possible to obtain the static efforts due to the passage of a random series of vehicles.

Table 3: Maximum average principal stresses under 28 t, 36 t and the Algerian regulation CPC.

Half span (m)	0	5	15	25	30.1
Maximum stresses according to CPC Regulation (Pa)	450000	499000	625000	745000	804000
Maximum stresses at 28 t (Pa)	420000	450000	550000	650000	700000
Maximum stresses at 36 t (Pa)	590000	585000	720000	850000	920000

Source: Own elaboration.

Recalling that the traffic calculation includes a certain proportion of trucks exceeding the legal limit and that it was a two-way traffic. The efforts calculated with a traffic of 28 t and 36 t are compared with those obtained by applying the loads of the national regulations.

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The dynamic coefficient is identical for all the models and does not interfere in this comparison. The efforts due to the traffic of 28 t and 36 t obtained by the calculations are taken equal to the average value. Fig. 5 shows the comparison for the slabs of multi-beam bridges. The maximum normal stresses calculated for the two traffics of 28 t and 36 t, are compared with those calculated according to the load models of the Algerian regulation, namely the CPC booklet 61 title II [1].

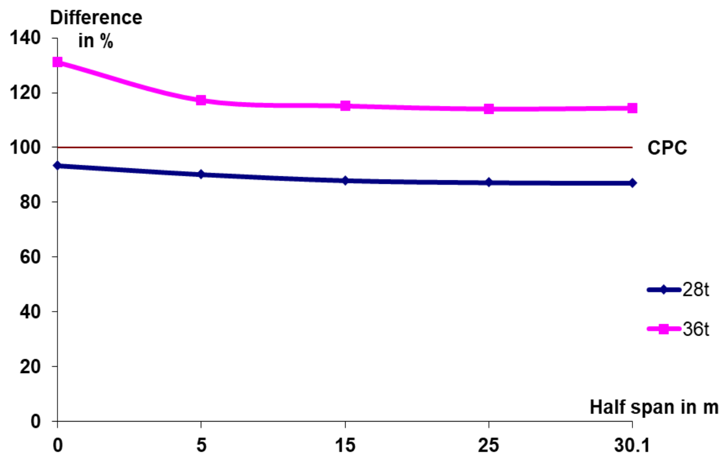

Fig. 1. Comparison of maximum normal stresses, according to CPC regulation, 28 t and 36 t. Source: Own elaboration.

6. RESULTS AND CONCLUSIONS

Table 4 summarizes the maximum increase in effort if the actual traffic calculated with the national regulation (CPC) increases to 28t or 36t, this increase is expressed in percentage. If this increase is negative, then it will be considered as a decrease.

Table 4: Relations between the efforts under trafficking 28 t and 36 t compared to Algerian regulation CPC

Half scope in m	Cpc-28t in %	Cpc-36t in %	28t-36t in %
0	-6,7	31,1	40,5
5	-9,8	17,2	30
15	-12	15,2	30,9
25	-12,8	14,1	30,8
30.1	-12,9	14,4	31,4

Source: Own elaboration.

The 28 t traffic is covered by the application of the national regulation for both types of bridges examined because the ratios of the efforts calculated by 28 t relative to calculated by the national regulations have decreased from 6.7% to 12.9%, while for the ratios of the efforts calculated by 36 t relative to those calculated by the national regulation, all the results exceeded the limits required by the Algerian regulation [1] with rather a significant increases varying from 14.1% to 31.1% and therefore as a conclusion of this work, the

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use of this 36 t load will be submitted to use conditions for each bridge case, that's why a case-by-case study is recommended.

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