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Traffic Loads in EC-1. How do they suit to highway bridges in Spain?

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Summary

When the definitive draft of the EC-1 Part 3 appeared in Spain, there were several comments on the differences and difficulties that the new proposal presented with respect to the current Spanish National Standard for Traffic Actions on bridges. In this paper, the results of a simulation process of real Spanish traffic flow over several bridges, are shown and compared to the predictions of EC-1 for the same cases. At the end, some conclusions regarding the feasibility of EC-1 to represent Spanish Traffic Loads are drawn.

1. Introduction

The current Spanish National Standard for Traffic Actions over Bridges, recommends a traffic model for the design of new structures formed by a three-axles truck with a total weight of 600 KN, and a uniform distributed load of 4.0 KN/m^2. Since no failure has been related because of an excess over the capacity of any bridge in the Spanish roadways' net, it was thought that the new EC-1 proposal could lead to highly conservative predictions. Given the difference between what has been the common practice till now and the new proposal, and the absence of an objective calibration of the present National Standard, a research project was planned to study real traffic actions over Spanish bridges, at the School of Civil Engineering in Barcelona [1]. One conclusion of this study will be a proposal for the set of adjusting factors α_i that EC-1 includes for each relevant authority to adapt EC-1 model to every specific traffic.

In this paper, the first results and conclusions of this research are shown. They are presented as a comparison between the results of a simulation of real flows of Spanish traffic over four representative bridges, and the results that EC-1 model predicts for these same cases. The values to compare, will be those obtained for different return periods. These specific return periods are: one week, (what EC-1 calls the frequent value), one year, (the infrequent value in EC-1), and one thousand years, (which corresponds to the value that has a probability of 10 per cent of being exceeded in one hundred years and is called the characteristic value by EC-

1). To quantify the differences, one bridge will be designed with the frequent values predicted by the simulation and EC-1 model, for the verification of the SLS of decompression. The total amount of postensioning steel area in both cases, will be compared, as well as their reliability in front of the ULS of bending.

2. Traffic model and simulation conditions

The simulation traffic model used, was originally created for the analysis of the fatigue performance of bridges [2]. So, it is a simulation model of real traffic flow. It is composed by two algorithms. First one, creates a fictitious traffic record and the second manages the pass of the vehicles of this record over the length of the bridge. The structure is taken into account as a surface of influence of the studied effect.

To include all the uncertainties inherent to the traffic phenomenon, a statistical treatment is given to the main variables that characterizes traffic action, e.g. type of each vehicle arriving, its gross weight, its distribution between the axles, the total length, its distribution to each pair of axles, its velocity, time of arrival, etc. [2]. To define all these variables, real Spanish traffic records have been used. Another important trait of the traffic model, is that different operations such us: to brake, to accelerate, to pass other vehicles, etc. are permitted to account for the interrelation between vehicles of different lanes.

Given that EC-1 tries to represent very heavy traffic conditions in Europe, the simulation of Spanish traffic is based on the heaviest conditions encountered in Spanish highways. These conditions can be found in the industrial zones of the Metropolitan Area of Barcelona, and have been translated into an average daily traffic of 20000 vehicles per day, with a 30 per cent of trucks in a roadway with two lanes in the same direction. It has been considered that one week traffic could be taken as the representative time [3], and two hundred weeks of traffic have been simulated for each case.

3. Examples and results

In fig. 1, the longitudinal layouts of the analysed structures, and their cross-sections are shown. They are: a continuous box girder bridge (CB), a continuous slab bridge (CS), a simply supported bridge formed by precast beams with an in-situs cast slab (SB) and a simply supported slab bridge (SS). In the continuous bridges both, the section over support and the one at midspan of the main span, were studied. In the simply supported, only midspan sections were analysed.

Once the simulation processes had been run, two hundred values corresponding to maximum weekly effects were available. These data were used to extrapolate to the values of the studied effect that corresponded to the different return periods. The methodology used for this extrapolation, is based on the study of tail probabilities through the analysis of extreme order statistics with Generalized Pareto Distributions [4], [5]. The final results are presented in table 1. Always, the calculated bending moments include the specific bridge's coefficient of eccentricity, (relation between the maximum and mean stresses in the whole cross-section).

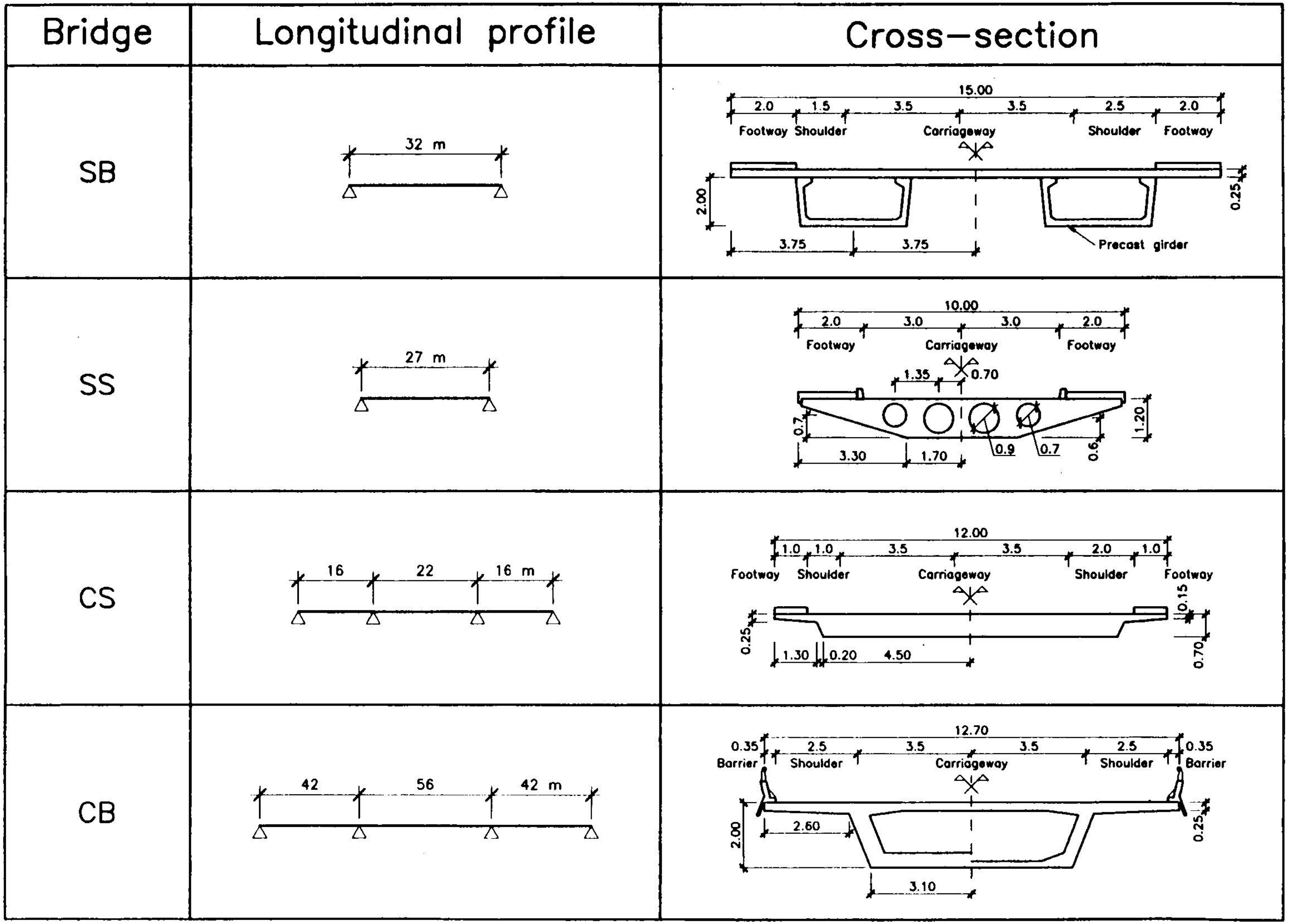

Figure 1. Layout and cross-sections of the studied bridges.

Bridge	Method	Return Period			
		1 week	2 weeks	1 year	1000 years
CBM	Simulation	7655.	9798.	11926.	18428.
	EC-1	13994.		19145.	23931.
CBS	Simulation	6507.	7639.	9782.	14258.
	EC-1	12134.		19006.	23758.
CSM	Simulation	2157.	2785.	3687.	5520.
	EC-1	4257.		5168.	6460.
CSS	Simulation	1757.	2294.	2792.	4565.
	EC-1	3200.		4368.	5460.
SB	Simulation	6748.	9621.	11861.	18273.
	EC-1	11039.		14294.	17867.
SS	Simulation	5130.	6937.	8499.	13709.
	EC-1	7064.		9202.	11503.

Table 1. Comparison of results from EC-1 and simulation (in KNxm).

Suffixes M and S added to the continuous bridges' notation, mean the sections at midspan of main span and over intermediate support, respectively.

As it was explained above, the result of the extrapolation to one thousand years corresponds to the value with 0.10 probabilities of being exceeded by the maximum effect in 100 years. To get this result, the parameters of the assumed Gumbel distribution of the maximum effect in 100 years were first calculated. These parameters were obtained through a simulation based on a wide, but particular, set of data. Because of this, and to account for possible not-considered conditions, it was decided to assume the calculated mean of the distribution as a true value but its coefficient of variation, (which was around the 7 per cent in all cases), was increased to the 12 per cent.

From the results of simply supported bridges, it can be seen that, although the predictions for the characteristic maximum value in 100 years from simulation are greater than those calculated with EC-1, the predictions for shorter return periods are lower. This shows that the methodology and the set of coefficients proposed to get the frequent and infrequent values of the traffic action, do not apply to the Spanish traffic particularities.

In continuous bridges, it can be seen that the results predicted by EC-1 for a return period of one week, are, in average, 85 per cent higher than those resulting from simulation. The results for a return period of one year are around 60 per cent higher and those corresponding to the return period of one thousand years, are 25 per cent greater. These excesses are more important in the sections over support than in midspan.

In the simply supported bridges, the differences are lower and, for the return period of one thousand years they are even negative. One reason that contributes to have a higher value predicted by simulation than by EC-1, in the beams' bridge (SB), is the coefficient of eccentricity. It is significantly greater for the case of a single lorry (as in the simulation), than for the set of three tandems proposed by Eurocode, placed side by side (the difference was 1.40 to 1.20). In the simply supported slab (SS), one of the reasons for having lower results from EC-1 than from simulation is its narrow traffic section (only 6.0 metres). The first consideration that could be made is about if it is acceptable that a bridge over which are expected to cross 6000 trucks per day has no shoulders. The second could be about if it is acceptable that 20000 vehicles with a 30 per cent of heavy vehicles crossed over an urban bridge as this seems to be. This example was chosen to show a possible case of a bridge that suffers very heavy traffic conditions when it was not originally thought for them. Could this bridge be assessed using the EC-1 traffic model to define the external action? The conclusion is clearly negative. This example also shows that EC-1 predictions depend on the width of the roadway platform, no matter how many real lanes are defined on the structure.

The analysis of the line of influence of the positive bending moment at midspan of the continuous box girder bridge (CB), of spans' lengths 42, 56, 42 metres respectively, shows a maximum of value around 9.0, at the centre of the main span. This value would also correspond to the maximum of the influence's line of a single span bridge of 36 metres length. So, in both cases, the maximum positive bending moment caused by an axial load would be the same. With a uniformly distributed load, it would not have happened like this. Because of the main continuous span is longer than the simply supported one, the contribution of the distributed load to the maximum positive bending moment would be more important in the continuous bridge that in the other. Given that 1) the results predicted by EC-1 in the case of this continuous bridge are greater than those resulting from simulation, 2) in the case of the simply supported bridge of 32. metres long it happens the contrary and 3) the effect of the tandems of EC-1 to its final predictions can be assumed to be similar in both cases, it can be concluded that the relative contribution of the distributed load seems to be too large in the continuous bridge.

To quantify the differences between the EC-1 predictions and the results of the simulation of the heaviest traffic conditions in Spain, the continuous slab bridge, (CS), was designed using both, the frequent value proposed by EC-1 and that corresponding to a return period of one week from the simulation. The representative values of the variable actions to use in the frequent combination to verify the SLS of Decompression, were calculated following the EC-2 recommendations, and are shown in table 2. The total amounts of postensioned steel area are shown in table 2, as well as the reliability indexes in front of the ultimate limit state of bending for both cases. The external traffic action adopted for both evaluations, corresponds to the results of the simulation of real traffic in Spain, considering two lanes.

Method	M_{sw}	M_{dl}	M_{temp}	M_{traf}	A_{st}(cm2)	F_{∞}(KN)	M_{prest}	β_u
Simulation	4219.	529.	902.	2157.	201.6	24122.	1165.	6.34
EC-1	4219.	529.	902.	4257.	252.0	29015.	1404.	7.11

(sw = self weight, dl = dead load)

Table 2. Design of the continous slab with traffic results of EC-1 and simulation, (in KNxm)

The results show that the security in front of the ultimate limit state of bending of these postensioned concrete bridges designed with a SLS verification criteria, is higher than what can be assumed as the minimum necessary, $\beta_u = 4.5$. So, the worldwide common practice of imposing SLS verifications for the design of new postensioned concrete bridges, leads to an excess of postensioning steel area. Therefore, it appears to be necessary to analyse the reasons why this practice is maintained. This study should reflect in quantitative terms, what negative effects for the security or for the functional service of the bridge, does this extended practice prevent the structures from. It has been the object of a parallel research [2],[6].

4. Conclussions

From the comparison of the results derived from the simulation of Spanish traffic and those predicted by EC-1 part 3, the following conclussions derive:

- Predictions of values of traffic effects for short return periods, using EC-1 are much higher that those from simulation, even in the case of simulating very heavy traffic conditions in Spain. Given their importance when designing a new structure, it is the authors opinion that further research should be carried in Spain to analyse a possible modification of the coefficients ψ_i proposed by Eurocode for the combinations of variable actions leading to these short time return periods (frequent and infrequent values). This modification should be based on quantifiable criteria instead of the subjective and qualitative current criteria, [6]. On the other hand, there is no justification for the placement of fictitious tandems or vehicles in all physically-possible lanes when calculating short terms representative values.

- Further research is needed in order to set definitive conclussions for a proposal for the adjusting factors (α_i) to apply to the representative magnitudes of the traffic load systems in EC-1, to addapt them to Spanish traffic conditions. The simulation presented in this paper, reflects very heavy traffic conditions. Since 70 per cent of bridges in Spain are placed in roadways with much lighter conditions, it could be interesting to study the possibility of defining those adjusting factors as a function of the roadway's traffic characteristics. This research is now in progress [1].

- It should be deeper studied if it is appropiate to divide the real platform into notional lanes for the calculation of representative values of the effects of traffic action. This practice leads to unsafe results in the assessment of the bearing capacity of old narrow bridges. This consideration illustrates again the need for specific live load models (or correction coefficients) for the assessment of existing bridges. It also can result in unsafe predictions for bridges with high coefficients of eccentricity, e.g. precast girders, double T sections, etc.

- The relative contribution of the distributed load has been found to be too large for continous bridges in Spain. So, it seems that the relative weight that the uniformly distributed load system has in the EC-1 model for traffic actions, should be decreased. This decrease would lead to very significant drops in the predictions for maximum negative bending moments over supports, closing them to the results from simulation.

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