EFFECTS OF REINFORCEMENT CORROSION ON STRUCTURAL ASSESSMENT OF R C CONCRETE BRIDGES

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Summary

The principal damage in bridges of the Brazilian federal network is due to reinforcement corrosion. In general, corrosion occurs in regions with insufficient concrete cover and/or excessive porosity and affects mainly the first layer of the reinforcement. In these cases the traditional deterioration models are not applicable or convenient. Although the appearance may reveal a very strong structural deficiency, some bridges continue to have a good performance and durability.

Some finite elements models were elaborated, using eight-node solid elements for concrete and bar elements for the reinforcement, in order to quantify the importance of reinforcement corrosion to the occurrence of flexural cracks. To simulate the reinforcement corrosion, the first layer of reinforcement was considered integral, 40% and 100% corroded.

This paper analyses the concrete and reinforcement stress distribution and the corrosion consequences to structure.

1. Introduction

In the inspection of 1.210 Brazilian federal network reinforced concrete bridges the principal damage found was the reinforcement corrosion caused by insufficient concrete cover and/or excessive concrete porosity. This was verified particularly by 68 bridges. In general, the corrosion affects mainly the first layer of the reinforcement bars. This leads the inspector to consider some structures with deficiency when the intensity of damage and its position are not sufficient to consider so.

The model in finite elements of a single supported reinforced concrete bridge using eight-node solid elements for concrete and bar elements for the reinforcement shows how the stresses redistributions in concrete and in the bars occur with cracking and reinforcement corrosion (Mendes 2009). The model considers a crack in beams at mid-span. The modification of the stresses at mid-span is not significant with the creation of others cracks along span. The model considers either the variation in reinforcement rates from ρ_1=3.78% to ρ_4=1.63% to take account the use of steel with different f_{yk} and rules to limit crack width, fatigue and so on. The effect of corrosion was considered by reducing the cross section of the bars in the first layer.

The results indicate that the maximum concrete compression stress, considering the permanent load and standard vehicle load with the impact coefficient, it is less than 32% of characteristic concrete strength and the redistribution with reinforcement corrosion is not significant.

In the same way the stresses in the bars depend naturally of reinforcement rates and the verification of the stresses produced by the real vehicles may quantify the importance of cracks and corrosion.

2. Model conception

The bridge model employed in this work considers that 83% of the bridges pertaining to the federal road network are slab bridges on two simply supported girders, 50% of them with a span length shorter than 20 m.

The figures 1 and 2 show the model with solid finite elements to consider the effect of crack, removing the concrete around the reinforcement bars and along the crack height. The figures 3 to 5 show how the reinforcement corrosion was considered, reducing the cross section of the bars in the first layer.

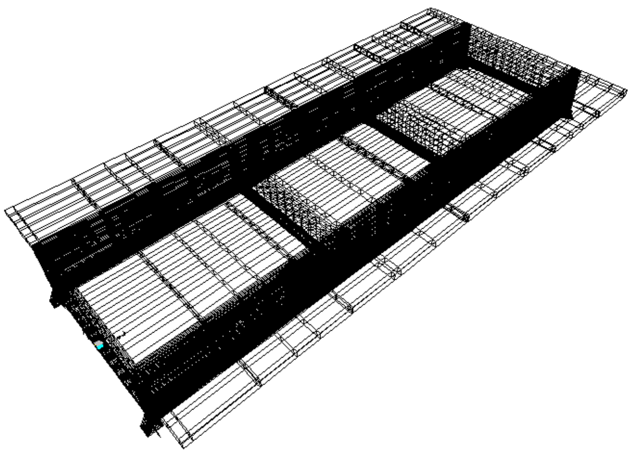


Figure 1 – The finite elements model

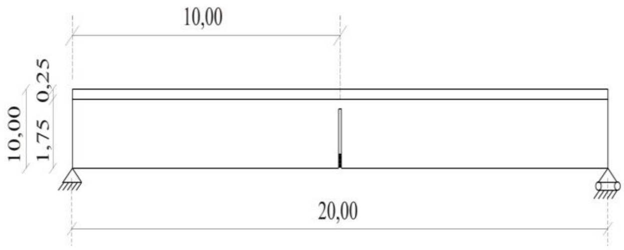
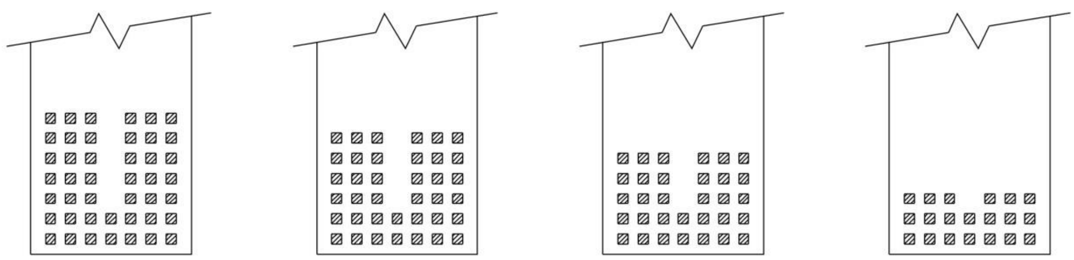
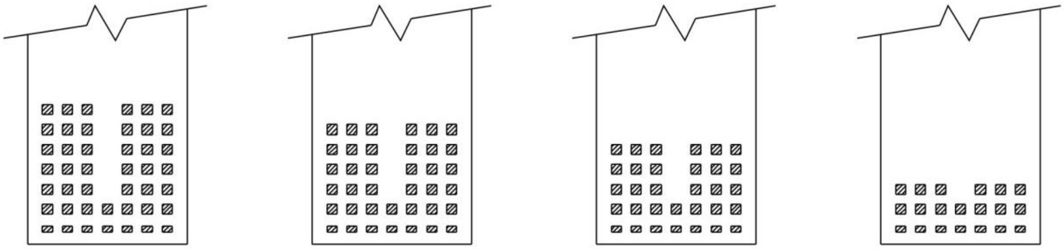


Figure 2 – Beam with a 1.50m crack at mid-span



(a) ρ_1=3.78% (b) ρ_2=3.22% (c) ρ_3=2.68% (d) ρ_4=1.63%

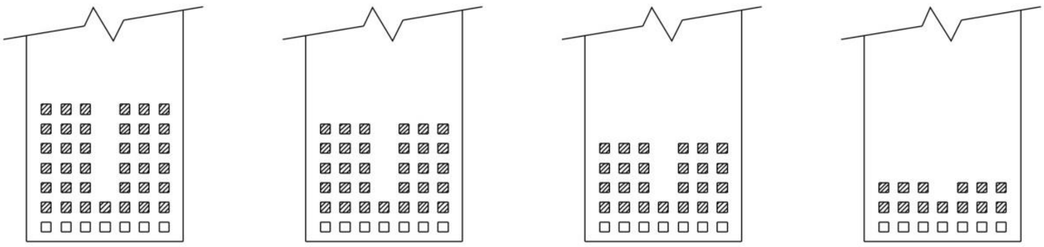
Figure 3 – Distribution of the bars in cross section beam, with the first layer not corroded



(a) (b) (c) (d)

ρ=3.56% ρ=3.00% ρ=2.46% ρ=1.41%

Figure 4 – Distribution of the bars in cross section beam, with the first layer 40% corroded



(a) (b) (c) (d)

ρ=3.23% ρ=2.67% ρ=2.12% ρ=1.08%

Figure 5 – Distribution of the bars in cross section beam, with the first layer 100% corroded

The existence of crack disturbs the stresses distribution in the bars and the maximum stress occurs in the layer nearst the neutral axis instead in the first layer.

3. Stress distribution in concrete and in reinforcement

The figure 6 shows the compressed elements in a half section of the bridge. The compression stresses in each element were considered in the top with the mean stresses of the two upper nodes and in the middle with the mean stresses of the four nodes.

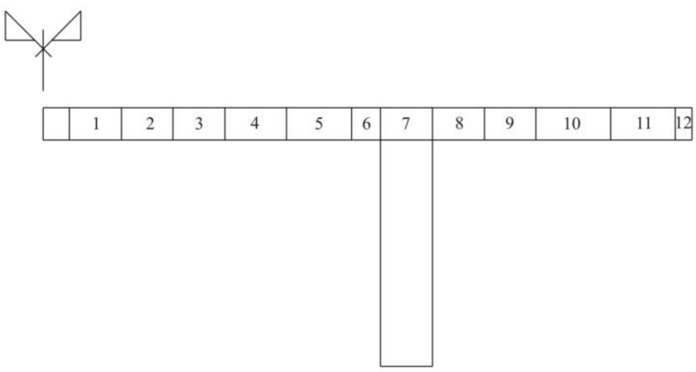


Figure 6 – Compressed elements of bridge deck

The figure 7 shows the compression stress distribution for permanent load plus the current standard load TB450 (ABNT 1982) with impact coefficient (450 kN total load equally distributed in three axis 1.50 m spaced). The maximun compressed stress obtained was 6.79 MPa, a low value in comparison with characteristic concrete strength used in bridge design.

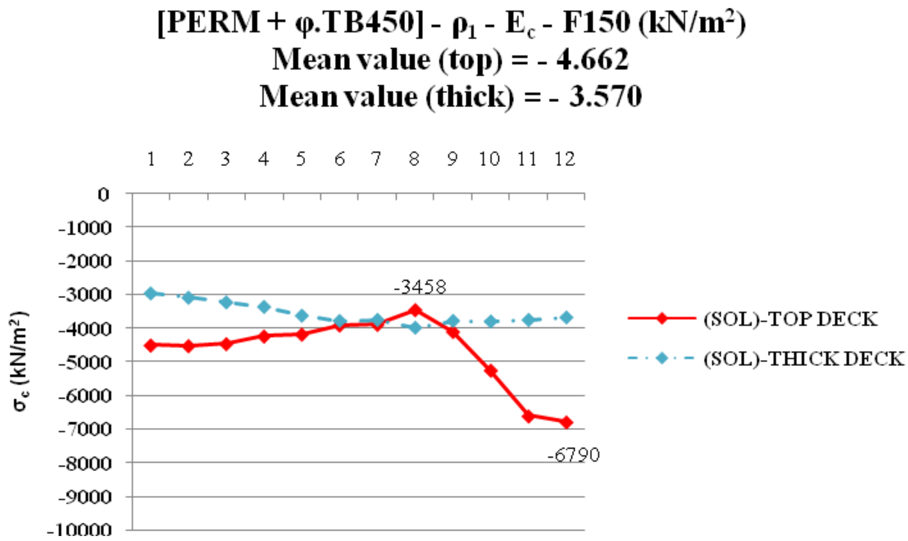


Figure 7 – Compression stress distribution

The figure 8 shows the tension stress distribution in reinforcement bars in cracked section. The maximun stress is not in a bar of the first layer, how is espected, but in the seventh layer, nearst the neutral axis.

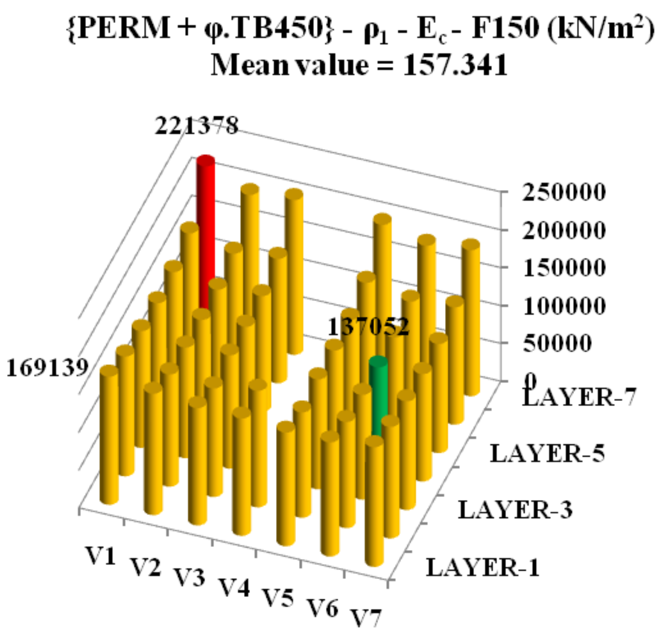


Figure 8 – Tension stress distribution in reinforcement bars in cracked section

The figure 9 shows how varie the maximum, medium and minimum compression stress with the variation of the reinforcement rate ρ. The compression stress is not so affected with the reinforcement rate variation. The TB360 (ABNT 1960) is a standard load too (360 kN total load equally distributed in three axis 1.50 m spaced).

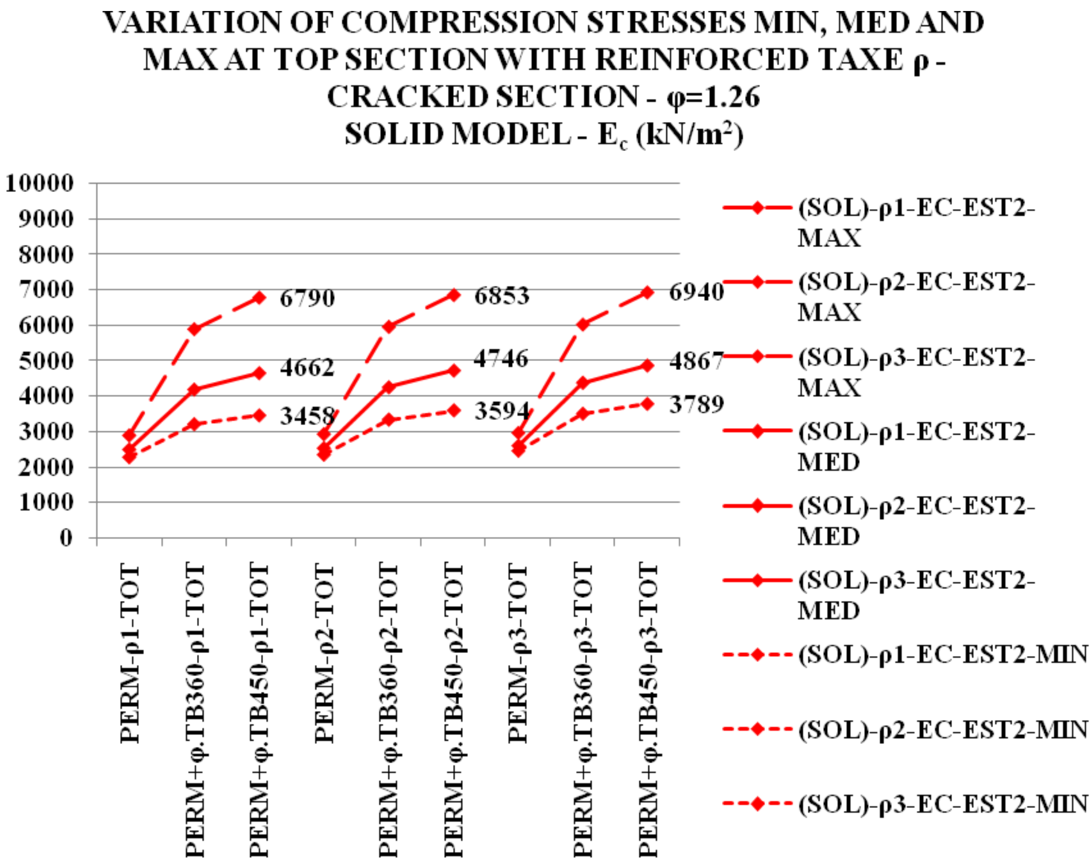


Figure 9 – Concrete compression stress variation with the reinforcement rate ρ in cracked section

In the same way, the figure 10 shows how varie the tension stresses in the reinforcement bars when varying the reinforcement rate ρ. Lower is the reinforcement rate ρ higher is the tension stress intensity.

Considering a reinforcement rate ρ_3=2.68%, the figures 11 and 12 show how the compression stresses and the tension stresses in the reinforcement bars vary with the reinforcement rate ρ and the corrosion of the first layer.

As well, the compression stress is not so affected by the reinforcement rate changes due to the reinforcement corrosion.

The corrosion of 40% of the first layer implies the increment of the medium stress in the reinforcement bars by 10.4% while the maximum stress increases only 4.2%. This may lead to the conclusion that in most cases the existence of corrosion in the first layer, even when it occurs at the id-span cross section, is not a great problem in terms of structural strength.

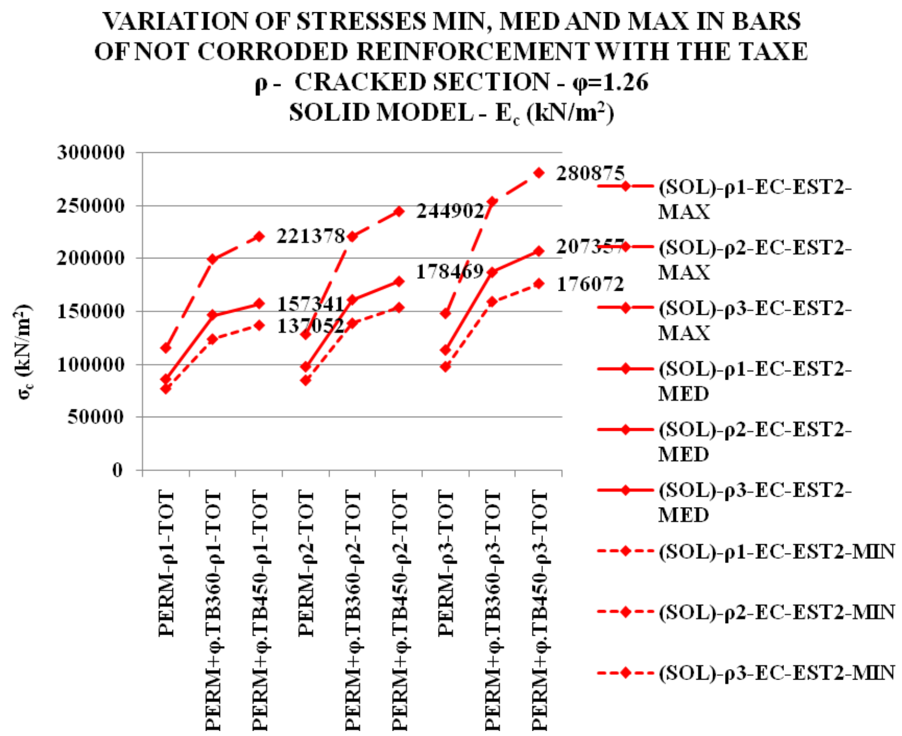


Figure 10 – Variation of the reinforcement tension stress with the reinforcement rate ρ

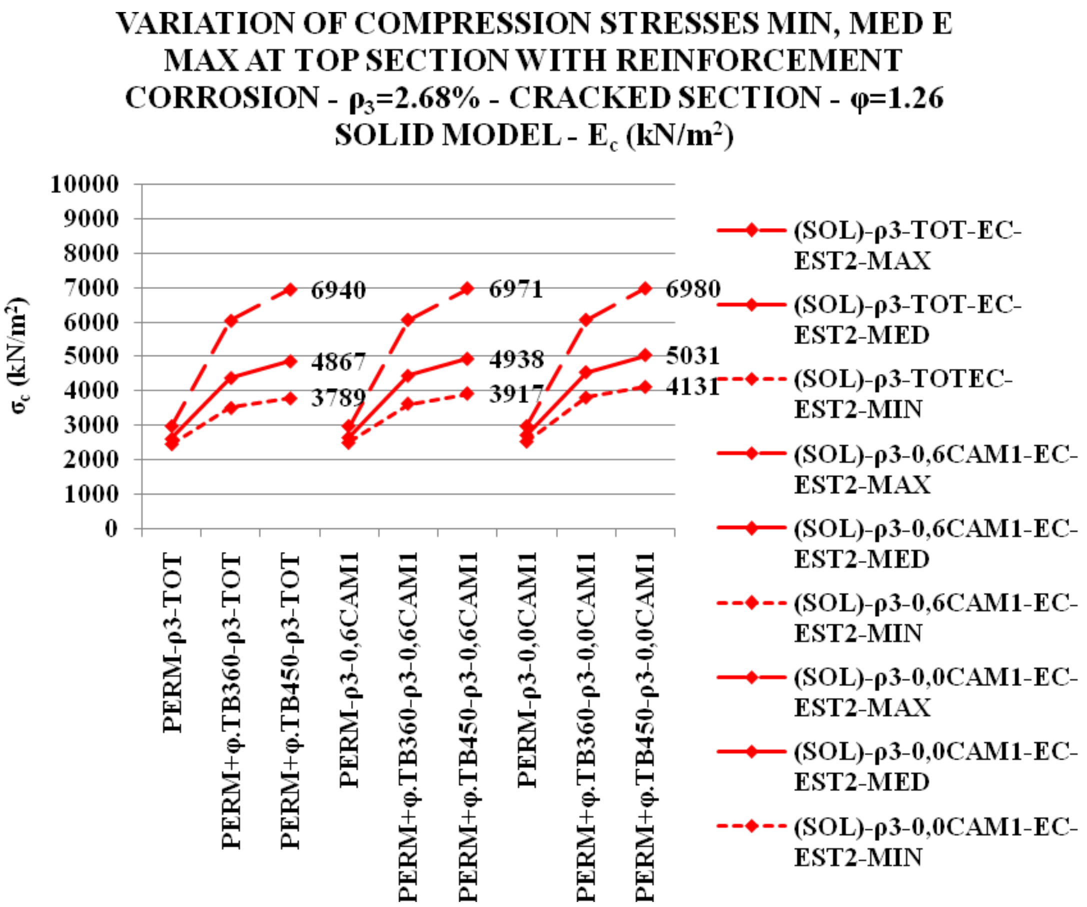


Figure 11 – Variation of concrete compression stresses with corrosion

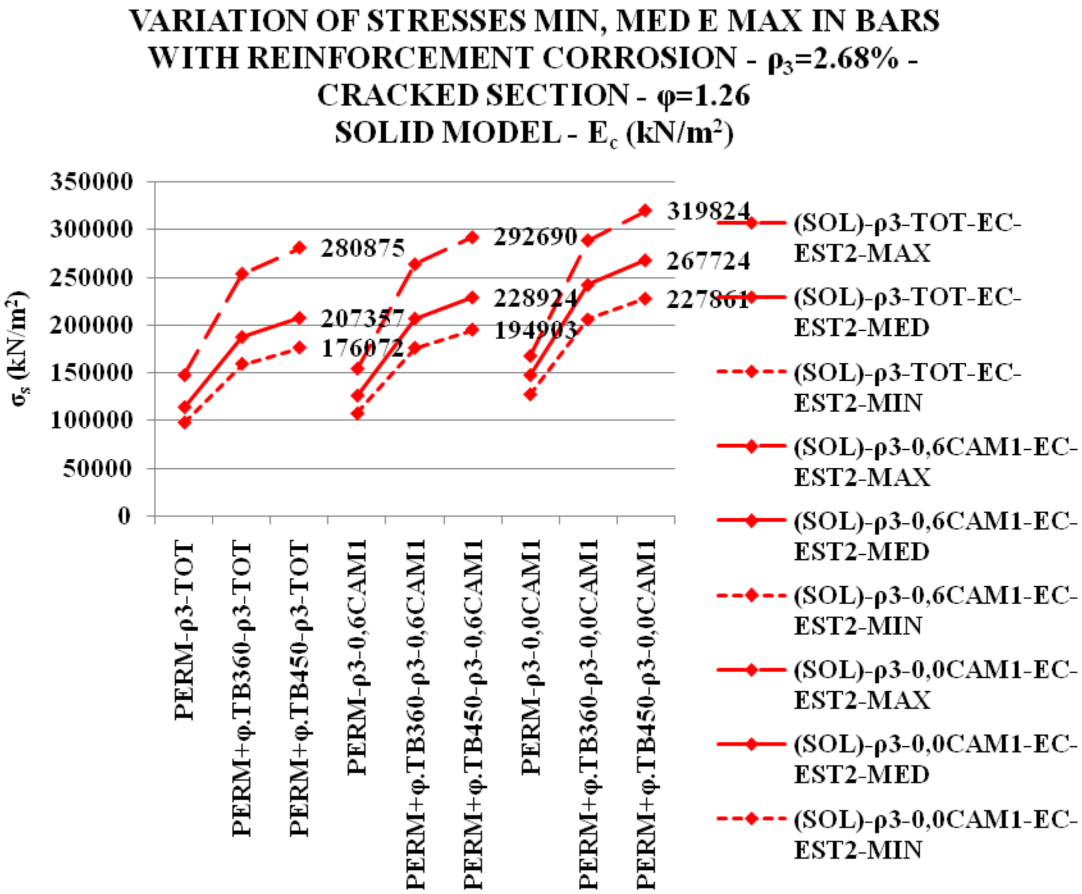


Figure 12 – Variation of the tension reinforcement stress with corrosion

4. Conclusions

Our finite element models show that the maximum concrete compression stresses in bridge cross section and its variation due to the reinforcement corrosion are very low and it is not expected that the compressed concrete will have any durability problem caused by the current traffic.

The reinforcement rate ρ_3=2.68% corresponds to design values f_{ck} = 18.0 MPa and f_{yk} = 250.0 MPa, considering the vehicle from the Brazilian standards of the 50´s. The vehicle from the present standard leads to higher stresses. Superposing this effect with the 40% corrosion of the corrosion of the first reinforcement layer, the model reveals an increase of only 10.4% of the reinforcement stresses, remaining less than f_{yk}.

Considering that the analysed section is in mid-span, the corrosion in other sections has a lower importance.

5. References

[1] Mendes, P. T. C. (2009), "Contribuições para um modelo de gestão de pontes de concreto aplicado à rede de rodovias brasileiras", *PHD Thesis*, *EPUSP*.

[2] ABNT - Associação Brasileira de Normas Técnicas. **NB 6**: Carga Móvel em Ponte Rodoviária e Passarela de Pedestre. Rio de Janeiro: ABNT, 1982.

[3] ABNT - Associação Brasileira de Normas Técnicas. **NB 6**: Carga Móvel em Pontes Rodoviárias. Rio de Janeiro: ABNT, 1960.