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European traffic on road bridges and recalibration of damage equivalence factor for fatigue verification

Auteur : Gianluca Bianchi

Encadrement : Prof. Alain Nussbaumer [1] / Prof. José Oliveira Pedro [2]

[1] Resilient Steel Structures Laboratory (RESSLab), EPFL / [2] Instituto Superior Técnico (IST) of Lisbon

1. Introduction

The evolution of European traffic, combined with the current works of revision of the Eurocodes (CEN250 project 2nd Eurocode generation), represents an opportunity to improve the simplified method for fatigue checks (also known as the lambda method) for road bridges. This thesis is focused in particular on the development of the factor for the damage effect of traffic λ_1 curves, which suffers unresolved inconsistencies and gaps regarding the types of models that have been used to obtain them, and for the total lack of correspondence between the results obtained with more recent models and the current curves present in the European Standard. Also the traffic volume factor λ_2 and the design life factor λ_3 have been studied in detail as they are strictly related to the factor λ_1 in order to propose some corrections.

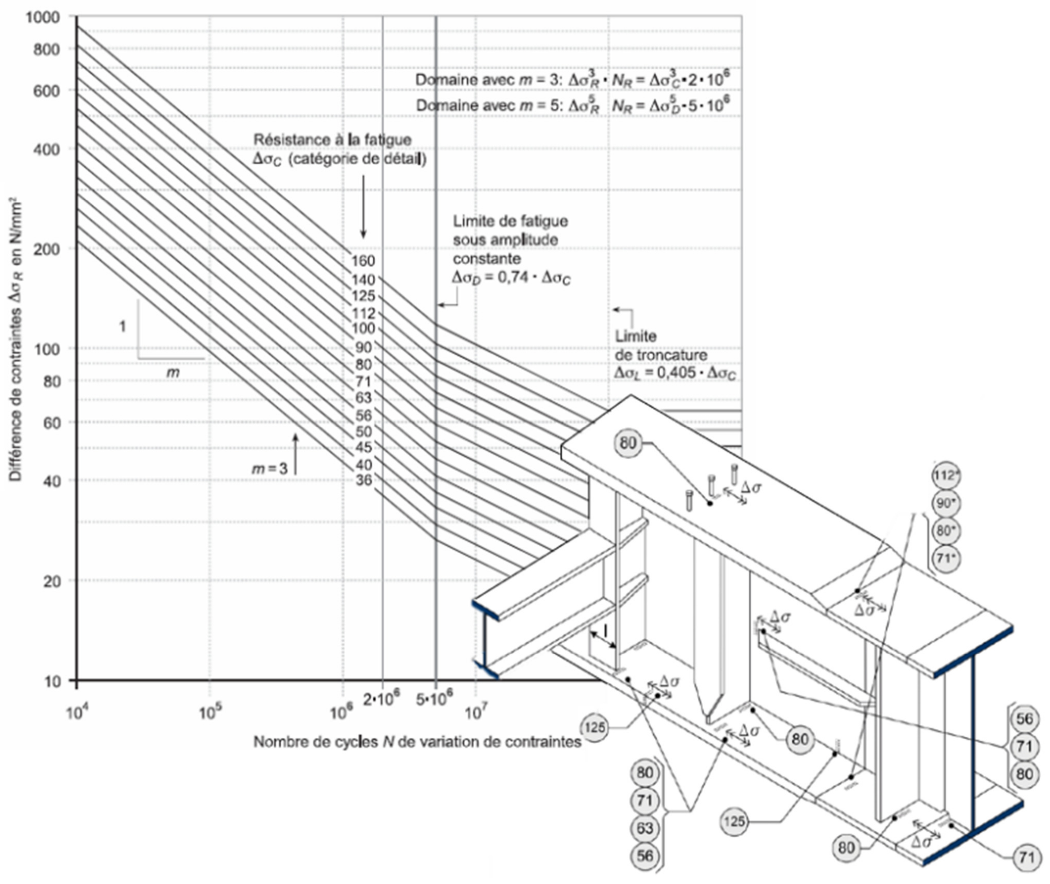
The objective of this thesis is therefore to model the real fatigue behaviour of different static systems and to obtain results as similar as possible to reality by introducing different parameters that were not present in the previous simulations, including the passage of multiple vehicles at the same time, the congested traffic and the division of vehicles into axles.

In addition to the development of the calculation code for single and multiple span bridges, work has been done in parallel for the study of the critical details and the case study of the Vasco da Gama cable-stayed bridge in Lisbon. This additional work has made it possible to further investigate the behaviour of the factor λ_1.

This approach to the development of the new λ_1 curves introduces a large number of new parameters, modelling the "real" traffic in the most advanced and detailed way performed so far. That may be taken into consideration to update the current λ_1 curves from EN 1993-2.

2. Basic concepts of fatigue design

In order to know the fatigue resistance of a construction detail, it is essential to carry out fatigue tests in which specimens are subjected to a variable load. It is necessary to provide a sufficient number of test samples to understand the dispersion of the results. Finally, the results are standardized to obtain a diagram in which the number of cycles (N), observed up to failure is plotted on the x-axis and the stress difference Δσ on the y-axis (known as the Wöhler curve).



The lambda method is a fatigue verification that has been developed to simplify the cumulative damage method, introducing lambda correction factor that correlates this last to the Fatigue Load Model 3, a simplified model easy to calculate for the engineers.

$$\gamma_{Ff}\,\Delta\sigma_{E,2} = \lambda\,\gamma_{Ff}\,\Delta\sigma(Q_{fat}) \leq \frac{\Delta\sigma_C}{\gamma_{Mf}}$$

where λ = damage equivalence factor; and $\Delta\sigma(Q_{fat})$ = stress difference calculated with the fatigue load model.

$$\lambda = \lambda_1\lambda_2\lambda_3\lambda_4 \leq \lambda_{max}$$

where λ_1 = factor for damage effect of traffic; λ_2 = factor for traffic volume; λ_3 = factor for design life; λ_4 = factor for traffic on other lanes; and λ_{max} = superior limit.

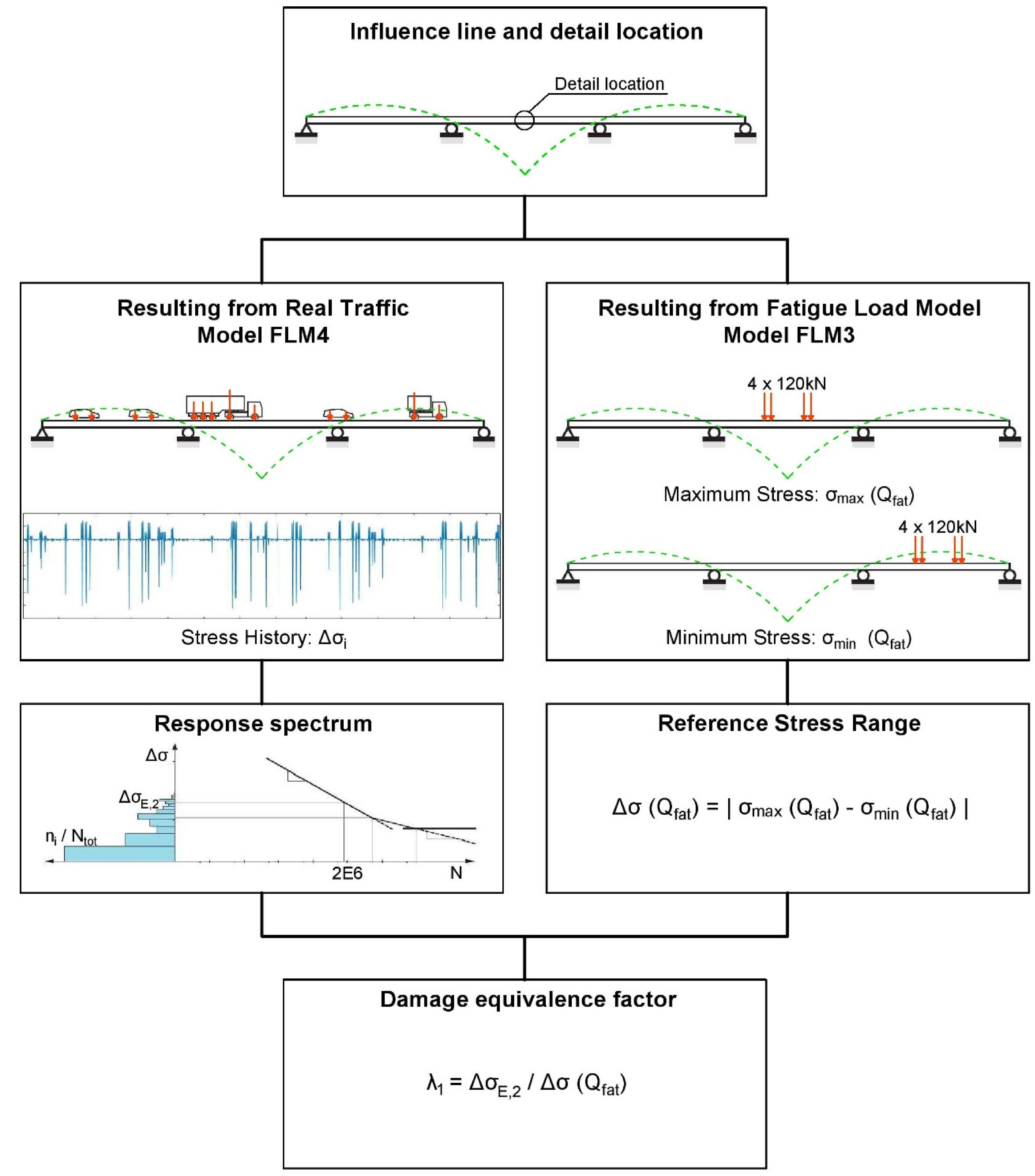
3. Improvements of the simulation models

It is possible to compare the new simulations with the simulations used in the past, especially with the simulations that were used to plot the actual Eurocode λ_1 curves which is the one that should be replaced.

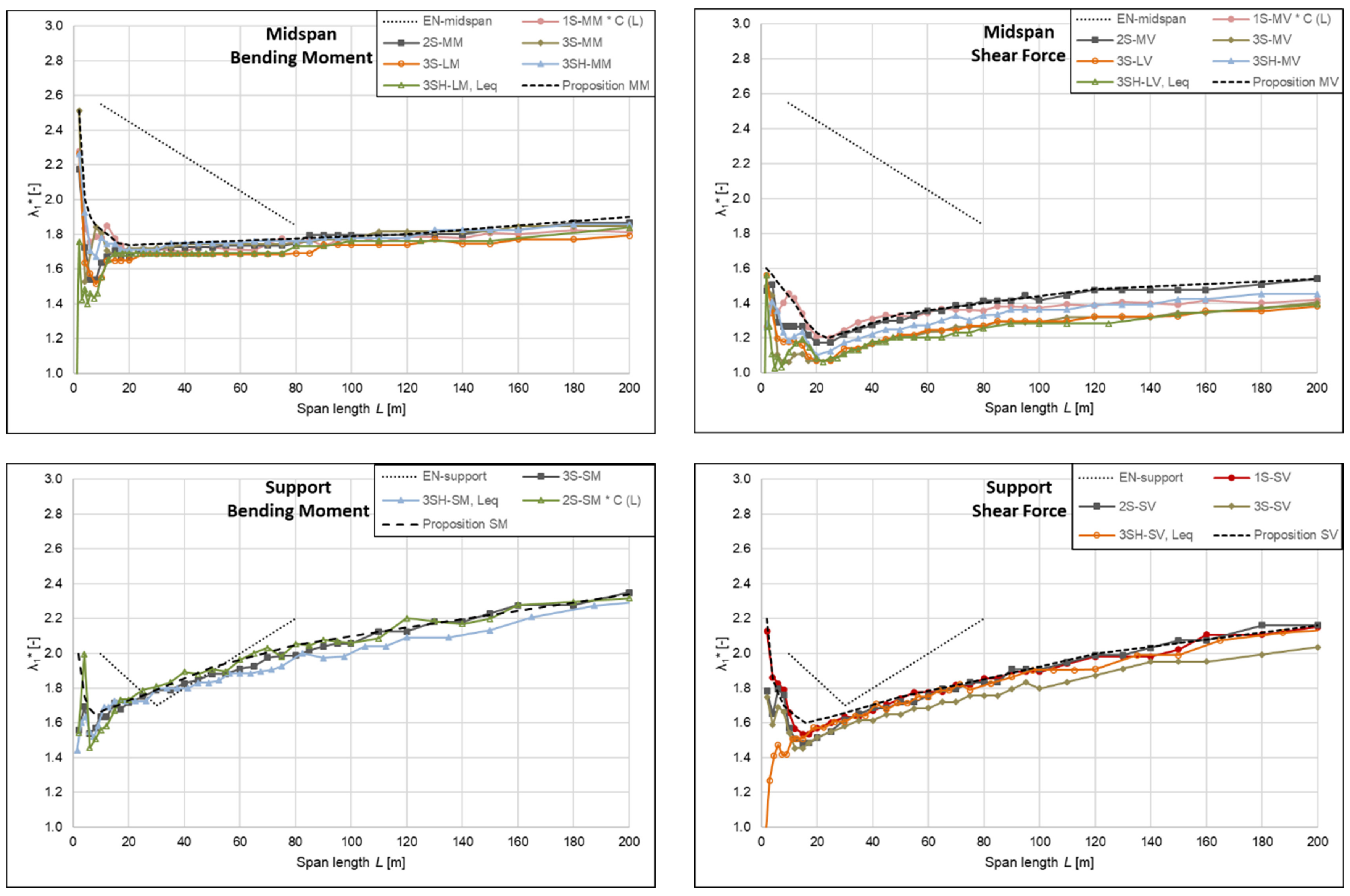
The large number of new parameters introduced makes the simulations as similar as possible to real traffic, correcting the different simplifications carried out in the previous versions.

Parameters	Merzenich and Sedlacek, 1995 (EN 1993-2)	Nussbaumer and Walbridge, 2009 (SIA 261)	Maddah, 2013	Bianchi, 2019
Enough influence lines	×	✓	✓	✓✓
Different m slope	×	×	×	✓
Varied set of lorries	✓	×	✓	✓✓
Different types of traffic	×	×	×	✓
Division by axles	×	×	×	✓
Lorries one-by-one	✓	✓	✓	✓
Free flowing traffic	×	×	✓	✓
Congested traffic	×	×	×	✓
Stop-and-go traffic	×	×	×	×
Detailed numerical analysis	?	?	?	✓
Spans longer than 100 m	×	×	×	✓

4. Procedure of calculation

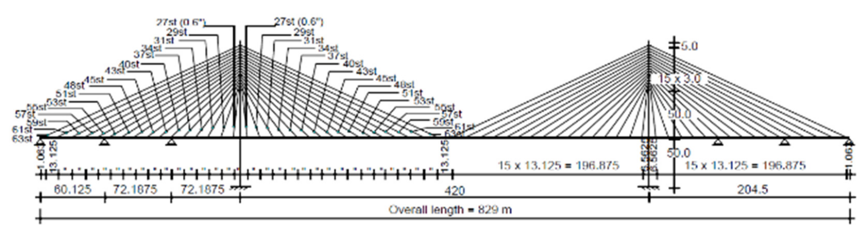


5. Results of simulations and proposition of new curves



6. Case study of a cable-stayed bridge

The length of the influence line is not the only parameter that affect the results but also the shape of the influence line and the percentage of positive and negative parts.



For cases different than the standard catalogued ones, it is necessary to do a calculation that considers the different shapes of the influence line. In future works, it is recommended that a method considering explicit features of the different influence lines be studied in order to extend the applicability of the method to more cases, including those not in the catalogue of the code.