Robustness of steel structures further to a column loss: influence of the yielding of the indirectly affected part on the global response of the structure

Auteur : Dewez, Jérôme
Promoteur(s) : Demonceau, Jean-Francois; Jaspart, Jean-Pierre
Faculté : Faculté des Sciences appliquées
Diplôme : Master en ingénieur civil des constructions, à finalité spécialisée en "civil engineering"
Année académique : 2017-2018
URI/URL : http://hdl.handle.net/2268.2/4637

Summary

Travail de fin d'études réalisé par Jérôme Dewez en vue de l'obtention du grade de master Ingénieur Civil des Constructions (année académique 2017-2018)

Work title: Robustness of steel structures further to a column loss: influence of the yielding of the indirectly affected part on the global response of the structure

Promoters: Jaspart J.-P.
Demonceau J.-F.

From several decades, the concept of robustness took its place in most building engineering institutions worldwide. Indeed, a growing interest for the subject was caused by a series of disasters involving the loss of many lives such as the Ronan Point collapse in 1968, the Murrah building collapse in 1995 and the 11th September 2001 World Trade Center disaster among others. Recommendations given in modern codes, allowing robustness checks to be performed when exceptional events occur, such as the loss of a column, are continually improving. Nevertheless, no tool is proposed to evaluate quickly and in an easily applicable way whether a given building is able to attain a stable deformed state after such exceptional events, i.e. if the structure is robust enough to sustain the loss of one of its bearing members for instance.

This is the scope within which several works on the topic of robustness were initiated at the University of Liège. Two PhD theses were written for that purpose. The current professor Demonceau J.-F. and Hai L.N.N have jointly developed an analytical method to predict the response of 2D frames under the exceptional "loss of a column" event. The previous method showed several weaknesses that were highlighted through the Master thesis of Huvelle C. and through her research subsequently conducted over several years. Finally, thanks to these years of research, a complete analytical procedure to assess the response of a frame submitted to a column loss was available at the University of Liège. The latter method makes it possible to derive the states of a frame losing a column when the directly affected part of the structure (the part above the lost element) by the event considered as exceptional may yield and when the indirectly affected part of the structure (the rest of the structure) remains elastic. In other words, this method considers that the lateral restraint brought about by the elements located elsewhere than just above the lost element is constant. Therefore, the predicted displacements in the structure are underestimating the displacements occurring in reality. Moreover, the predicted redistribution of loads in the structure is associated with fictive states of the latter as the indirectly affected part is considered fully elastic.

This is the scope of the present work. The first goal consists of analysing the effect of the progressive yielding of the indirectly affected part on the global response of a 2D steel frame losing one column. More particularly, the study is aiming to evaluate how far the analytical predicted behaviour is from the realistic behaviour of a frame losing a column reflected by an indirectly affected part that may progressively yield. This is achieved by performing numerical simulations on three structures with a differing number of spans. The second goal of the present work is to determine analytically the moment of collapse of the structure and the associated state of the latter (i.e. the internal forces and the deformations). Indeed, on the basis of the latter, everything will thus be gathered to perform robustness checks, i.e. to verify if a structure is able to find a stable deformed state after the loss of one of its bearing elements.

It is shown that the first yielding of the indirectly affected part leads to a chain formation of plastic hinges in the structure inducing a rather quick collapse of the latter. Moreover, a series of identified

failure modes are presented thanks to the analysis of the redistribution of loads following the loss of the column. Therefore, a series of verification recommendations are exposed for the investigated structures.

Finally, a breakpoint estimating the collapse of a structure losing one of its bearing elements is analytically determined on the basis of an easy to apply approach exploiting the results given by the existing complete analytical procedure. The developed method shows fairly good results but has still some weaknesses such as the significant underestimating value of the displacements of the elements located above the lost element.

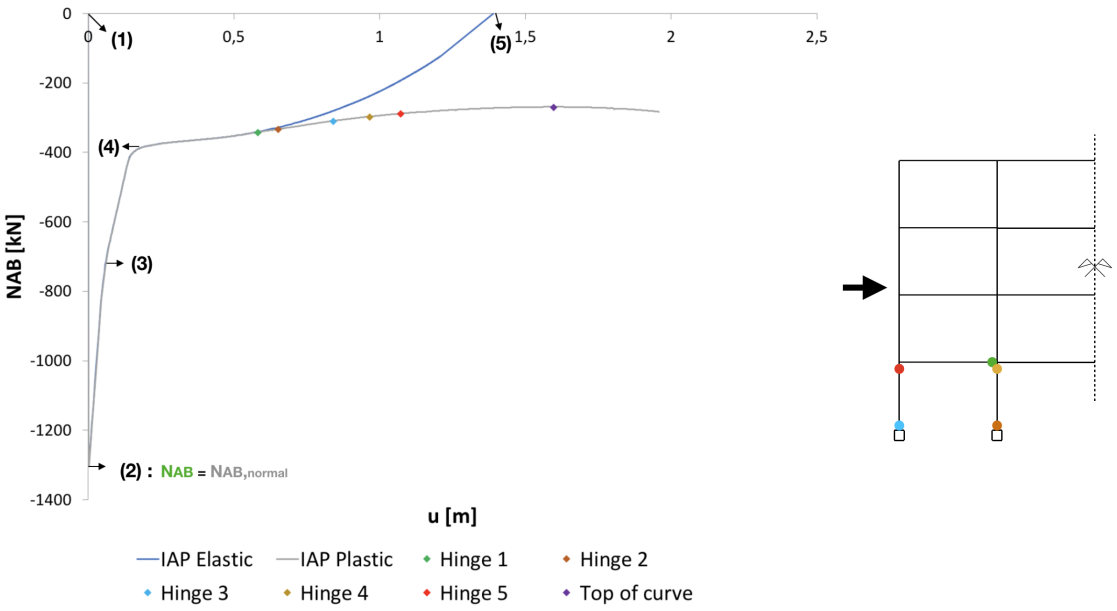

Figure 1: Progressive formation of hinges in a 2D frame losing its central column

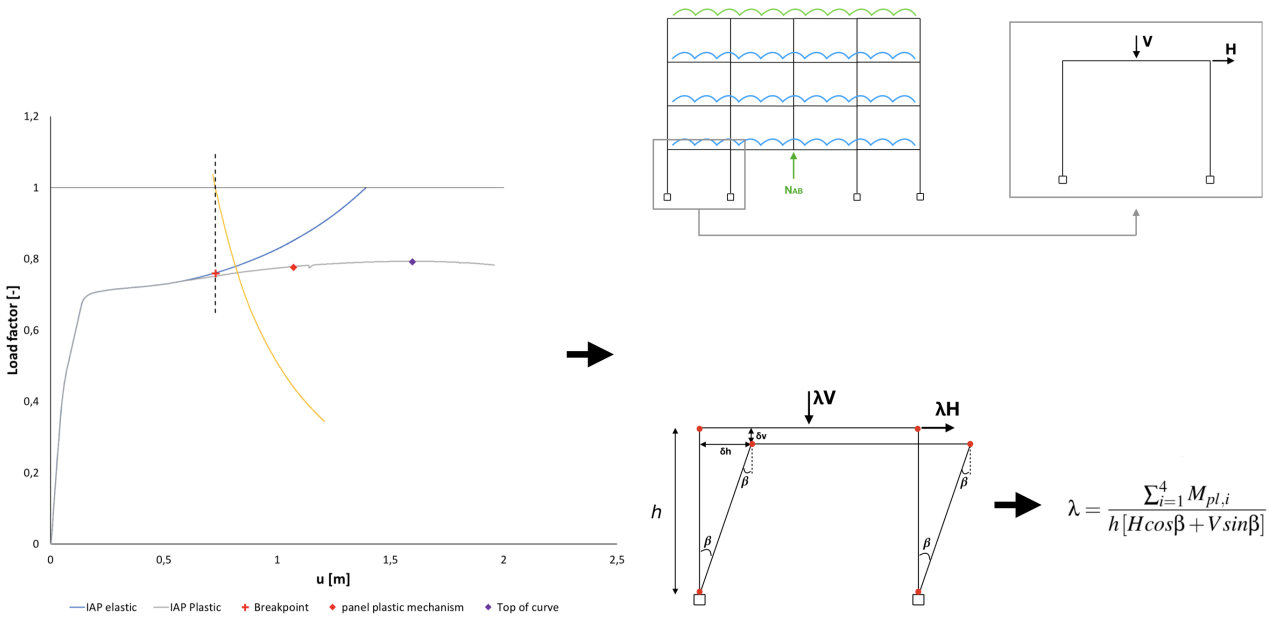

Figure 2: Identification of a breakpoint on the analytically determined (u;λ) curve based on the derived second order rigid plastic curve (yellow curve)