Reg. No: 2019/35/B/ST8/02823; Principal Investigator: prof. dr hab. inż. Maria Kotełko

Implementation of yield line theory to the load-capacity estimation of thin-walled members under combined load

One of the main demands, which should be fulfilled in the design process is a high load-capacity to weight ratio, in other words, an optimal usage of structural material. This demand is fulfilled by the light steel structure, particularly build from thin-walled cold-formed steel elements. The range of use of cold-formed steel sections specifically as load-bearing structural components is very wide, encompassing residential, office and industrial buildings (Fig. 1), the automobile industry, shipbuilding, rail transport, the aircraft industry, highway engineering.

Fig.1. Examples of applications of buildings made of thin-walled cold-formed steel members

Thin-walled cold-formed steel structures are usually made of members having the cross-sections that are prematurely prone to local or distortional buckling and they do not have a real post-elastic capacity. A failure of such members is initialized by the local-global interactive buckling of plastic-elastic type. Thus, the failure at ultimate stage of those members, either in compression or bending, always occurs by forming a local plastic mechanism (Fig. 2.).

(a) (b)

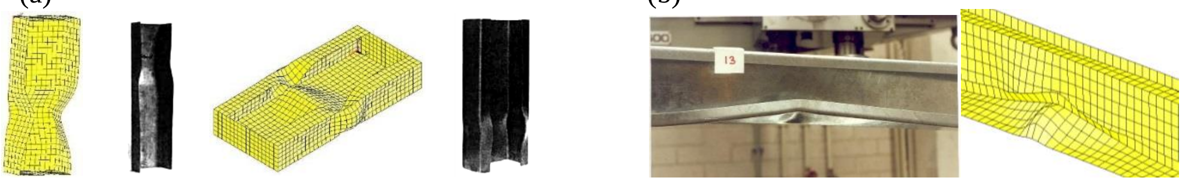

Fig. 2. Local plastic mechanisms of failure (numerical and experimental evidences): a) members in compression, b) members in bending

In order to determine properly the load-carrying capacity (ultimate load) and load capacity at failure of the thin-walled cold-formed steel member, a correct theoretical model of the plastic mechanism of failure should be developed. It can be achieved by means of experimental tests or numerical simulations (Fig. 2). The problem of the load-carrying capacity of such members subjected to simple loading systems (pure bending or uniform compression) has been with satisfactory accuracy solved within the theory of thin-walled structures, as well as in design code specifications. However, the same problem concerning members subjected to combined load (compression and bending, eccentric compression) is still an open question.

The aim of the proposed project is the development of new and more accurate analytical-numerical solutions of the load capacity and progressive collapse problem of TWCFS members subjected to combined load (compression, bending and eccentric compression). These solutions will be based on the yield line theory , eg plastic mechanism analysis, which will be developed on the basis of experimental tests and Finite Element (FE) numerical simulations.

The main goals of the proposal are (1) the implementation of the analytical models for plastic mechanisms to load-carrying capacity estimation, to improve the exiting code specifications for that case and (2) implementation of the plastic mechanisms in pushover analyses of cold-formed steel structures to understand more about the behavior of structures to accidental loading (seismic loads, impact etc.). A correct identification of the plastic mechanisms of failure is necessary to perform such an analysis. Thus, among others, this proposal investigates the progressive collapse of cold-formed steel structures subjected to accidental loading, using pushover analysis. Implementation of plastic mechanisms of failure to the pushover analyses will be an original contribution of the project into the progress in the Mechanics of Thin-Walled Structures.

Pushover Analysis is a static, nonlinear procedure, in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. In effect, the structure is pushed sideways well into the inelastic range till total failure or collapse occurs; hence, this method is called pushover analysis. The basic procedure of this method is to perform a sequence of elastic static analysis under monotonically increasing lateral loads in each of its principle directions to stimulate the loading history of the structure during collapse. The potential of the pushover analysis has been recognized in the last decade and it has found its way into seismic guidelines.