Structural responses of stocky I-section columns with web openings

Numerous experimentally-, numerically- and analytically-based research have been performed to evaluate the structural responses and ultimate capacity of perforated beams, but mostly under bending. Also, the draft version of the new European code prEN1993-1-13 gives supplementary design provisions and rules to the design of rolled and welded steel I- or H-sections with various shapes of web openings, but again, only under bending with an explicit limitation of the pressure force that can appear. However, in practice, the application of steel cellular elements dominantly loaded by axial pressure is very common. With the lack of appropriate design approaches, we rely on engineering judgement, which can result in uneconomic, time-consuming or unsafe solutions. MSc thesis is defined to accomplish an adequate and easy-to-use design method to ensure the safety of a structure. The experimental study on compressed I-section short columns with web openings, assessment of the impact of openings' size and shape on cross-section deformation and resistance, as well as evaluation of different design predictive models for cross-section resistance under pure compression was performed. A numerical simulation of the experiments was performed using the finite element method. Moreover, beside the research work, this master's thesis includes a practical recommendation for example: global analysis of a multi-span hall with a supporting structure consisting of cellular elements has been conducted.

Firstly, experimental study of compressed I-section short columns with web openings was explained, aiming at providing insight into the specific mechanical behavior, including the local buckling of the web panel around the opening. The I-section elements with web openings possess a reduced flexural stiffness caused by lack of web contribution to the cross-section deformation capacity. This structural feature implies the high combined stresses around openings caused by compression force, global bending moment and shear force developed during buckling, and local bending moments due to Vierendeel action. The total of four stub column tests on IPE300-sections with widely spaced (isolated) and closely spaced circular and square web openings was performed to determine their susceptibility to local buckling. It has shown the failure mode of the tested specimens was local buckling triggered by the weakening of the section web by the openings and the consequent reduction of its flexural stiffness. It was also found that the ultimate resistances of specimens with circular openings are higher than those measured for the corresponding specimens with square openings. Moreover, in the case of circular openings specimens the measured axial strains around openings are higher than the strains at the web post, indicating the shear transfer around the openings.

The experimental data allowed the quantitative assessment of design procedures stated in draft version of new European code prEN 1993-1-13 based on EWM, in American standard AISI S100-16 based on DSM and defined by CSM method. Although none of them include all aspects of observed case – hotrolled perforated elements under compression (Eurocode has strict limit of axial force, American standard refers to coldformed sections and CSM method doesn't recognize existence of openings at all), they turned out to be quite accurate. The corresponding results were obtained by modifying those procedures so they better reflect a case of interest. Thus, DSM method didn't need any modifications, and CSM had the most.

Afterward, numerical investigation in Abaqus CAE was conducted defining finite element models that simulate executed stub-column tests. In order to validate established numerical models, a comparison of key results obtained by numerical analysis and experimental tests was performed. The appropriate ultimate resistance is reached by implementing material model obtained from standard tensile test of cupones taken from specimens itself. Suitable deformation is achieved by taking into account geometric imperfections through LBA analysis. Mesh density was chosen so that denser mesh doesn't have significant effect on the results. In this way, the tools for further investigation, that includes developing more general modifications of design methods, are defined.

At very end, procedures stated in draft version prEN 1993-1-13 that refer to the modeling structure with cellular elements are shown for the purpose of familiarize public with its usage and show engineers its practical application with clear guidelines and additional explanations that are non-existing in standard itself. Software that was used is RobotStructuralAnalysis because lot of engineers are already familiar with it. It has shown that modeling such the construction elements in RobotStructualAnalysis require manual classification of some cross-section and even ULS calculation in some special cases that are explained in this thesis.

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