Strength, Stability and Load-Bearing Capacity of Thin-Walled Beams with Modified C-Channel Cross-Sections Subjected to Local Bending and Torsion under Service Conditions

The main goal of the project is to assess the load-bearing capacity and structural behavior of thin-walled steel channel sections with modified cross-sectional geometry, subjected to local bending and torsional loads. Thin-walled beams are widely used in lightweight steel structures – such as storage racks, machine frames, scaffolding, technical supports, and various auxiliary structural elements. Under real operating conditions, they are often exposed to non-standard loads that are not accounted for in traditional design models. One typical example is a situation in which a worker steps onto the flange of a channel section while passing through an industrial production line (e.g., conveyor systems). Such localized loading induces not only bending of the cross-section, but also torsion, which may lead to instability and failure mechanisms that are difficult to predict.

The channel sections currently in use are typically hot-rolled profiles that are often oversized relative to actual in-service requirements. This oversizing results from the lack of comprehensive experimental data for thinner, more economical profiles and the need to apply high safety factors. The proposed approach in this project involves developing new channel-section geometries with reduced weight and increased material efficiency, which can better resist localized bending and torsion while enabling a reduction in material consumption. This in turn offers the potential to reduce production costs and minimize environmental impact.

The research will be conducted in two stages. The first stage will involve experimental testing on full-scale steel sections subjected to concentrated loads simulating service conditions, such as the pressure from a human foot or a machine component. The second stage will involve numerical simulations using the Finite Element Method (FEM), allowing for detailed analysis of stress distributions, deformations, and instability modes. A key innovation of the project will be the incorporation of real geometric imperfections – such as local distortions, corner rounding, or irregularities introduced during cold forming – into the analysis. To this end, the sections will be 3D-scanned, and the resulting precise geometry will serve as the basis for the computational models that reflect the actual physical characteristics of the tested elements.

The project bridges scientific research with engineering practice. Its outcomes will be applicable in mechanical engineering and structural design, supporting the development of safer and more cost-effective thin-walled structures. The knowledge gained from the project will help close the current gap in understanding the behavior of channel sections under complex service loads, making a substantial contribution to the advancement of modern design methods and material optimization. The results will also serve as a foundation for future design recommendations for new thin-walled section types, as well as for the improvement of engineering software tools used in practice. Furthermore, the project will contribute to the development of numerical methods for analyzing components with irregular geometries, which have so far been difficult to model due to local and global shape imperfections. In the long term, the research findings may be used to support the development of future design standards for lightweight steel structures operating under realistic service conditions.