GHEORGHE ASACHI TECHNICAL UNIVERSITY OF IAȘI

Faculty of Civil Engineering and Building Services

IOSUD TUIASI · Doctoral field: Civil Engineering and Building Services

HABILITATION THESIS Lecturer George Țăranu, PhD

Mineral composites and thin-walled steel elements: contributions to the study of structural behaviour and applications in the assessment and rehabilitation of existing structures

Abstract

This habilitation thesis examines the link between mineral composites, components made from cold-formed steel (CFS) sections, and structural systems under static and dynamic loading. Hybrid CFS–EPS systems combine steel sections with expanded polystyrene (EPS). The contributions developed after completion of the doctorate address how material properties, connection deformability and component configuration determine system response. Doctoral research provides the background to this approach. Four principal contributions concern mineral composites and their structural applications, axial deformability of CFS connections, stability and strengthening of perforated uprights, and dynamic characterisation of CFS and CFS–EPS systems.

The first contribution concerns mineral-matrix composites and their structural applications. The 2010–2013 postdoctoral programme initiated this research on synthetic-fibre-reinforced mineral-matrix composites and their use in panels and modular systems. For the investigated composite, a fibre volume fraction of 10% increased tensile strength from 1.13 to 6.24 MPa, while compressive strength increased by approximately 12%. Subsequent studies of mortars containing expanded perlite and concrete containing rubber particles extended the work to residual properties, stiffness and damping. Comparisons of static and dynamic moduli at later ages highlighted the role of composition when selecting mechanical parameters.

The second contribution concerns the axial deformability of CFS connections. Tests identified the contribution of slip, screw–sheet contact and local sheet deformation to connection displacement. Detailed ANSYS models and equivalent axial relationships for member models were developed. Finite axial stiffness allows relative displacement to be included while retaining free joint rotation. In a truss sensitivity study, the calculated displacement increased from 1.0 to 19.8 mm when deformable links were introduced. This establishes the relevance of connection idealisation to serviceability assessment and motivates further investigation of parameter transfer to subassemblies.

The third contribution combines stability assessment and local strengthening of perforated uprights. Testing the same cross-section at three lengths enabled the interaction of local, distortional and global buckling to be examined. FEM capacities were approximately 1.5–5.6% below the tabulated experimental values for the adopted material and initial imperfection. Comparisons with EWM and DSM showed the influence of the calculation assumptions. An internal C-section increased axial capacity by approximately 25%, compared with approximately 3% for two angles in the tested configurations, highlighting the role of engaging the upright web.

Research on uprights with damaged connections extends this direction to residual capacity and the effect of additional bolts. Experimental observations were compared with FEM results, while machine-learning predictions were developed within the team. The individual contribution comprised FEM modelling, comparative interpretation, and preparation of the initial and final manuscripts. The results show that intervention effectiveness depends on the cross-section family and provide a basis for comparing mechanical and data-driven predictions. Together, these studies identify parameters and failure mechanisms relevant to the analysis of CFS systems.

The fourth contribution concerns the dynamic response of structural systems. For the CFS frame tested on a shaking table, axial stiffness identified from cyclic connection tests improved the agreement between calculated and measured displacements before extensive damage. Added mass reduced the frequency from 8.09 to 2.98 Hz, while subsequent loading of the mass-loaded frame was accompanied by a reduction to 2.48 Hz. In the industrial rack study, the synchronous amplitude ratio at the excitation frequency remained between 2.89 and 3.04, whereas the ratio of peak accelerations increased from 3.43 to 5.82. Comparing these indicators clarifies the interpretation of dynamic amplification and its dependence on the response measure.

The full-scale ThermaSteel programme characterised systems with thin-walled steel sections embedded in EPS through frequencies, displacements, accelerations and observed damage. Identified frequency reductions were approximately 8–21%, with local deformation concentrated mainly at the base and fastening zones. These findings provide reference data for the investigation of interfaces and panel connections. Comparison of the dynamic campaigns shows why mass, response amplitude, structural state and the measured quantity must be considered together. Material, component and system tests therefore form complementary parts of the research methodology. The experimental observations guide model selection and the development of further tests that separate the contribution of individual mechanisms.

Comparative models of masonry buildings and reinforced-concrete frames quantified the effects of connection continuity and infill participation. For the frame with an ideally bonded frame–infill interface, Y-direction displacements were 69–76% lower than in the bare-frame model under the same earthquake records. Comparisons of strengthening solutions related stress reduction to added mass and construction details. These complementary studies support the choice of structural idealisation and identify measurements needed to assess predictions.

Academic activities connect applied research, structural design and education. Industrial contracts, the THS-FEOPT project funded through an Innovation Voucher, PED proposals and international collaboration support research development. Laboratory manuals and thin-cardboard bridge design–build–test activities link prediction, measurement and failure interpretation. Supervision of undergraduate projects and one master's dissertation, informal mentoring of doctoral researchers, guest editing and peer review complete this experience.

Design projects disseminated through publications, including the Bulletin of the Polytechnic Institute of Iași, and teaching examples connect professional practice with structural analysis, observations during building use and engineering education.

The 2027–2031 programme addresses CFS connections and components, CFS–EPS interaction, and dynamic identification. The initial campaign will test transfer of a connection law to a compatible subassembly, using local slip measurements and separate calibration and evaluation data. Interface studies, frame tests and AI models will build on this foundation. Planned outputs include two doctoral topics, publications, documented datasets and a methodological guide, with predictions assessed against measured behaviour.