# 1. PUBLISHABLE SUMMARY

**Summary of the context and overall objectives of the project (For the final period, include the conclusions of the action)**

HOLLOSSTAB successfully achieved the following objectives:
• Developing new, "direct" design rules for the cross-sectional strength/capacity of slender, innovative mild and high-strength steel (HSS) hollow sections, based on a newly-developed "Generalised Slenderness-based Resistance Method" (GSRM) and with the aim of obtaining a continuous strength representation throughout slenderness ranges - from compact "class 1" to slender "class 4". The cross-sectional slenderness is calculated for the "overall" load-case and the complete cross-section, using numerical methods (FEM, GBT), thus taking advantage of mutual restraining effects in the different parts of the cross-section and the real stress state;
• Expanding the developed "direct design" functions for the applications in beam-columns (members failing in global buckling). This allows practitioners to treat global "G", local "L" and combined "L +G" buckling phenomena in a uniform format;
• Studying the elastic buckling behaviour of hollow sections in a systematic, semi-analytical way using the Generalized Beam Theory - GBT; this led to a deep insight in the behaviour of hollow sections with different shapes and subjected to different load cases;
• Determining the safety level of the newly developed design rules on the basis of the methodology of EN 1990, making use of the test data provided in the project (physical and numerical tests) as well as production data regarding material properties and geometric tolerances provided by the industrial partners;
• Studying the fields of industrial application and of possible product improvement in a systematic technical/scientific way by R&D and engineering representatives of major European hollow section producers. Case-studies of structures built in the past are reassessed to determine the economic and technical advantages of the new design rules and new developments in steel grades, shapes, and wall thickness;
• Developing specific design tools (freeware software) and guidelines and delivering them to practice through the appropriate channels.

**Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far (For the final period please include an overview of the results and their exploitation and dissemination)**

HOLLOSSTAB included the following research, technical and administrative work:
• Meetings every six months at various locations in Europe to discuss the progress of the project (WP1).
• Studies of market trends for the use of high-strength and other innovative hollow sections and benchmark cases for the application of the new GSRM design rules (WP2)
• The design and conceptualization of specific test procedures, the completion of 172 full-scale tests and of corresponding auxiliary tests (3D scanning, tensile tests, residual stresses) in WP3 to WP5;
• Large parametric studies of the behavior of CHS, RHS/SHS and bespoke-shaped hollow sections, using advanced non-linear FEM calculations (GMNIA) calibrated against the already large set of full-scale experimental tests in WP3 to WP5.

• The assessment of the elastic buckling behavior of SHS, RHS and RPHS members,the assessment of the post-critical behaviour and imperfection sensitivity of RPHS columns, as well as the development of analytical formulae and of efficient computational algorithms for the elastic buckling load calculation in (WP6);
• Data collection on production values of European hollow section producers in WP7
• Development, validation and statistical evaluation of new GSRM design rules for cross-sections and members (local and global buckling), using two alternative approaches: a stress-based and a strain-based approach. Significant increases of strength, accuracy and reliability could be demonstrated to be achieved by the new rules.
• Preparation and validation of numerical tools for the calculation of the reference elastic and plasticcross-sectional resistance Rel and Rpl as well as the linear elastic buckling load at the cross-sectional level for the determination of the GSRM slenderness in WP8 and WP7.
• Preparation of comprehensive design guidelines with worked examples and holding a final workshop to disseminate the project results among practitioners and other stakeholders of the European steel industry (WP9).

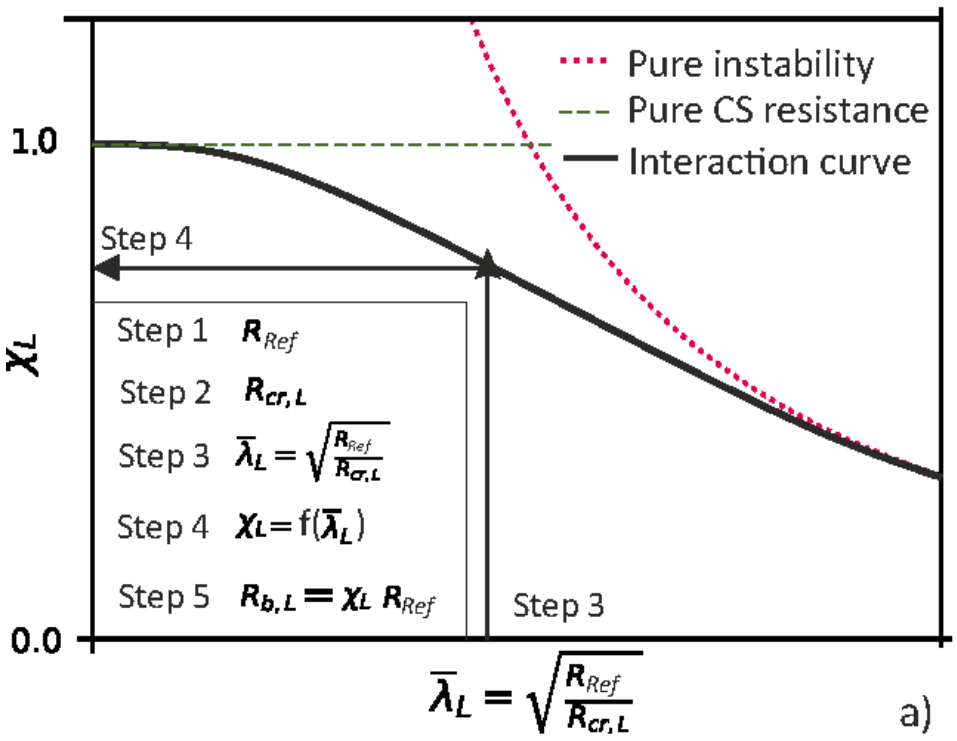
**Progress beyond the state of the art, expected results until the end of the project and potential impacts (including the socio-economic impact and the wider societal implications of the project so far)**

The new GSRM design rules developed in Hollosstab lead to significant improvements in the design practice of hollow sections against instability (local, global and local+global buckling). They imply an overcoming of the drawbacks of the classification into cross-sectional classes in Eurocode 3 and similar standards, which cause particular large discontinuities for hollow sections at the class borders. Furthermore, the methods allow for an explicit consideration of mutual support between parts of the cross-section with different plate boundary conditions and loading states and utlizations. Compared to traditional design approaches, significant gains in economy and safety could be highlighted in the project. The development of a dedicated design tool, which will be made available as freeware through a vast dissemination effort (ECCS, CIDECT member companies) leads to the expectation that the developed methods will be widely accepted as an easy, economic way of checking the local and global stability of hollow section members.

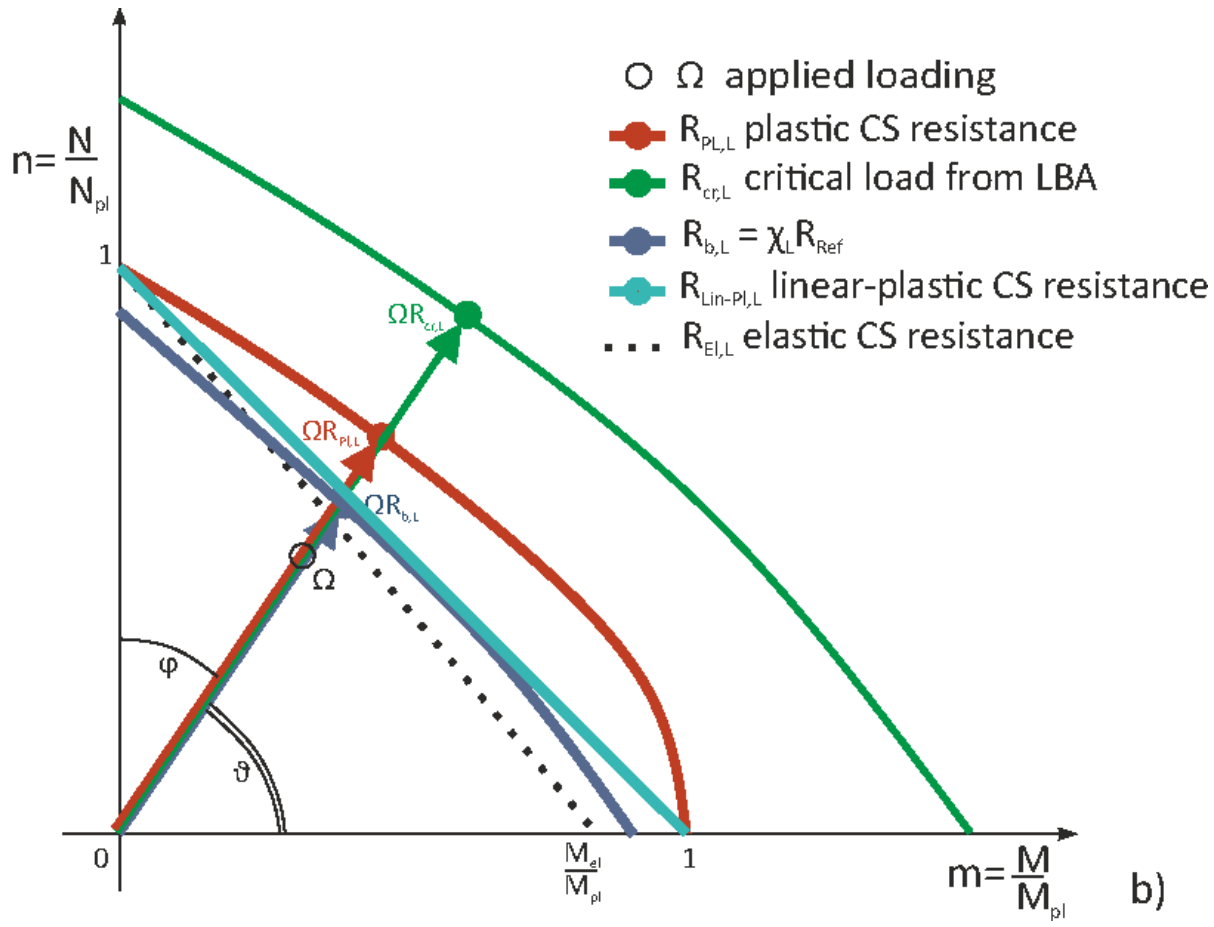
**Address (URL) of the project's public website**

https://www.steelconstruct.com/eu-projects/hollosstab/

## GSRM for Local Buckling / Cross-Sectional Strength Checks

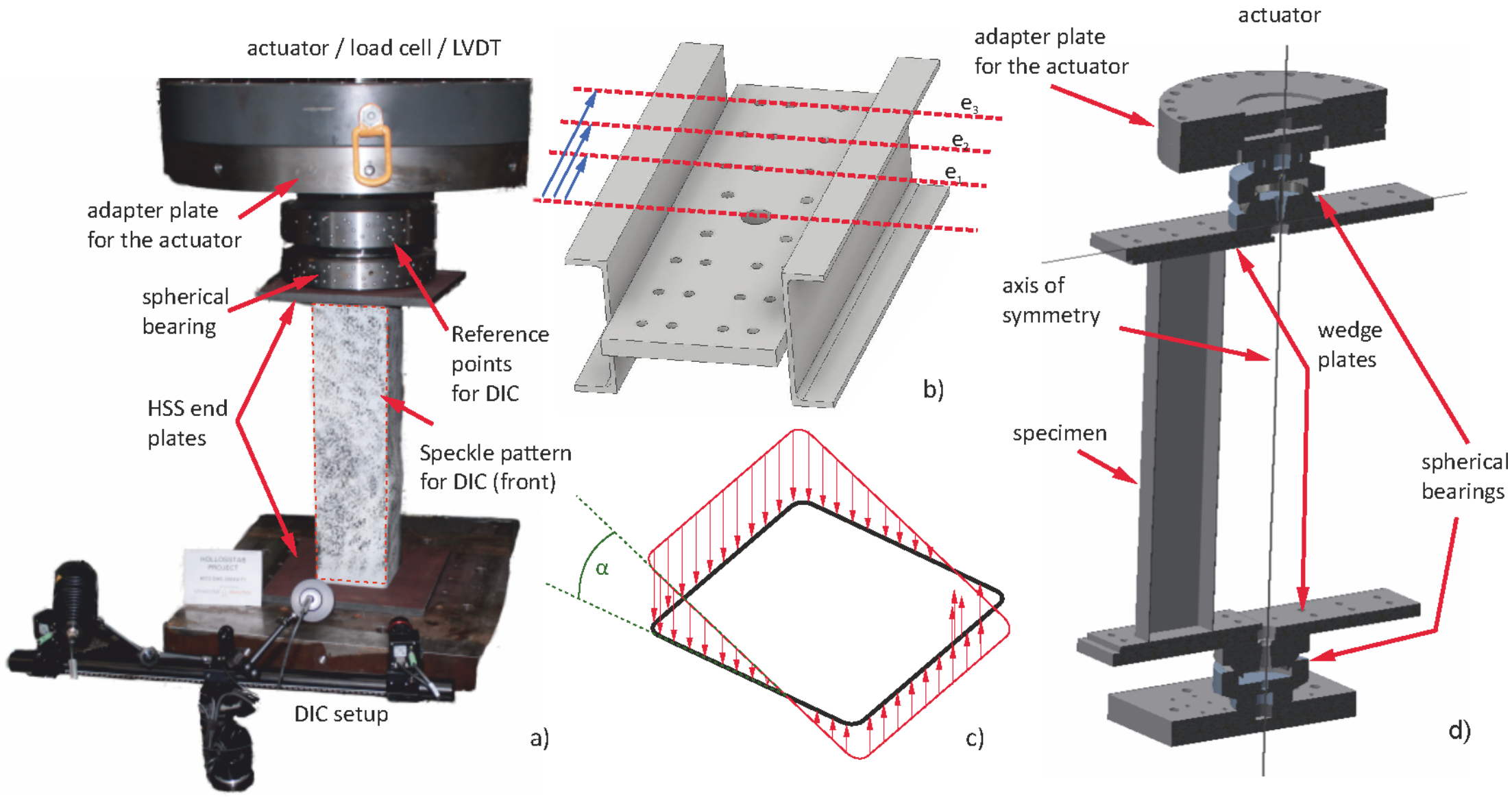



a)

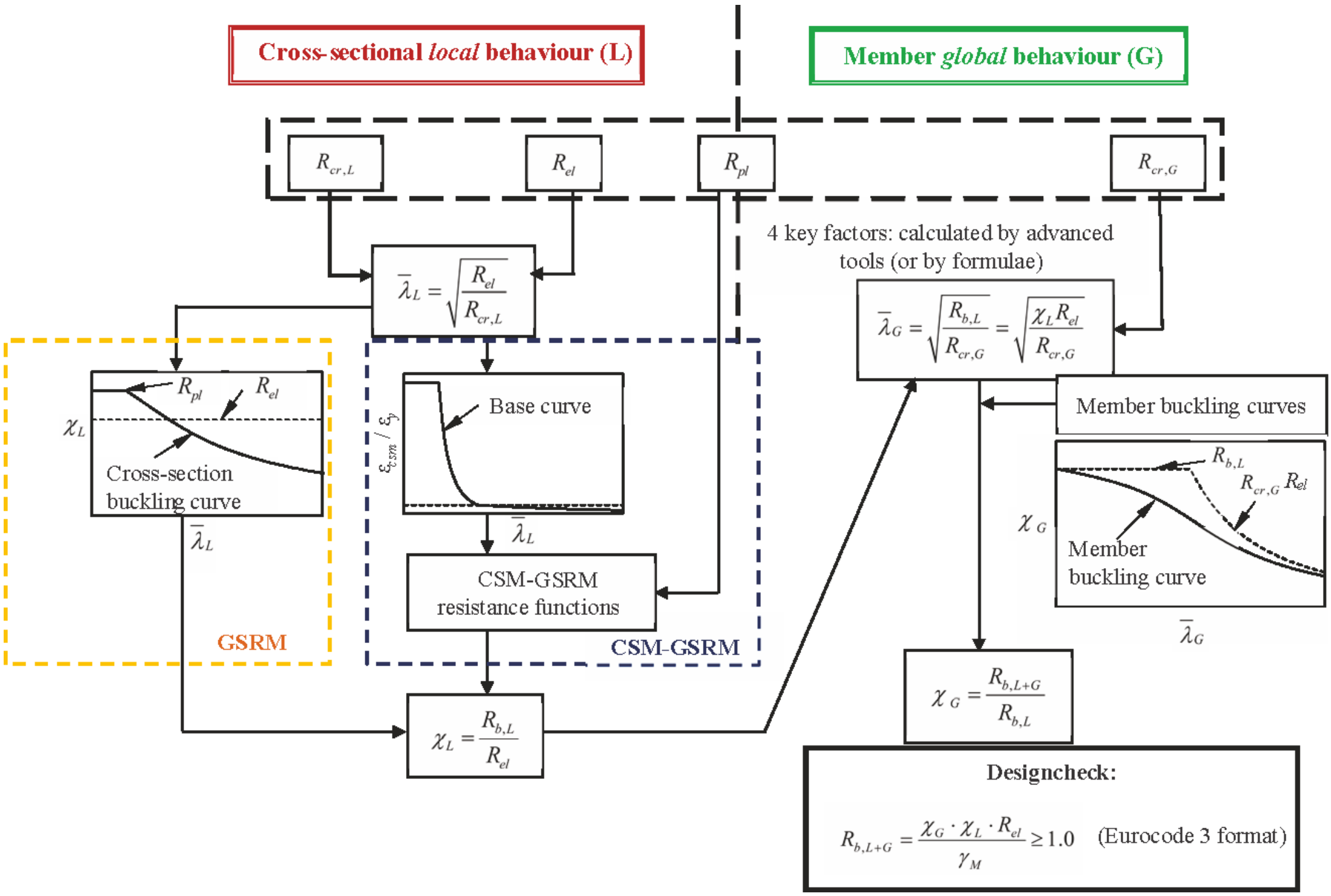



b)

## Test procedure at UniBWM



## Flowchart of the GSRM Design Methodology



**Stub column tests carried out at ICL**