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Imperfection sensitivity of cylindrical shells subject to hoop compression - numerical buckling analyses versus experimental results

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ABSTRACT

The strong load drop in the post buckling area and the huge number of possible buckling modes at almost the same load level cause a considerable imperfection sensitivity of thin-walled shell structures. Thus, the inevitable deviations from the nominal resistance parameters have to be explicitly included in the numerical simulation.

Because of the big dimensions of the structures of civil engineering and plant engineering, experiments at original structures are very expensive and are only exceptionally maintainable. Data from buckling experiments are available only for some basic buckling cases of fundamental shell geometries. However in the most cases, only the buckling loads but not the imperfections are documented well.

In order to assess the carrying capacity of buckling cases which are not yet sufficiently investigated, the new shell buckling code EN 1993-1-6:2007 allows numerical buckling strength verifications. Bearing in mind the complexity, diversity and sensitivity of shell buckling phenomena, it is not astonishing, that a number of application problems have not been solved yet [4]. Existing regulation deficiencies may be explored best at the basic buckling cases because of the available comparative experimental data. In the presentation, experiences and research needs are presented which result from performing geometrically and materially nonlinear calculations with imperfections included for the basic buckling case of a circular cylindrical shell subject to hoop compression. The mentioned Eurocode advises the use of equivalent geometric imperfections in order to cover the effect of different accidental imperfections in a safe manner.

In the first part of the presentation, the challenge of equivalent geometric imperfections is discussed. This problem divides up into the questions about the imperfection pattern and the imperfection size. Imperfection modes which have the most detrimental effect should be used according to the Eurocode. It is reasoned in the presentation, that eigenmode-affine imperfections are not appropriate for the buckling case hoop compression. Moreover, *the* most unfavourable imperfection pattern does not exist for shell structures but only different unfavourable patterns depending on the imperfection amplitude [3]. This amplitude-depending pattern can not be determined with certainty because of the

substantial influence of the material non-linearity and because of the numerous post-buckling paths which cross each other. However, the method of quasi-collapse-affine imperfections allows a reasonable approximation to the most unfavourable imperfection pattern [3]. Single longitudinal predeformations resulting from this concept are well suited as equivalent imperfections. Regarding the imperfection amplitude, the question is addressed, what imperfection amplitudes are necessary to gain numerically the experimentally based lower bound buckling resistance of the stress design. Using the imperfection amplitudes recommended in the Eurocode, partly considerable discrepancies result from a numerical analysis of the circular cylindrical shell subject to hoop compression [2]. In order to overcome the knowledge gaps and to relate the accidental imperfections to the buckling resistance, for the first time extensive experimental series of test cylinders with the same nominal data have been performed at the Gdansk University of Technology. The geometric imperfections and the buckling process are well documented.

The numerical simulation of these experiments is dealt with in the second part of the contribution. Using static analyses, only the imperfection parts which initiate the buckling process may be reliably detected. In contrast, this statement is not valid for the buckling pattern. The inert forces must not be neglected performing a numerical simulation of the buckling process, because the collapse takes place with high velocities even though the load is increased very slowly. Therefore, a dynamic analysis is necessary in order to simulate the buckling in a mechanically consistent manner [1]. By means of a dynamic analysis, the arising buckling pattern is closely captured. Dynamic analyses are especially reasonable at the basic buckling case hoop compression, because the buckling process takes place by a sequence of several local buckling phenomena. The succession of stable and unstable areas of the load-displacement path of a static analysis, which is connected with loading and unloading, does not correspond to mechanical reality. Finally, the minor differences between experiments and numerical simulations, which underline the high imperfection sensitivity of shell buckling, are discussed in detail.

Summarising, conclusions are drawn concerning the imperfection parts initiating the buckling process as well as concerning the equivalent imperfection modes and amplitudes which should by used performing a numerical buckling strength verification.

REFERENCES

[1] W. Schneider, and Y. Ribakov, “Collapse Analysis of Thin Walled Cylindrical Steel Shells Subjected to Constant Shear Stress” *Computers and Structures*, Vol. 82 / 29-30, pp. 2463-2470, (2004).

[2] W. Schneider and A. Brede, “Consistent Equivalent Geometric Imperfections for the Numerical Buckling Strength Verification of Cylindrical Shells under Uniform External Pressure”, *Thin-Walled Structures* Vol. 43 / 2, pp. 175-188, (2005).

[3] W. Schneider, I. Timmel and K. Höhn, “The Conception of Quasi-Collapse-Affine Imperfections - A new Approach to Unfavourable Imperfections of Thin-Walled Shell Structures”, *Thin-Walled Structures* Vol. 43 / 8, pp. 1202-1224, (2005).

[4] W. Schneider and M. Gettel, “Numerical Buckling Strength Verification of Cylindrical Steel Shell Structures Subject to Combined Loading”, *Int. J. of Structural Stability and Dynamics*, Vol. 7, No.2, pp. 295-311, (2007).