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BUCKLING OF GRIDSHELLS
FROM DOME TO FREE-FORM STRUCTURES

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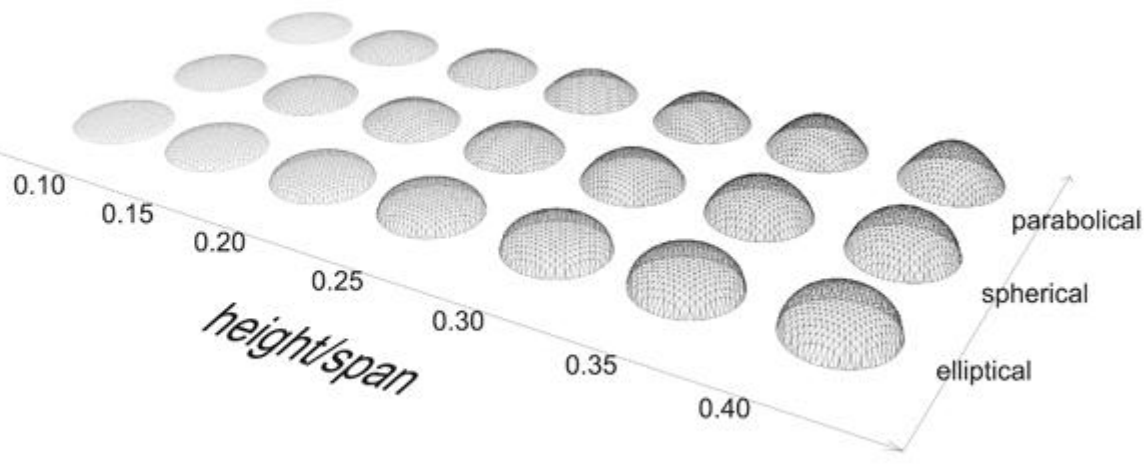
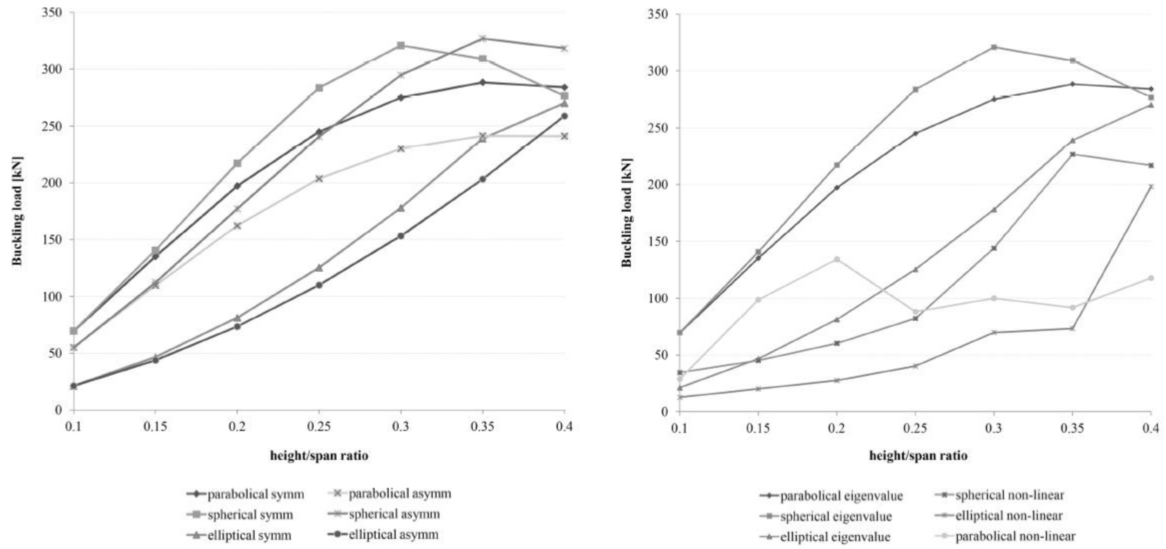
Stability failure is one of the main issues concerning gridshell design. Member slenderness in steel gridshells is usually very high, and structural collapse is generally caused by buckling instead of material failure. Stability checks are therefore of great importance in a proper design process. Since there are many types of potential failure modes and critical loads are in fact influenced by several parameters, the need of an accurate research is fundamental. This work investigates the effect of various parameters on the buckling load of gridshells by means of first order and second order Finite Element Analyses (FEA).
Stability analyses of a variety of domes are conducted as a first step. The domes have circular plan, variable curvature and different height/span ratios. Geometrical data is chosen alike to that of recent research works in order to allow for comparison between results. To further investigate the connection between form and structural behaviour, stability analyses of two very popular freeform reticulated shells (the British Museum court roof and the House for Hippopotamus at Berlin zoo) are carried out.
To investigate the influence of various parameters on the buckling load and buckling behaviour of gridshells, several benchmarks are developed as a first step. This serves to develop a method to both model and analyse the structures. To further observe the correspondence between form and structural behaviour, stability analyses of the two freeform case studies are carried out as a second step. Imperfection sensitivity and effects of grid optimization are taken into account.
Numerical analyses are carried out for differently curved domes (Fig.1) in order to determine the influence of several parameters on buckling behaviour. The variable parameters involved are, along with the type of dome: rise to span ratio, load distribution, imperfection magnitude. First off, linear static analyses are carried out to understand the effect of self weight and as an essential step in order to perform the eigenvalue buckling analyses. Eigenvalue buckling (Euler buckling) analyses are made to understand the overall buckling behaviour of the domes since mode shapes are computed. Buckling load factors are also provided by this type of analysis, which in this case correspond to elastic critical loads since unit loads were adopted.



Dome benchmarks

Critical loads obtained by means of eigenvalue buckling analysis are not reliable for real structures, as the actual critical load is often much lower. However, they are useful to set the load cases for non-linear analyses and to compute imperfection vectors. Eigenmodes are also useful to understand where and how a structure is most likely to experience buckling. After eigenvalue buckling analysis, geometrical non-linearities are taken into account and non-linear static analyses are performed. The same analysis process is followed for the two free-form case-studies. Both linear and non-linear stability analyses are carried out.
The analyses for the British Museum court roof are carried out for both the starting grid configuration and the relaxed grid, to observe the behaviour of the structure under different conditions and the actual contribution of grid optimization.



Buckling loads of symmetrically and asymmetrically loaded domes (left), buckling loads obtained by linear and non-linear analysis of domes (right)

The results from analyses of domes outline some general trends of the buckling behaviour (Fig.2). It can be observed that one of the most influencing parameters is the shape and magnitude of the imperfection. For what concerns the two free-form case studies, several observations can be made. In the first case study it can be seen that the variation of curvature directly affects the buckling behaviour, showing local instabilities in transition areas. Imperfection sensitivity is quite high also. The second case study shows imperfection sensitivity and a big difference of the load/displacement path between the structure with relaxed grid and the starting non-relaxed configuration.

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