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Suspen-domes: design and assessment of progressive collapse

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Declaration of originality

I confirm that the dissertation entitled '**SUSPEN-DOMES: DESIGN AND ASSESSMENT OF PROGRESSIVE COLLAPSE**' for the partial fulfilment of the degree of MSc in STRUCTURAL ENGINEERING has been composed by myself and has not been presented or accepted in any previous application for a degree. The work, of which this is a record, has been carried out by myself unless otherwise stated and where the work is mine, it reflects personal views and values. All quotations have been distinggueshed by quotation marks and all sources of information have been acknowledged by means of references including those of the internet.

Adam Nagy 15th September 2019.

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Abstract

In the last, nearly three decades suspen-domes have become popular solutions for covering sports halls, stadiums and venue halls particularly in China and Japan. While suspen-domes can be easily constructed and maintained, their application extends the span limits for grid dome systems. Unlike for cable domes, special construction methods are not required, still a more cost-efficient, stiffer and more robust structure is created for mid- and large-spans. This hybrid spatial structure is composed from an upper single layer dome, and a lower , concentric tensegritic system.

This project focuses on the design and collapse resistance of suspen-domes, in the first part of the work a literature review is presented as the preparation to the actual case study of preliminary design and progressive collapse analysis of the dome.

The review discusses the typical design features, the behaviour and the applicable acceptance criteria of suspen-domes. Also the aspects of progressive collapse are presented in general and specifically for suspen-domes.

A preliminary design study is carried out for a forty-meter spanning trimmed lamella suspen-dome. It has been proven that global stability is a governing design aspect, the outermost-ring stiffened suspen-dome can fail even with moderate stress utilisation ratio and deflections, if the nonlinear stability with imperfect geometry is not assessed.

The progressive collapse analyses of the work were carried out according to the strategy of limiting the extent of localised failure. In case of most space structures, including suspen-domes, the alternative load path method with notional member removal is the most viable approach. The first, beam only model (Han et al., 2015) was found efficient for locating those member configurations of notional removal, that are mostly likely causing progressive collapse. In the other hand, a combined beam & shell model was found as safer and more reliable for predicting the stability and integrity of the remainder structure. The results of the two analyses are compared and discussed. Flowcharts of the used methodologies are presented.

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In the early 1990s a novel structural system for large spans were introduced by Professor Mamoru Kawaguchi and his team. As presented in 1993 on the Symposium of the International Association for Shell and Spatial Structures, the proposed new space structure is an optimal combination of an upper single layer grid dome and a lower tensegrity system. A lightweight and stable hybrid solution was demonstrated that brings the advantages of the large span reticulated steel domes and the already existing cable dome structures of the era.

Their structural behaviour and mechanical characteristics can be relatively easily described. Significant numbers of research publications identify the excellent stability properties of such a system Due to the presence of tensegritic elements in combination with lattice dome members, specific failure modes may occur on suspen-domes and these shall be assessed in any collapse analyses.

The available research literatures separately discuss the topics of geometry optimisation, optimised initial pretension, simplified analysis, assessments of static nonlinear behaviour, stability and dynamic properties of suspen-domes.

Assessment of collapse mechanisms and more importantly, the potential of progressive collapse is a key requirement for all structures, for roofs and space structures as well. The highly statically indeterminate systems are built of lightweight slender members in complex geometric patterns, typically cover spaces crowded by people. Exposure and significance of stadium roofs are obvious when judging measures versus disproportionate failure. Unfortunately, instability related disproportionate collapse of single layer domes still occur from time to time. The existing research papers may advise the methods of collapse analysis separately for single layer dome and the cable system. A complete progressive collapse analysis study requires substantial, often excessive resources in daily engineering practice.

The aim of this dissertation is to review this novel hybrid solution, its behaviour in conjunction with the available findings of research; to summarise design options in aspects of strength and stability performance; then to carry out a preliminary design case study and arrive to the assessment of ultimate capacity and progressive collapse through a preliminary designed example.