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Experimental study of critical and post-buckling behaviour of prestressed stayed columns

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ABSTRACT

A full scale experimental investigation into the strength and behaviour of prestressed steel stayed columns in compression has been conducted. Results, including full load versus end-shortening curves, for a total of 18 test specimens are presented. Two critical modes of buckling — symmetric and antisymmetric — with interactive post-buckling are demonstrated experimentally and the imperfection sensitivity of the stayed columns is investigated. Interactive buckling is observed primarily when the individual buckling loads of the antisymmetric and symmetric modes are close or when the antisymmetric mode is critical. Analysis of the results reveals that increased prestress leads to an increased load-carrying capacity when instability occurs in the symmetric mode, but the reverse trend is found when the antisymmetric mode is critical.

1. Introduction

The load-carrying capacity of slender columns is limited by global instability. However, through the addition of cross-arms and external prestressed cable stays, buckling displacements can be inhibited and the load-carrying capacity considerably enhanced. Such systems, known as prestressed stayed columns (Fig. 1), offer efficient and lightweight structural solutions. Examples of recent applications include the temporary supports utilized during the erection phase of the main stage of the Rock in Rio III stadium in Rio de Janeiro, Brazil [1,2] and the façade system employed in Building 5 at the Chiswick Park development in West London (Fig. 2).

In a bid to improve the understanding of this type of structural system, a number of investigations have been conducted since the 1960s that have sought to evaluate the critical buckling loads [3–7], the post-buckling behaviour [8–10], the imperfection sensitivity [11–13] and assess the maximum axial strength [8,9]. Previous experimental investigations have focused on the maximum axial load-carrying capacity of stayed columns with single cross-arms [8,14] and with bipods [15], which offer two points of lateral restraint.

For stayed columns with single cross-arms, there are three possible global instability modes as shown in Fig. 3: a symmetric mode, an antisymmetric mode and an asymmetric or *interactive* mode. The latter is not an eigenmode; in theory it can only appear in the post-buckling range after a secondary instability [16]. However, in a recent finite element (FE) study of stayed columns [17], the system was seen to take this distinctive shape practically immediately after the initial instability, under certain geometric configurations. To the knowledge of the authors, experimental investigations into the antisymmetric and interactive modes of buckling in stayed columns have hitherto not been attempted. A full scale experimental investigation of the possible buckling profiles is therefore the subject of the present work; an imperfection sensitivity study of the system is also presented.

The main columns and cross-arms of the test specimens were fabricated from Grade 355 cold-formed steel circular hollow sections (CHS). Cross-section sizes were chosen to be class 1 according to EN 1993-1-1 [18] to avoid local buckling prior to yielding, which is beyond the scope of this work. The average outer diameter and wall-thickness were 42.6 mm and 3.00 mm respectively for the main column sections and 27.5 mm and 2.96 mm respectively for the cross-arm sections. The system dimensions were carefully chosen to represent practical structural proportions and to illustrate the increase in strength of slender columns with the introduction of the cable stayed system.

Material testing, including the characterization of the prestressing cables, is described in Section 2, while the description of the testing procedure and the experimental specimens of the stayed columns is presented

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