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Structural behaviour of prestressed stayed columns with single and double cross-arms using normal and high strength steel

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ABSTRACT

One solution to improve load carrying capacity of slender columns is to add prestressed cables and cross-arms as they provide additional restraints along the length. Such columns are called prestressed stayed columns (PSSC). This solution is very effective, but there are no experimental results on long columns which is a practical case for such columns. This paper presents the results of an experimental study on 18 m PSSC with single and double cross-arms along the length and using normal and high strength steel. In total, 77 tests were carried out to investigate the structural behaviour of such systems and improvements made by using high strength steel and stay systems. The results in this paper provide detailed data on the behaviour of realistic PSSC which was not available before and highlight the advantages of the using high strength steel in such systems.

1. Introduction

Nowadays, designing long span structures is a common solution by structural engineers which means using long (slender) columns. However, two important parameters should be considered: (a) slender columns are a practical solution when self-weight is not dominant and (b) depending on the design, global buckling often happens in the elastic range and using high strength steel (HSS) may not improve the load carrying capacity. These issues are known for a few decades and since then researchers are trying to find solutions to avoid them.

One solution to improve the load carrying capacity of slender columns is to add prestressed cables and cross-arms as they provide restraints which reduce the slenderness of the column. Such columns are called prestressed stayed columns (PSSC). Fig. 1 illustrates a typical PSSC used in practice.

PSSC have been investigated experimentally, numerically and analytically by researchers since 1960 [12–19], a thorough literature review being found in Serra et al. [1].

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Fig. 1 – Prestressed stayed column in stadium of Algarve, Portugal [3].

Recently, Araujo et al. [2] reported on an experimental investigation on 12 m long PSSC with low initial pretension in cables. Subsequently, Serra et al. [1] reported on an experimental investigation of 12 m long PSSC with HSS and high initial pretension in the cables. However, since PSSC are commonly used in normal and higher lengths, it is important to assess the structural behaviour of such columns. In addition, there are no experimental results on full scale PSSC with double cross-arms (Fig. 2b) with practical lengths. As mentioned before and as later reported, adding cross-arms and additional cables reduces the slenderness of the PSSC hence improving its load carrying capacity.

Unfortunately, there is no practical method for designing PSSC with double cross-arms as most of the research studies were focused on single cross-arm. A detailed review of design methods has been reported in [1] and the objective of this paper is to report an experimental investigation and structural analysis of 18 m PSSC with single (Fig. 2a) and double cross-arms (Fig. 2b) using normal (S355) and HSS (S690).

2. Test configuration

2.1. *Test specimens and their differences*

A total of 77 tests were carried out on 18 m long PSSC. Specimens were divided into seven groups and for each group one test was performed without any stayed cables, five tests were performed for 10 mm and 13 mm cable sizes, respectively.

Five groups have a single middle span cross-arm (4 arms) and 8 prestressed cables (Fig. 2a), and two groups have double span cross-arms (double 4 arms) and 12 prestressed cables (Fig. 2b). Table 1 summarises the details of the specimens. These tests were designed to investigate the effect of:

Table 1 – Summary of tested PSSC.

Column	Length (m)	Type	Column		Cross-arm			Stay		Initial pretension
			Section	Steel grade	Section	Steel grade	Length (m)	φ_s (mm)	A_s (mm^2)	T_{ini} (kN)
C05	18	Single	CHS 101.6 × 8.0	S355	CHS 101.6 × 8.0	S690	0.6	10	47	2.0
								13	89	3.5
										5.5
										7.5
										9.0
C06	18	Single	CHS 139.7 × 6.3	S355	CHS 101.6 × 8.0	S690	0.6	10	47	2.0
								13	89	3.5
										5.5
										7.5
										9.0
C07	18	Single	CHS 139.7 × 6.3	S690	CHS 101.6 × 8.0	S690	0.6	10	47	2.0
								13	89	3.5
										5.5
										7.5
										9.0
C08	18	Double	CHS 139.7 × 6.3	S355	CHS 101.6 × 8.0	S690	0.6	10	47	2.0
								13	89	3.5
										5.5
										7.5
										9.0