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Effect of axial restraint on the performance of Elliptical Hollow Section steel columns, in hydrocarbon fire

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ABSTRACT

This paper presents the findings from a novel experimental programme that examines the influence of axial restraint on the loading and buckling capacity of Elliptical Hollow Section (EHS) steel columns, when exposed to the hydrocarbon fire curve. When fire occurs in a structure, the steel columns are subject to thermal expansion, and in practice this thermal expansion is normally restrained by the cooler surrounds of the structure. Restraining this thermal expansion, subsequently introduces restraint forces, which are not present in the structural element prior to heating. This experimental programme comprised of 12 EHS column tests of two slenderness $\lambda_z = 40.1$ and $\lambda_z = 50.8$, under three different loading levels ($\alpha_L = 0.3$, 0.45 and 0.6), exposed to a hydrocarbon heating regime. Initially, six EHS columns were tested unrestrained followed by six restrained EHS column tests. The fire resistance of the restrained columns were subsequently compared with the previous unrestrained column tests, tested under the same mechanical and thermal loading conditions. This paper will provide the recorded axial displacements, temperature profiles and induced axial forces of the restrained EHS columns, comparing these findings with the unrestrained EHS columns.

1. Introduction

The Steel Hollow Section (SHS) family has seen the introduction of the Elliptical Hollow Section (EHS) in recent years. This new section introduced by the steel industry is currently manufactured by the hot finishing process, with a steel grade S355J2H and a minimum yield strength (f_y) of 355 N/mm^2 [1]. The EHS is currently available in a wide range of sizes, ranging from 120 × 60 × 3.2 mm to 500 × 250 × 16 mm. The full listing of sizes and dimensions are available in European standard EN10210-2:2006 [2]. The manufacturing process of this unique oval shape is also available in the European production standard EN 10210-1:2006 [3]. Fig. 1 illustrates the 2:1 geometry and dimension parameters of the Elliptical Hollow Section.

A research programme at the Imperial College London has made a significant contribution to the much needed design guidance, required by structural design engineers, for the Elliptical Hollow Section. Prior to this comprehensive investigation programme, there was a considerable absence of viable design knowledge available for this new hollow oval shaped section. The purpose of the main research programme at Imperial College was to develop safe and efficient design rules to aid structural design engineers in the usage of the EHS. It was recognised by Gardner and Ministro, [4] that the lack of design guidance and procedures for the use of EHS in structural design, had forced structural engineers to be over conservative in their design limits.

The investigations at Imperial College consisted of laboratory experiment testing and Finite Element Method (FEM) modelling, to aid in parametric analysis. The research programme included the section classification of the EHS by Gardner and Chan [5], and Chan and Gardner [6], this programme also consisted of tensile coupon testing, compression coupon testing, stub column tests, beam and column testing (major and minor axis bending) and beam–column tests. An additional experimental study by Eckhardt [7] of the University of Southampton investigated the minor axis bending behaviour, with subsequent analysis of these results preformed by Gardner and Ministro [8]. Gardner and Chan [9] outlined here the structural design rules for Elliptical Hollow Sections that emerged from these extensive studies, for axial compression, bending, shear and column buckling. The provision of fire resistance design guidelines is the final requirement needed to enhance this suite of design guidance.

In the early 90s, Twilt and Comité [10] developed for CIDECT, design guides based on previous studies, for the fire resistance of unfilled Structural Hollow Section (SHS) columns exposed to fire. The methods developed for calculating the fire resistance of an unfilled SHS's were based on the standard fire curve exposure ISO-834, and assumed a uniform temperature distribution across the section. These studies were based only on Circular (CHS) and

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