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Optimisation of novel elliptically-based web opening shapes of perforated steel beams

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ABSTRACT

A new study was carried out and presented herein, on the optimisation of novel elliptically-based web opening shapes which enhance the structural behaviour of the perforated beams as well as lead to economic design in terms of both manufacture and usage.

The finite element (FE) model used in the study was validated against experimental work conducted by the authors and the results of the comprehensive study are presented in this research paper. For ease of comparison, the yield patterns and deflected shapes of the perforated beams are presented at three 'characteristic' load level points. Finally, shear–moment interaction FEM curves are presented for six novel web opening shapes to allow for easy use of the empirical design formulas that have previously been proposed by the authors in a complementary research paper.

An overall study of many standard and non-standard web opening shapes, it was shown that perforated beams with vertical and inclined classic elliptical web openings (3:4 width to depth ratio) behave more effectively compared to perforated beams with conventional circular and hexagonal web openings, mainly in terms of stress distribution and local deflection. Therefore, perforated steel beams with large novel elliptically-based web openings with short critical opening length at the top and bottom tee-section as well as straight-line edges are presented for first time and examined in the current research programme.

1. Introduction

1.1. Advantages

Since the 1940s many attempts have been made by structural engineers to find new ways to reduce the cost of steel structures. Due to limitations on maximum allowable deflections, the high strength properties of structural steel cannot always be utilised to the best advantage. As a result, several new methods have been aimed at increasing the stiffness of steel members without any increase in the weight of steel required. Hence, castellated and cellular beams have been used extensively in recent times.

It is recognised that the ease of integration of services, such as hydraulic and ventilation pipes as well as electric cables, within the structural depth of the beams provides a major benefit in the construction. The effect is that the overall building height is reduced, by the decrease in the floor to ceiling height for every storey level, compared to the conventional plain webbed beam usage where the services are supported beneath the beam. Typical savings in such terms could be up to half a metre per storey level. The outcome of this is a more sustainable and economic construction method. Moreover, there have been significant improvements in the structural design of commercial multi-storey buildings in recent years, based on the development of long span composite systems. Long span beams have the advantage of flexibility of internal planning by limiting the number of columns resulting in savings in the number of foundations and in speed and cost of erection. Long span beams are more competitive in the industry, mainly when they are manufactured for car parking structures, curved roof beams or stadium cantilever roof tapered beams.

The manufacturing method [1,2] of the aforementioned perforated beams is a very important factor as it affects the cost and the structural behaviour of the final product. Many advantages are gained by using the profile cutting procedure to manufacture a perforated steel beam, but this process needs to be optimised to keep costs down. The well used profile cutting procedure for the fabrication of perforated beams is considered in this paper and the novel web opening shapes are specifically designed to improve it in terms of cost and time [3].

2. Introduction to present study

2.1. Aims

The aim of this research work is to investigate the behaviour of perforated steel beams with different novel web opening shapes

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