Flexural Behavior of Perforated Steel Beams with Multiple Web-Corrugations and Openings

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Abstract

Web perforations in corrugated web beams (CWBs) are essential in buildings for easy installation of services, etc. However, web openings lead to frequent instability and new failure modes compared to solid flat-web beams. A detailed nonlinear finite element analysis was performed on CWBs to examine their behavior under three-point loading for rectangular and triangular corrugated web profiles having hexagonal and octagonal openings. The numerical models were first verified against five documented flexural tests. Then a parametric study was performed on 16 CWB profiles having variations in dimensions, shapes of web openings and corrugation profiles. The results showed that a rectangular CWB with hexagonal openings was most efficient, having a maximum of about 24% reduced web thickness for a load-carrying capacity similar to that of tested flat-web specimens.

Keywords: Corrugated web; finite element analysis; hexagonal and octagonal openings; load-carrying capacity; steel beams; web perforations.

1 Introduction

The web openings in steel beams are essential for service lines in modern building construction, carrying ducts for air conditioners, sewage, electrical and electronics gadget connections, etc. (Figure 1, [1]). Providing sequential web openings reduces the steel quantity required for manufacturing and improves capacity through increased depth of the cellular types of the beam. Perforated steel I-beams are commonly used in buildings and have a more complex behavior than flat-web beams. In design, simplified procedures for each limit state are necessary for interpreting complex behavior due to web perforations in steel beams. This requires detailed investigations through testing and nonlinear finite element (FE) analysis.

Morkhade and Gupta [2] performed tests on seven flat-web steel beams with circular and rectangular web openings. The experimental results were later used for a detailed FE-based optimization of spacing-to-diameter (S/D) and aspect ratio of web openings. SCI P355 [3] provides a lower limit of S/D equal to 1.08, which is also a critical limit for perforated beams in BS 5950 [4]. Morkhade and Gupta concluded that the optimized range of S/D from 1.33 to 1.5 maximized the load-carrying capacity of flat-webbed beams with web perforations. The upper limit of S/D equal to a 3.0 yielded load-carrying capacity similar to that of flat-web beams without perforations [2]. Thevendran and Shanmugam 5] used an energy approach to predict the effect of web openings on the critical lateral-buckling load capacity in steel I-beams. Chung and Lawson [6] extensively analyzed steel composite beams with large rectangular and circular web openings to develop a design method in a format similar to Eurocode 4. Chung et al. [7] analytically studied steel beams with circular web openings and investigated the Vierendeel mechanism. They proposed shear-moment interaction for the perforated steel sections with

https://doi.org/10.2749/newdelhi.2023.1339