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Impact Response of Steel Beams with Large Web Openings

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Abstract

Impact loads are dynamic loads applied on their targets within a relatively short period. It occurs as a result of construction equipment accidents, mountain rocks falling on neighboring facilities, collisions of ships with marine constructions, flying debris due to explosions, floor-to- floor falling, and aircraft landings on various surfaces.

The current study aims to numerically investigate the key parameters that affect the impact response of steel beams with large web openings (SBLWOs), including the prediction of failure modes and dynamic shear and moment capacity. The finite element (FE) method was employed using ABAQUS/ Explicit to achieve this goal. Numerical models were built and then rigorously validated against two up-to-date experimental tests. FE models produced accurate predictions of the displacement-time history, impact force, and the investigated deformation patterns. The validated FE models were further used to perform a parametric study to obtain more knowledge on the key factors that affect the response of SBLWOs under impact load, which covers different impact masses, impact velocities, and impact locations in addition to the shape of the impactor and openings, types of strengthening of openings, and eccentricity of openings. It was found that ABAQUS/ explicit is an effective tool for simulating the behaviour of steel beams under the impact, provided the appropriate material properties definition.

The parametric study has emphasized that the elongated openings slightly aided in reducing the maximum displacement corresponding to considerable enhancement against local deformation compared with rectangular ones by a ratio of (4 - 6) %. Based on the parametric studies performed, higher local failure or/and web-post buckling would be obtained by applying higher mass and lower velocity. Additionally, the strengthening of SBLWOs using horizontal and vertical stiffeners together considerably improved the resistance to web-post buckling, Vierendeel mechanism, and local failure. The need for a novel strengthening configuration to resist impact load is still required. The results of the parametric study also showed that higher deformation was obtained as the impact location moved toward the supports. In addition, the wedge impactor resulted in greater local deformations than spherical and flat impactors. The results also showed that shifting the neutral axis of a web opening with an eccentricity had no major effect. The dominant failure modes of SBLWOs under impact were found to be a local failure and web-post buckling failure. Comparing the impact results with static predictions showed that the impact moment was larger by a range of (31%) to (48%) than the static moment at energy 21,500 J. This may give a preliminary indication of the dynamic increase factor that could be used to propose an equivalent static force.

Finally, the modest design guidelines adopted to design structures under impact loads, which are limited to performing dynamic analysis, should be enhanced by valuable studies to present detailed design guidelines. The current study provided comprehensive knowledge of the key parameters that affect the impact response of SBLWOs and may help in proposing a design formula to predict the impact capacity of SBLWOs.

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