Failure Characteristics of Thin-walled Flanged Composite I-Sections

Himanshu Chawla[1,†], S. B. Singh[2], Princepal Singh[3]

[1,†]Assistant Professor, Thapar Institute of Engineering and Technology, Patiala, India.

[2]Senior Professor, Birla Institute of Technology and Science, Pilani, India.

[3]Engineer, Public Works Department Buildings and Roads, Punjab, India, 147001

[1,†] himanshuchawla11@gmail.com

[2]sbsinghbits@gmail.com

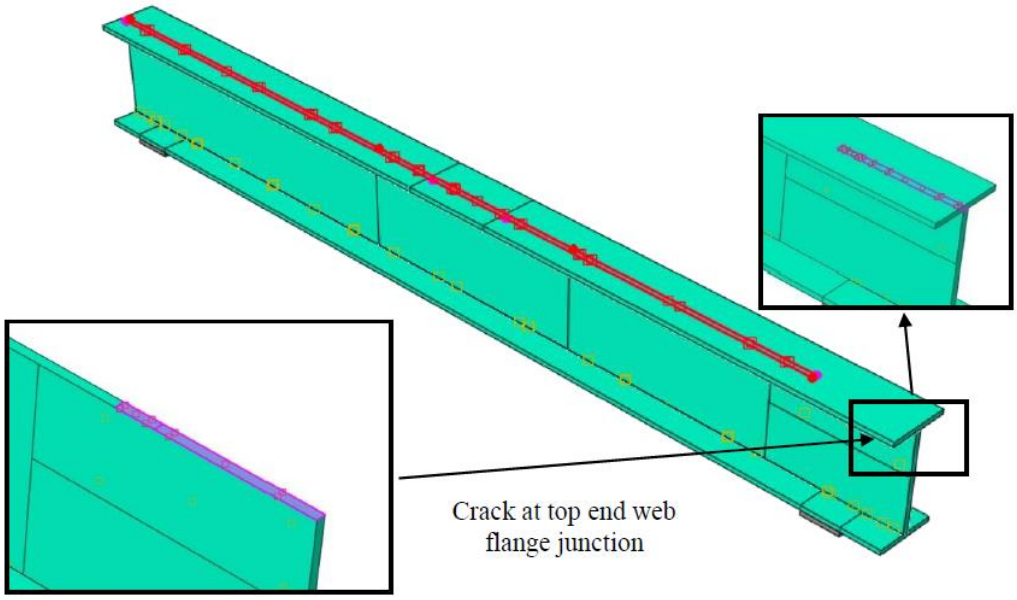
[3]prince123ahi@gmail.com

Abstract

Floor beams play a crucial role in the aerospace industry, particularly in the design and construction of aircraft. These beams are structural components that provide support, rigidity, and strength to the aircraft's fuselage and interior cabin. FRP I-section beams are made using the pultrusion process, in which fibers are pulled through resin and the heated mould of the I-section. Fibers at the web-flange junction are discontinuous, due to which failure starts at junction and leads to the premature failure of the section [1, 2]. The present study aims to identify possible techniques to mitigate the failure of web-flange junctions by addition of different stiffening elements. Various stiffening elements, such as cover plate, bearing stiffener, longitudinal stiffener and carbon layer is used. It is noted that addition of a carbon fiber layer enhances the stiffness at the web-flange junction, but the other stiffening elements marginally enhance the stiffness. On the other hand, strength is higher for the beams having bearing stiffeners. Along with the discontinuity of fibres, some cracks are also produce at the web-flange during manufacturing. Therefore, in this study, a detailed investigation is performed on the FRP beams that have cracks at compression and/or tension web-flange junction. It is noted that repairing the cracked portion with CFRP and adding bearing stiffeners at the web-flange junction can achieve the failure load of up to 80% of the beam without cracks. The failure of beams is caused by local buckling of web near the end of carbon fiber layers, which led to the delamination at the web-flange junction. Further, an extensive parametric study is performed on pultruded glass fibre reinforced polymer beams to access the flexural response of strengthened pre-cracked beams. In this study, variation in crack lengths with different Length-to-depth (L/d) ratios of beams are considered. Material constitutive relations and the Hashin damage failure criterion are used in ABAQUS tools with the help of USDFLD user-subroutine. The cracks/delamination at the web-flange junction is modelled using cohesive layer methodology as shown in Figure 1. The cohesive layer has a tendency to delaminate the flange from the web on the basis of energy release criteria. The beams having cracks at the compression web-flange junction with L/d ratio of 11 and strengthened with web stiffeners and CFRP laminates showed 40–50% higher load carrying capacity than the cracked beams, and the stiffness was equal to that of beams without cracks. In the case of beams having L/d ratio 7, 20–25% increase in load carrying capacity is observed. For a smaller L/d ratio of 3, web crushing is seen, and no major difference is noted in the load-displacement curves of beams with cracks and strengthened with carbon fiber layers. The outcomes of this study will help the engineers repair the I-sections with delamination at the web-flange junction and modeling of delamination at web-flange junction using a cohesive layer.

Keywords: Cohesive layer; Delamination; FRP beams; Hashin Damage criterion .

†Corresponding Author : Himanshu Chawla, Tel: +91-8233114245, E-mail: himanshuchawla11@gmail.com



(a) Cracked cohesive layer in compression end.

(b) Cracked cohesive layer at compression end in x y plane

Figure 1 Crack at compression end of beam.

References

[1] S. B. Singh, H Chawla. "Stability and failure characterization of fiber reinforced pultruded beams with different stiffening elements, Part I: Experimental investigation" Thin-Walled Structures, vol. 141, pp. 593-605, 2019.

[2] L.C. Bank, J. Yin, "Progressive Failure of the Web-Flange Junction in Post-buckled Pultruded I-Beams" Journal of Composite Construction, vol. 3, no. 1, pp. 177-184, 1997.

†Corresponding Author : Himanshu Chawla, Tel: +91-8233114245, E-mail: himanshuchawla11@gmail.com