ABSTRACT

In the design and construction of steel bridges, current codes and standards focus primarily on drilled and subpunched methods for hole cutting. Guidance for thermal cutting technologies in fatigue applications is limited and thus, drilling and subpunching followed by reaming are the only two methods explicitly listed as acceptable in American bridge codes and standards for primary load-carrying members subject to cyclic loading. Plasma arc cutting has demonstrated production and economic benefits over drilling holes, but limited existing research and industry concerns around the effect of thermal cutting processes on ductility behavior in cold environments have prevented their acceptance into bridge standards. There is industry interest in using plasma arc cut holes in primary members in bridge applications, especially because plasma cutting is currently approved and used for edges and secondary members. Thus, this experimental study utilizes large-scale axial testing to evaluate the ductility performance of holes using plasma arc cutting at both ambient and cold temperatures. A total of twenty-three plates were tested: nineteen axial test plates were fabricated using plasma arc cutting and a smaller subset of four drilled test plates were used to establish baseline data. Test plates varied by plate thickness, fabricator, and test temperature. Instrumentation included linear position sensors to measure displacement and elongation, thermocouples to ensure test temperature accuracy, and strain gages to observe the test setup behavior. Data between plasma cut and drilled holes were compared through graphical representation as well as calculated load, displacement, and fracture ratios. The experimental study included hole quality analysis via a metallurgical study to compare the width of the heat affected zone and material hardness across varying fabricators and technology used. The analytical study utilized finite element analysis to explore the effect of the arc termination notch location angle around the hole. Experimental results revealed the ductility of plasma cut holes perform comparably to drilled holes and dispute the concern that the heat affected zone is directly responsible for brittle behavior at very low temperatures. The results of the experimental study demonstrate that plasma arc cut holes are acceptable for ductility applications, and the analytical study established a notch location tolerance. It is proposed that plasma arc holes using CNC programming with a notch location angle of 90° ± 30° be prescribed for future research and adoption into the codes and standards.