Project Summary

Texas Department of Transportation

0-4624: Performance and Effects of Punched Holes and Cold Bending on Steel Bridge Fabrication

Background

The first part of this project was a study of the performance of punched holes in tension elements. Earlier studies had shown that members with punched holes had a reduced tensile and fatigue strength relative to members with drilled holes. This reduced strength resulted in the requirement that punched holes in load-carrying members be made undersize and reamed to full size. Non-load-carrying members could be punched full size, and typically cross frames between girders used punched holes. The AASHTO LRFD specifications designated the cross frames in curved girder bridges as load-carrying members, which meant full-size punched holes could no longer be used. The project was to determine the design requirements that should be used to size tension members in cross frames and other secondary members.

The second part of this project involved an investigation of the effects of bending on the ductility and fracture toughness of flange plate. The bending of flange plate is necessary for certain details used in the fabrication of steel highway girders such as dapped end details. Heat is sometimes applied to assist in the bending operation, particularly to help reduce the forces required to bend the plate. Bridge fabricators have, on occasion, experienced the formation of cracks in the flange plate during the bending operation, particularly when heat is applied.

What the Researchers Did

For the punched hole portion of this project, the study investigated the effect of plate thickness, strength of the plate, hole size, punch-to-die clearance, and temperature upon the static and fatigue strength of members with punched holes. The behavior of plates with slotted holes was also studied. The study was carried out by side-by-side testing of specimens with holes punched and drilled.

For the bending portion of this project, the study investigated the cracking problem using both experimental and analytical techniques. The experimental study involved the use of small tensile specimens loaded to different strain levels under varying temperature conditions. A finite element analysis of the heating process was then used to extend the results of the experimental study.

Plates with punched holes had a reduced strength and an even larger reduction in ductility. The reduction in strength was the largest in lower-strength plates. Hole punching provides a rapid and economical means of making holes and should be allowed without reservations for secondary members, provided the recommended reduction in tension strength is used when designing these members.

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What They Found

For the heat-assisted bending portion of the project, the results show that strain levels above 10 percent generally reduced the ductility and fracture toughness of the plate. Additionally, it was found that application of heat during the bending process significantly reduced ductility and fracture toughness of the plate and was the major contributor to the formation of cracks. It is noted, however, that the location where bends are detailed usually occurs in non-critical areas of the finished bridge girder. For example, the dapped girder detail occurs at the end of the girder where bending stresses are minimal.

What This Means

The design and fabrication recommendations based upon the results of the research are the following:

- Full-punched holes can be used for cross frames, lateral systems, and connection plates but not in main load carrying members due to the reduction in ductility. Punched holes in main members can be sub-punched and reamed full size, which is presently allowed in the specification.
- The tensile and block shear strength of members with punched holes should be reduced by multiplying the design strength by 0.90.
- The fatigue strength category of open holes, holes without a pretensioned high-strength bolt installed, is Category D. This is for all holes regardless of the method of hole making.
- The fatigue strength of connections with punched holes and pretensioned high-strength bolts is comparable to that of connections with drilled holes. The former should be classified as Category B fatigue details.
- The 1/16 in. increase in hole size used when calculating the net section of a member in tension is not necessary and should be eliminated from the specification requirement. The hole size increase does not compensate for the reduction in strength from punching. The reduction from punched holes is larger and is included in the 0.90 strength reduction factor.
- Limits on the size of hole punched and limitations on hole size relative to plate thickness are not necessary, nor are limits on the punch-to-die clearance.
- Recommended minimum bend radii by plate thickness are given in Table 1 below.
- Use of heat during the bending process is discouraged. Hot-bending plate can result in the formation of cracks. If heat-assisted bending is used, the plate temperature must be limited to a maximum of 1,200ºF. The bend radius must conform to the limits given in Table 1. The heating must be uniform through the thickness of the plate prior to application of the bending force. The bending force must be applied at a rate slow enough to minimize severe local distortion in the plate and prevent cracking.

Plate Thickness (inches)	Minimum Bend Radius* (inches)
1/2	2-1/2
1	5
1-1/2	7-1/2
2	10
2-1/2	12-1/2
3	15

Table 1

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