

# The Effect of Burrs on the Shear Capacity of Bearing Connections

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## ABSTRACT

Research was conducted to assess the effect of burrs on the shear capacity of bolted connections. This paper describes results relevant to the performance of bearing connections. Forty-five specimens were tested with burr heights ranging from 0 to 0.176 inches. Results show that the presence of burrs in bearing connections does not significantly reduce the shear capacity of the connection.

## INTRODUCTION

In Section 3(b) of the *Specification for Structural Joints Using ASTM A325 or A490 Bolts* (Research, 1988), it is required that burrs be removed which prevent solid seating of connected parts in the snug tight condition. In the commentary to this section, research is cited which demonstrates that the slip resistance of joints is unchanged or slightly improved by the presence of burrs. However, the requirement is repeated that burrs be removed which prevent solid seating in the snug tight condition. Section 3(b) of the *Specification* has been used as justification for requiring grinding around every bolt hole in a structure.

Research was conducted to determine if the presence of burrs extending above faying surfaces in bolted connections adversely affects load-carrying capacity of these connections. A total of 45 bearing connections were tested, with bolts loaded in double shear. All specimens were constructed with  $\frac{3}{4}$ -in. diameter ASTM A325 bolts and A572 Grade 50 steel plate. Burr heights ranged from 0 to 0.176 inches. Performance of specimens with burrs is evaluated by direct comparison to specimens without burrs and by comparison to other research results.

## PREVIOUS WORK

The shear capacity for high strength bolts specified by the American Institute of Steel Construction (AISC) (American, 1986) is based largely on the work of Wallaert and Fisher

(1965) and Rumpf and Fisher (1963). These references form the basis for design recommendations in *Guide to Design Criteria for Bolted and Riveted Joints* (Kulak et al., 1987) (subsequently referred to as the *Guide*) which, in turn, forms the basis for the AISC criteria. Extensive research has also been conducted by Chesson, Faustino, and Munse (1965).

Wallaert and Fisher (1965) report the shear strength of A325 bolts to be approximately 80 ksi and the ultimate tensile strength to be approximately 120 ksi. This same 120 ksi ultimate tensile strength is the minimum ultimate tensile strength permitted in ASTM A325-89 for bolts 1 inch in diameter or less. In the *Guide* it is shown that the shear strength of a high-strength bolt is equal to slightly more than 60 percent of the ultimate tensile strength of that bolt. Sixty percent of 120 ksi is 72 ksi, which is the value specified by AISC for the nominal strength of A325 bolts with threads excluded from the shear plane.

Since the shear strength of a high-strength bolt is slightly more than 60 percent of the ultimate tensile strength of the bolt, and the ultimate tensile strength is generally greater than the 120 ksi minimum (Kulak et al., 1987), it is expected that the AISC nominal strength will form a lower bound to experimental data. To demonstrate that the data reported here are consistent with previous data, reported strengths must consistently exceed the AISC nominal strength of 72 ksi and scatter around the 80 ksi strength reported by Wallaert and Fisher.

Chesson, Faustino, and Munse (1965), and Sterling and Fisher (1966) studied the effect of grip size on bolt shear capacity. Both of these studies conclude that increasing the grip causes an increase in bolt shear strength, but Sterling and Fisher state that the increase is not of major consequence. In both studies it is hypothesized that the increase in capacity is the result of increased bending in the bolt which leads to larger projected area in the shear plane. The current tests are also expected to increase grip size and bending in the bolt, but the conditions are not exactly the same as the referenced studies. In the current tests any increase in grip size will be the result of gaps between plates so that bearing on bolts will not be continuous.

The results of tests more similar to the current work have been reported by Yura, Hansen, and Frank (1982). In these tests, undeveloped fillers were placed between main plates and splice plates. Bolts were fully tensioned and slip coeffi-

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cients as well as ultimate shear strengths were reported. Specimens with fillers  $\frac{1}{4}$ -in. thick achieved 98.8 percent of the shear capacity achieved by specimens with no fillers. Capacity dropped to approximately 87 percent when  $\frac{3}{4}$ -in. fillers were used. Since burrs in the present tests are well under  $\frac{1}{4}$ -in. in height, the work of Yura, Hansen, and Frank suggests that burrs are not detrimental.

### SPECIMEN PREPARATION

All specimens were constructed from A572 Grade 50 steel plate. A photograph of a typical specimen is shown in Figure 1 and a drawing is provided in Figure 2. Specimens were constructed to match those tested by Wallaert and Fisher (1965). Individual plates comprising the specimen were flame cut from a much larger plate by a local steel fabricator. Plates were trucked to the testing laboratory for cleaning, punching, and bolting.

Cleaning involved chipping slag away from the cut edges of the plate. This slag sometimes extended onto the surface of the plate and could have interfered with contact between faying surfaces. Care was taken not to damage the surface of the plates with the chipping hammer.

Once the edges of the plates had been cleaned, hole locations were marked and the plates were carried to a drill press. The pair of holes seen at the top of the specimen in Figures 1 and 2 were formed by drilling. These holes were not the test holes and burrs resulting from the drilling operation were removed by grinding. The single hole at the bottom of the specimen was formed by first drilling through approximately half the plate thickness and then punching the remainder of the way through the plate.

Punching was carried out in a universal test machine outfitted with a  $\frac{13}{16}$ -in. punch and a  $\frac{7}{8}$ -in. die. It was necessary to complete the holes with a punch, instead of drilling completely through the plate, to form desired burr sizes. The hole was not formed completely by punching because it is not

possible to punch a  $\frac{13}{16}$ -in. hole in a 1-inch thick grade 50 steel plate.

Burr size was controlled by the condition of the cutting edge on the die. In the as-received condition, the die produced thin, irregular shaped burrs with maximum heights ranging from  $\frac{1}{32}$ - to  $\frac{1}{16}$ -in. Larger burrs were produced by punching holes through a die with a beveled cutting edge. A  $\frac{1}{16}$ -in.,  $45^\circ$  bevel cut around the inside diameter of the die caused burrs approximately  $\frac{1}{16}$ -in. in height to form completely around the hole. A  $\frac{1}{8}$ -in.,  $30^\circ$  bevel produced burrs slightly larger than  $\frac{1}{8}$ -in.

Plates for control specimens were taken from the group of plates punched with the die in the as-received condition. For the control specimens, burrs were removed by grinding. To the extent possible, grinding was restricted to the burr. An effort was made to avoid damaging or modifying the plate surface away from the hole.

Specimens were cleaned by wiping with a dry rag. No attempt was made to completely remove cutting oil from specimen surfaces. Since these plates would be used in bearing connections, any oil present would have the desirable effect of reducing friction between faying surfaces.

The final step before testing involved measuring burr heights. Burr heights were measured using a dial indicator as shown in Figure 3. The plate shown in Figure 3 is not of the style used in the bearing tests and is shown only for illustrative purposes. The maximum burr height was located by moving the dial indicator around the hole. When the maximum height was determined, this value was recorded and burr heights were measured and recorded for positions  $90^\circ$ ,  $180^\circ$ , and  $270^\circ$  from the maximum burr. Burr heights for holes punched through beveled die were reasonably consistent in terms of size and shape around the hole; there was no tendency to have a large burr on one side of the hole and no burr on the other.

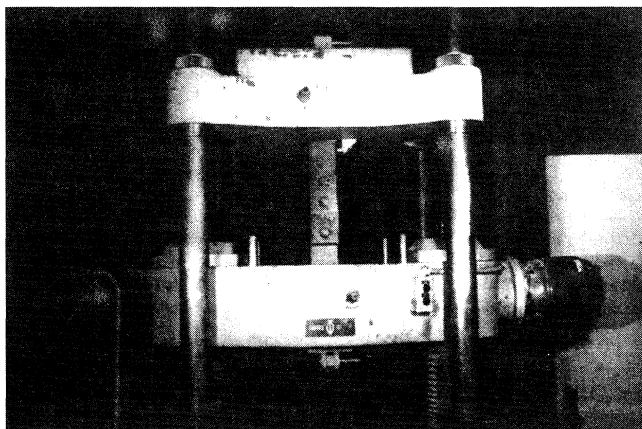


Fig. 1. Photograph of bearing connection specimen.

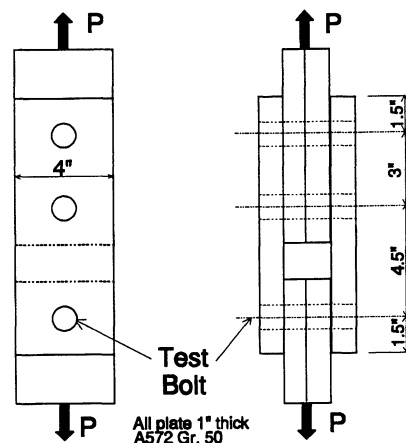


Fig. 2. Drawing of bearing connection specimen.

## TEST PROCEDURE

The two top plates in Figures 1 and 2 were clamped into the upper crosshead with their bolt holes aligned. The two bottom plates were dropped into the lower crosshead with their burrs facing out. The two plates at midheight were loosely bolted to the two upper plates. To prevent burr orientation on the midheight plates from biasing the data, in half the tests the burrs on these plates faced in toward the center of the specimen and in half the tests the burrs faced out. When the midheight plates had been attached to the top plates, the bottom crosshead was raised or lowered until the test bolt could be inserted into the single hole through the midheight and bottom plates. All nuts were tightened by hand. The bottom plates were then centered in the lower grip and clamped into the crosshead.

To quantify the extent to which the burrs forced the connected plates apart, the grip in the vicinity of the test bolt was measured with a dial caliper. The average of two measurements made on opposite sides of the bolt for each specimen is plotted versus burr height in Figure 4. The burr height plotted is the average of the maximum burr height on each of the four connected plates. As expected, the grip increases as burr height increases. The separation of faying surfaces produced by the burrs can be seen in Figure 5 for a specimen with an average maximum burr height of approximately  $\frac{1}{8}$ -in.

When the specimen was set in the grips, load was continuously applied to failure. Failure was always defined as the shearing off of the single test bolt. Some ovaling did occur in the single bolt hole, but never enough to be regarded as a bearing failure. At the conclusion of the test, the load at failure was recorded, the midheight and lower plates were removed and replaced with new plates, and the process was repeated.

## RESULTS

Results of the tests are plotted in Figure 6. Shear stresses are calculated assuming both shear planes are in the unthreaded

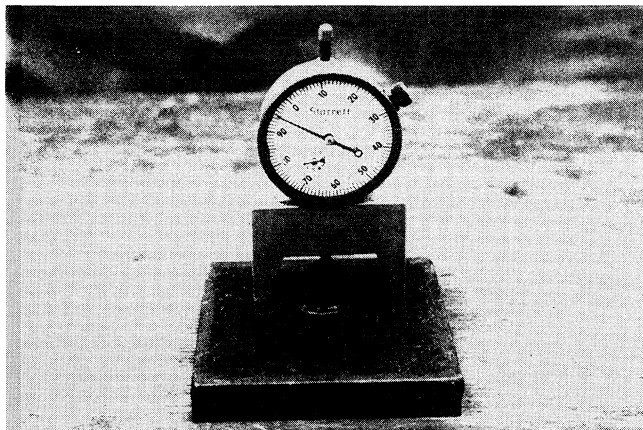


Fig. 3. Measurement of burr height.

portion of the bolt. This assumption was correct for all but a few of the specimens with the largest burrs. In cases where the grip exceeded  $4\frac{1}{2}$  inches, the inside surface of one of the outer plates fell on the threaded portion of the bolt. However, assuming that both shear planes are fully on the unthreaded shank results in a conservative calculated failure stress.

Also shown in Figure 6 are a line representing the AISC specified nominal shear strength, a line representing the shear strength reported in Wallaert and Fisher (1965), a linear regression line fit to the data, and the 99 percent confidence limits for the regression. It can be seen that as burr size increases there is a slight decrease in shear strength. However, it can also be seen that only one data point falls below the AISC specified nominal strength of 72 ksi and the mean strength for all specimens with burr sizes larger than  $\frac{1}{8}$ -in. is above 80 ksi.

## SUMMARY AND CONCLUSIONS

To produce burrs as consistently large as the ones used in these tests, it was necessary to severely damage the die and to punch the holes very slowly in a universal test machine. To avoid compressing these large burrs prior to tests, nuts were only hand tightened. Under these conditions, there were many cases in which the face of the nut on the test bolt could not be brought flush with the end of the bolt. In a fabrication shop, if hole-punching equipment is properly maintained and operated, burrs comparable to the largest burrs used in these tests should not develop. During erection, all bolts should be tightened at least "by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench" (Research, 1988), causing compression of the burrs and reduction in the grip.

Even under the extreme conditions tested, increasing burr size is accompanied by only a minor decrease in shear strength. At the largest burr sizes, average strength matches strength reported in the literature and exceeds the AISC

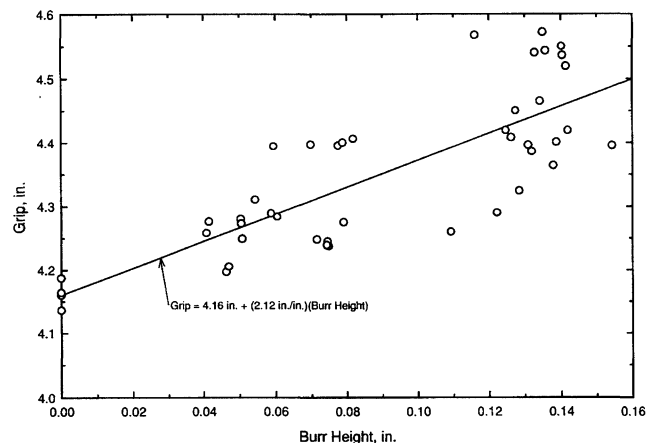


Fig. 4. Grip versus burr height.

nominal strength. Based on these test results, it is concluded that required strength can be achieved in bearing connections without removing burrs from around bolt holes.

The research reported here was not undertaken to promote or excuse sloppy workmanship. Extreme conditions were tested to preclude arguments over how large a burr must be before it is too large or how tight is snug tight. Certainly, if bolts are properly sized and nuts cannot be brought flush with the ends of the bolts, corrective action is required. Just as certainly, this research has demonstrated that it is not necessary to remove burrs from around every bolt hole to achieve specification shear strengths.

### ACKNOWLEDGMENTS

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Fig. 5. Separation of faying surfaces.

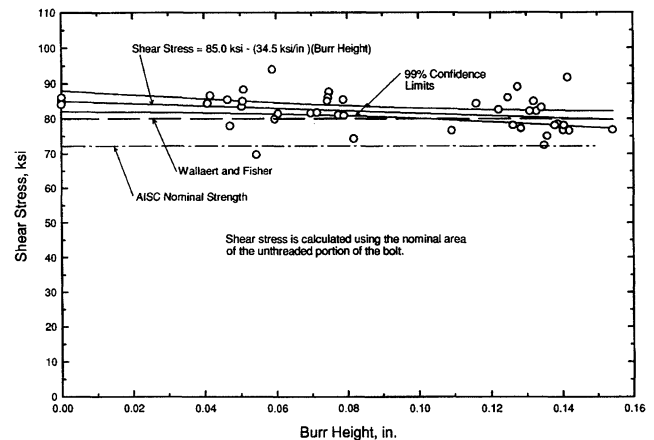


Fig. 6. Ultimate shear stress versus burr height.