Effect of Burrs on Bolted Friction Connections

D. POLYZOIS and J. A. YURA

Burrs develop at the edge of drilled or punched holes during the fabrication process. As shown in Fig. 1, they are usually quite small. But, depending on the speed with which the bolt hole is formed and the condition of the drills or punching equipment, burrs may be large enough to prevent the solid seating of connected parts, as required by the present Research Council on Structural Connections (RCSC) *Specification for Structural Joints Using A325 or A490 Bolts,*[1] hereafter referred to as the RCSC Specification.

Since it is not clear in the specification what size burr will prevent contact within the faying surface, fabricators go through the expense of removing all burrs prior to assembly to satisfy this provision of the specification. Although a considerable amount of research has been directed towards evaluating the static shear capacity of joints with solid seating of the connected parts, there are no data that address the slip resistance of joints when the plates are not in solid contact because of burrs at the edges of the holes.

This paper deals with the results of an experimental program carried out at The University of Texas-Austin to determine the effect of burrs on the slip performance of both paint-free and painted connections, and also to examine the effect of burrs on the clamping force produced by the turn-of-nut installation.

The test variables considered in this investigation were limited to the thickness of the steel plates used, the grade of steel and the orientation of the burrs in the joint. To this end, two thicknesses of steel were chosen, namely, 3/8 in. and 3/4 in., and two grades of steel, A36 and A572 Gr. 50.

The fabrication process of punching holes resulted in the development of burrs on only one side of the steel plate elements. Thus, during assembly of the individual elements at the connections there were three possible burr orientations of any one plate element. One such orientation was *burrs against burrs,* where the side of a plate element with burrs was in direct contact with the side of another plate element which also had burrs. A second orientation was *burrs against plate* where the side of a plate element with burrs was in contact with the side of a plate element without burrs. In some cases, the contact surfaces were entirely free of burrs (*plate against plate*). In this case, the fabricator had removed the burrs with a grinder.

The size of the burrs varied from plate to plate as well as around the circumference of each hole. Usually, burrs peaked at one point and tapered around the hole, ranging in size from zero to a maximum of 1/8 in., and, in most cases, covering less than half of the hole edge. The objective of the research study was not to relate a specific size of burrs to slip connection performance, but rather to determine how the presence/absence of burrs effects this slip connection performance.

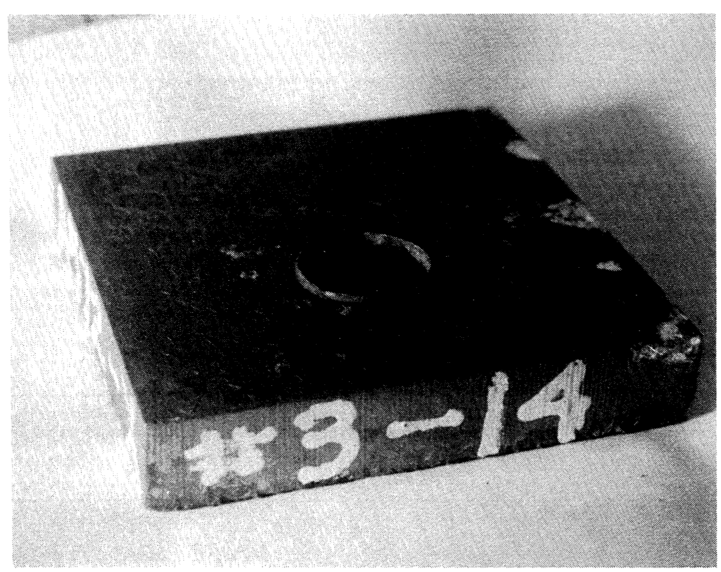

Fig. 1. Typical plate specimen with burrs

D. Polyzois is Assistant Professor of Civil Engineering, The University of Texas, Austin, Texas.

J. A. Yura is Professor of Civil Engineering, The University of Texas, Austin, Texas.

PART A: EFFECT OF BURRS ON SLIP CONNECTION PERFORMANCE

The test procedure used in this investigation was developed at The University of Texas for testing shear connections with painted contact surfaces.[2] This setup required identical plates with the same hole pattern to be arranged in a symmetric fashion, as shown in Fig. 2, and the shear load to be applied directly to the specimen. This test setup allowed the preclamping force to be applied by a high-strength steel rod, 7/8-in. dia., and held constant at the desired value of 39 kips throughout the testing.

To better understand what happened to the hole burrs under the pretension load, the bolt in selected specimens was pretightened in the connection to 25, 50, 75 and 100% of the required preclamping force, then loosened and removed with the resulting condition of the hole burrs documented. Because of the localized nature of the burrs, it was possible in some cases that burr contact with the adjacent surface was missed altogether. In these instances, the burrs fell into the hole of the adjacent plate. When these plates were clamped, no change in the size of the burrs was observed. Instead, the burrs filled the gap between the bolt and the edge of the hole, placing the plate into almost direct contact with the bolt.

If, on the other hand, there was a direct contact between the burrs and the adjacent plate, flattening of the burrs began almost immediately upon application of the clamping force, with most of the change in the burr size occurring at or below 25% of the required preclamping force. The gap remaining between adjacent plates after complete tightening to 39 kips was measured by a feeler gage and found to vary between 0.002 and 0.012 in.[4] An examination of the contact surfaces upon removal of the clamping force, in this case, revealed a substantial interlocking of the plates had taken place.

A total of 51 specimens were tested. Eleven of these tests involved specimens with *burrs against burrs*; 18 of the tests involved specimens with *burrs against plate,* including five totally painted plates. The remaining 22 specimens involved plates with no burrs, 10 of which were painted. Painting of the specimens was done with a spray gun using a red oxide primer (50% solids). The dry paint thickness ranged from 1.4 mils to 4.3 mils with an average of 2.6 mils.

Two of the specimens with no burrs consisted of plates supplied by the fabricator without holes. Holes were subsequently drilled at the laboratory to obtain plate elements with no burrs and avoid the alteration of the surface which usually results from removal of punched hole burrs.

The actual testing involved the measuring of the relative movement between the middle plate(s), shown in Fig. 2, and the base of the test specimen at various stages of loading. The results were plotted automatically to produce a load-deflection curve characteristic of the particular connection tested. The slip load determined from the load-deflection plots consisted either of:

a. the maximum load before the plates went into bearing with the bolt, or
b. the load at which a sudden increase in deflection took place.

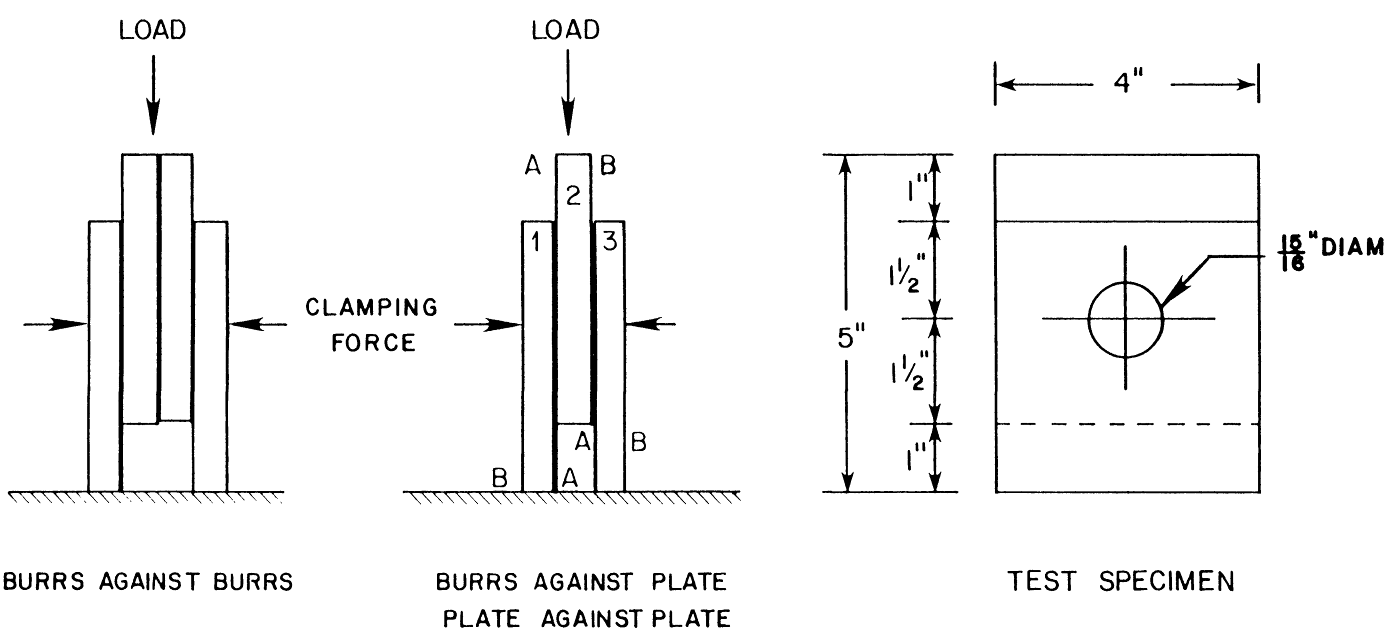

Fig. 2. Arrangement of plate elements for testing

The experimental slip coefficient k_s was then determined from the following expression:

$$k_s = \frac{\text{slip load}}{\text{clamping force} \times \text{number of slip planes}}$$

A graphical representation of the experimental slip coefficients is given in Fig. 3.

These results indicate:

- For plates with mill scale surface, consistently higher slip coefficients were obtained in connection with burrs than in connections without burrs. The average slip coefficient for plates with burrs ranged from 0.29 to 0.46 with an overall average of 0.38, whereas the average slip coefficient for plates with no burrs was 0.31.
- The slip coefficients for two specimens whose holes were drilled at the laboratory were 0.34 for the 3/8-in. plates and 0.27 for the 3/4-in. plates. The corresponding average slip coefficients for plates whose burrs had been removed by the fabricator were 0.30 and 0.32, respectively.
- While the presence of burrs improved the slip performance of the connections with mill scale, there was no significant difference between painted plates with burrs and painted plates without burrs (average slip coefficients 0.15 and 0.16, respectively).

PART B: EFFECT OF BURRS ON THE CLAMPING FORCE

To examine the effect of the burrs on the clamping force produced by turn-of-nut installation, five additional tests were conducted. Two tests were carried out with the punched hole burrs of both plates in contact with each other, Tests 1A and 2A; two tests were carried out with the burrs of one plate against a plate whose burrs had been removed, Tests 1B and 2B; and one test was conducted with plates without burrs, Test 1C.

The testing procedure for evaluating the load-nut rotation relationship involved the tightening of the bolt using an electric impact wrench. Each nut was tightened in one-eighth of a turn intervals and the clamping force obtained through a load cell was recorded.

The results are shown graphically in Fig. 4. The results indicated:

- Plates without burrs required approximately 5/16 of a turn to reach the snug position, assumed to be 10 kips of clamping force, whereas plates with burrs required twice as much, approximately 5/8 of a turn.
- Plates with burrs required approximately 1/2 of a turn beyond the snug position to reach the required minimum pretension load of 39 kips, while plates without burrs required 1/4 of a turn. The present RCSC Specification[1] requires 1/3 of a turn from the snug position to achieve the specified bolt tension.

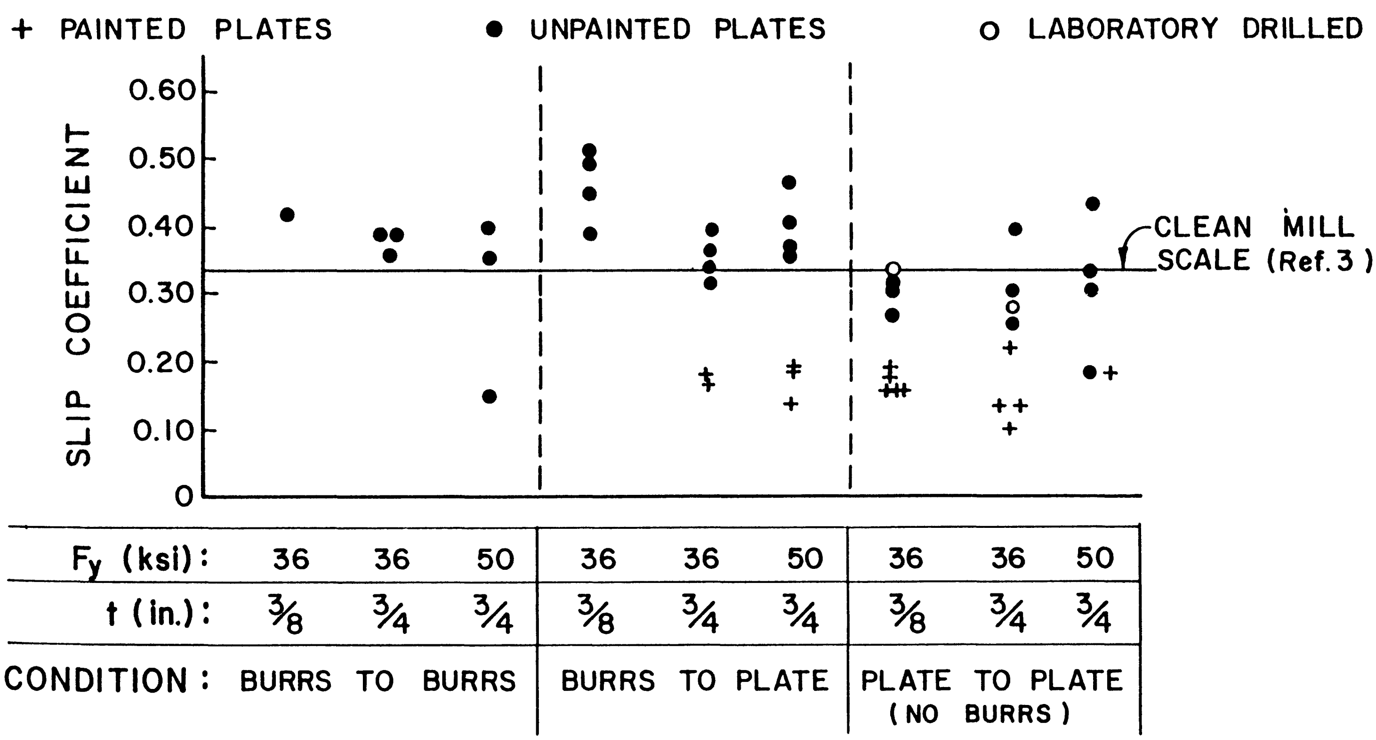

Fig. 3. Summary of results: slip coefficients for paint-free and painted plates with and without burrs

CONCLUSIONS

Present design specifications require all faying surfaces in structural joints utilizing high-strength bolts be free of burrs and other foreign material that prevent full contact between the connected parts. The experimental results showed the presence of burrs improved the slip performance of paint-free connections. They also showed the gap formed as a result of the presence of burrs in the connection did not effect the slip performance. It was, however, important that the preclamping force was maintained at the desired value. Separate tests conducted to determine the effect of burrs on the clamping force showed that the rotation of the nut required to reach the minimum specified tension in the plates with burrs was twice that required for plates without burrs. No data were collected to determine the effect of burrs on the clamping forces developed using other permissable types of tightening procedures.

Although the presence of burrs improved the slip performance of paint-free connections, there was no noticeable difference in the performance of painted connections.

Based on the results of the present experimental program, it is recommended:

a) Clause 3b of the RCSC Specification,[1] governing the surface conditions of joints, be changed by removing the condition that ". . . all joint surfaces, . . . be free of burrs, . . .", and

b) the last column in Table 4 of the RCSC Specification,[1] governing the number of turns required to reach the specified bolt tension, when both faces of the bolted parts are sloped not more than 1:20 from normal to bolt axis, be used when burrs are present.

ACKNOWLEDGMENTS

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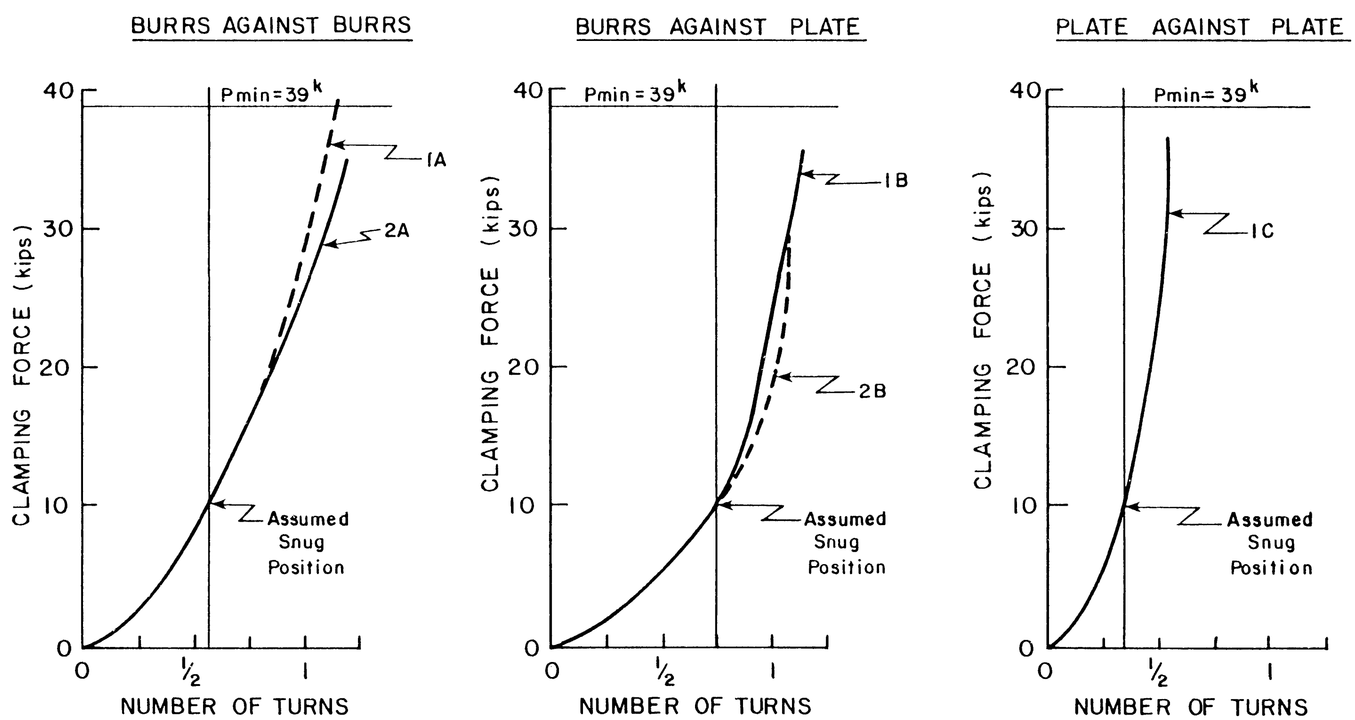

Fig. 4. Load-nut rotation relationship