

Improvement of Fatigue Strength of Steel Girders with Tapered Partial-Length Welded Cover Plates

Ahmed F. Hassan and Mark D. Bowman, *Purdue University*

The fatigue strength of beams with tapered cover plate ends, which were repaired with one of three methods, was investigated experimentally. Most of the test specimens were precracked before the cover plate ends were repaired. Three repair methods were investigated: a friction-type bolted splice plate connection; air-hammer peening; and a hybrid combination of the previous two, known as partial bolted splice. Although specimens repaired with the bolted splice plate connection achieved Category B design life after repair, the splice plates did not prevent subsequent crack growth. Also, splice plate thickness was found to have a large influence on crack growth rate. Air-hammer peening was found to be effective in increasing the fatigue life of noncracked cover plate ends and details with small initial cracks. The partial bolted splice repair method was found to significantly improve the fatigue strength of precracked details, although it was not effective in preventing subsequent crack growth.

Cover plates have been widely used to increase the flexural capacity of steel bridge girders at high moment locations. Although cover plates could be riveted, bolted, or welded to the beam member, welding has been widely used in the more recent past because of fabrication simplicity. Welded cover plate ends are known to have a low fatigue resistance and are

classified in the AASHTO specifications (1) under Categories E and E'.

A particular detail that has been utilized in many of the highway bridges in Indiana, as well as in many other states, involves a partial-length cover plate with a tapered end that is welded to the beam flanges. This paper discusses an experimental evaluation of the fatigue strength of tapered cover plate details repaired using one of three techniques: a friction-type bolted splice plate connection, air-hammer peening, and a combination of the previous two known as a partial bolted splice connection.

EXPERIMENTAL PROGRAM

The following sections discuss briefly the design variables, fabrication, experimental procedures, and repair methods used in this study. A more detailed discussion can be found elsewhere (2).

Design Variables

Thirty-three W14 \times 30 beam specimens were cyclically tested using constant-amplitude load control. A single 245-kN (55-kip) actuator was used in conjunction with

a spreader beam to apply a pair of loads to the top of the beam. The loads were 610 mm (2 ft) apart and were applied in the middle of the 4.88-m (16-ft) span, 457 mm (18 in.) from the cover plate ends.

The beam configuration and specimen dimensions are shown in Figure 1a. Tapered cover plates 1.52 m (60 in.) long and 13 mm (0.5 in.) thick were positioned in the center of the beams and welded to both beam flanges. The welded, tapered cover plates investigated had two different widths, as shown in Figure 1b: the narrow cover plate (N) was 140 mm (5.5 in.) wide, and the wide cover plate (W) was 203 mm (8 in.) wide. The cover plate width at the tapered end was 51 mm (2 in.) for all cases. Three different cover plate end-weld conditions were used, as shown in Figure 1c: no end-weld (N), return end-weld (R), and full end-weld (F). Individual test specimens are identified by using a code that is composed of two letters and a number: the first letter refers to cover plate width (N,W); the second letter refers to end-weld detail (N,R,F); and the number refers to the test number for a given detail.

Three repair methods were investigated: a friction-type bolted splice plate connection, air-hammer peening of the weld toes at the cover plate ends, and a partial bolted splice plate connection. Two splice plate thick-

nesses were investigated for the bolted splice connection: 8 mm ($5/16$ in.) and 11 mm ($7/16$ in.). Only splice plates 11 mm ($7/16$ in.) thick were used for the partial bolted splice connection.

Fabrication

All test beams and plates were fabricated from ASTM A36 steel. Eleven W14 \times 30 beams 15.55 m (51 ft) long were cut to the required length of 5.03 m (16 ft 6 in.) to obtain the 33 test specimens. Ten of the eleven beams 15.55 m (51 ft) long were obtained from the same heat of steel.

Tack welds were used to hold the cover plates in position on the beam flanges. The cover plates were then manually welded to the beam flanges using the Gas Shielded Flux Cored Arc Welding Process. Flux core wires, E70T-1, 2 mm ($5/64$ in.) in diameter were used as electrodes to obtain the required 8 mm ($5/16$ in.) weld size.

Experimental Procedure

The test beams were first cycled until a visible crack was detected through either visual inspection with a 10 \times magnifying glass or ultrasonic detection. The precracking was achieved by subjecting the test beams to sinusoidal load cycles, with an R-ratio of 0.05, that produced a stress range of 138 MPa (20.0 ksi) in the bare beam section immediately adjacent to the cover plate end. When cracks were detected at only one of the two beam ends, a temporary splice plate connection, consisting of one plate 610 \times 152 \times 25 mm (24 \times 6 \times 1 in.) and two plates 610 \times 51 \times 25 mm (24 \times 2 \times 1 in.), was attached to the cracked end using eight heavy-duty C-clamps to prevent further crack growth. After fatigue cracks developed at both ends of the beam, the two cover plate ends were repaired. The loading was then resumed to evaluate the effectiveness of the repair.

Repair Methods

Bolted Splice Repair

The bolted splice repair connection, shown in Figure 2a, was designed to compensate for the cracked flange by assuming that the tension flange was completely severed. Using this assumption, a splice plate thickness of 8 mm ($5/16$ in.) was selected so that the maximum stress did not exceed 138 MPa (20.0 ksi) in the beam at the cover plate end. Because the splice plates needed to be quite long to extend beyond the taper, it was believed

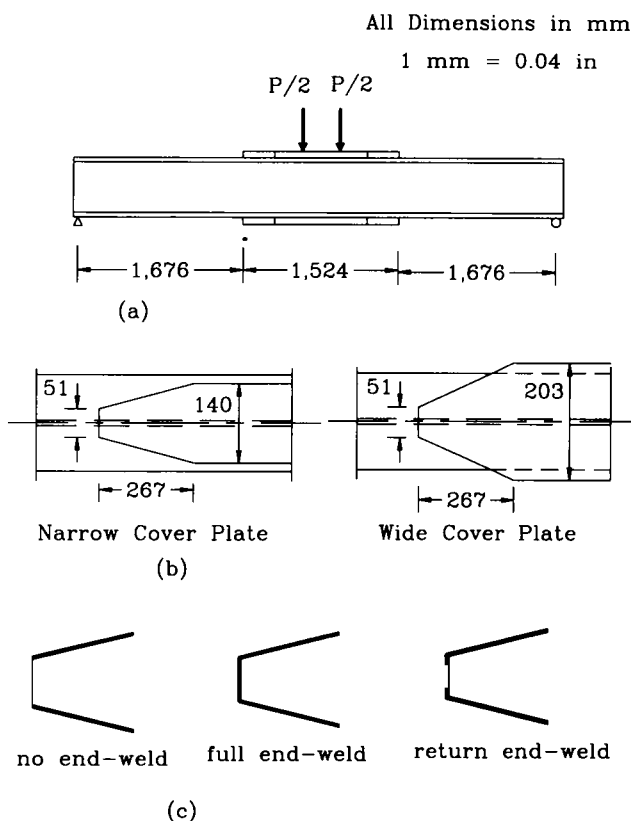


FIGURE 1 Specimen dimensions and cover plate details: (a) specimen configuration and dimensions; (b) cover plate end details; (c) end weld conditions.

that the combination of the plate flexibility and the fact that the tension flange was not completely severed (as assumed) meant that significant stresses would still exist at the cover plate end. Consequently, it was postulated that splice plates thicker than those required for the maximum stress limitation would be needed to reduce the stress at the cover plate end. To study this effect, a splice plate connection 11 mm ($7/16$ in.) thick was also tested.

A total of 19 specimens, with 38 end details, were repaired using the bolted splice plate connection. All of the specimens, with one exception, were precracked before the repair procedure was applied. After repair, 18 specimens were subjected to the same precracking load cycle (138-MPa stress range), while one specimen was subjected to a 103-MPa (15.0-ksi) stress range with an R -ratio of 0.05.

Air-Hammer Peening

Air-hammer peening introduces compressive residual stresses by striking the work piece with a hardened tool that is inserted in a pneumatic air hammer. Figure 2b

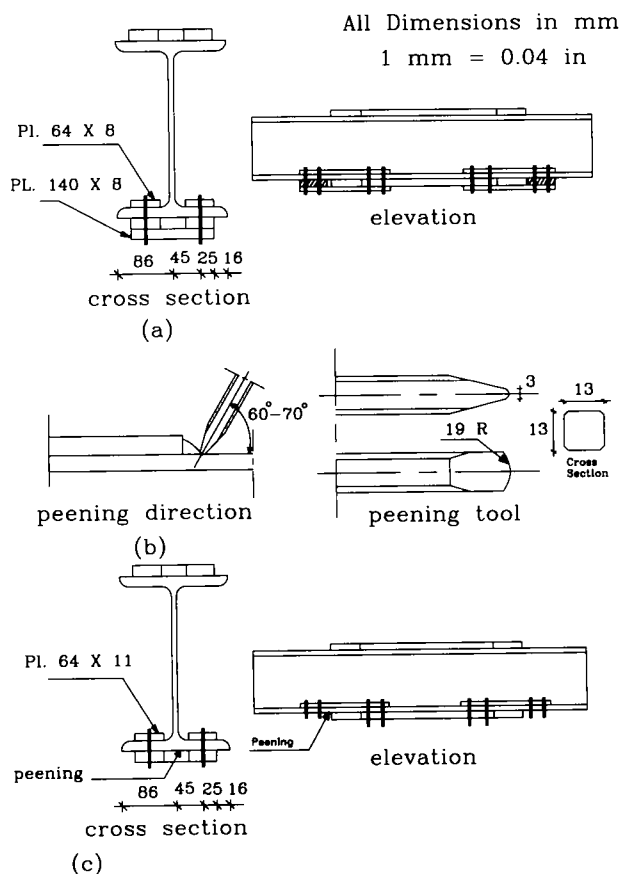


FIGURE 2 Repair methods for cover plate end welds: (a) bolted splice connection; (b) air-hammer peening; (c) partial bolted splice connection.

shows a sketch of the hardened tool used for the peening procedure. The compressive residual stresses delay the initiation of fatigue cracks or the propagation of existing cracks.

A total of eight specimens were used to study the effect of peening: five beams were peened after cracking and three were peened before cracking. The three beams peened before cracking were subjected to a 138-MPa (20.0-ksi) stress range for 75,000 cycles and then inspected to confirm that no cracks had developed. The 75,000 cycles of preloading was intended to model damage that may occur in actual bridge girders that have been in service for a number of years, but that have not yet initiated detectable cracks.

Partial Bolted Splice

The partial bolted splice repair method involves the use of both a bolted splice plate connection and air-hammer peening at the weld toe, as shown in Figure 2c. Only the top two splice plates, on each side of the web, are used to carry a portion of the flange force. The bottom fibers of the tension flange at the weld toe are peened to introduce compressive residual stresses.

A total of six specimens were repaired using the partial bolted splice repair, all of which were precracked before they were repaired. After repair, five specimens were subjected to the same stress cycle used during the precracking stage (138-MPa stress range), whereas one specimen was subjected to a 103-MPa (15.0-ksi) stress range with an R -ratio of 0.05.

RESULTS

Bolted Splice Plate Repair Method

A previous study on the repair of beams with square-ended, welded cover plates using bolted splice plates (3) indicated that this detail has a fatigue life described by Category B in the AASHTO specifications (1). Sahli et al. (3) recommended that the splice plates be designed for the full design moment if the flange were precracked. On the other hand, for noncracked flanges the splice plates need to be designed only for the portion of the moment not carried by the web.

Of the 19 tapered cover plate specimens repaired with the bolted splice method, 23 ends were repaired using the 8-mm ($5/16$ in.) splice plate detail (all of which were subjected to a 138-MPa stress range), whereas the remaining 15 ends were repaired using the 11-mm ($7/16$ in.) splice plate detail (13 ends were subjected to 138-MPa stress range, and 2 ends were subjected to 103-MPa stress range). The first specimen tested was repaired with an 8-mm ($5/16$ in.) splice before any cracks

were initiated; at the end of 1,800,000 loading cycles after repair, both cover plate ends were inspected and no cracks were detected. The remaining 18 specimens were all precycled at 138 MPa (20 ksi) at the cover plate end until small fatigue cracks were detected at both cover plate ends. The beams were then repaired with the splice plate detail. The number of loading cycles applied to the test beam specimens after repair is given in Table 1.

All of the beams, regardless of the crack size before repair or the splice plate thickness, were able to achieve a Category B cyclic life after repair. The 18 specimens, which were subjected to a loading equal to that which caused a 138-MPa (20-ksi) stress range in the bare beam at the cover plate end, all carried 1,800,000 cycles of loading after repair without failing. Although the flanges in a number of beams fractured before reaching

1,800,000 cycles, the splice plates were able to carry the cyclic loading to achieve Category B behavior. In contrast to Sahli, et al. (3), none of the splice plates cracked during the test program. This difference in behavior can be explained by the higher flexibility of the splice plates compared with those used by Sahli et al. (3) because the splice plates needed to be long to extend beyond the cover plate taper.

Out of the 23 ends repaired with the 8-mm ($5/16$ in.) splice plate detail, 14 beam flanges fractured and the remaining 9 reached at least 1,800,000 cycles without the flange fracturing. For these nonfractured nine ends, four ends developed cracks in the compression flange at the cover plate end. These ends were repaired using a bolted splice plate connection or the temporary repair connection 25 mm (1 in.) thick. In both cases, the stress at the cover plate end was altered. Out of the 15 ends

TABLE 1 Number of Cycles Applied with Bolted Splice Repair

| Specimen | End | Number of Loading Cycles | | Comments |
|------------------|----------------|------------------------------|---------------|-----------------------------------|
| | | Flange Fracture ^d | Total Applied | |
| DB1 ^s | N ¹ | 1,375,000 | 1,800,000 | Compression flange fractured. |
| | S ¹ | --- | 1,800,000 | Flange did not fracture. |
| DB2 ^s | N ¹ | 951,000 | 1,800,000 | Compression flange fractured. |
| | S ¹ | 951,000 | 1,800,000 | Compression flange fractured. |
| DB3 ^s | N ¹ | --- | 1,800,000 | Flange did not fracture. |
| | S ¹ | --- | 1,800,000 | Flange did not fracture. |
| NR1 | N ¹ | 1,564,000 | 2,000,000 | Hole drilled in web at crack tip. |
| | S ¹ | 2,000,000 | 2,000,000 | |
| NR2 | N ² | 2,000,000 | 2,500,000 | Compression flange fractured. |
| | S ² | --- | 2,500,000 | Flange did not fracture. |
| NR3 | N ² | --- | 3,000,000 | Flange did not fracture. |
| | S ² | 1,883,000 | 3,000,000 | Compression flange fractured. |
| NR4 | N ² | --- | 2,000,000 | Flange did not fracture. |
| | S ² | --- | 2,000,000 | Flange did not fracture. |
| NR8 ⁷ | N ² | 10,782,000 | 10,782,000 | Compression flange fractured. |
| | S ² | 7,134,000 | 10,782,000 | Compression flange fractured. |
| NN1 | N ¹ | --- | 1,800,000 | Flange did not fracture. |
| | S ¹ | 1,333,000 | 1,800,000 | Compression flange fractured. |
| NN2 | N ¹ | --- | 1,800,000 | Flange did not fracture. |
| | S ² | 995,000 | 1,800,000 | Compression flange fractured. |
| NF1 | N ¹ | 1,049,000 | 1,800,000 | Two holes in web at crack tip. |
| | S ¹ | 1,179,000 | 1,800,000 | Two holes in web at crack tip. |
| NF2 | N ¹ | 1,095,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ² | 1,457,000 | 1,800,000 | Compression flange fractured. |
| NF3 | N ¹ | 1,680,000 | 1,800,000 | |
| | S ² | --- | 1,800,000 | Flange did not fracture. |

TABLE 1 Continued

| Specimen | End | Number of Loading Cycles | | Comments |
|----------|----------------|------------------------------|---------------|-----------------------------------|
| | | Flange Fracture ⁴ | Total Applied | |
| WF1 | N ² | 1,744,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ¹ | 900,000 | 1,800,000 | Two holes in web at crack tip. |
| WF2 | N ¹ | 1,485,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ¹ | 1,315,000 | 1,800,000 | Hole drilled in web at crack tip. |
| WF3 | N ¹ | 1,324,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ² | --- | 1,800,000 | Flange did not fracture. |
| WR1 | N ¹ | 1,174,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ¹ | 1,495,000 | 1,800,000 | Hole drilled in web at crack tip. |
| WR2 | N ¹ | 1,561,000 | 1,800,000 | Hole drilled in web at crack tip. |
| | S ² | --- | 1,800,000 | Flange did not fracture. |
| WR3 | N ² | --- | 1,800,000 | Flange did not fracture. |
| | S ¹ | 1,211,000 | 1,800,000 | Hole drilled in web at crack tip. |

¹ 8-mm (5/16-in) splice repair connection.

² 11-mm (7/16-in) splice repair connection.

³ Specimen subjected to 103-MPa (15.0-ksi) stress range.

⁴ Dash indicates flange did not fracture.

⁵ NR type specimen; different heat of steel.

repaired with the 11-mm (7/16 in.) splice plate detail, only one beam flange fractured. Six ends developed fatigue cracks in the compression flange at the cover plate end.

Figure 3 shows the stress range versus the number of loading cycles applied after repair for the bolted splice repair detail. The number of loading cycles corresponds to the end of test, tension flange fracture, or repair of the compression flange using a splice connection, whichever occurred first. The test results are scattered around the number of loading cycles for a Category B design life.

Figure 4 compares the number of loading cycles applied after repair of the precracked flange until fracture of the flange or end of test, whichever occurred first, versus beam end type for 18 of the 19 beams tested (138-MPa stress range tests only are shown). When the compression flange fractured and was repaired with a splice plate, the number of cycles to compression flange repair was used. (After repair of the compression flange, the stress in the tension flange was altered; however, these details still sustained many additional cycles of loading.) It can be seen that all of the NR- and NN-type beams sustained more loading cycles than the Category B design life without the beam tensile flanges fracturing (disregarding specimens with compression flange

fractures). The NF, WF, and WR beam results were scattered around the Category B design life value. Although some of the beam flanges fractured before reaching the Category B design life value, the splice plates were able to carry the load, and the tests were continued until the beams reached at least 1,800,000 cycles.

A comparison of splice plate details [8 mm (5/16 in.) versus 11 mm (7/16 in.) thick] is shown in Figure 5 for specimens tested under the 138-MPa (20.0-ksi) stress range. Again, the number of cycles to compression flange repair was used whenever appropriate. It can be seen that all beam flanges repaired with the 11-mm (7/16 in.) splice plate detail surpassed the Category B design life without fracturing (disregarding specimens with compression flange fractures). The beam flanges repaired with the 8-mm (5/16 in.) splice plate detail were not as consistent, with a number of the beam ends fracturing at load repetitions less than the Category B design value.

Figure 6 illustrates the test results reported by Sahli et al. (3) for square-ended cover plates, along with results in the present study. However, in the results reported by Sahli et al. (3), the tests were continued until failure occurred, whereas in the present study the values reported correspond only to flange fracture or compression flange repair—not failure.

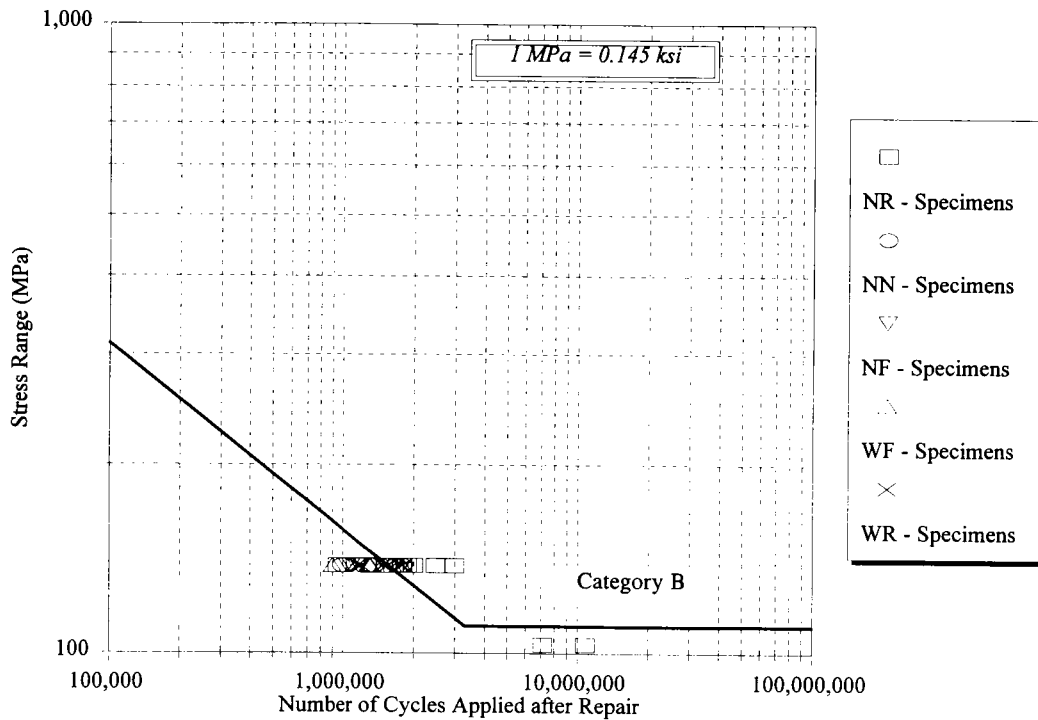


FIGURE 3 Stress range versus number of cycles applied after repair (bolted splice beams).

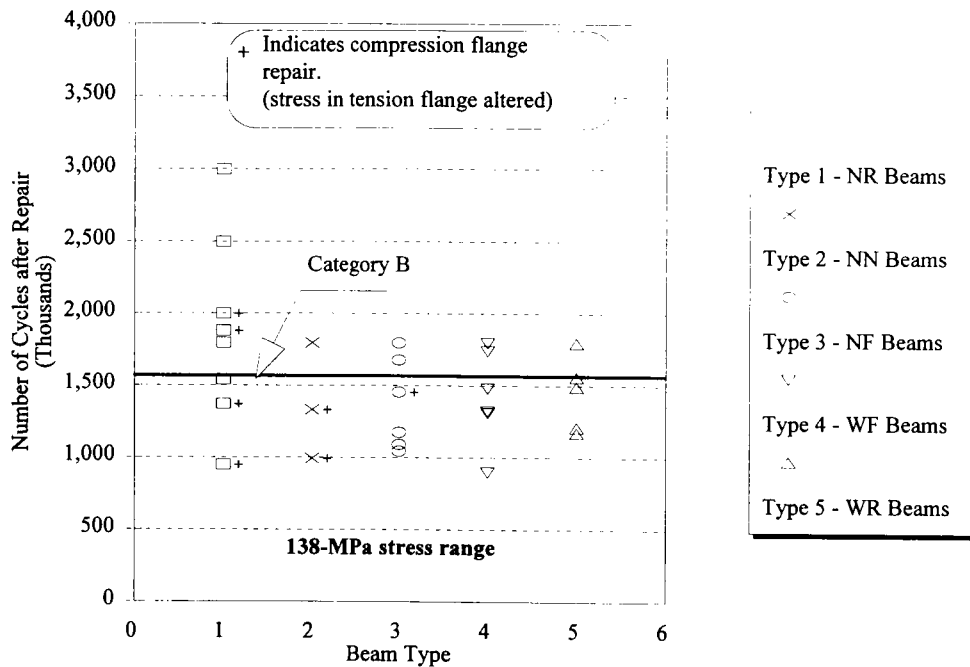


FIGURE 4 Number of loading cycles versus beam type (bolted splice beams).

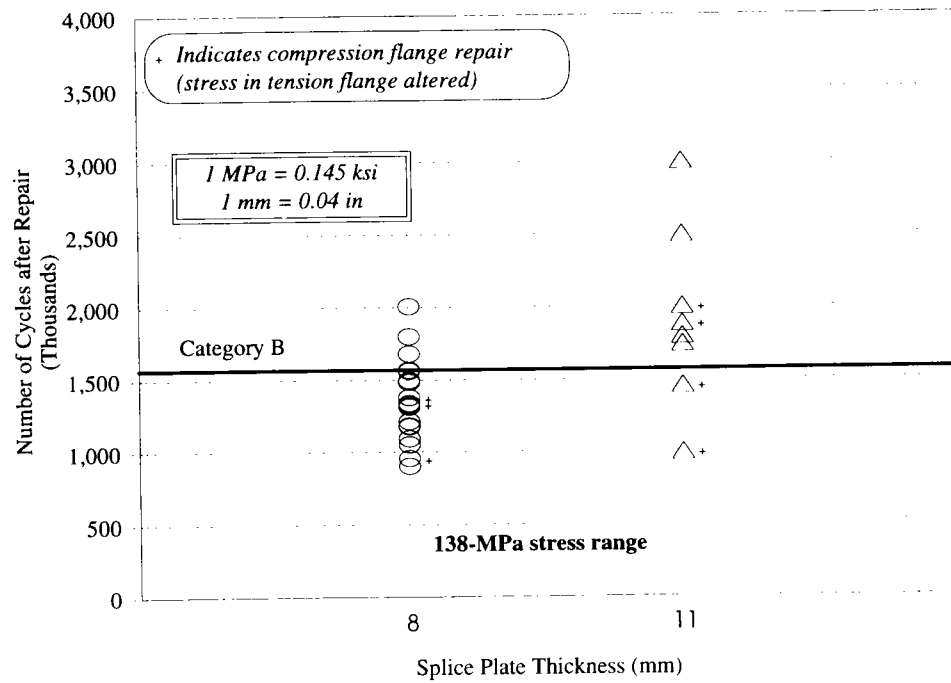


FIGURE 5 Number of cycles versus splice plate thickness.

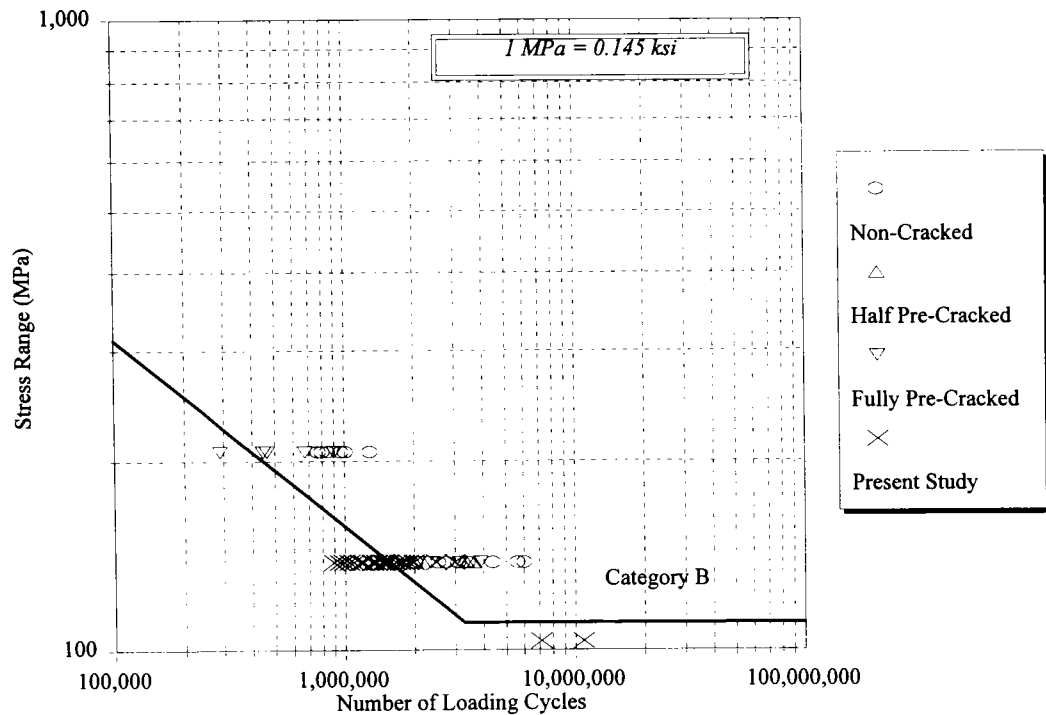


FIGURE 6 Results of comparison of tapered cover plate with square end cover plates (3).

TABLE 2 Number of Cycles Applied after Peening Repair

| Specimen | End | Number of Loading Cycles to Flange Fracture | Comments |
|------------------|-----|---------------------------------------------|------------------------------|
| NR9 | N | 265,000 | 1-in thick plates were used. |
| | S | 401,000 | |
| NR10 | N | 506,000 | 1-in thick plates were used. |
| | S | 436,000 | |
| NF4 | N | 590,000 | 1-in thick plates were used. |
| | S | 369,000 | |
| WR4 | N | 300,000 | 1-in thick plates were used. |
| | S | 216,000 | |
| WR5 | N | 223,000 | 1-in thick plates were used. |
| | S | 160,000 | |
| NR5 ¹ | N | 1,511,000 | 1-in thick plates were used. |
| | S | 1,186,000 | |
| NR6 ¹ | N | 1,006,000 | 1-in thick plates were used. |
| | S | 1,733,000 | |
| NN3 ¹ | N | 308,000 | 1-in thick plates were used. |
| | S | 413,000 | |

¹ Specimen Peened after 75,000 of loading cycles, but prior to cracking.

As noted earlier, a distinct difference in the dominant failure mode was observed for the splice plates used to repair the tapered and square-ended cover plates. It is believed that this difference is attributed to the significant flexibility of the splice plate connection used with the tapered cover plate: because of differences in length, the splice plates used by Sahli et al. (3) were four times stiffer than those used in the present study. This higher flexibility reduces the force carried by the splice plate and, consequently, increases the stresses in the flange at the weld toe. This would explain why significant crack growth occurred in the present study, whereas little additional crack growth was observed in the tests by Sahli et al. (3).

Peening Repair Method

A study on the fatigue strength of beams with square-ended, welded cover plates (4) indicated that crack depths less than $\frac{1}{8}$ in. could be successfully repaired using air-hammer peening. Three cases were investigated: peening of as-welded specimens (PA), peening of specimens cycled to 75 percent of the lower confidence limit (PL), and peening of specimens after detection of visible cracks (PV). Air-hammer peening increased the fatigue life of the cover plate detail from Category E to Category D for low minimum stress values.

The eight tapered cover plate specimens repaired by peening were all subjected to a 138-MPa (20.0-ksi) stress range. Five specimens were precracked before peening, whereas the remaining three specimens were cycled for 75,000 cycles before peening. The number of loading cycles applied to the test beams until fracture of the tension flange is reported in Table 2.

Figure 7 shows the stress range versus the number of loading cycles applied after repair for the five precracked beams. Considerable scatter in the fatigue life of the peened beams is evident, with the cyclic life extending from Category E (134,000 cycles) to Category C (500,000 cycles). The wide cover plate beams demonstrated the lowest fatigue life. This might be attributed to the fact that the wide cover plate beams initiated longer detectable cracks than the narrow cover plate beams. Figure 7 suggests that by peening existing cracks the fatigue life of the cover plate detail can be improved such that an additional number of loading cycles equivalent to Category D can be applied for the NR and NF beam types. An additional cyclic life equivalent only to Category E was achieved for the WR beam type.

Figure 8 shows the stress range versus the number of cycles applied after repair for the three beams peened before cracking (two NR beams and one NN beam). The test results of the two NR beams suggest that peening of noncracked beams can significantly improve the fatigue life of the detail to reach Category B'. In both

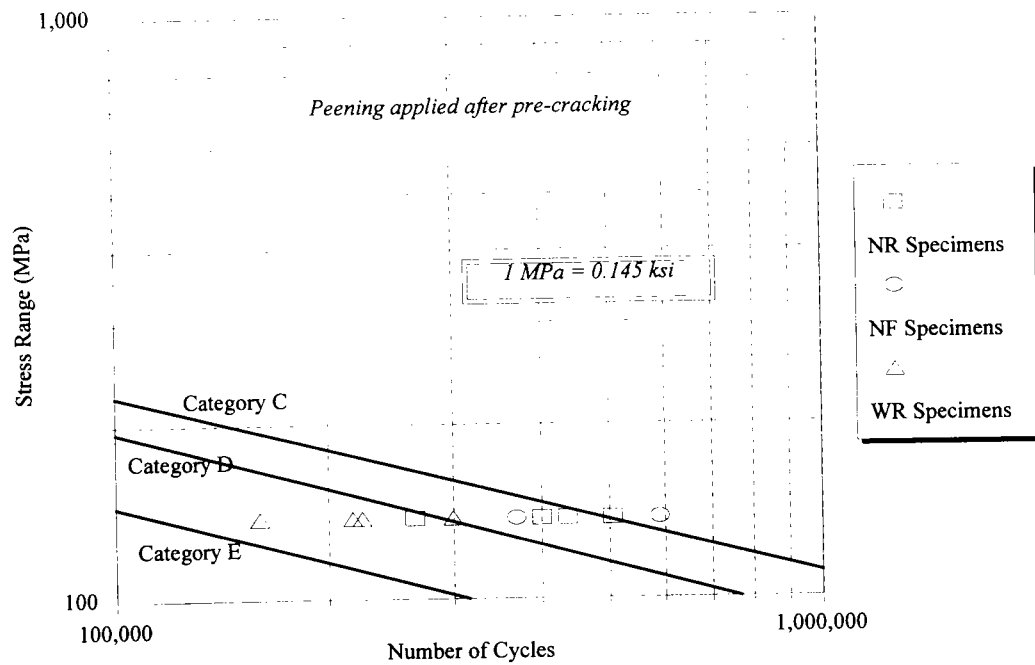


FIGURE 7 Stress range versus number of cycles applied after peening (precracked peening beams).

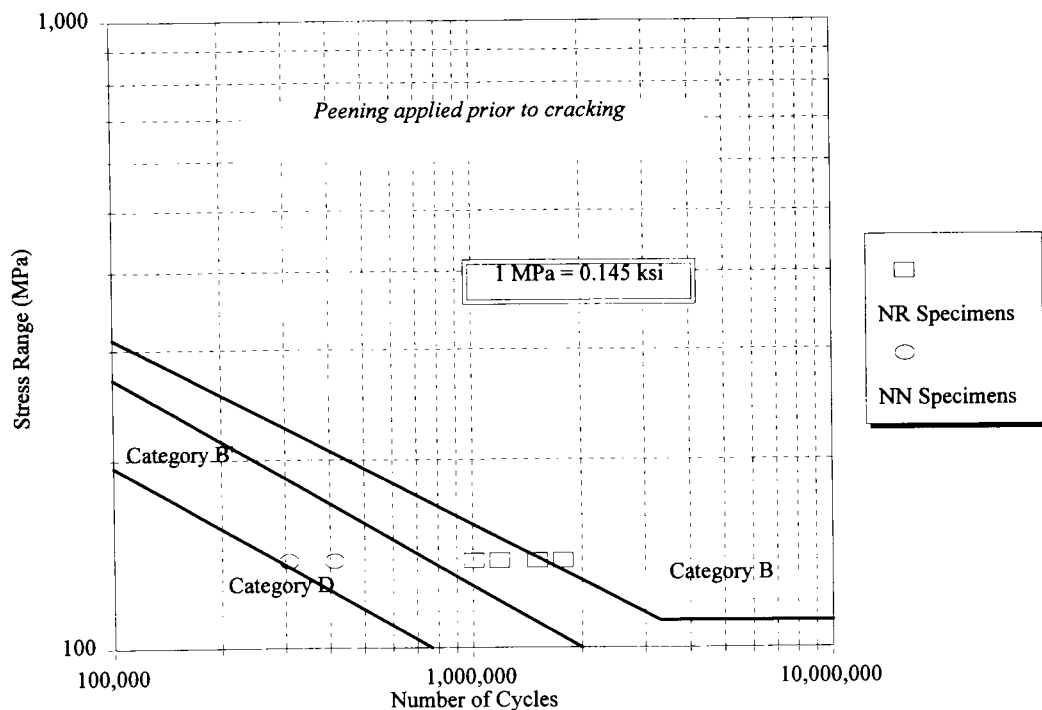


FIGURE 8 Stress range versus number of cycles applied after peening (noncracked peening beams).

beams, the fatigue cracks propagated through the weld, cutting the weld return into two parts. Fatigue cracks in most of the other test specimens initiated at the weld toe, rather than at an interior weld location. The change in crack location demonstrates the effectiveness of the compressive residual stress, induced at the weld toe by peening, in extending the fatigue life.

The NN specimen reached the fatigue design life of Category D only. The no end-weld detail is significantly different from the return and full end-weld details. The welds in the latter details are fully accessible to treatment by peening, whereas the weld end in the no end-weld detail is difficult to peen in those regions adjacent to the tapered cover plate. Also, cracks in the no end-weld details can propagate under the cover plate which is not accessible to peening. Thus, peening is expected to be less effective in the case of the no end-weld detail.

The results of the 24 peened beams tested by Fisher et al. (4) are shown in Figure 9, along with the results of the eight peened beams from the present study. Using linear regression analysis of the data by Fisher et al. (4), the average fatigue life for the PA, PL, and PV specimens tested at a 138-MPa (20.0-ksi) stress range was found to be about 353,700 cycles, 217,300 cycles, and 211,000 cycles, respectively. The average fatigue life from the present study, however, was about 352,000 cycles for specimens peened after the detection of visible cracks, and 1,369,000 cycles for specimens peened after

75,000 cycles of loading but with no initial cracks that could be detected visually.

Partial Bolted Splice Plate Repair Method

All six beams repaired with the partial bolted splice were precracked before repair. Five beams were subjected to a 138-MPa (20.0-ksi) stress range, whereas the remaining beam was subjected to a 103-MPa (15.0-ksi) stress range. The tension flange in most specimens fractured, although two ends developed fatigue cracks in the compression flange at the cover plate end. The number of loading cycles applied to the test beams after repair is indicated in Table 3.

Figure 10 shows the stress range versus the number of loading cycles applied after repair for the six beams. Considerable scatter in the fatigue life of WR beams repaired with the partial bolted splice technique is evident, with the cyclic life extending from Category C (500,000 cycles) to higher than Category B (1,500,000 cycles). The narrow cover plate beams exhibited a fatigue life greater than Category B' design life. Although the flange may have fractured, the detail was still capable of sustaining some additional loading cycles; one specimen sustained 874,000 cycles after the flange fractured. The cracks, however, kept growing at a relatively high rate—higher than that for the bolted splice plate

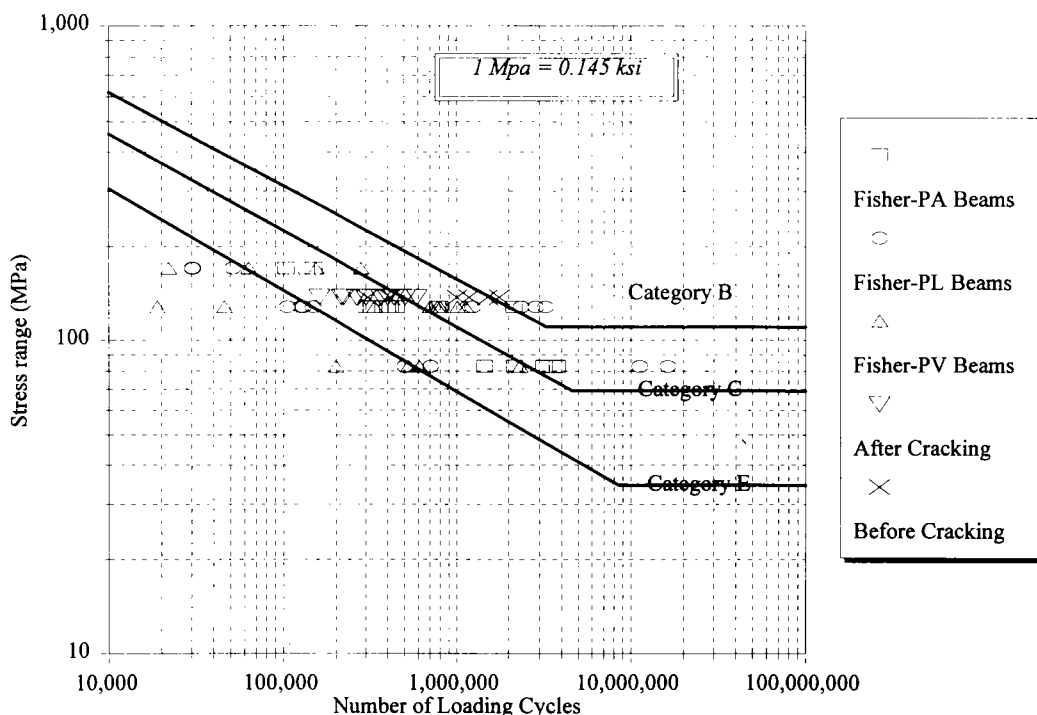


FIGURE 9 Comparison of test results with those of Fisher et al. (4).

TABLE 3 Number of Cycles Applied with Partial Bolted Splice Repair

| Specimen | End | Number of Cycles | | Comments |
|------------------|-----|------------------------------|---------------|----------------------------------------|
| | | Flange Fracture ² | Total Applied | |
| NR11 | N | --- | 1,898,000 | Flange did not fracture. |
| | S | 1,480,000 | 1,898,000 | Two holes drilled in web at crack tip. |
| NR12 | N | 1,347,000 | 1,800,000 | Two holes drilled in web at crack tip. |
| | S | 1,234,000 | 1,800,000 | Two holes drilled in web at crack tip. |
| WR6 | N | 1,326,000 | 2,200,000 | Compression flange fractured. |
| | S | 1,326,000 | 2,200,000 | Two holes drilled in web at crack tip. |
| WR7 | N | 631,000 | 1,313,000 | Two holes drilled in web at crack tip. |
| | S | 604,000 | 1,313,000 | Two holes drilled in web at crack tip. |
| NF5 | N | 1,111,000 | 1,152,000 | Hole drilled in web at crack tip. |
| | S | 800,000 | 1,152,000 | Two holes drilled at web crack tip |
| NR7 ¹ | N | 8,340,000 | 8,340,000 | |
| | S | 6,540,000 | 8,340,000 | Compression flange fractured. |

¹ Specimen subjected to 103.42-MPa (15.0-ksi) stress range.

² Dash indicates flange did not fracture.

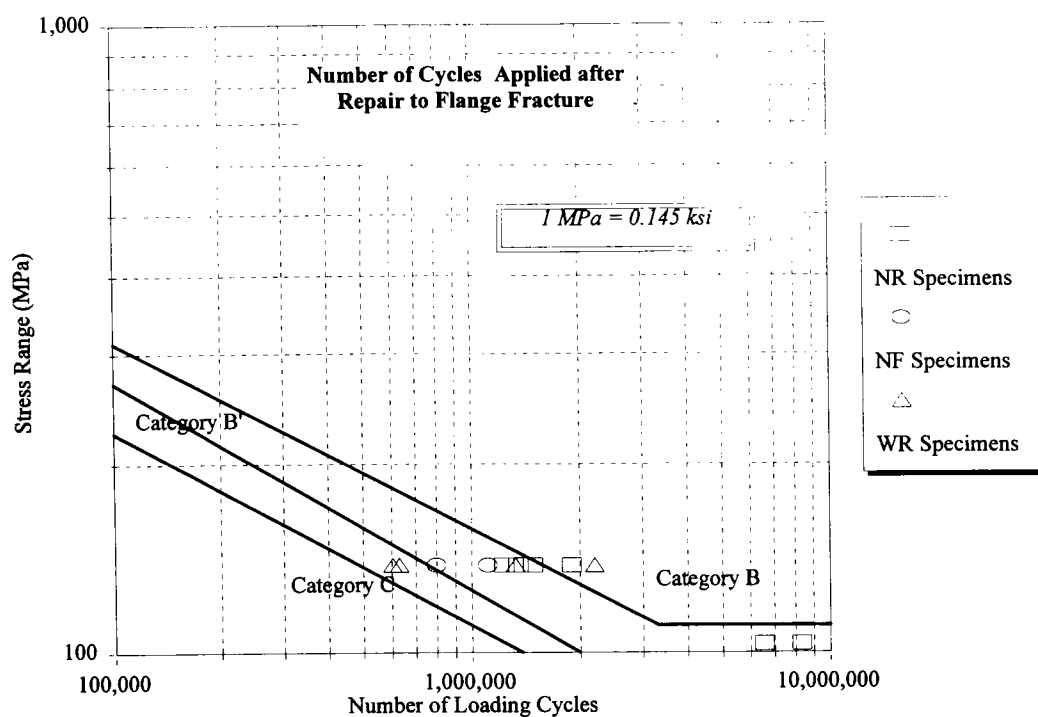


FIGURE 10 Stress range versus number of loading cycles (partial bolted splice beams).

repair method. Also, it should be noted that intentional efforts were made to slow crack growth in the beam web by drilling a hole through the web to eliminate the crack tip. In some cases, an additional hole was required when the crack propagated beyond the first web hole.

CONCLUSIONS

Thirty-three W14 \times 30 steel sections were tested to examine the fatigue strength of beams with welded partial-length, tapered cover plates that have been repaired. Three repair methods were examined: a friction-type bolted splice plate connection, air-hammer peening, and a combination of the previous two known as partial bolted splice connection. On the basis of the experimental test results and corresponding observations, the following conclusions can be stated:

1. Neither the 8-mm ($5/16$ in.) nor the 11-mm ($7/16$ in.) bolted splice plates completely prevented subsequent crack growth, except for the case of repair before crack initiation.
2. Splice plate thickness has a large influence on crack growth rate. Thicker plates decrease the stresses in the beam flange and, consequently, decrease the growth rate.
3. Both the 8-mm ($5/16$ in.) and the 11-mm ($7/16$ in.) splice plates significantly improved the fatigue life of the cover plate detail. Even when the flanges fractured, the splice plates were still effective and allowed the detail to achieve a Category B design life after repair.
4. Peening is an effective method for repairing precracked cover plate end details if the crack is small—less than 5 mm long. In that case, peening can extend the fatigue life of the detail an additional number of cycles equivalent to Category D design life.

5. Peening is effective in increasing the fatigue life of noncracked cover plate ends for the return end-weld detail. Tests demonstrated that peening improves the fatigue life of the detail to a Category B' level.

6. Peening is not recommended for the no end-weld detail. Some portions of the weld cannot be effectively peened, and resultant crack may grow under the cover plate in an inaccessible region.

7. The partial bolted splice plate repair is an effective method of repairing precracked cover plate end details. The method extends the fatigue life of the detail an additional number of cycles equivalent to Category C design life.

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