# REMR Technical Note CS-ES-1.12

# Guidelines for Assessing Condition of Riveted Spillway Gates

## Purpose

To provide guidelines for assessing the condition of riveted spillway gates. Guidelines are presented below on assessing six conditions commonly encountered in the evaluation of riveted spillway gates: buckled or plastically deformed structural elements, damaged lifting mechanisms, corrosion, fatigue cracking, rivet replacement, and weld repairs.

### Buckled or plastically deformed structural members

When buckled or plastically deformed structural members are found during the inspection of a spillway gate, an assessment of the strength and serviceability of these members must be made. To accurately assess the effect of the reported condition, detailed information must be obtained from the inspection report. This information should include:

*a*. Location of damaged (deformed) member.

*b*. Components of member damaged (i.e., web or flange).

*c*. Detailed description of damage including magnitude and wavelength of buckle or deformation.

*d*. Condition of adjacent members.

*e*. Possible cause of damage.

*f*. Effect of deformation on gate performance (if any).

If it is determined that the deformation was caused by an unusual or extreme event and is limited to a small area on one member and does not affect gate performance, immediate repairs would most likely not be necessary. In this case, the damaged area should be closely monitored through more frequent inspections to see if the condition deteriorates. If these more frequent inspections reveal that the amount of damage is increasing or is spreading to adjacent members as the load is redistributed, an analysis of the structure should be conducted. It would be satisfactory to use a two-dimensional (preferably) or three-dimensional model which places hinges in the member at the location of damage. In more severe cases, it may be appropriate to assume the member is removed. However, in a situation where the amount of damage is continuously increasing, a repair or replacement of the member(s) should be scheduled immediately.

## Damaged lifting mechanism

If distress or damage is reported for the lifting mechanism of a gate, the problem should first be classified as either mechanical or structural in nature. If the condition reflects a structural problem, details on which member of the lifting mechanism (lift hoist or connection to gate) are damaged and the type of damage (e.g., frayed or misaligned cable, or cracked connection fitting) are necessary to make an accurate assessment. It should also be noted whether the condition may have been caused by previous structural damage to the gate, or whether it has caused damage to other components of the gate. In general, because the lifting assembly is a non-redundant structural element, any problems should be corrected immediately by either maintenance, repair, or replacement.

## Corroded members

When corrosion is reported, the type and location of corrosion and its possible cause should be identified. The effect of the corrosion on the section properties and functional performance of the members should also be determined.

Corrosion typically is a slow-growth process. Therefore, if rapidly developing corrosion is reported, air and water samples should be collected and analyzed to check for unusual changes. If crevice corrosion is becoming more severe, consideration should be given to maintenance of the region during a regular maintenance period, including eliminating any buildup of corrosion product and then recoating with a more effective crevice-sealing coating or paint.

When specific members are affected by corrosion, the portion of the member most affected should be assessed. For example, if the member is a flexural member, does the corrosion have an effect on either the bending moment capacity or the shear capacity of the member? Measuring the remaining section thicknesses may be necessary to make this determination. If the section properties are reduced more than 10 percent, a new analysis of the structure should probably be made. If the reduction is greater than 25 percent, consideration should be given to replacing the member during the next scheduled maintenance if the member is functionally critical.

## Members with fatigue cracks

When a fatigue crack is detected in a gate structural component, some important questions are as follow:

*a*. What is the size, orientation, and location of the crack?

*b*. Is the crack growing?

*c*. Is the crack significant if it continues to grow?

*d*. Is remedial action urgently needed?

Cracks in non-redundant members or components are significant and require more attention. Hoist cables and attachment points of lifting mechanisms to the gate, for example, are non-redundant; continued crack growth could cause fracture of these components and impair the operation of the gate. Cracks such as those in the roller gate end shield do not pose danger of imminent failure of the gate.

To determine whether a crack is growing and what the growth rate is requires nondestructive monitoring. The crack growth threshold can also be determined analytically. However, unless the crack is caused by flow-induced vibration or other recurring causes and is in a non-redundant component of the gate, nondestructive evaluation usually is not necessary.

The majority of known cracks in gates have been found in redundant components; repairing these cracks does not need to be made immediately. It is more important to assess the cause of the crack and then to repair accordingly.

## Rivet replacement

When there are deteriorating rivet heads, one recommendation has been to replace any rivet where 50 percent or more of head projection beyond the shank is missing if the rivet is subject to an applied tensile force or tension resulting from prying action. Corollary recommendations are to replace missing rivets, loose rivets, headless rivets, and rivets with rosette heads.

It is also important to adhere to the following guidelines for what not to do for deteriorating rivet heads: Rivet heads with rosettes and rivet heads with deteriorating projections should not be built up using weld metal or other materials (brazing, caulking), since these could aggravate rather than remediate the condition.

The current practice for replacing rivets on structures such as gates involves using high-strength bolts as the replacement fasteners. These bolts have greater strength than the rivets they replace. However, removing the deteriorated rivet is sometimes difficult. The most accepted method of rivet removal is to knock off the rivet head using a pneumatic "rivet buster" and then force the rivet shaft out of its hole with a powered impact tool. If needed, the rivet hole is drilled out to obtain an aligned hole through the connected parts. Then the high-strength bolt is installed and tightened by an accepted method such as the turn-of-the-nut technique.

Unfortunately, one generally unacceptable method of rivet removal is often used, burning with an acetylene torch to remove the rivet head and shaft. This technique can cause localized metallurgical damage to the gate structure due to heat, and also has a risk of causing burn gouges or other damage that can then adversely affect fatigue strength and corrosivity. Burning off rivet heads should be done only when there are experienced burners and a supervised environment and when pneumatic rivet busters are unavailable.

### Weld repair

If welds for repair or for adding components on riveted structures must be made, the riveted gate must first be judged (through trials or tests) to have adequate weldability. Then, the welds must be made according to Table 1 and today's structural welding codes.

The welded details need to be assessed for fatigue strength using the appropriate fatigue criteria and methods (Bower et al., in preparation).

## References

Bower, J. E. Kaczinski, M. R., Ma, Z., Zhou, Y., Wood, J. D., and Yen, B. T. (1994). "Structural evaluation of riveted spillway gates," Technical Report REMR-CS-43, prepared by Lehigh University, Bethlehem, PA, for U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Stout, R.D., and Doty, W.D. (1953). *Weldability of steels*, 1st ed., Welding Research Council, New York.

Stout, R.D., Ott, C.W., Pense, A.W., Snyder, D.J., Somers, B.R., and Somers, R.E. (1987). *Weldability of steels*, 4th ed., Welding Research Council, New York.

## Table 1
## Suggested Practices for Sound Welding with A7 and A36 Steels (Stout and Doty 1953, Stout et al. 1987)

### A7 Steel

**Conditions Requiring No Preheating, Postheating, or Special Electrodes**

| Steel Specification | Conditions for Which No Special Precautions Are Required: Carbon Range, % | Conditions for Which No Special Precautions Are Required: Thickness Range, in. | Remarks | Grade or Quality | Specification Requirements (Abridged) — Composition: C | Mn | Si | Ni | Cr | Mo | Other | Yield Point psi | Tensile Properties: Tensile Strength psi | Elongation % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ASTM A7-50T Steel for bridges and buildings | Up to 0.25, incl | Up to 1, incl | Over 1 in., see Table II | . . . | (Not specified) | (Not specified) | (Not specified) | . . . | . . . | . . . | 0.20 min. Cu when specified | 33,000 min. | 60,000-72,000 | 21 in 8 inches (min.) |
| | 0.26-0.30, incl | Up to 1/2, incl | Over 1/2 in., see Table II | | | | | | | | | | | |
| | | | Over 0.30 carbon, see Table II | | | | | | | | | | | |

**Table II. Conditions Requiring Some Control Over Heat Input and Requiring Low Hydrogen Electrodes or Preheat and Generally Postheating**

**Conditions for Which Precautions Are Required**

| Carbon Range % | Thickness Range in. | Recommended Arc Welding Conditions General Notes: Electrodes should be of suitable composition when alloy steels are welded. Welding conditions are not given for materials over 4 inches thick. |
|---|---|---|
| Up to 0.25 incl | Over 1-2, incl | Condition A or B |
| | Over 2-4, incl | Condition C |
| 0.26-0.30 incl | Over 1/2-1, incl | Condition A or B |
| | Over 1-2, incl | Condition B or C |
| | Over 2-4, incl | See Table III |
| 0.31-0.35 incl | Up to 1/2, incl | Condition A or B |
| | Over 1/2-1, incl | Condition B or C |
| | Over 1-4, incl | See Table III |

Condition A = 100°F minimum preheat and interpass temperature, 1100-1250°F stress relief optional.

Condition B = No welding below 10°F, EXX15 or EXX16 electrode, 1100-1250°F stress relief optional.

Condition C = 200°F minimum preheat and interpass temperature, 1100-1250°F stress relief optional.

**Table III. Conditions Requiring Preheat, Special Welding Techniques, and Postheating and/or Peening**

**Conditions for Which Precautions Are Required**

| Carbon Range, % | Thickness Range, in. | Recommended Arc Welding Conditions General Notes: Electrodes should be of suitable composition when alloy steels are welded. Welding conditions are not given for materials over 4 inches thick. |
|---|---|---|
| 0.26-0.30 incl | Over 2-4, incl | Condition J |
| 0.31-0.35 incl | Over 1-2, incl | Condition J |
| | Over 2-4, incl | Condition K |

Condition J = 100°F minimum preheat and interpass temperature with EXX15 or EXX16 electrode or 300°F preheat with other than EXX16 electrode, 1100-1250°F stress relief optional, peening may be necessary for thicknesses over 1 inch.

Condition K = 200°F minimum preheat and interpass temperature with EXX15 or EXX16 electrode or 300°F preheat with other than EXX15 or EXX16, 1100-1250°F stress relief optional, peening may be necessary for thicknesses over 1 inch.

### A36 Steel

**Suggested Welding Conditions**

| Steel Specification | Carbon Range % | Thickness Range in. | Minimum Preheat and Interpass Temperature, °F: Low-Hydrogen | Other Than Low-Hydrogen | Post-Weld Heat-Treatment Range, °F | Peening May Be Necessary |
|---|---|---|---|---|---|---|
| ASTM A36-81 Structural Steel | Up to 0.25 incl | Up to 1, incl | Ambient, Above 10°F | Ambient, Above 10°F | Optional 1100/1250 | — |
| | | Over 1 to 2, incl | 50 | 200 | Optional 1100/1250 | — |
| | | Over 2 to 4, incl | 150 | 300 | Optional 1100/1250 | Yes |
| | 0.26-0.29 incl | Up to 1/2, incl | Ambient, Above 10°F | Ambient, Above 10°F | Optional 1100/1250 | — |
| | | Over 1/2 to 1, incl | 50 | 200 | Optional 1100/1250 | — |
| | | Over 1 to 2, incl | 150 | 300 | Optional 1100/1250 | Yes |
| | | Over 2 to 4, incl | 200 | 300 | Optional 1100/1250 | Yes |

Note: For welding and post-weld heat-treatment requirements for boilers or pressure vessels fabricated from this material refer to appropriate section of ASME Boiler & Pressure Vessel Code.

**Specification Requirements (Abridged)**

| Steel Specification | Class, Grade or Quality | Composition: C | Mn | Si | Ni | Cr | Mo | Other | Tensile Properties: Yield Point psi | Tensile Strength psi | Elongation % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ASTM A36-81 Structural Steel | — | 0.25-0.29 Max. depending on thickness & mill product | 0.80-1.20 for plates over 3/4 in. 0.60-0.90 for bars over 3/4 in. (not specified for shapes or for bars or plates up to 3/4 in.) | 0.15-0.40 (not specified for shapes or bars or for plates up to 1-1/2 inc.) | — | — | — | 0.20 Min. Cu when specified | 36,000 Min. | 58,000-80,000 | 20 Min. in 8 inches |