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Safety in a Second Guardrail Safety Loop Test Report

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SAFETY IN A SECOND
GUARDRAIL SAFETY LOOP TEST REPORT

FINAL REPORT

12 January 2012

Submitted to:

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Safety in a Second

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BMT DOCUMENT QUALITY CONTROL DATA SHEET

REPORT: Safety in a Second Guardrail Safety Loop Test Report

DATE: 12 January 2012

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Issue 01	14 Dec. 2011	Initial Issue.
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ACRONYMS AND ABBREVIATIONS

A_m	Shear area of the effective fusion face in mm^2
A_w	Area of the effective weld throat in mm^2
BMT FTL	BMT Fleet Technology Limited
F_u	Ultimate tensile strength of steel in MPa
kN	KiloNewton (or, 224.81 lbf)
lbf	Pounds force (or 0.004448222 kN)
mm	Millimetre
MPa	MegaPascals
NDE	Non-destructive examination
X_u	Electrode ultimate tensile strength in MPa
φ_w	Resistance factor for welded connections, 0.67

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LIST OF FIGURES

REFERENCES

A. CAN/CSA S16-01 – Limit States Design of Steel Structures, 9th Edition (2007);

B. CSA Standard W59-03 – Welded Steel Construction (Metal Arc Welding), (2003);

C. CSA Standard W47.1-03 – Certification of Companies for Fusion Welding of Steel (2003).

1 GUARDRAIL SAFETY LOOP TEST

1.1 Introduction

"Safety in a Second" supplied two sample Guardrail Posts with corresponding detailed drawings to BMT Fleet Technology Limited (BMT FTL) for evaluation of the safety loop as a fall arrest attachment point. The evaluation consisted of a static load tension test of the safety loop for each sample provided.

1.2 Objectives

The evaluation included the following steps:

a. Review of Guardrail Post welded connections:

   i. The configuration and dimensions associated with the welded connections for a sample guard rail post were compared to the drawings provided; and,

   ii. With respect to a fall arrest type load applied at the safety lug, the structural resistance of the welds and members were calculated using CAN/CSA S16-1 and compared to the prescribed load of 5,000 lbf (or, 22 kN).

b. Static load tension tests of two sample Guardrail Post safety loops:

   i. A tensile load was applied to the safety loop, aligned with the base plate, as shown schematically in Figure 1.1. A load corresponding to the prescribed value of 5,000 lbf (or, 22 kN) was applied to demonstrate compliance for fall arrest attachment systems; and,

   ii. An overload of approximately 10,000 lbf (or, 44 kN) and equal to 2.0 times the proposed load of 5,000 lbf (or, 22 kN) was applied subsequently.

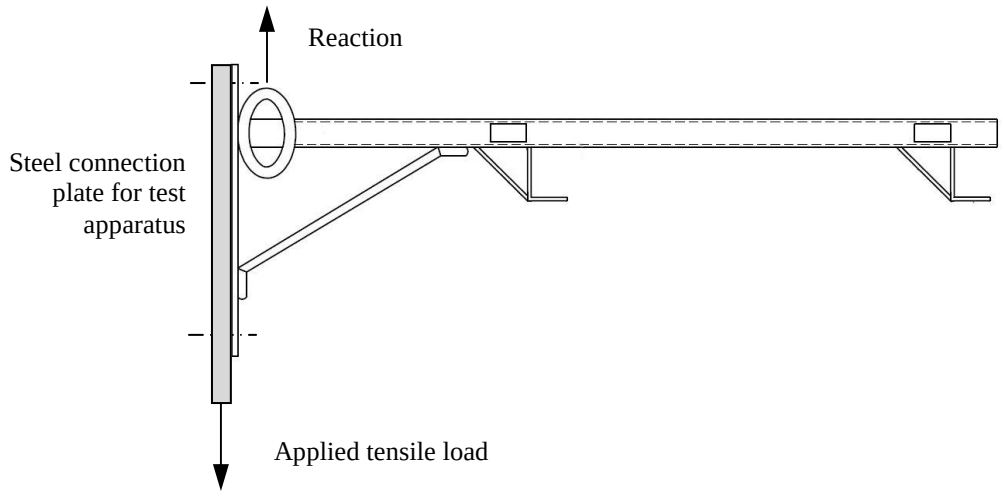


Figure 1.1: Guardrail Post Safety Loop Tension Test Arrangement

c. Documentation:

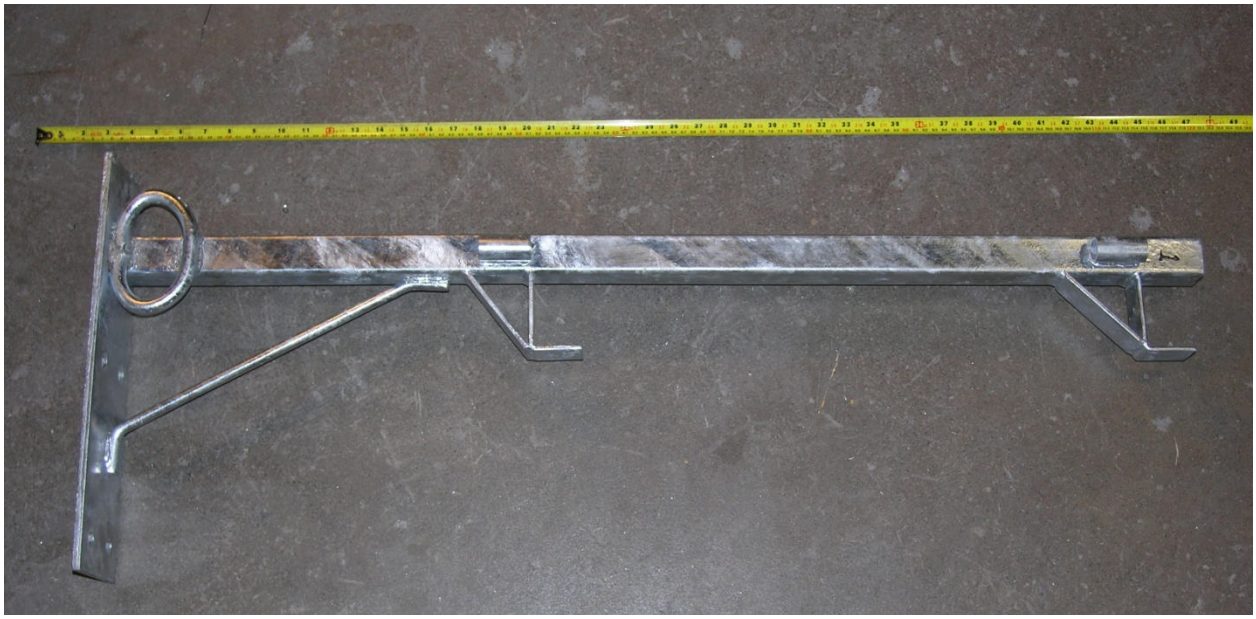
i. This brief report includes a summary of the calculations, testing process and results.

2 REVIEW OF GUARDRAIL POST WELDED CONNECTIONS

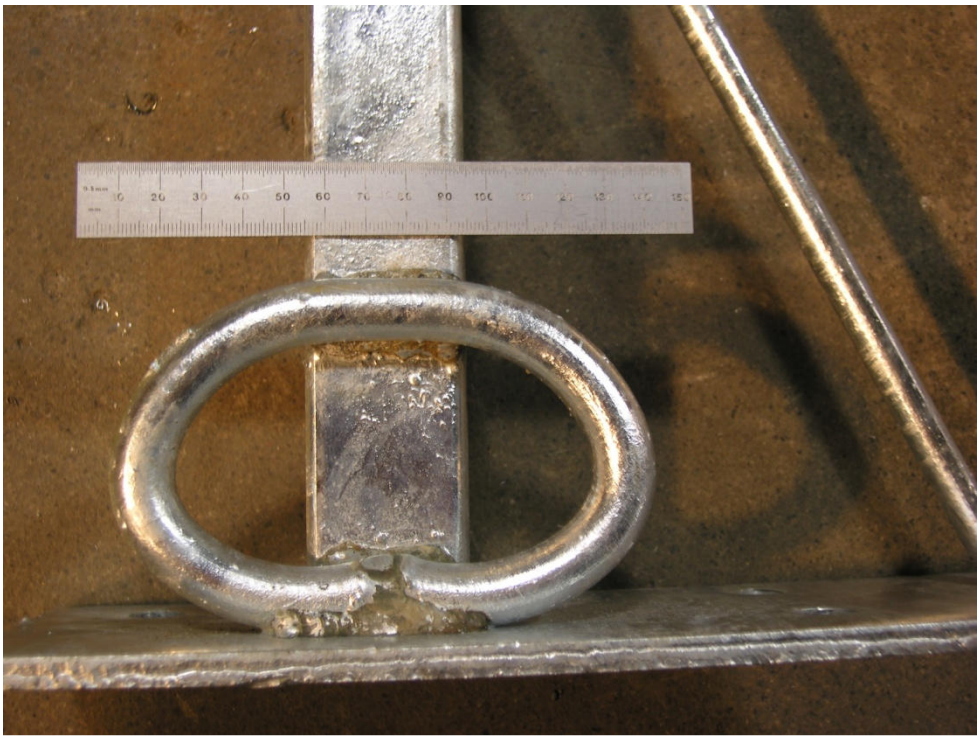
2.1 Drawings and Samples

The samples provided, identified as Sample 1 and Sample 2, are shown in the photographs of Figure 2.1 and Figure 2.2, respectively. The posts measured approx 42″ (or, 1067 mm) in height. The posts correspond to square HSS 1.5″×1/8″ sections having a wall thickness of approximately 0.125″ (or, 3.2 mm). The rod bent into an oval ring and used for the safety loop, or fall arrest attachment point, has a nominal diameter of 5/8″ (or, 16 mm).

Based on a visual review of the welded connection associated with the safety loop, there are localised instances of weld splatter and concavity, but likely not affecting the effective design capacity of the welds. A more detailed visual inspection or non-destructive examination (NDE) of the welds would provide confirmation that the required weld capacities could be achieved.

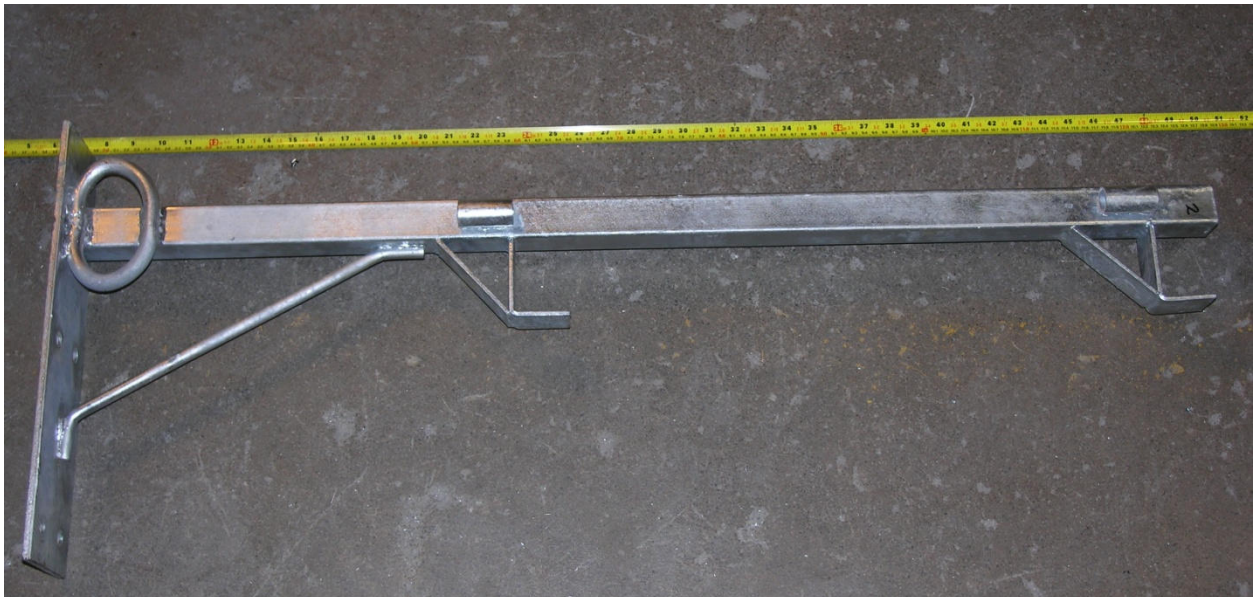


(a) Overview



(b) Safety Loop Welded to Guardrail Post

Figure 2.1: Guardrail Post Sample 1



(a) Overview

(b) Safety Loop Welded to Guardrail Post

Figure 2.2: Guardrail Post Sample 2

2.2 Weld Capacity Calculations

The following calculations were completed with reference to CAN/CSA S16-1 to determine the capacity of the welded connections related to the safety loop.

2.2.1 Safety Loop Welds at Base Plate and Square HSS Post

As fabricated, the welds associated with the safety loop correspond to partial penetration flare bevel groove welds with a 1/8″ (3.2 mm) fillet weld added. The minimum length of each weld is 30 mm used for calculation.

The width of the fusion face for these welds is taken as 3/16″ (4.8 mm). The effective throat for these welds is taken as 1/8″ (3.2 mm). At the safety loop, there are four such welds connecting the loop to both the base plate and the square HSS post.

The factored shear resistance of the welds is taken as the lesser of:

(i) $V_R = [0.67\phi_w A_m F_u] \times 4$ [1]

(ii) $V_R = [0.67\phi_w A_w X_u] \times 4$ [2]

Where:

- φ_w = 0.67, the resistance factor for welded connections;
- A_m = 4.6 mm × 30 mm = 138 mm^2, the area of the fusion face;
- A_w = 3.2 mm × 30 mm = 96 mm^2, the area of the effective weld throat;
- F_u = 450 MPa, the ultimate strength for 350W steel by CAN/CSA G40.21M; and,
- X_u = 490 MPa, the matching E490XX electrode ultimate tensile strength for 350W steel by CAN/CSA G40.21M.

The calculated limiting shear resistance of the welded connection for the safety loop is 84 kN, or approximately 18,880 lbf.

2.2.2 Square HSS Post Welds at Base Plate

As fabricated, the welds associated with the square HSS post at the base correspond to 3 legs of 1/8″ (3.2 mm) fillet welds around the perimeter of the HSS section (total length of 102 mm) plus one 30 mm leg of the flare bevel groove weld associated with the safety loop connection to the base plate.

For the fillet welds, the width of the fusion face is taken as 1/8″ (3.2 mm). The effective throat for the 1/8″ (3.2 mm) welds is taken as 0.707 × 3.2 mm = 2.3 mm

The contribution from the flare bevel groove weld corresponds to 0.25 times the limiting value from Section 2.2.1, or 0.25×84 kN = 21 kN.

The factored shear resistance of the fillet welds is taken as the lesser of:

(i) $V_R = 0.67\phi_w A_m F_u$ [3]

(ii) $V_R = 0.67\phi_w A_w X_u$ [4]

Where:

- φ_w = 0.67, the resistance factor for welded connections;
- A_m = 3.2 mm × 102 mm = 326.4 mm^2, the area of the fusion face;
- A_w = 2.3 mm × 102 mm = 234.6 mm^2, the area of the effective weld throat;
- F_u = 450 MPa, the ultimate strength for 350W steel by CAN/CSA G40.21M; and,
- X_u = 490 MPa, the matching E490XX electrode ultimate tensile strength for 350W steel by CAN/CSA G40.21M.

The calculated limiting shear resistance of the fillet welds is 51 kN, or approximately 11,465 lbf.

Including the contribution for the single leg of the flare bevel groove weld, the total factored shear resistance for the welded connection at the base of the square HSS post is 51 kN + 21 kN = 72 kN, or 16,186 lbf.

3 STATIC LOAD TENSION TESTS

Two Guardrail Post samples were supplied and tested to confirm the performance of the safety loops in response to an applied tensile load of 5,000 lbf (or, 22 kN).

The tension tests were conducted in a 300,000 lbf Satec Universal Baldwin test machine, as shown in Figure 3.1. The test assembly included a steel plate (thickness ≥ ½ inch), indicated in the schematic of Figure 1.1, to which the base plate of the Guardrail Post samples are bolted. Each test was completed at a quasi-static loading rate, as follows:

- The test with Sample 1 was completed at a constant cross-head displacement rate of 1/16″ per minute up to a load level of approximately 5,000 lbf. When subsequently increasing the applied load to approximately 10,000 lbf, the loading rate was increased to 1/8″ per minute.

- The test with Sample 2 was completed at a constant cross-head displacement rate of 1/8″ per minute up to the load levels of both 5,000 lbf and 10,000 lbf.

The test includes a record of the load versus displacement, with the latter corresponding to the movement of the test frame cross-head. Plots illustrating the recorded load versus cross-head displacement are shown in Figure 3.2 for Sample 1 and Sample 2.

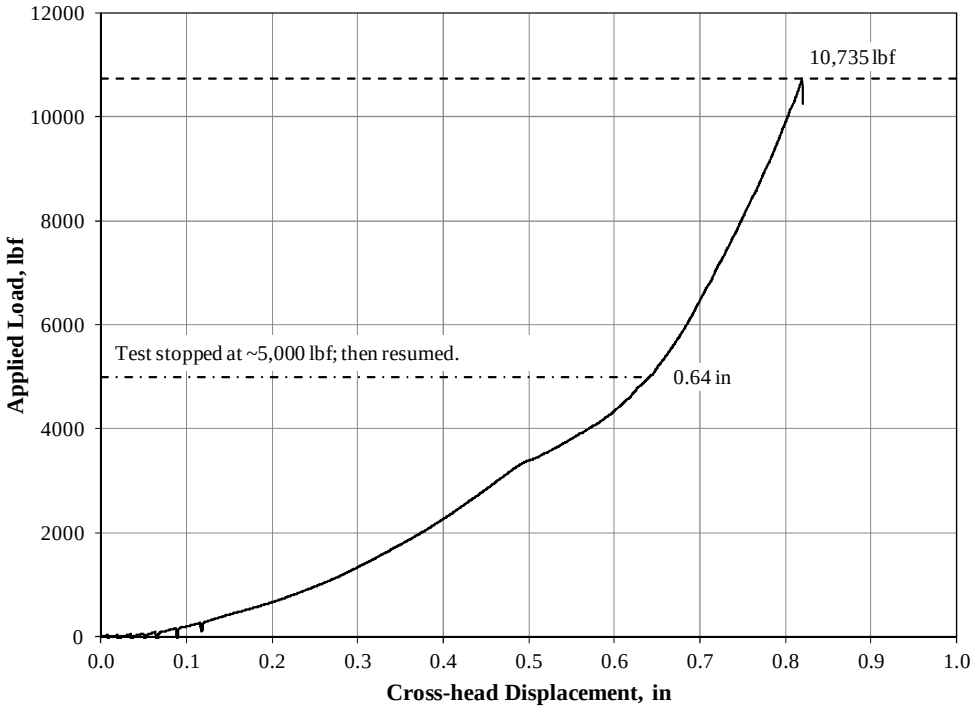
For either Sample 1 or Sample 2, the maximum cross-head displacement recorded is approximately 0.64″ (or, 16.3 mm) at the prescribed load level of 5,000 lbf. Note that the displacement of the safety lug does not correspond to that for the cross-head and would be less. Displacements of the specimens were not measured for this test.

Following the completion of each test, the condition of the safety loop for each sample was checked visually. In each case, and up to the maximum applied load of 10,000 lbf, no deformation of the loops or the associated welded connections was observed.

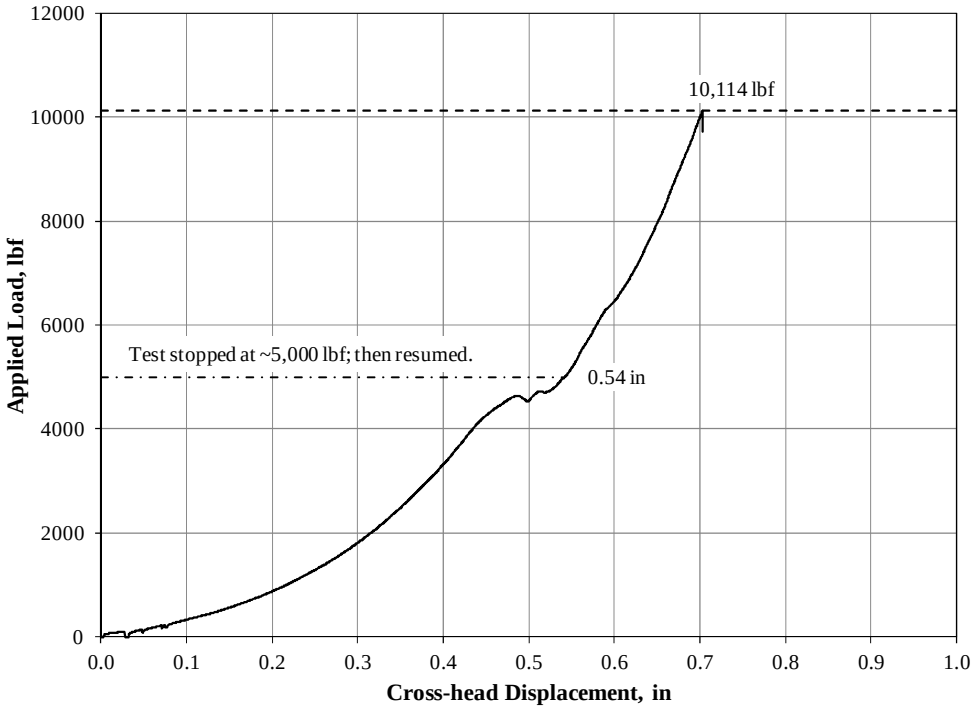
(a) Overview

(b) Safety Loop Connection to Test Apparatus

Figure 3.1: Guardrail Post Sample in Test Apparatus



(a) Sample 1



(b) Sample 2

Figure 3.2: Recorded Load-Displacement

4 CONCLUSIONS AND RECOMMENDATIONS

"Safety in a Second" supplied two sample Guardrail Posts with corresponding detailed drawings to BMT Fleet Technology Limited (BMT FTL) for evaluation of the safety loop as a fall arrest attachment point. The evaluation consisted of a static load tension test of the safety loop. This evaluation has demonstrated that:

- The calculated factored resistance of the welded connections associated with the safety loop of 16,186 lbf (or, 72 kN) exceeds the proposed applied load of 5,000 lbf (or, 22 kN).

- The structural performance of the safety loop and welded connection as tested meets the requirement to carry an applied static load of 5,000 lbf (or, 22 kN) without noticeable deformation.

- Further, the structural performance of the safety loop and welded connection as tested was shown to carry an applied static load of up to 10,000 lbf (or, 44 kN), equivalent to 2.0 times the prescribed load level, without noticeable deformation.

The test results described in this report are specific to the geometry and materials used to fabricate the two samples provided. Different load carrying capacities will be measured if different materials or structural configurations are used to fabricate the assembly. It is also noted that the capacity of the anchor bolts to support the prescribed load was not considered in this investigation.

BMT Fleet Technology is an innovative leader in providing through-life engineering support from concept development through design, construction, operations, life extension/upgrade and disposal. The company employs its technological expertise and practical experience to provide services to clients in the Marine, Defence, Energy & Environment, Civil & Industrial Infrastructure, and Transport industry sectors. We are committed to retaining and applying practical knowledge of sector-specific factors in developing responsive solutions to customer's needs. The company's hallmark of engineering excellence involves the provision of leading edge structural and mechanical system damage assessment, materials and welding engineering, inspection and maintenance management, naval architecture and marine engineering, environmental and cold regions engineering services.

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