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Mr. Dave Arnston
Mechanical Project Engineer
SLOPE INDICATOR COMPANY
P.O. Box 3015
Bothell, WA 98041-3015

Subject: Engineering Review of Inclinometer Casing Strength Tests

Dear Mr. Arnston:

Your firm requested that Pacific Testing Laboratories (PTL/PSI) review four strength tests which Slope Indicator Company (Slope Indicator) applies to its inclinometer casings. This letter is a summary our observations and conclusions.

BACKGROUND

PTL/PSI visited the Slope Indicator manufacturing facility on April 25 and May 14, 1997, to review existing manufacturing and testing procedures as they are applied to current product. The focus of the site visits was to review the performance of tests which characterize the structural integrity of the inclinometer casings. The casings are, in regular service, subjected to high levels of mechanical stress and strain. Loading typically includes tensile pulling on ends, torsion about the axis of the casing, bending of the casing as it emerges from the hole, and hydrostatic loading due to ground fluids. These loading scenarios are emulated via four distinct mechanical tests which are applied to the assembled casing sections.

The casing tested is produced from a high grade blue-pigmented ABS polymer which is extruded and machined to final shape. Slope Indicator's typical machining operations were observed in order to verify that the test samples were virtually identical to production product in raw material, processing, and handling.

ANALYSIS AND OBSERVATIONS

As with any mechanical system, the connections between the elements are the weakest link. Thus, section joints are included in all test units. Slope Indicator Engineering has elected to orient the joints under test in the various testing fixtures in such a manner as is most likely to cause the joint to fail. This practice reflects a conservative engineering approach. Since all tests are completely destructive, separate test samples are utilized for each test.

Observations follow regarding each of the four structural tests for the casings:

Pull Test

The pull test was a tensile end load which tests the resistance of the casing joints to tensile loads which could cause sections to pull apart. Used for this test were a loading frame, a hydraulic cylinder with an effective ram area of 2.7 sq in, and a 1,000 psi hydraulic pressure gage, in current calibration and traceable to the National Institute of Standards and Technology (NIST). Gage pressure at tensile failure for five samples was observed to be 600-625 psi. This is indicative of a minimum tensile load of 1,620 lbf. The test was performed uniformly, with highly repeatable results.

Torque Test

The torque test was performed across a section joint which tests the resistance of the joints to twisting loads which could cause misalignment of the internal grooves. A torque lever arm and free weights were used to perform this test. The torque arm was measured to be 12.0 in using a ruler, and the weights were identified with individual stamped numbers, making the weights traceable to NIST as Class F. The rotary bearing supporting the torque arm was examined and found to be in good condition with free movement. Results of the torque test ranged 24 to 28 lb-ft. This test was observed to be performed in a repeatable, appropriate manner.

Bending Test

The bending test was performed to simulate bending loads which may be applied on the free end of a casing section which is emergent from a hole. Lateral loading on the free section produces significant bending within the casing at the location near the hole. The bending test was performed using four-point loading to produce a theoretically constant bending moment between the two middle supports.

The casing joint was located in this middle region. Load application was via the calibrated free weights described above for the torque test. Both samples observed failed after load had been steadily applied over approximately three minutes, with a momentary peak of 140 lb-ft. This test was observed to be performed in a repeatable, appropriate manner.

Collapse Test

The collapse test was performed to test the resistance of the casing to hydrostatic compression, as it experiences in ground holes. The test was performed using an O-ring sealed pressure vessel constructed from a large aluminum tube. The vessel seals around the outside diameter of the casing and applies positive pressure to its outer surface. Pressure is sensed using a 500 psi calibrated pressure gage. Pressurization is via a hand water pump. Failure modes are water leakage or diametral buckling. Two samples were tested with pressure results at failure of 280 and 220 psi, respectively. Failure was due to buckling in both cases. No water leakage was observed in either test. The test was observed to be performed in a repeatable, appropriate manner.

CONCLUSIONS

Based on the observations made of testing on the inclinometer casings at Slope Indicator and all information available at the time, we conclude the following:

1. Shop floor and engineering personnel appear to have a clear understanding of what is important to the customers who buy their product.

2. The four casing strength tests observed are set up in a reasonable manner using high quality equipment and properly calibrated instruments and free weights.

3. The tests are executed in a reasonable manner which is consistent with sound engineering practice.

4. The test values which were recorded and reported here accurately represent the capabilities of the product.

This test has been made and report prepared based upon the specific sample provided to us by the client for testing. We assume no responsibility for variations in quality of samples made by persons or under conditions over which we have no control.

This report is provided for the information of Slope Indicator Company only. If this report is to be reproduced and/or transmitted to a third party, it must be reproduced and/or transmitted in its entirety. Any exceptions will be made only with the written permission of PTL/PSI.

Thank you for using PTL/PSI. If you have any questions, or if we can be of further assistance to you, please contact us at (206) 282-0666.

Reviewed by: Thomas Strickland, Manager, Metrology/Calibrations TRS,

Sincerely,

Mark J. Suryan, P.E., Manager
Consulting Engineering

MJS/lmm