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TENNESSEE VALLEY AUTHORITY

Division of Engineering Design

Civil Engineering and Design Branch

Posttensioned Anchor Tendons in Rock

Installation and Testing of Tendons by Inland-Ryerson Construction Products Company

R. E. Bullock
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POSTTENSIONED ANCHOR TENDONS IN ROCK

INSTALLATION AND TESTING OF TENDONS BY INLAND-RYERSON

Summary

Three wire tendons with button-head anchorages were installed in holes drilled into rock at the Bellefonte Nuclear Plant site. They were first-stage grouted and subjected to load testing. The loads were adequately transferred to the rock.

Introduction

As a test of anchorage for the proposed prestressed concrete containment vessel, two contracts were awarded for the installation and testing of posttensioned anchor tendons in rock at the Bellefonte Nuclear Plant site. The first contract was for wire tendons with button-head anchorages, and the second contract was for strand tendons with wedge anchorages. This report relates only to the first contract which was with Inland-Ryerson Construction Products Company.

The tendons were installed on August 8, 9, and 10, and were tested on August 28. At the site G. Johnston and T. Brown represented Inland-Ryerson. D. Loflin and W. Hall represented the Construction Services Branch. R. E. Bullock represented DED during installation and testing. DED was also represented by J. H. Coulson during testing. Rock deformation test results from instruments installed by Mr. Coulson are covered in a separate report dated November 6, 1973.

Purpose

The tests were designed to provide documented evidence of the ability of grouted anchor tendons to transfer load to rock, to establish required length of grout, and to provide information on rock deformation.

Scope

Requirements are in Specification 1868 for Testing of Prestressed Grouted Rock Anchors, X-14 and X-15 Nuclear Plant, and details are on drawing 41N714-1R1 for Bellefonte Nuclear Plant. Three wire tendon assemblies were to be installed in holes drilled by TVA through a concrete bearing pad on which the bearing plates were to bear. Two tendons, designated A and B, were to extend 40 feet below the top of the bearing plate, and one tendon, designated C, was to extend 20 feet. Tendons A and B were to have approximately 20 feet of first-stage grout, and tendon C was to have approximately 7 feet. First-stage grout is placed and permitted to harden before tensioning. Second-stage grout is installed for corrosion protection after tensioning.

Tendon A was to be loaded twice to 80 percent of its rated ultimate while load and deformation measurements were made on the tendon and the rock. Tendon B was to be cycled 100 times between 60 and 70 percent of ultimate with periodic load and deformation measurements. Tendon C was to be loaded three times to 80 percent of ultimate and then to 95 percent of ultimate.

Tendon Description

The preassembled tendons arrived on the site by truck on August 8, 1973. They are composed of 170 wires of 1/4-inch diameter and were specified to conform to ASTM A 421, type BA. The rated ultimate capacity of each tendon is 2000 kips.

At each end of the tendons the wires are placed through drilled holes in steel fittings and button heads are cold formed. The steel fitting at the lower end, termed anchor head, is 6-1/4 inches in diameter and 3 inches thick. At the upper end, stressing head, it is 9-3/8 inches in diameter and 4 inches thick and has external threads for coupling to the stressing jack. The diameter to the centerline of the outer drilled holes is 5.9 inches. Down the center of the tendon is a 3/4-inch steel pipe for grouting. A pipe coupling and lock nut fix the anchor head's position with respect to this pipe. At the intended top of first-stage grout a left-hand threaded coupling is placed so that the piping can be broken there, while tightening other couplings, as soon as first-stage grout is pumped. At the approximate mid-height of the tendon six bent wire arms were welded to a pipe coupling to help center the tendon. The iron workers only approximately distributed the tendon wires between the arms so that some of the tendon wires were not straight when installed.

Tendon Installation

All three holes in rock were drilled with an 8-5/8-inch drill but were approximately 9 inches in diameter. The water level in the holes was found to be about 12 feet below the surface. Oil covered the water in hole B. A can on the end of a length of conduit was used to dip off the oil. It appeared to be almost clean oil of 30 or 40 weight, and was estimated to have a depth of 1/4 inch. After extensive dipping, little oil droplets remained in the water. To remove these a detergent was added and the water level slowly raised as it was churned with the dip can. Water was added until that overflowing out of the hole was clean.

The grouting equipment supplied by the contractor consisted of a Moyno pump with an agitator tank just above it and a mixing tank immediately above the agitator tank. The mixing tank had a capacity of about one cubic foot and used a single propellor. It was probably inadequate, but the electrical generating equipment failed to operate properly so that contractor's equipment was not utilized. A TVA air-operated mixer and pump was obtained. It required manual batch mixing in a 55-gallon drum and dipping into the pump hopper, but it worked satisfactorily.

An expansion test was run on the first grout batch and no expansion or bleeding was observed. The grout additive dosage was doubled for subsequent batches, but no expansion could be measured. It was later learned from Sika Chemical Company, the admix supplier, that the expansion producer had been omitted from the admix. Grout proportions and significant test results are as follows:

Cement	94 pounds	94 pounds
Fly ash	19 pounds	19 pounds
Sand	71 pounds	71 pounds
Water	50 pounds	50 pounds
Sika DP23-37	0.5 pound	1.0 pound
Expansion CRD-C81	0	0
Bleeding	0	0
Cube strength - 28 days	6700 psi	5400 psi

A pressure gage at the pump outlet manifold indicated a maximum pressure of 200 psi during the grouting.

Both holes A and B had clear water coming out the bearing plate bleed holes until almost all the grout was in place and then the water turned brown clay color. Water from hole C remained clear.

Grout was pumped in a calculated amount to be approximately 2 feet above the final desired level of first-stage grout. The grout pipe was then broken loose at the left-hand threaded coupling, lifted about 1 foot, and water pumped through the grout system. It was presumed that this would wash out the excess grout. Water coming out the bearing plate bleed holes at first appeared to be carrying cement and then turned clear. It appears probable that the water broke channels through the grout above the lifted grout pipe end and washed out only some of the finer cement particles. Attempts to measure the hardened grout elevations were inconclusive. A 3/4-inch pipe was pounded through weak grout or sand to a distance below the bearing plate of 17 feet in hole A, 14.5 feet in hole B, and 12 feet in hole C.

Stressing Procedures

The stressing equipment, hydraulic jack, gage, and electric-driven pump, were adequate. Calibration of the jack and pressure gage had been done by Inland-Ryerson using equipment which had been calibrated by others. The only method of measuring elongation was by holding a 6-foot rule from the jack housing to the rounded edge of the upper end of the ram.

The jack was set over the stressing head by crane and the ram rotated to couple it to the head. This was done quickly for tendons A and B, but for tendon C considerable difficulty was experienced. The stressing head was twisted through an appreciable arc, possibly 180 degrees, and the wires were shoved against the bearing plate several times before the threads were adequately engaged.

Test Results

The jack pressure versus scaled distance curves for tendons A and B are shown on figure 1 together with some associated calculations. Both tendons were specified as 40 feet long with 20 feet of free length from the bearing plate to the grout. The calculated effective tendon lengths are equal to the area of the steel times the modulus of elasticity times the slope of the loading curve. The curves indicate that up to 0.3 fpu (specified ultimate strength of the steel), the free length of the tendon is effective. From 0.3 to 0.7 fpu, bond has failed along the wire sufficiently for the effective length to be approximately 5 feet into the grout. Above 0.7 fpu, the tendon is elongating over a length substantially to the anchor head. When the load is released, friction along the wires maintains a substantial strain in them and this is probably responsible for the offset between first and later loadings.

Tendon B was cycled 100 times from 0.6 to 0.7 fpu. At 50 cycles, distances were again scaled with the load at 0.8 fpu. At this time one button head popped off. This is only 0.6 percent of the wires and no further distress occurred at 100 cycles. This loading did not significantly increase tendon elongation.

The results of the test on tendon C are shown in figure 2. An apparent proportional limit of the tendon material occurs slightly below 0.6 fpu. No completely satisfactory explanation for this behavior is available. If a 180-degree twist was maintained in this tendon while stressing, the outer wires would yield at approximately 0.6 fpu. However, such a condition should produce a flatter slope for the initial portion of the loading curve. The initial change in effective length occurs at a lower stress in tendon C than it did in tendon A or B. The shorter free length of tendon C would make any length variation and any angularity of the wires at the top of the grout column more critical. The short grout column did transfer approximately 0.95 fpu to the rock, but it appears that any conclusions with respect to required length would be hazardous.

Conclusions

1. Posttensioned anchor tendons will transfer either a steady or cyclic load through grout to the rock at the Bellefonte Nuclear Plant site.

2. An adequate free length of tendon, that between grout and jacking point, is necessary to minimize the effect of unequal load distribution between individual wires. This is in excess of 13 feet.

TENDON MARK A TENDON MARK B

SPECIFIED LENGTHS 40'
SPECIFIED GROUT 20'

NOMINAL LENGTH TO GROUT 20'

STEEL AREA A_{ps} = 8.33 sq. in. RAM AREA 211.3 sq. in.

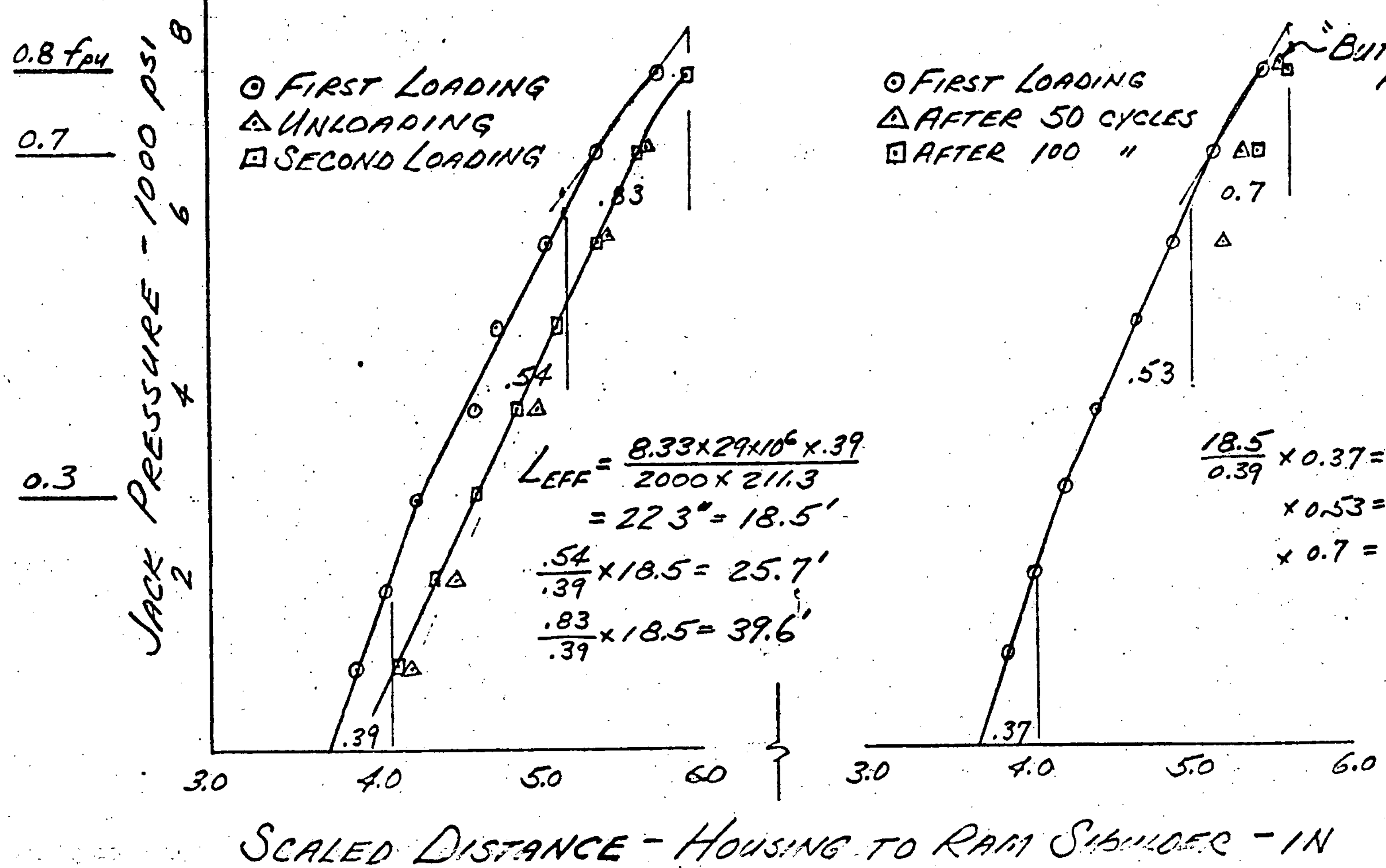


FIGURE 1

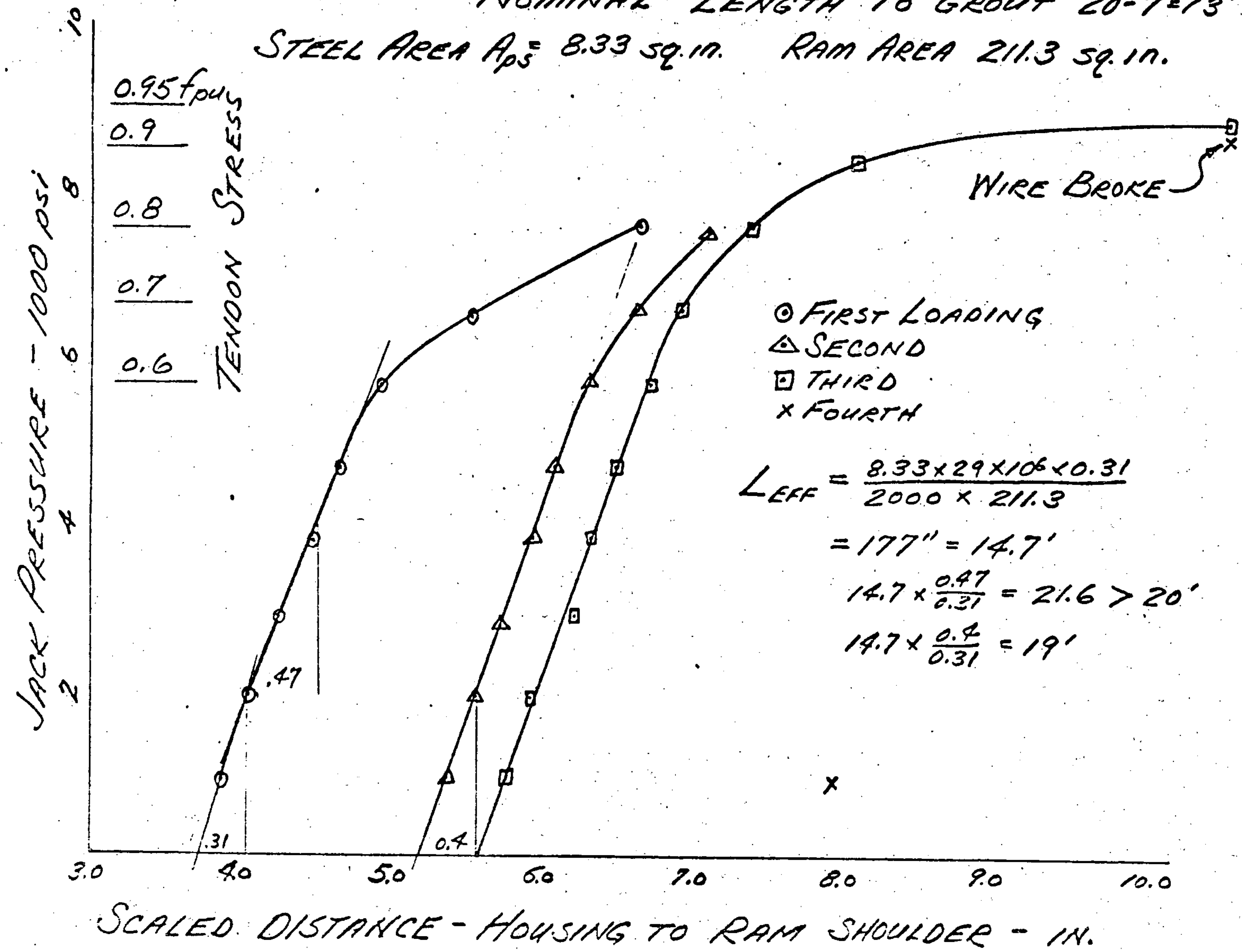
BWP ROCK ANCHOR TESTS

TENDON MARK C

SPECIFIED LENGTH 20'
SPECIFIED GROUT 7'

NOMINAL LENGTH TO GROUT 20-7=13'

STEEL AREA A_{ps} = 8.33 sq.in. RAM AREA 211.3 sq.in.



BNL ROCK ANCHOR TESTS

FIGURE 3