GAI REPORT NO. 2074

EVALUATION OF PRESTRESSED TENDON FORCES

FOR

ROBERT E. GINNA NUCLEAR POWER STATION

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BY

GILBERT ASSOCIATES, INC.
READING, PENNSYLVANIA

2) Concrete Shrinkage

For the Ginna site region, the Mean Daily Relative Humidity is in the 70% to 80% range. Therefore, from Table 1 of Reference 5, the 40 year shrinkage strain is 100×10^{-6} in/in. For purposes of plotting on a log-time (log t) scale, shrinkage is taken to start 1 hour (0.00011 yr.) after the date corresponding to the average date of containment wall concrete placement. The containment wall construction and stressing dates are given in Figure 2. The shrinkage strain varies linearly with log t from zero at t = 0.00011 yr. to 100×10^{-6} in/in at t = 41.4 years (40 years after initial stressing) and is shown in Figure 3.

Only the containment shrinkage which occurs after initial stressing (t = 1.41 years) influences the loss of tendon force. Based on the assumed shrinkage strain variation, a strain of 78×10^{-6} in/in at t = 1.41 years is calculated. The tendon force loss at t = 41.4 years is predicted to be:

$$(100 \times 10^{-6} \text{ in/in} - 78 \times 10^{-6} \text{ in/in})\ (29 \times 10^{6} \text{ psi})\ (4.42 \text{ in}^2) = 2.8 \text{ kips}$$

which is shown in Figure 3.

A variation of ±20% in the predicted values is allowed by Reference 5:

3) Concrete Creep

The recommended specific creep formula from Appendix A of Reference 5 is:

$$\frac{\varepsilon_c}{f_c} = A\alpha \left[1 - e^{-(t-t_o)/30}\right] + B \log_{10} (t/t_o)$$

0.45 and 0.34 for the 5000 psi concrete used in the Ginna containment. The specific creep curves in Appendix C of Reference 6 were used in the calculations.

From Figure 2, the average age of the containment wall concrete at time of initial stressing was 515 days (1.41 years). A specific creep curve for a concrete age 515 days was obtained by extrapolating from the curves in Appendix C of Reference 6. Based on this extrapolated curve, the concrete in the containment wall is predicted to have a 1 year specific creep of 0.08×10^{-6} in/in/psi and a 40 year specific creep of 0.23×10^{-6} in/in/psi. The corresponding losses of tendon force are:

<u>At 1 year after initial stressing (t = 2.4)</u>

$(0.08 \times 10^{-6}$ in/in/psi) (628 psi) (29×10^{6} psi) (4.42 in^2) = (0.08×10^{-6}) (80497×10^{6}) = 6.4 kips

<u>At 40 years after initial stressing (t = 41.4)</u>

(0.23×10^{-6}) (80497×10^{6}) = 18.5 kips

The creep loss is zero at t = 1.41 years after concrete placement and varies with log t as shown in Figure 3. A variation of +25% and -15% in the predicted value is allowed by Reference 5.

4.3 <u>QUESTION</u>: Was there a chemical analysis of the groundwater at the site?

<u>RESPONSE</u>: Not to our knowledge. Corrosion protection for the anchor was provided by grouting. This method has been successfully used on a number of projects. See References 7 and 8.

TABLE 3
TEN YEAR LIFT-OFF FORCE ESTIMATE

TENDON NUMBER	FIGURE NUMBER	FORCE LAST TEST (kips)	LAST TEST (Year)	PREDICTED FORCE (kips)	REMARKS
53	4-1	625	8	621	All predicted forces are based on the Base Value predicted slope through last test data unless noted otherwise.
133	4-2	630	8	626	
45	4-3	637	8	634	
17	4-4	632	8	627	
36	4-7	632	8	679(627)	Based on predicted slope thru 3 year test data (based on 8 year test data).
95	4-13	615	8	611	
142	4-18	612	8	607	
8	4-24	612	8	655(607)	Based on predicted slope thru 3 year test data (based on predicted slope thru 8 year test data).
84	4-30	588	8	584	
126	4-31	687	8	683	
160	4-33	612	8	607	
76	4-35	605	8	602	
117	4-42	663	8	658	
110	4-37	657	8	653	
60	4-19	647	1	621	
63	4-14	647	3	630	
150	4-40	658	3	640	
159	4-10	673	3	650	
51	4-12	665	1	636	
83	4-11	653	1	624	
100	4-16	627	3	610(575)	Based on actual slope thru 1 and 3 year test data (based on predicted slope thru 3 year test data).
132	4-25	653	6 mo.	614	
				631	Average Lift Off Force in 22 Tendons tested (estimated)

FIGURE 1-A
TENDON STRESSING SEQUENCE

Jack #1	Jack #2	Jack #3	Jack #4
13	53	93	133
149	25	69	105
1	45	81	127
21	57	101	137
17	65	97	145
9	61	89	141
5	49	85	129
157	44	77	121
153	26	73	108
151	27	71	107
185	36	75	111
139	43	79	128
3	47	85	125
7	51	87	131
11	55	91	135
15	59	95	139
19	63	99	143
23	67	103	147
24	68	104	148
22	66	102	146
20	64	100	144
18	62	98	142
16	60	96	140
14	58	94	128
12	56	92	136
10	54	90	134
8	52	88	132
6	50	86	130
4	48	84	123
2	46	82	126
160	41	80	124
158	42	78	122
156	40	76	112
154	30	74	110
152	28	72	109
150	29	70	106
32	31	113	117
33	37	114	118
34	38	115	119
35	39	116	120

___ = Retensioned at 1000 hours.

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FIGURE 1-A
TENDON STRESSING SEQUENCE

The tendons were also overstressed to approximately 6% above the force required to produce lift-off, and the tendon elongations recorded. The results are presented in Table I-2. The elongations ranged from 3/16 inch to 11/16 inch, and the corresponding tendon force increases ranged from 8.9 to 51 kips. The average tendon force increase was 33.7 kips, and the average elongation was 8/16 inch. The predicted elongation for a straight tendon under the 33.7 kip force is 6/16 inch. Therefore, the tendon elongations appear to be reasonable, and no abnormal tendon behavior is indicated. Differences in elongations (for approximately the same tendon force increase) are attributed to (1) inaccuracy in determining the point of lift-off, which could be significant for the relatively small tendon force increment, and (2) variations in the friction at each tendon.

The retest indicated higher values than the 8 year tests and general agreement with the slopes of the predicted curves. Where several previous tests are available, Figures 4-4, 4-7, 4-24, the retest value appears to be in line with other earlier tests. Of the 22 tendons, only tendons 51 and 63, Figures 4-12 and 4-14, show greater slopes than predicted. The results would indicate that many of the 8 year test values were in error.

The average force in the tested tendons was found to be 634 kips. The predicted average force was 631 kips. The average force based on the technical specification requirement that the tendon stress be at least 144,000 psi is 636 kips. The technical specification also allows for 5% broken wires. If no wires are broken and the allowance were applied to the stress, the minimum required force per tendon would be 604 kips.