Performance of Cable Guiderail in New York

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Cable guiderail with insufficient tension may deflect excessively on impact, allowing vehicles to contact fixed objects behind the barrier. In 1980 a two-phase study was initiated by the New York State Department of Transportation to investigate causes of tension loss in cable guiderail and formulate corrective measures. The study's first phase documented performance of new cable barriers in the field and the results of laboratory testing. Anchor movement and permanent cable stretch were identified as major causes of tension loss, sufficient to affect barrier performance adversely. Several changes have already been made based on these results: construction specifications and standard sheets were changed to ensure proper soil compaction and better initial and long-term cable tension. In the second phase, field performance of selected improved installations was documented from 1984 to 1987. In addition, prestressed cable was used on some projects in 1985 to investigate its effectiveness in reducing tension loss due to cable stretch. Laboratory stretch tests were conducted using normal and prestretched cable to determine any significant differences appearing in cable strain due to long-term loading. Results from field and laboratory tests indicated that cable guiderail installations continually lose tension and need to be retensioned periodically and that substituting prestretched for normal cable does not reduce the tension-loss problem.

Lightweight cable guiderail now in use in New York State was developed in the late 1960s (*1,2*). The cable is designed to separate from S3 × 5.7 steel posts on vehicle impact, with tension in the cable developing the force necessary to retain and redirect vehicles. The tension in the barrier before impact affects the total cable deflection that must occur to develop this force. The rail elements consist of three ¾-in. galvanized steel cables mounted on the posts by hook bolts. The cables are secured to concrete anchor blocks at the ends of each installation to develop tension. Details of the cable-guiderail system are shown in Figure 1. Spring-compensator devices are included to allow for cable length change due to temperature change. When properly adjusted, these spring compensators should maintain a working range of cable tension between 450 and 1,800 lb throughout the annual temperature cycle without any need for periodic adjustment. The standard sheets require that in cases where the cable run is 1,000 ft or more, springs are required at each end; otherwise they require springs at only one end (*3,4*).

During the 1979 New York State Department of Transportation (NYSDOT) Highway Safety Review, a problem was detected related to the safety of cable guiderails, concerning their inability to redirect traffic because of insufficient tension in the cables. During inspections almost every cable installation observed was found to have insufficient tension. Initially, there was concern that proper installation procedures had not been followed. After further investigation, it became apparent that cable guiderail could become slack even if installed and tensioned correctly.

Besides being unattractive, slack cable guiderail is a potential safety hazard because it limits the ability of the barrier to redirect vehicles within the allowable deflection range. A vehicle that impacts an installation with insufficient tension can be guided into an object while being redirected.

To address these concerns, a research study was initiated in the spring of 1980. Its objectives were fourfold:

1. Determine the extent of slack cable guiderail,
2. Identify the causes,
3. Propose corrective action, and
4. Verify that proposed solutions are effective by conducting long-term follow-up surveys.

The investigation began monitoring several cable guiderail installations. It was determined that these installations quickly lost cable tension, thus reducing their potential effectiveness. In the first phase, several possible causes were investigated, including anchor movement, post settlement, cable creep, post movement, spring compensator failure, accident impacts, inadequate maintenance, incorrect initial installation procedures, and turnbuckle backing off. Major causes were identified as anchor movement, cable creep, and nonuniform tension distribution throughout the barrier caused by frictional drag at the posts. Even after these installations were retensioned, they experienced unacceptable degrees of cable tension loss.

Based on the findings of Phase 1 (*5*), several changes were made. First, construction specifications were changed in 1982 to ensure proper soil compaction during the placement of concrete cable anchors and to reduce anchor movement to acceptable levels. Second, the standard sheet for cable guiderail was revised to ensure better initial and long-term cable tension through improved installation procedures. Third, revised specifications requiring prestressed cable were used on some projects in 1985. With such cable, it was assumed that tension loss due to stretch could be reduced.

To determine the long-term performance of these corrective measures, a second phase was initiated in 1984. The Phase 2 objectives were to monitor the effectiveness of the new specifications and corrective measures and to document the results of field and laboratory tests on prestretched cable.

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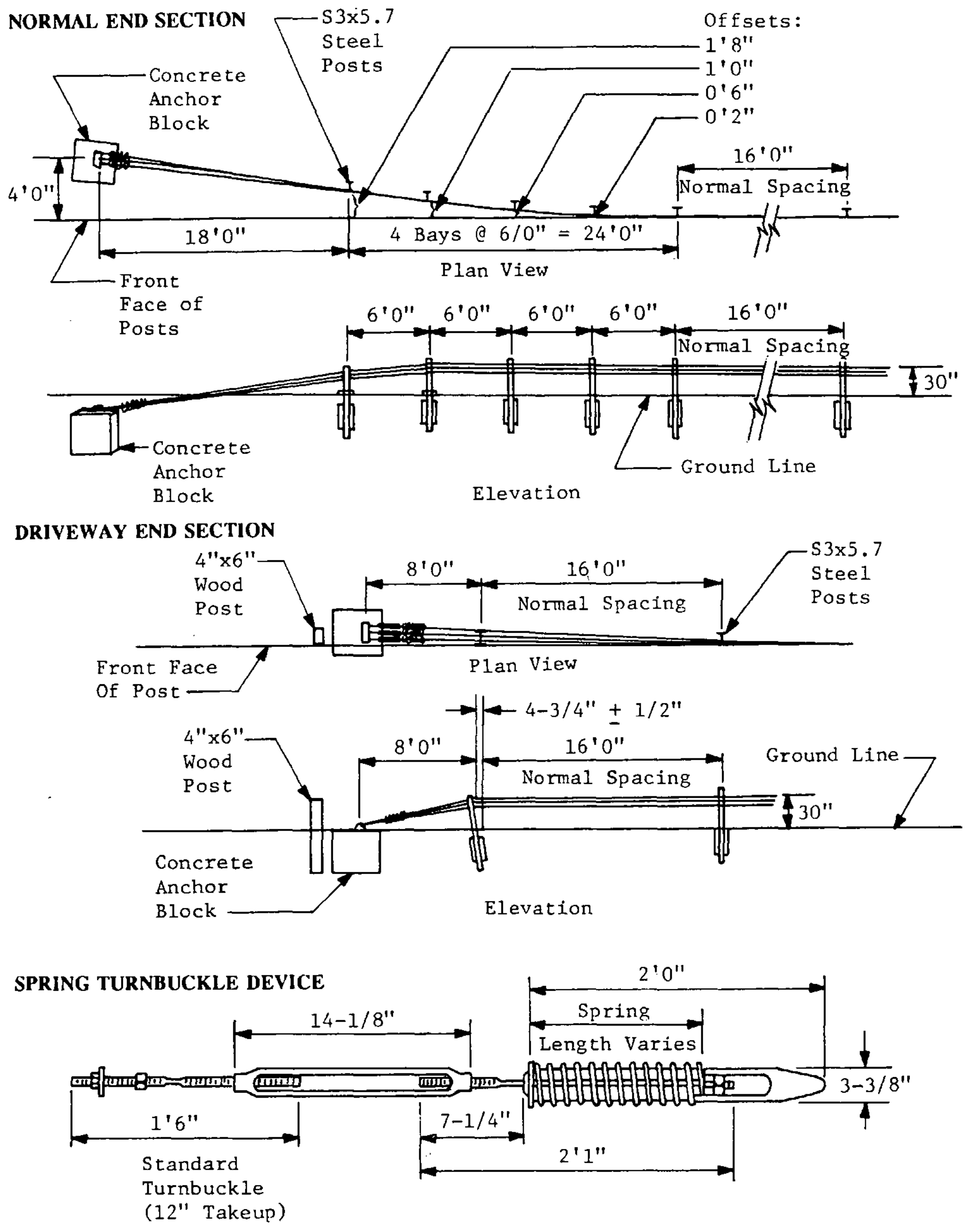

FIGURE 1 Cable-guiderail detail (1 mm = 0.04 in.).

Periodic condition surveys were carried out for 3 years, monitoring both normal and prestretched cables. Laboratory tests were conducted to determine the difference in stretch between the two cable types. The effectiveness of the corrective measures and use of prestressed cable are documented in a final report (*6*).

INVESTIGATION AND RESULTS

Phase 1

In the first phase, possible causes of tension loss were investigated and identified. A total of 53 new installations on 12 construction projects were monitored during 1980 to observe and document installation procedures, and reference systems were installed to monitor changes in the barrier. In addition, individual site parameters were recorded for each sample to determine what effect, if any, they had on tension loss. These parameters included the presence and degree of horizontal and vertical curves, length of run, contractor who installed the barrier, temperature at the time of tensioning, and whether inspections were by state or consultant personnel. Minor alterations in the tensioning procedure were also tried on 15 of these runs in an attempt to remedy the problem of tension loss. After promising corrective measures were formulated, these modifications were included on 21 new installations in 1981 to evaluate their effectiveness. Some of the cables placed in 1980 were also retensioned in 1981 to see if setting proper tension a second time would aid in maintaining tension.

Cable tension, occurrence of accident damage, and any changes occurring with respect to the reference systems were monitored throughout the year by conducting spring, summer, and fall surveys. Snow and ice made it impossible to obtain winter measurements, but reconnaissance surveys were made throughout winter months to keep track of accident and snowplow damage. If any sample installations were readjusted or experienced damage that would affect tension, they were no longer surveyed. All data obtained from the surveys were organized in tabular form to facilitate statistical analysis. As discussed later, the tensioning procedure, anchor movement, and permanent cable stretch were identified as major causes of tension loss and were found sufficient to harm barrier performance (*5*).

Evaluation of Tensioning Procedure

Four tensioning procedures were compared to verify whether any benefits were obtained by changing normal tensioning practice: (a) a normal-tension group with 154 samples, (b) a 1980 revised-tension group with 78 samples, (c) 1981 revised-tension group with 63 samples, and (d) a retensioned group with 73 samples.

The sequence for installing cable guiderail using these four procedures was as follows:

1. Normal-tension procedure: After posts were driven and anchors placed, the cable was unrolled and cut to the approximate length. The cable was strung through the J-bolts, unloaded spring lengths marked on the compensator rod, and the anchor hardware attached to the cable at one end and secured to the anchor. With the cable now fixed at one end, it was pulled straight by applying tension at the opposite end with a hand winch or pulling with a truck to remove the slack. With this tension held by the truck, or winch, or locking pliers clamped on the cable against posts, the cable was cut to the final length. The anchor hardware was then installed at this end and secured to the anchor, and the slack between the anchor and the point at which the tension was being held was taken up with the turnbuckle. The temporary clamps were then released, leaving the cable secured to both anchors with some initial tension present.
2. 1980 revised-tension procedure: This procedure involved placing 1,600 lb of initial tension on each cable. This value equates to 3.5 in. of spring compression, slightly below the upper limit of 4 in. After 2 to 3 weeks, tension was set to the standard-sheet value if the cables had not already relaxed to that level.
3. 1981 revised-tension procedure: This procedure included two additional modifications of the 1980 revised-tension procedure. First, to overcome the problem of frictional drag, the springs were compressed by applying tension at the opposite end of the barrier. By pulling the cable the entire length of the barrier, the amount of tension at any point had to be at least the value indicated by the springs at the far end. Second, these runs were tensioned according to 10°F temperature intervals corresponding to ¼-in. spring compression increments as presented in Table 1.

TABLE 1 Spring Compression Settings for Cable Tensioning

Previous Settings (20 deg F, ½-in. increments)		Revised Settings (10 deg F, ¼-in. increments)	
Temperature Range, F	Spring Compression, in.	Temperature Range, F	Spring Compression, in.
-20 to -1	4.00	-20 to -11	4.25
0 to 19	3.50	-10 to -1	4.00
20 to 39	3.00	0 to 9	3.75
40 to 59	2.50	10 to 19	3.50
60 to 70	2.00	20 to 29	3.25
80 to 99	1.50	30 to 39	3.00
100 to 120	1.00	40 to 49	2.75
		50 to 59	2.50
		60 to 69	2.25
		70 to 79	2.00
		80 to 89	1.75
		90 to 99	1.50
		100 to 109	1.25
		110 to 119	1.00

Note: $t_C = (t_F - 32)/1.8$
1 N = 0.225 lbf

4. Retensioned procedure: Samples installed with the normal tensioning procedure were retensioned according to the updated temperature-spring compression settings to see whether setting proper tension a second time would help maintain it better.

The cables in the normal-tension group experienced an average 26 percent loss (298 lb) between the time they were tensioned during late summer and fall 1980 and the fall 1980 survey. This loss is based on the difference between actual measured values and theoretical tension values at the measurement temperature. After the first winter, an average 46 percent loss (465 lb) had occurred, and by spring 1983 average loss was 602 lb, or 56 percent. Seventy-seven percent of the total loss measured in spring 1983—after three winters in service—had occurred by spring 1981, and thereafter the gap between theoretical and measured tension widened at a much slower rate. Also, it was found that tension was not distributed uniformly through the cable. Figure 2 shows measured tension values throughout a 1,946-ft barrier just after tensioning by the normal procedure. Tension in the middle portion of the run was about 50 percent less than that indicated by spring compression at the ends. Frictional drag at the cable-post connection caused nonuniform tension throughout the barrier.

The cables in the 1980 revised-tension group experienced an average loss of 19 percent, or 315 lb, during the 2- to 3-week period when tension was left at the high initial level. By spring 1981, after one winter in service, average tension loss was 196 lb, or 19 percent of the theoretical value, referenced to the tension value at the end of the pretensioning period. By spring 1983, actual losses averaged 32 percent of the theoretical value, or 325 lb. Losses occurring by spring 1981 averaged 78 percent of the 1983 loss. Forty-nine percent of the spring 1983 total loss—that was occurring during the 2- to 3-week pretensioning period, plus the loss taking place thereafter—occurred before final adjustments were made at the end of the pretensioning period. The high loss during the high initial tension period was not critical since it occurred after final adjustments were made. After one winter, tension loss in the normal-tension group was 137 percent greater than

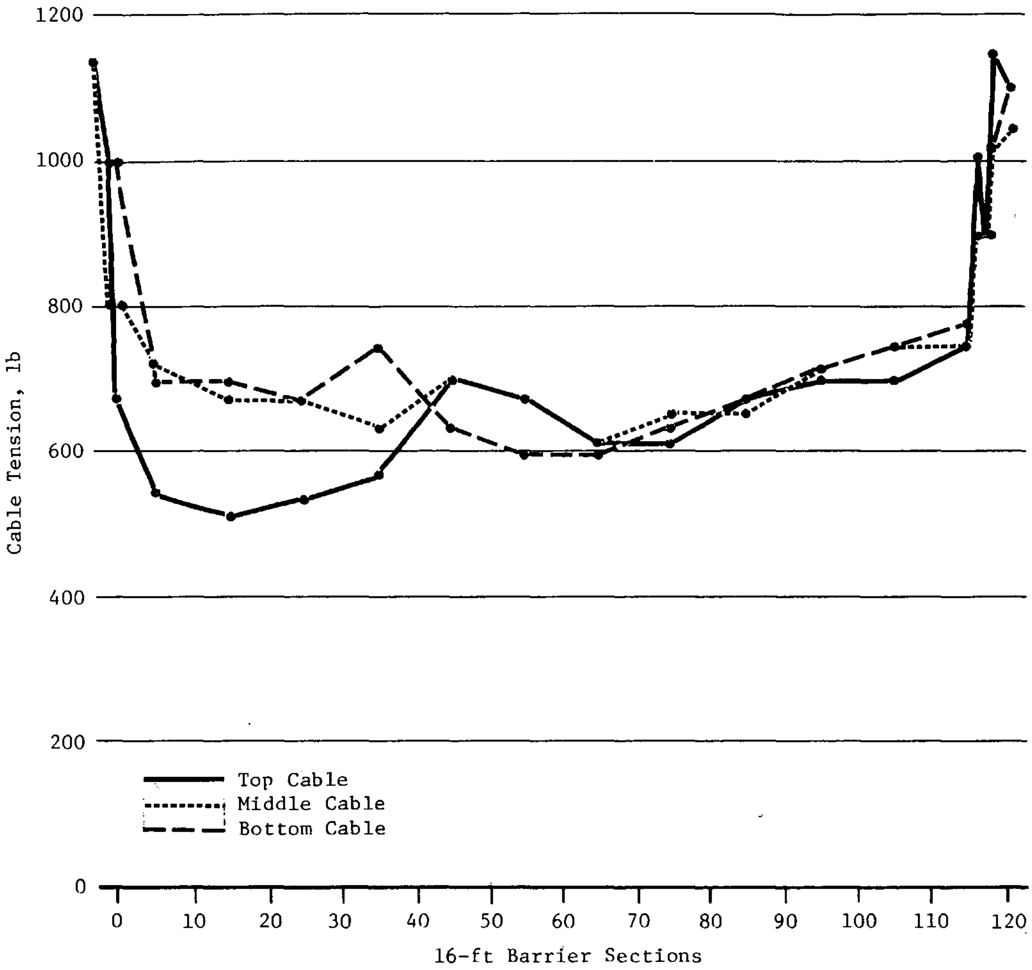

FIGURE 2 Distribution of tension through barrier after tensioning by former normal procedure (1 N = 0.225 lbf, 1 m = 3.28 ft).

in the 1980 revised-tension group, but by spring 1983 tension loss in the normal-tension group was 85 percent greater.

Figure 3 shows that by spring 1983, all samples from both the normal-tension group and the 1980 revised-tension group experienced tension losses greater than 200 lb, considered the maximum acceptable loss. However, only 10 percent of the 1980 revised-tension group had experienced losses greater than 400 lb by 1983, compared with 95 percent of the normal-tension group. The 200-lb maximum tension loss was established so that the minimum tension in the cable would not drop below 450 lb. The rationale for this criterion was developed as follows (*5*): First, initial tensions and field temperatures were recorded for the maximum length of the cable used, 2000 ft. Second, these tensions were adjusted to a maximum design temperature of 95°F. Third, maximum tension loss was calculated so that barriers may not drop below the minimum desired tension of 450 lb at 95°F.

The 1981 revised-tension group, installed in fall 1981, experienced a 483-lb (28 percent) loss during the high-initial-tension period. After final adjustments, additional losses of 430 and 527 lb (37 and 46 percent) occurred by spring 1982 and spring 1983, respectively. By spring 1983, 94 percent of the sample experienced tension loss greater than 400 lb, ranging up to 681 lb. This group lost considerably more tension than the 1980 revised-tension group. The 1981 revised-tension samples were set at higher average tension on final adjustment than the 1980 revised-tension sample for two reasons. First, the 1981 procedure pulled out all slack from the total length of barrier at one end, so average tension throughout those runs was higher than in the 1980 group. Second, the 1981 group was set to 10°F intervals rather than the 20°F intervals used in 1980. Because the 1981 runs were tensioned to a higher level, the greater loss was less critical. Average measured tension values are in the same range as the 1980 revised-tension group, even though the theoretical loss for the 1981 group was greater.

The retensioned group experienced significant tension loss after being readjusted in the fall of 1981. Relative to the final adjustment, this group of 15 runs experienced average tension losses of 253 lb (26 percent) and 308 lb (28 percent) by spring 1982 and spring 1983, respectively. This group contained six runs—two 1980 normal-tension and four 1980 revised-tension—that were retensioned by the contractor in late spring 1981. These six runs thus were retensioned twice. Considering

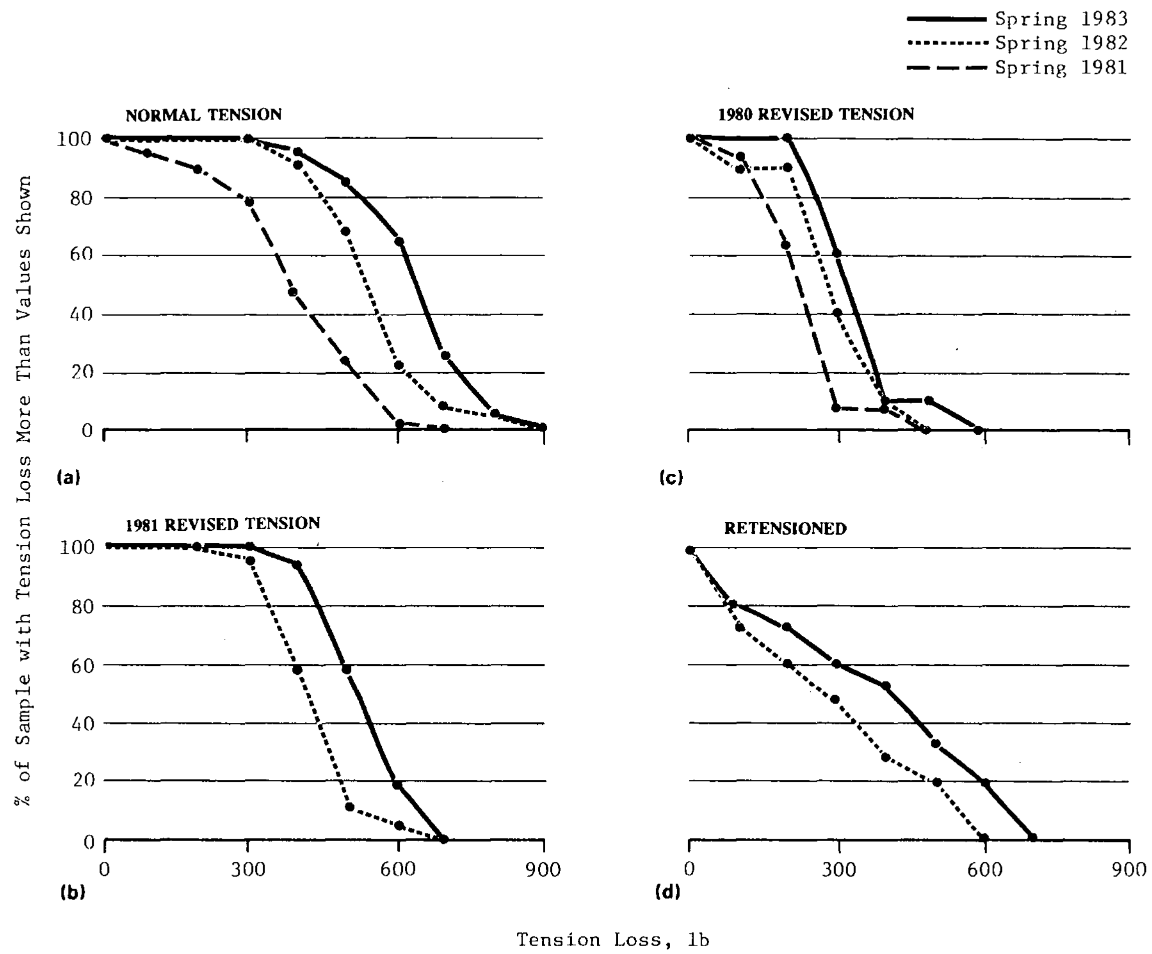

FIGURE 3 Distribution of tension loss after final adjustments 1980 revised tension (1 N = 0.225 lbf).

the six separately reveals a relatively small tension loss by spring 1983 of only 119 lb, or 11 percent.

Tension throughout two barriers tensioned by the 1981-revised procedure is shown in Figure 4. The expected tension distribution did not always occur, and Barrier A shows a slightly lower tension at mid-run than at the ends. However, variation throughout this run is only about 10 percent, compared with as much as 50 percent for barriers tensioned by the normal procedure. Tension in Barrier B is more uniform, with the top and middle cables having tensions higher than the spring-indicated value, and only the bottom cable has some measured tension values slightly lower than the springs indicate. Even though this procedure did not precisely duplicate the expected results, it produced a more uniform distribution of tension throughout the barrier than the normal procedure.

Anchor Movement

The four groups just described were also monitored for anchor movement. Some movement occurred during tensioning of most of the sample runs, and resulted in a visible gap between the anchor and the earth behind it as springs were compressed. By the time the last cable was tensioned, this movement was sometimes large enough to result in decreased spring compression for the other two cables. Research personnel told the contractor about this movement so that corrections could be made. Anchor-movement measurements presented here are the combined movements of both anchors relative to their position immediately after the barrier was tensioned.

Anchor movement for each sample group is summarized in Figure 5. The curves represent average measured anchor movements for the samples in each survey. Most movement occurred immediately after tensioning and between the first fall and spring surveys. After the first spring, a slight decrease in average anchor movement was often noted, probably caused as the anchors settled back. During and after tensioning, the anchors tipped forward, pressing against the fresh fill and compacting the soil beneath the front portions of the anchors. Most guiderail is installed during late summer and fall, and falling temperatures maintain a load on the anchors. Movement probably ceases during winter because soil around the anchor freezes, but high moisture levels and thawing in spring result in low soil support. This poor support is normally coupled with relatively high cable tension from the cool temperatures, compared with installation, and this situation probably produces the significant movement measured in the first spring

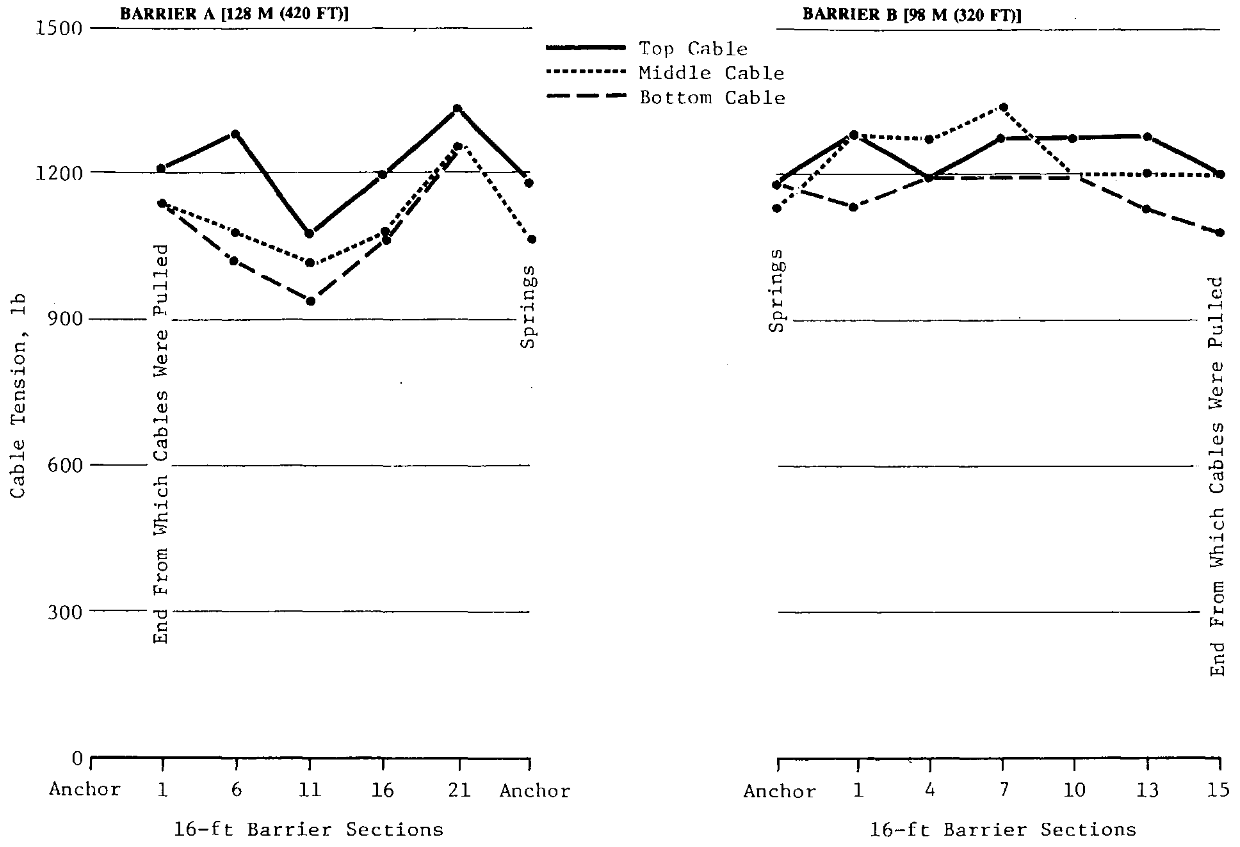

FIGURE 4 Distribution of tension in two barriers after final adjustments for four sample groups (1 N = 0.225 lbf).

survey after installation. As temperatures moderate, cable loads decrease, allowing the anchors to press against the soil behind and beneath them. As this soil compacts, the anchors settle back, thus negating some of the forward movement. After the first spring, anchor movement generally fluctuated slightly, but significant movement rarely occurred unless the barrier was retensioned, at which point movement showed another major increase.

For the 1980 revised-tension group, 56 percent of the total spring 1981 anchor movement occurred during the high-initial-tension period, and for the 1981 revised-tension group, 54 percent of the total spring 1982 movement occurred during this period. Total anchor movement for the revised-tension groups—which is the sum of the values above and below the datum line—is greater than the total amount experienced by the normal-tension group, but movement affecting working tension in the barrier is less. Anchor movement for the retensioned samples is also shown in Figure 5. This group of 15 samples contains 6 installations that were retensioned twice—once by the contractor, and then once by researchers. Before retensioning, the anchor movement trend for the whole group was similar to the other sample groups, with substantial movement totaling 2.82 in. by the first spring. Movement then leveled off until the samples were retensioned by researchers in fall 1981, at which point significant movement again occurred, totaling an additional 1.09 in. by spring 1983. The movement that occurred before retensioning in fall 1981 appears below the datum line in Figure 5.

Thirty-seven percent of the normal-tension sample experienced anchor movement exceeding 2 in., ranging up to 6¼ in. By comparison, none of the 1980 revised-tension group, the 1981 revised-tension group, or the retensioned-group experienced anchor movement greater than 2 in. by the first spring after final adjustment. The revised procedures thus resulted in very significant reduction in critical anchor movement compared with the normal-tension group.

Although the revised tensioning procedures reduced the effect of anchor movement on tension loss, additional measurements were desirable to stabilize the anchors. Anchor placement was observed on 12 projects to determine typical procedures used. Generally, the hole was dug with a backhoe, the anchor placed, and soil then backfilled and compacted around the anchor; however, time and effort spent placing and compacting the fill varied. Some crews placed the backfill in five or six lifts, tamping each, while others dumped the backfill around the anchor and simply dropped the backhoe bucket around the top of the fill to compact it. Rocks and large chunks of asphalt pavement were sometimes included in the backfill, making compaction difficult. Careful backfill procedures generally resulted in less movement, but did not guarantee stable anchors. Placing the anchor in the ground a few weeks before tensioning also seemed to have the favorable

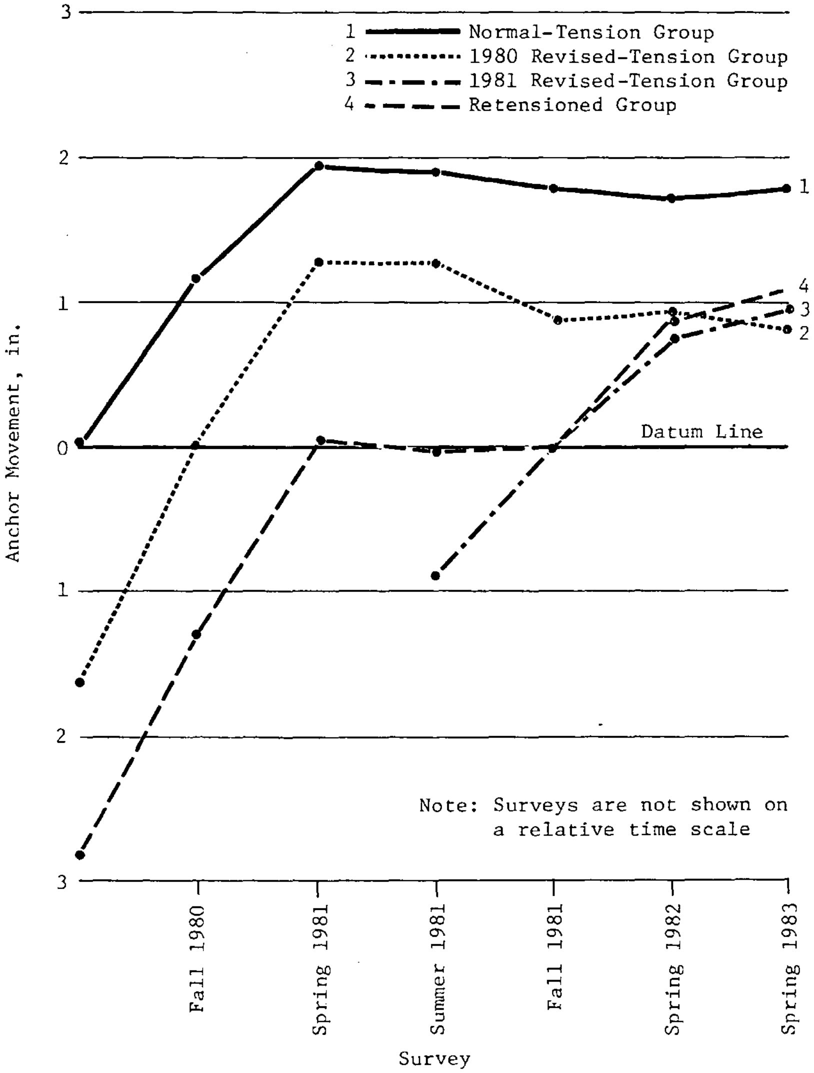

FIGURE 5 Summary of anchor movement for four sample groups (1 mm = 0.04 in.).

effect of reducing movement. Construction specifications permitted considerable latitude in placement procedure, and firm guidelines for backfilling and compaction were not included. This problem was brought to the attention of the NYSDOT Soil Mechanics Bureau, and standard sheets were revised in the hope of ensuring that adequate compaction is achieved around all anchors. Specifically, limits of excavation have been provided, and the revised specification requires suitable fill material to be paced in 150-mm (6-in.) lifts and compacted to 95 percent of standard Proctor maximum density.

Permanent Cable Stretch

Constructional stretch is an inherent property of all wire rope products. This deformation is permanent and remains after load is released. Constructional stretch can be removed by prestretching, which involves subjecting the cable to repetitive loadings of up to 50 to 60 percent of its ultimate strength (7). Manufacturers of a wire rope contacted in this study claimed that guiderail cable may experience a permanent stretch of 0.25 to 0.50 percent of its unloaded length (personal correspondence, S. E. Chehi, Bethlehem Steel Corporation, March 1981). This much stretch would produce large tension loss in cable guiderail. According to industry representatives, guiderail working loads of up to 2,000 lb would never remove all the potential stretch, which would continue as long as the cable was loaded (personal correspondence, S. E. Chehi, Bethlehem Steel Corporation, March 1981). They further indicated that even setting initial tension in the upper range of the working load will not remove all potential stretch, but probably would help reduce tension loss from subsequent cable stretch. Prestretching the cable at loads of 1,200 to 15,000 lb would be the only way to remove all the stretch, but this was not considered feasible by one major manufacturer because of lack of facilities to perform the work. The manufacturer did prestretch one reel containing 1,078 ft of cable. This material was then made available for field instal-

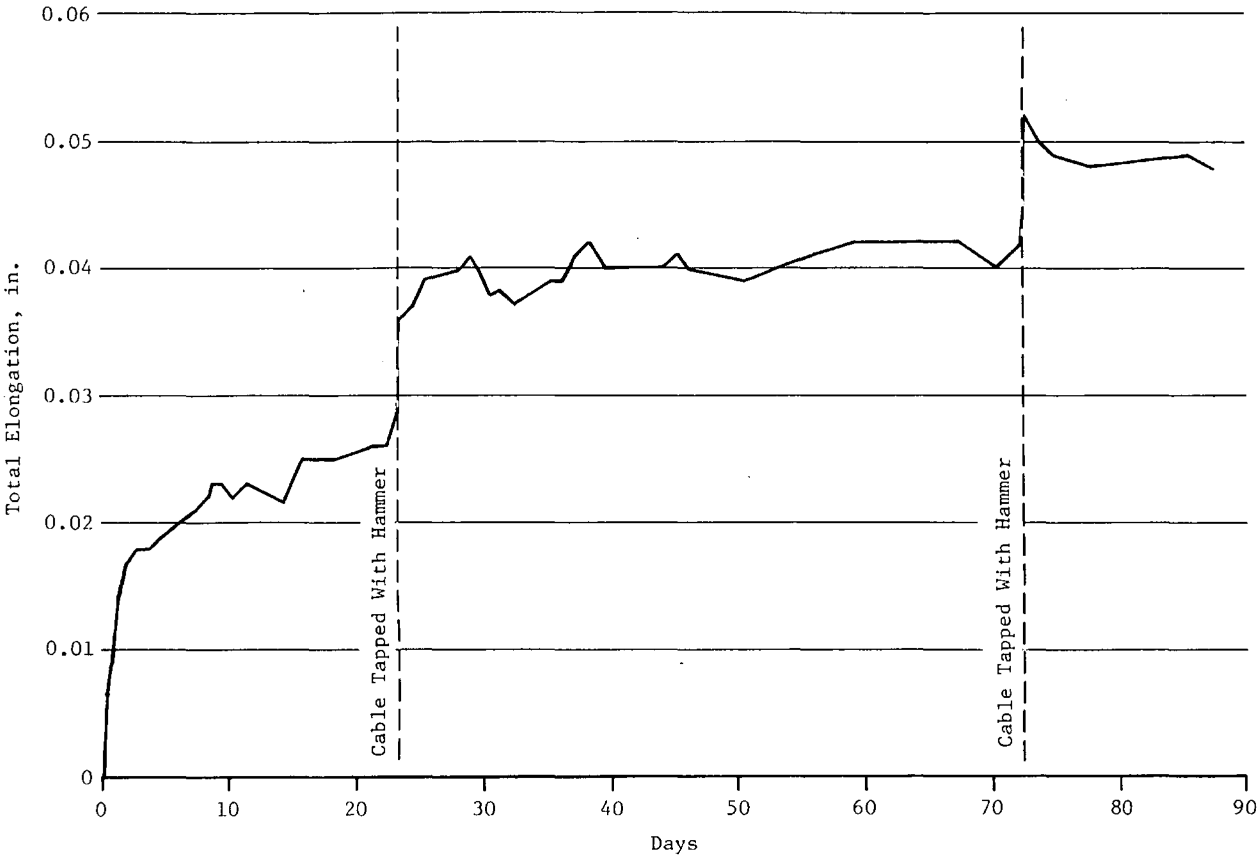

FIGURE 6 Permanent cable stretch over 12-week period (1 mm = 0.04 in.).

lation to monitor its performance. However, no data were recorded during prestretching to determine cable length changes, so testing to determine the behavior of guiderail cable under working loads was initiated as part of this study.

Figure 6 shows the stretch that occurred over a 12-week period under a load of about 1,900 lb. Much of the total stretch occurred during the first 2 days that the cable was placed under load. Additional significant stretch occurred when the cable was tapped with a hammer, creating vibrations that apparently helped seat the wires and lays. By the beginning of the twelfth week, a total of 0.052 in. of permanent stretch had occurred over the instrumented length of 8 ft 10 in., equating to strain of 0.0005 in./in.

This cable stretch testing was initiated late in the project schedule, after learning that the manufacturer did not document the prestretch testing. Thus, time allowed for only one test, which is insufficient for firm conclusions. These preliminary test results, based on only one sample of cable, plus information supplied by manufacturer of wire rope indicate that permanent stretch is a major contributing factor in tension loss. This problem is not easily remedied in the field because normal working loads are not large enough to remove all potential constructional stretch (the stretch during installation). More testing is necessary to determine the total range of constructional stretch to be expected for a large sample of cable.

The reel of prestretched cable donated for this project was installed in the fall of 1982. This 250-ft run was tensioned according to the 1982 revised procedure, except for excluding the period of high initial tension, because all pending constructional stretch was supposed to have been removed. The barrier thus was tensioned according to the revised tensioning table and left at this value. The primary interest in this test was the reaction of other barrier components if the cable did not undergo constructional stretch. By spring 1983, an average tension loss of 681 lb had occurred for the three cables, caused mostly by anchor movement. The combined anchor movement of 2½ in. is equivalent to a theoretical loss of 723 lb for this run. These results support the hypothesis that if cable stretch does not occur, the anchors or some other portion of the barrier yield instead to relieve the load.

In 1984 selected projects were constructed with normal cable guiderail using improved installation procedures. Conditions were surveyed periodically for 3 years from 1984 to 1987 to determine their effectiveness. Methods similar to those used previously and described for Phase 1 again documented installation and long-term performance.

Phase 2

To determine long-term performance of prestretched cable, the NYSDOT Materials Bureau responded to a request by research personnel by issuing a special specification for pre-

TABLE 2 Field Survey Results

		Avg Tension Loss, lb (acceptable loss = 200 lb)						
Group	Location Tested	Fall '87	Spring '87	Fall '86	Spring '86	Fall '85	Spring '85	Fall '84
INSTALLED 1984								
1	Sag	295	521	348	428	220	284	186
	Spring	232	275	185	226	122	164	47
	Avg	264	398	267	327	171	224	117
2	Sag	337	607	453	463	236	240	0
	Spring	399	341	302	313	278	232	94
	Avg	368	474	378	388	257	236	47
3	Sag	378	589	468	458	258	364	95
	Spring	338	327	259	279	230	240	141
	Avg	358	458	364	369	244	302	118
4	Sag	-	661	531	608	180	610	379
	Spring	-	154	158	62	182	151	127
	Avg	-	408	345	335	181	381	253
5	Sag	544	681	582	622	367	560	440
	Spring	512	462	229	207	271	199	217
	Avg	528	572	406	415	319	380	329
7	Sag	313	512	449	338	56	358	0
	Spring	291	279	238	250	231	217	0
	Avg	302	396	344	294	144	288	0
8	Sag	487	739	608	663	600	576	391
	Spring	514	279	246	289	378	255	435
	Avg	501	509	427	476	489	416	408
				Average = 333				
INSTALLED 1985								
10 (Normal)								
	Sag	367	670	451	469			
	Spring	349	488	340	308			
	Avg	358	579	396	389			
				Average = 431				
11 (Prestretched)								
	Sag	397	641	392	408			
	Spring	371	466	290	325			
	Avg	384	554	341	367			
				Average = 412				

Note: 1 N = 0.225 lbf

stretched cable guiderail in 1985. Such cable should experience smaller degrees of permanent stretch, placing greater loads on guiderail components over longer periods. This may or may not have a long-term effect on guiderail components, and ultimately on tension. Using this special specification, additional test sections were installed in 1985, and were also surveyed twice a year in 1986 and 1987 using the same procedures.

During each field condition survey, cable tensions were measured at two positions for sag at a low point on each cable's run between posts and at the spring-compensator. The weight of the cable and cable deflection were used to compute cable tension. Tensions of all three cables (top, middle, and bottom) at these two positions were measured and averaged to represent tension at that particular position. The difference between design tension and measured tension is the tension "loss" given in Table 2. Average tension loss in Table 2 is the average of tension loss measured at sag and at the spring-compensator. Groups 1 through 7 were installed in 1984 and monitored for 3 years. Groups 8 and 9 were installed in 1985 using the revised specification to compare the difference between normal and prestretched cable. These new installations were also monitored twice a year for 2 years. From the field results, overall average tension loss for the first set of installations (Groups 1 through 7) was about 330 lb. For the other installations (Groups 8 and 9) it was greater than 400 lb. Both exceed the acceptable level of 200 lb.

Laboratory stretch tests were conducted using normal and prestretched cable to find any significant differences in cable strain due to long-term loading. Bethlehem Steel Corp. pro-

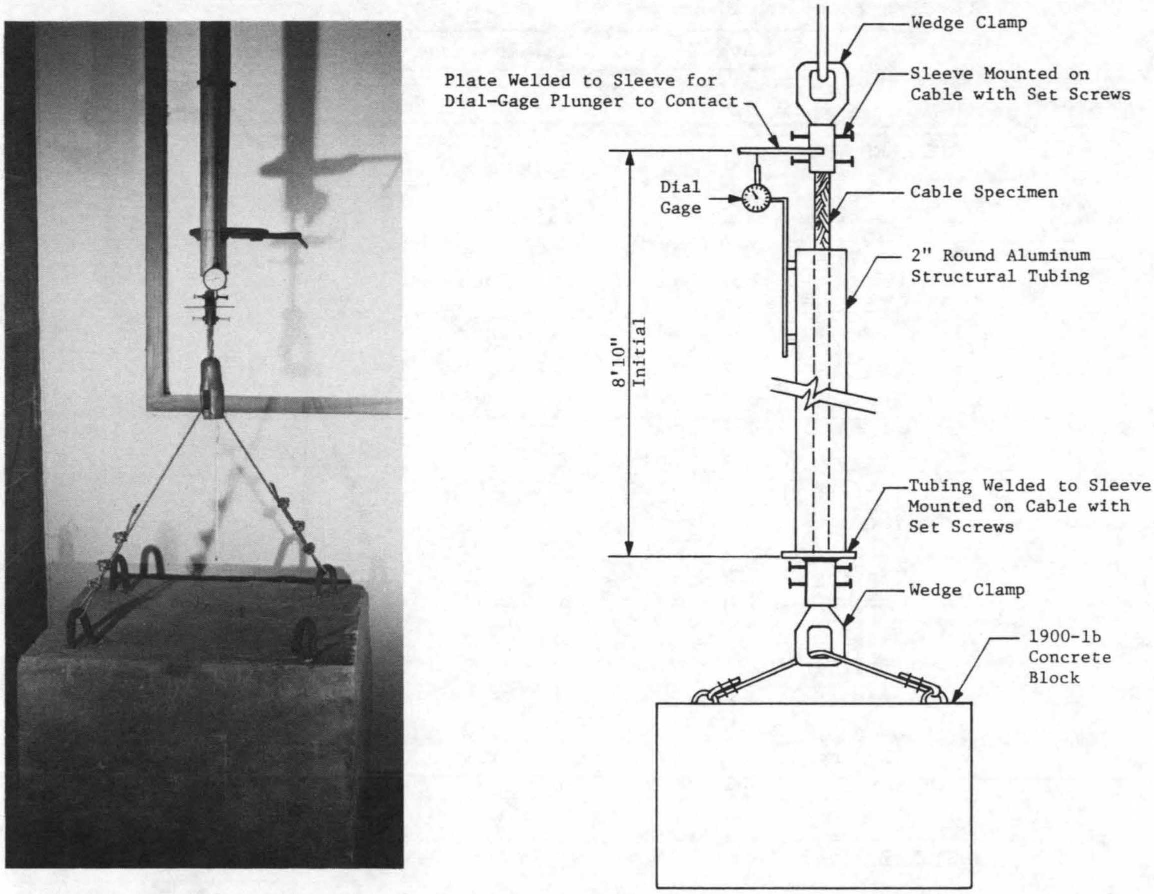

FIGURE 7 Cable stretch tests: as cable specimen elongates under load, structural tubing fixed to cable bottom moves down with it, and gauge mounted on top of tubing registers this movement with respect to plate fixed above cable (1 m = 3.28 ft, 1 mm = 0.04 in., 1 kg = 2.21 lb).

vided a reel of prestretched cable for this purpose. A series of tests was conducted in the laboratory to document the amount and nature of permanent stretch occurring during normal working loads to which guiderail is subjected. This involved suspending a length of new cable and loading it with a concrete block weighing about 1,900 lb—near the upper extreme during the annual temperature cycle, if the spring constant were at the upper acceptable limit of 500 lb/in. The spring limit is specified as 450 ± 50 lb/in. Thus, extreme cable loads would vary from 400 to 2,000 lb with a spring compression range of 1 to 4 in. over the anticipated temperature range. Amount of stretch was measured with a dial gauge reading to thousandths of an inch. Figure 7 shows the apparatus and experimental setup.

To ensure that the tests simulated field conditions, the following observations were made. During field tensioning, spring compression is set at the completion of the tensioning procedure, so that stretch occurring during tensioning does not affect barrier performance. Only stretch occurring after tensioning is of concern in terms of effect on barrier performance. In the laboratory, dial-gauge readings thus began immediately after the 1,900-lb load was applied.

Results of laboratory cable stretch tests are given in Table 3, which gives results of tension loss if the same cable stretch experienced in the laboratory occurred in the field. The data show that cable samples tested under a constant 1,900-lb loading elongated to an unacceptable length. If the same constant tension were placed on guiderail in the field, an unacceptable level of cable stretch would occur. The degree of elongation experienced by these laboratory samples would translate into unacceptable tension loss, if cable used in guiderail installations elongated the same amount, as shown in Table 4. Since the cable used in such installations does not experience constant tension, these laboratory results cannot be used to predict how much tension will be lost; however, they can predict that the cable is capable of stretching to unacceptable lengths if the tension is maintained. This experiment may show that another less plastic material might be used in place of steel cable, although this imaginary product would still have to be plastic enough to allow the barrier to deflect if impacted. Results of the laboratory stretch tests show that prestretched cable elongates less than normal cable, but that elongation is enough that guiderail installations would lose all their tension in a relatively short time.

TABLE 3 Laboratory Cable Stretch Tests

	Strain in Normal Cable, in. (corrected for temperature)								
Days	Test 1	Test 9	Test 10	Test 11	Test 12	Test 13	Test 14	Test 16	Average
25	0.0343	0.005	0.006	0.011	0.0096	0.008	0.017	0.014	0.013*
27	0.0365	0.006	0.006	0.012	0.007	0.009	0.017	0.014	0.013
29	0.0380	0.007	0.006	0.010	0.009	0.009	0.017	0.014	0.014
30	0.0368	0.006	0.006	0.009	0.009	0.009	0.017	0.015	0.014
31	0.0368	--	0.006	0.009	0.009	0.008	0.017	0.015	0.014
36	0.0366	--	--	0.014	0.02	0.010	0.017	0.015	0.019
40	0.0360	--	--	--	--	0.011	0.017	0.016	0.020
48	0.0368	--	--	--	--	0.011	0.017	0.016	0.021
49	0.0388	--	--	--	--	0.011	0.017	0.016	0.022
50	0.0386	--	--	--	--	0.011	--	0.017	0.022
88	0.0468	--	--	--	--	0.008	--	0.020	0.025
141	--	--	--	--	--	0.015	--	0.021	0.018
214	--	--	--	--	--	--	--	0.023	0.023

	Strain in Prestretched Cable, in. (corrected for temperature)							
Days	Test 2	Test 3	Test 4	Test 6	Test 7	Test 8	Test 15	Average
25	0.0165	0.011	0.0063	0.0102	0.0073	0.0053	0.012	0.009
27	0.0165	0.011	0.0068	0.0093	0.0073	--	0.012	0.010
29	0.0155	0.012	0.0068	0.0106	0 0073	--	0.012	0.011
30	0.0158	0.0118	--	--	0.0075	--	0.013	0.012
31	0.0161	0.0103	--	--	0.0075	--	0.013	0.012
36	0.0161	0.0105	--	--	0.0079	--	0.013	0.012
40	0.0164	0.012	--	--	0.0077	--	0.014	0.013
48	0.0168	0.0110	--	--	--	--	0.015	0.014
49	0.0162	0.0127	--	--	--	--	0.016	0.015
50	--	--	--	--	--	--	0.016	0.016
88	--	--	--	--	--	--	0.015	0.015
141	--	--	--	--	--	--	0.019	0.019
214	--	--	--	--	--	--	0.018	0.018

*Value used in Table 4.

Note: 1 mm = 0.04 in.

TABLE 4 Guiderail Tension If Cable Stretch in Laboratory Occurred in Field

		Normal Cable Barrier Length, ft					Prestretched Cable Barrier Length, ft				
Days	Dimension	500	1000	1500	2000	2500	500	1000	1500	2000	2500
25	δ, in.	0.79*	1.57	2.37	3.16	3.95	0.59	1.18	1.77	2.36	2.95
	P, lb	318*	636	954	1272	1590	240	479	719	958	1198
50	δ, in.	1.33	2.66	3.99	5.32	6.65	0.97	1.94	2.91	3.88	4.85
	P, lb	538	1076	1614	2152	2690	391	782	1174	1565	1956
88	δ, in.	1.52	3.04	4.56	6.08	7.60	0.91	1.82	2.73	3.64	4.55
	P, lb	611	1222	1833	2444	3055	367	734	1101	1468	1835
141	δ, in.	1.09	2.18	3.27	4.36	5.45	1.15	2.3	3.45	4.6	5.75
	P, lb	440	880	1320	1760	2200	464	929	1393	1858	2322
214	δ, in.	1.39	2.79	4.18	5.58	6.97	1.09	2.18	3.27	4.36	5.45
	P, lb	561	1121	1682	2243	2803	440	879	1319	1759	2198

*Sample Calculation:

$\Delta = 0.013$ (from Table 3).

$A = 0.22 \text{ in.}^2$

$E = 11 \times 10^6 \text{ lb/in.}^2$

$\varepsilon = \Delta \text{ in.}/99 \text{ in.}$

$\delta = PL/AE$

$\delta = L \times 12 \text{ in./ft} \times \varepsilon \text{ in./in.} = 500 \text{ ft} \times 12 \text{ in./ft} \times 0.013/99 = 0.79 \text{ in.}$

$P = \delta AE/L = (0.79 \text{ in.} \times 0.22 \text{ in.}^2 \times 11 \times 10^6 \text{ lb/in.}^2)/500 \text{ ft} \times 12 \text{ in./ft} = 318 \text{ lb}$

Note: 1 m = 3.28 ft

CONCLUSIONS

From the results of this study, the following conclusions may be drawn:

- Barriers installed using either the normal or revised tensioning procedures experienced greatest tension loss soon after the barrier was first tensioned and over the first winter. Tension losses generally continued after this point, but at a much slower rate. If the barrier is retensioned, a new cycle of tension loss occurs.
- Even with the proposed retensioning procedures, tension loss will continue to occur in cable guiderail, regardless of the installation procedures used. The revised procedure coupled with at least two retensionings will probably be necessary to confine losses to 200 lb.
- Substituting prestretched for normal cable in these guiderail installations does not solve the tension-loss problem. Installations using prestretched cable lose tension at almost the same rate as those using normal cable.
- Cable guiderail installations continually lose tension, and thus must be retensioned periodically. The data, however, were insufficient to estimate how often this must be done.

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