Evaluation of Several Brands of Anaerobic Threadlocking Compounds Used for Nut Retention on the Threaded Rod Ends of Bridge-Restrainer Cables

February 2000, addendum 7/00

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This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT
Caltrans uses bridge-joint restrainer cables on many bridge structures to limit longitudinal displacement during seismic events. Each end of the cable is terminated with a 1” diameter ASTM A449 hot-dipped galvanized threaded rod with a matching ASTM A563, Grade DH nut. This nut is secured on the threading rod with an anaerobic threadlocking compound. The 1992 Caltrans "List of Approved Threadlocking Compounds" contains products which are no longer available.

Caltrans tested three different anaerobic threadlocking products to see if they would produce breaking torque and prevailing torque values that are similar to the values obtained in 1992. These products are manufactured by Loctite Pro-Lock Division, Permabond International, and Hernon Manufacturing, Inc. All three of the anaerobic threadlocking compounds tested had a breaking torque higher than 70 Nm and a prevailing torque higher than 75 Nm. These results can only be assured if all traces of oils, debris, and dry lubricants are thoroughly removed from all threaded surfaces prior to application of the primer or adhesives.

This study produced a list of threadlocking compounds that are approved for use only on this particular application. This list is part of the "Caltrans Qualified Product List" on the Internet at: http://www.dot.ca.gov/hq/esc/approved_products_list/

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threadlocking, anaerobic, threaded fasteners, cable restrainer

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Evaluation of Several Brands of Anaerobic Threadlocking Compounds Used for Nut Retention on the Threaded Rod Ends of Bridge-Joint Restrainer Cables

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5. **ABSTRACT**
   Caltrans uses bridge-joint restrainer cables on many bridge structures to limit longitudinal displacement during seismic events. Each end of the cable is terminated with a 1” diameter ASTM A 449 hot-dipped galvanized threaded rod with a matching ASTM A 563, Grade DH nut. This nut is secured on the threaded rod with an anaerobic threadlocking compound. The 1992 Caltrans "List of Approved Threadlocking Compounds" contains products which are no longer available.

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   This study produced a list of threadlocking compounds that are approved for use only on this particular application. This list is part of the "Caltrans Qualified Product List" on the Internet at: http://www.dot.ca.gov/hq/esc/approved_products_list/

6. **KEY WORDS**
   threadlocking, anaerobic, threaded fasteners, cable restrainer
NOTICE

The contents of this report reflect the views of the New Technology & Research Program which is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Neither the State of California nor the United States Government endorse products or manufacturers. Trade or manufacturers' names appear herein only because they are considered essential in establishing the completeness and accuracy of this document.
**Conversion Factors**

**Torque:**
To convert Newton-meter (N·m) to pound-foot (lb·ft) multiply (N·m) by 0.7376.
To convert pound-foot (lb·ft) to Newton-meter (N·m) multiply (lb·ft) by 1.3558.
Note that both lb·ft and ft·lb are used as units of torque. Most torque wrenches are labeled with, or report results in, ft·lb. In the U.S customary system of units a moment of force (torque) should be reported as lb·ft while a force acting over a distance (work) is reported as ft·lb.

**Temperature:**
To convert degrees Celsius (°C) to degrees Fahrenheit (°F), multiply °C by 1.8 and add 32.
To convert degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32 from °F and divide that result by 1.8.

**Force:**
To convert Newton (N) to pounds (lb) multiply (N) by 0.22481.
To convert pounds (lb) to Newton (N) multiply (lb) by 4.4482.

**Length:**
To convert meters (m) to feet (ft) multiply (m) by 3.2808.
To convert feet (ft) to meters (m) multiply (ft) by 0.3048.
To convert meters (m) to inches (in) multiply (m) by 39.3701.
To convert inches (in) to meters (m) multiply (in) by 0.0254.
**RESEARCH STAFF**

The Office of Research was responsible for conducting the tests, developing the list of approved threadlocking compounds, and writing the final report.

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1. INTRODUCTION
Caltrans uses bridge-joint restrainer cables on many bridge structures to limit longitudinal displacement during seismic events. Each end of the cable is terminated with a galvanized threaded rod section. The cable assembly is secured to the bridge with a single nut near each end of this threaded rod section. The nut is not tightened against the structure, but is secured on the threaded rod with an anaerobic threadlocking compound. A series of tests on anaerobic threadlocking compounds was performed by Phil Spartz and John Dusel in 1992 and a list of Caltrans approved compounds was produced which cable manufacturers could use as a source list.

1.1 Overview of Report Contents
This report describes the problems related to the unavailability of products currently on the approved products list of threadlocking compounds that do not include different sizes and materials being used. The report also lists the products that were tested in hopes of producing a list for use by the cable manufacturer(s). These products were tested on representative samples for various bolting applications of different diameter rods sizes and materials and those that provided an acceptable level of breaking torque were then approved. The results of the testing are described herein and were also posted on the Caltrans Website under the Qualified Products List (QPL). The report also makes recommendations that may be incorporated into future Caltrans Standard Specifications.

1.2 Problem Statement
The 1992 Caltrans list of approved threadlocking compounds for use on bridge joint restrainer cables contains products which are no longer available.

1.3 Background
These bridge-joint restrainer cables are currently supplied by Cable Moore Inc. of Oakland, CA. In July of 1999, the manufacturer of these restrainer cables requested the assistance of Caltrans in resolving problems with the list of Caltrans approved threadlocking compounds. Cable Moore’s Product Manager, Mr. Ed Vick, has outlined changes with the threadlocking compound suppliers resulting in the unavailability of products originally listed on the approved list. A copy of this letter is contained in Appendix C. None of the compounds currently on the 1992 approved list are available today. This became a problem for Cable Moore, as well as Caltrans, when the restrainer units with the last of the approved threadlocking compound began to run short. This would have happened very quickly and would have left Caltrans without a source for bridge-joint restrainer cables unless evaluation of currently available threadlocking compounds was started immediately.

1.4 Literature Search
A literature search was not deemed necessary due to the simple nature of the proposed testing and the time constraints involved.

1.5 Objective and Scope
The objective of this minor research project was to produce a list of approved anaerobic threadlocking compounds which the cable manufacturers can reference when supplying completed cable units. This was accomplished by evaluating the performance of several new anaerobic threadlocking
compounds as supplied by the bridge-joint restrainer cable manufacturer. These compounds were tested to see if they could provide a breaking torque similar to, or higher than, that obtained in the original testing done in 1992. The breaking torque value used in the 1992 tests was used as a base value for these tests because there have not been any significant problems with the nuts migrating under normal service conditions.

1.6 Benefits

The main benefit of this research was to provide a list of approved anaerobic threadlocking compounds for use by manufacturers of bridge-joint restrainer cables. Information gathered might also be useful in other areas where Caltrans has the need to secure nuts onto threaded rods. It is important to note that this information applies only to the same type and size of threaded rods.

Warning: Care must be taken to ensure that the resulting list of approved anaerobic threadlocking compounds is not used in applications that are significantly different from those tested here. The breaking torque expected in this research project may vary significantly from other types of fasteners based on variables such as; lubrication, nut-to-rod clearances, finishes such as galvanized or plain, or non-finished stainless steels, and whether or not the nut (or bolt) is torqued against a positive stop.

2. TECHNICAL DISCUSSION

2.1 Products

Caltrans purchased a supply of 1” diameter ASTM A 449 hot-dipped galvanized threaded rods with matching ASTM A 563, Grade DH nuts from Cable Moore Inc. These threaded rods sections and matching nuts are the same as those supplied on completed bridge-joint restrainer cable assemblies. Cable Moore supplied Caltrans with three different anaerobic threadlocking products that they believe are comparable to the originally approved products. These products are:

1. Loctite Pro-Lock Division
   a) Loctite 7070 Cleaner. Part No. 22355
   b) Pro-Lock “Klean-N-Prime” Part No. 30566
   c) Pro-Lock High Strength Threadlocker. Part No. 81792

2. Permabond International
   a) Perma-Lok Anaerobic Surface Conditioner. Part No. ASC10
   b) Perma-Lok Heavy Duty Bolt and Stud Locking Anaerobic Adhesive/Sealant. Part No. HH120

3. Hernon Manufacturing, Inc.
   a) Hernon Cleaner. Part No. EF-62
   b) Hernon Primer. Part No. EF-49
   c) Hernon Nuts N’ Bolts Anaerobic Adhesive. Part No. 429
2.2 Test Facility
All testing related to this research project was conducted at the Transportation Laboratory (Translab) of the California Department of Transportation in Sacramento, California.

2.3 Test Equipment
The “as received” threaded rod sections had two flats milled into their center sections to prevent rotation during testing by securing them in a vise. The flats were milled by the machine shop at the TransLab.

The torque required to break the nuts free was applied using a Mitutoyo brand digital torque wrench with a range of 0 to 340 N-m.

2.4 Specimen Preparation
Four test specimens were assembled for each of the three threadlocking compound manufacturers. Each test specimen consisted of a ASTM A 449 hot-dipped galvanized threaded rod with a matching ASTM A 563, Grade DH nut secured with one of the compounds listed above. The following instructions were used to secure the nut onto the threaded rod. In the event of conflict between these instructions and those of a manufacturer, the manufacturer’s instructions shall take precedence.

2.4.1 Clean Threads
Brush or spray the required cleaner/solvent onto the threads of both the nut and stud at the desired final nut location to remove any lubricants; use only in a well-ventilated area. Scrub nut threads thoroughly using a small wire brush. Remove all traces of the dry lubricant from the internal threads of the nut. Allow the cleaner to completely evaporate before applying primer or wait the required drying time as recommended by the threadlocker manufacturer.

2.4.2 Prime Threads
Apply primer liberally onto cleaned threads of both the stud (only in area where nut will be positioned) and the nut. Wait briefly until threads appear dry.

2.4.3 Bond Threads
Apply the anaerobic compound liberally onto the threads of both the stud and the nut according to the instructions provided by the manufacturer. Coat the stud only in the threaded area where the primer was applied (the final desired position to be occupied by the nut).

2.4.4 Adjust Nut
Thread the nut onto the rod until it contacts the threadlocking compound. Then install the nut by turning it in one full turn and then backing it off one-half turn to evenly distribute the adhesive. Continue this procedure until the nut is one complete turn past the desired final location. Place a small bead of threadlocking compound around the outboard side of the nut/rod interface. Then slowly back the nut up one complete turn to the final desired position. This procedure will ensure an even distribution of the adhesive on the rod threads and seal any thread gap at the ends.
2.5 Test Method

The test method used to evaluate these threadlocking compounds is very similar to that contained in ASTM D5649-94 "Standard Test Method for Torque Strength of Adhesives used on Threaded Fasteners." The minor deviations involved do not affect or invalidate the results.

To simulate curing conditions in the field, the assembled test specimens were supported at the ends and placed in a horizontal position so the nuts were not supported. These assemblies were then allowed to cure for 48 hours. After the curing period, the maximum torque required to initiate unseating movement of the nut on the threaded rod was recorded with either a dial or digital torque wrench (click type torque wrenches cannot be used for this testing). This number was recorded as the "breaking torque." Another torque reading was taken as the nut was rotated through 180 degrees and this number was recorded as the "prevailing torque."

2.6 Test Results

All three of the anaerobic threadlocking compounds tested had an average breaking torque that was higher than the desired 61 N·m when the nut was properly cleaned of all traces of the dry lubricant applied by the nut manufacturer. The test specimens were cured for only 48 hours, which is longer than required for the Hernon and Perma-Bond brands. The Loctite brand needs slightly more than 48 hours to achieve 100% of it's advertised strength when large gaps between mating surfaces are encountered (as is the case with these hot-dip galvanized nuts and rods). This may be the reason why the breaking torque values for the Loctite product were somewhat lower than the Hernon and Perma-Bond brands. The specific results for each manufacturer are listed in Table 1 below.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Breaking torque (N·m)</th>
<th>Prevailing torque (N·m)</th>
</tr>
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<tr>
<td></td>
<td>Sample number</td>
<td></td>
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<tr>
<td></td>
<td>Avg.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>2</td>
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<tr>
<td>Loctite Pro-Lock Division</td>
<td>68</td>
<td>81</td>
</tr>
<tr>
<td>Permabond International</td>
<td>76</td>
<td>102</td>
</tr>
<tr>
<td>Hernon Manufacturing, Inc.</td>
<td>114</td>
<td>104</td>
</tr>
</tbody>
</table>

Table 1. Test results.
2.7 Evaluation

All three of the anaerobic threadlocking compounds tested had average breaking torque and prevailing torque values that were acceptable. These results can only be assured if all traces of oils, debris, and dry lubricants are thoroughly removed from all threaded surfaces prior to application of the primer or adhesives.

3. CONCLUSIONS and RECOMMENDATIONS

The three brands of anaerobic threadlocking compounds tested should provide breaking and prevailing torque values high enough to prevent the nut from becoming loose on the threaded rod or migrating due to normal vibration of the structure or from thermal effects.

The following recommendations are made as a result of the this project:

1. The information pertaining to threadlocking compounds contained under the Qualified Products List section of the above mentioned Caltrans website should be maintained and updated as the need arises.
2. The list of approved threadlocking compounds should be made available to the current (and future) cable restrainer manufacturer as well as made available to anyone through the Caltrans website.
3. The contents of Appendix A should be submitted to the Caltrans Specifications Unit for possible inclusion in the current SSP as well as incorporation into the next Standard Specifications.
4. Changes to Section 75-1.035 should be drafted and submitted to the Specifications Unit to ensure that a completed cable restrainer unit includes an approved cleaner, primer, and anaerobic threadlocking compound.

3.1 Future Research

It has been determined that designers and field crews are using the 1992 list of approved anaerobic threadlocking compounds for uses that were not intended in the original study. That list was developed for hot-dipped galvanized bridge-joint restrainer cables only. If designers and crews have a need for threadlocking, then further testing of these types of threadlocking compounds on other sizes and types of threaded fasteners should be done as soon as possible. Designers and crews need to be made aware of the narrow scope of the original approved threadlocking compound list and educated on when and where it can be used.

Caltrans has experienced corrosion problems when these cable restrainer units are used near bodies of salt water and has undertaken steps to protect the main body of the cable. Further research should be conducted as soon as possible on the ability of these threadlocking compounds to effectively seal and prevent corrosion within the threadlocked area.

4. IMPLEMENTATION

4.1 Short Term
A list of approved threadlocking compounds and an installation procedure were developed as a result of this project and are included here as Appendix A. This same information was made available to Cable Moore Inc. for immediate use with their “as supplied” bridge joint restrainer cable units. This information was also placed on the Caltrans website as part of the Qualified Products List (QPL) at:


4.2 Long Term

The nuts supplied with the cable restrainer units are manufactured to ASTM Designation A 563 which requires that the nut manufacturer provide them with a lubricant which is "clean and dry to the touch." This lubricant is intended for applications in which the nut is tightened onto the rod and torqued down against some positive stop (as in a structural fastening application). When used for this cable restrainer application, the nut is not torqued down but is positioned on the threaded rod away from any positive stop. As such, the lubrication is not required and must be completely removed in order for the threadlocking compounds to achieve the desired breaking torque. It is best if this task is performed in a shop environment rather than in the field in order to reduce crew, or contractor, exposure to hazardous traffic conditions.

Section 75-1.035 of the 1999 Caltrans Standard Specification, which covers Bridge Joint Restrainer Units, contains wording that should be changed to make it clear that the nuts supplied with these restrainer units should be supplied with the lubricant already removed. The current wording (See Appendix B) is as follows:

"Nuts shall conform to the requirements in ASTM Designation: A 563 or A 563M including Appendix X1, except lubrication is not required."

This should be changed to read:

"Nuts shall conform to the requirements in ASTM Designation: A 563 or A 563M including Appendix X1, except all traces of lubrication shall be removed by the cable restrainer manufacturer."  

The current wording relies on the Contractor or the field crews to properly clean all traces of lubricant from the nut, which is essential to attaining the required 61 N·m of breaking torque. The new wording would place the burden of cleaning the nuts on the cable manufacturer who is in a better position to ensure the cleaning is done thoroughly.
5. APPENDICES

Appendix A  Caltrans Approved Threadlocking Systems to be used only for galvanized bridge-joint restrainer cable units with 1” UNC threads.

Appendix B  Copy of Section 75-1.03, Miscellaneous Bridge Metal, and Section 75-1.035, Bridge Joint Restrainer Units, from the 1999 Caltrans Standard Specifications.

Appendix C  Copy of the letter sent to Caltrans by Cable Moore Inc. detailing why the list of approved threadlocking compounds required updating.
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Appendix A

Caltrans Approved Threadlocking Systems to be used only for galvanized bridge-joint restrainer cable units with 1” UNC threads.

This 2 page document lists the Caltrans approved threadlocking products as well as installation instructions and is intended to replace the current approved list which is dated 9/18/1992. This information should either be incorporated directly into the latest Standard Special Provision (SSP), 75-610_B09-21-99 or the web address mentioned below should be listed in the SSP.

The most recent version of this information will be maintained on the Qualified Products List (QPL) on the Caltrans Website. The address for the QPL is:

http://www.dot.ca.gov/hq/esc/approved_products_list/

Once there, click on the hypertext which reads "Restrainer Cable Threadlocking Compounds." There are plans to incorporate other threadlocking compounds for various applications into this website which may necessitate making a general “Threadlocking Compounds” category with the results of this study contained therein. At the time of this printing however, there is only one “approved list” which is for the application detailed in this report.
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CALTRANS-APPROVED
ANAEROBIC THREADLOCKING SYSTEMS

When required, one of the following approved chemical anaerobic threadlocking systems shall be used to secure hot-dip galvanized heavy hex nuts (ASTM A 563, Grade DH) to 1” diameter UNC galvanized threaded bars (ASTM A 449).

These systems have been tested and approved for use only on galvanized bridge restrainer cable units with 1” UNC threads. Other applications may require different components and application procedures. Consult Michael White at (916) 227-7076 if you wish to use these products for applications other than that stated above.

Each of these Caltrans-approved anaerobic threadlocking systems has three required components:
1) CLEANER - to clean lubricant and oils from the threads of the stud and nut.

2) PRIMER - to promote rapid curing of the anaerobic compound and to minimize migration of compound on threads.

3) ANAEROBIC THREADLOCKER ADHESIVE - to secure nut onto stud by filling the gap between nut and stud threads. Note: Anaerobic threadlocker adhesive compounds will set only where no oxygen is available.

**TABLE 1. APPROVED ANAEROBIC THREADLOCKING SYSTEMS**

<table>
<thead>
<tr>
<th>Manufacturer Information</th>
<th>Component</th>
<th>Trade Name</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Loctite Pro-Lock Division</strong>&lt;br&gt;1001 Trout Brook Crossing&lt;br&gt;Rock Hill, CT 06067-3910&lt;br&gt;(800) 562-8483&lt;br&gt;www.loctite.com</td>
<td>Cleaner</td>
<td>ODC-Free Cleaner &amp; Degreaser (Formerly 7070 cleaner)</td>
<td>22355</td>
</tr>
<tr>
<td></td>
<td>Primer</td>
<td>Pro-Lock “Klean-N-Prime”</td>
<td>30566</td>
</tr>
<tr>
<td></td>
<td>Adhesive</td>
<td>Pro-Lock High Strength Threadlocker</td>
<td>81792</td>
</tr>
<tr>
<td><strong>2. Permabond International</strong>&lt;br&gt;480 South Dean Street&lt;br&gt;Englewood, NJ 07631&lt;br&gt;(800) 370-9647&lt;br&gt;www.permabond.com</td>
<td>Cleaner &amp; Primer</td>
<td>Perma-Lok Anaerobic Surface Conditioner</td>
<td>ASC10</td>
</tr>
<tr>
<td></td>
<td>Adhesive</td>
<td>Perma-Lok Heavy Duty Bolt and Stud Locking Anaerobic Adhesive/Sealant</td>
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</tr>
<tr>
<td><strong>3. Hernon Manufacturing, Inc.</strong>&lt;br&gt;121 Tech Drive&lt;br&gt;Sanford, FL 32771&lt;br&gt;(800) 527-0004&lt;br&gt;www.hernonmfg.com</td>
<td>Cleaner</td>
<td>Hernon Cleaner</td>
<td>EF-62</td>
</tr>
<tr>
<td></td>
<td>Primer</td>
<td>Hernon Primer</td>
<td>EF-49</td>
</tr>
<tr>
<td></td>
<td>Adhesive</td>
<td>Hernon Nuts N’ Bolts Anaerobic Adhesive</td>
<td>429</td>
</tr>
</tbody>
</table>

All components used in a single threadlocking application shall be from one of the systems above and
from the same threadlocking adhesive manufacturer.
Note: Refer to Page 2 of 2 for installation instructions.
Application Instructions for

Caltrans-approved Anaerobic Threadlocking Systems:

The following application instructions shall be used for all Caltrans-approved anaerobic threadlocker systems previously listed. In the event of conflict between application instructions stated here and those of a manufacturer, the manufacturer’s instructions shall take precedence.

The following 4-step application procedure shall be used for anaerobic threadlocker systems:

1) **Clean Threads:** Brush or spray the required cleaner/solvent onto both nut threads and stud threads at the desired final nut location to remove any lubricants; use only in a well-ventilated area. Scrub nut threads thoroughly using a small wire brush. Remove all traces of the dry lubricant from the internal threads of the nut. Allow the cleaner to completely evaporate before applying primer. Wait the required drying time as recommended by the threadlocker manufacturer.

2) **Prime Threads:** Apply primer liberally onto cleaned threads of both the stud (only in area where nut will be positioned) and the nut. Wait briefly until threads appear dry.

3) **Bond Threads:** Apply the anaerobic compound liberally onto the stud threads according to the instructions provided by the manufacturer. Coat only in the threaded area where the primer was applied (the final desired position to be occupied by the nut).

4) **Adjust Nut:** Thread the nut onto the rod until it contacts the threadlocking compound. Then install the nut by turning it in one full turn and then backing it off one-half turn to evenly distribute the adhesive. Continue this procedure until the nut is one complete turn past the desired final location. Place a small bead of threadlocker compound around the outboard side of the nut/rod interface. Then slowly back the nut up one complete turn to the final desired position. This procedure will ensure even distribution of the adhesive on the rod threads and seal any thread gap at the ends.

**Basic Performance Requirements:** To be acceptable for securing nuts on bridge joint cable restrainer units, approved threadlocker systems shall achieve a minimum breaking torque of 45 ft. lbs. when installed according to the above directions (or the manufacturer’s recommended installation instructions) and cured for a minimum of 48 hours.

Breaking torque is the initial torque required to cause the nut to begin to move on the threaded rod after the adhesive has fully cured. It is measured using a dial or digital (not click type) torque wrench, at the point the nut first begins to move relative to the threaded rod, while attempting to move/turn the nut in the direction that will unseat the nut.

Note: Refer to Table 1 on Page 1 of 2 for a listing of Caltrans-approved anaerobic threadlocking components.
Appendix B

Copy of Section 75-1.03, Miscellaneous Bridge Metal, and Section 75-1.035, Bridge Joint Restrainer Units, from the 1999 Caltrans Standard Specifications
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Bridge joint restrainer units, of the type or types shown on the plans, consisting of cables or cable assemblies and associated materials or components, shall conform to the details shown on the plans and the requirements of these specifications and the special provisions.

The associated materials or components required for each restrainer unit type shall be as shown on the plans or as specified in the special provisions and include various combinations of the following: structural steel components, bolts, bearing plates, cable drum units, pipe sleeves, polyvinyl chloride pipe, elastomeric pads, expansion joint filler, expanded neoprene, expanded polystyrene, sheet neoprene, hardboard and incidentals.

Cables shall be 19 mm preformed, 6x19, wire strand core or independent wire rope core (IWRC), galvanized in conformance with the requirements in Federal Specification RR-W-410D, right regular lay, manufactured of improved plow steel with a minimum breaking strength of 200 kN. Two certified copies of mill test reports of each manufactured length of cable used shall be furnished to the Engineer.

Cable assemblies shall consist of cables, swaged fittings, studs, nuts, cable yield indicators, disk springs and when shown on the plans, turnbuckles and shall conform to the following requirements:

The swaged fitting shall be machined from hot-rolled bars of steel conforming to the requirements in AISI Designation: C1035, and shall be annealed, suitable for cold swaging. A lock pin hole to accommodate a 6-mm plated spring steel pin shall be drilled through the head of the swaged fitting to retain the stud in proper position. The manufacturer's identifying mark shall be stamped on the body of the swaged fitting. The 25-mm diameter stud shall conform to the requirements in ASTM Designation: A 449 after galvanizing. Prior to galvanizing, a 10-mm slot for the locking pin shall be milled in the stud end.

Nuts shall conform to the requirements in ASTM Designation: A 563 or A 563M including Appendix X1, except lubrication is not required.

The cable yield indicator shall be machined from hot-rolled bars of steel conforming to the requirements in AISI Designation: C 1035 and shall be annealed, suitable for cold swaging. The heat number and manufacturer's identifying mark shall be stamped on the end surface of each cable yield indicator. The wall thickness of the reduced section of the cable yield indicator shall be machined by the Contractor so that the indicator yields at a load between 160.2 kN and 169.1 kN when tested in compression along the major axis at a test speed not to exceed 12 mm per minute. Two certified copies of the mill test and heat treating reports of each heat of bars used for cable yield indicators shall be furnished to the Engineer.

The disc springs shall be made from steel conforming to the requirements in ASTM Designation: A 684/A 684M, Grade 1075. Galvanizing of the disc springs will not be required. The disc springs shall be cleaned and painted with a paint recommended by the manufacturer and color coded as shown on the plans.

Turnbuckles shall be the steel pipe type. Pulls for the turnbuckles shall consist of a swaged fitting and stud assembly. The swaged fittings, turnbuckles, stud and nut assembly shall develop the specified breaking strength of the cable. The cable assemblies shall be shipped as a complete unit including cable yield indicator, disk springs, stud and nut and, when required, turnbuckle. The Contractor shall be responsible for determining the required lengths of the cable assemblies. The Contractor shall notify the Engineer, in writing, at least 2 days prior to tightening and setting of cable restrainer units.

The following materials shall be furnished to the Engineer at the manufacturer's plant:

1. One sample cable assembly, consisting of a cable properly fitted with a swaged fitting and right hand thread stud at both ends, one meter in total length, for each 200 cable assemblies or fraction thereof produced.
2. One turnbuckle fitted with a 200 mm stud at each end for each 200 turnbuckles or fraction thereof produced.
3. One percent of the cable yield indicators, but not fewer than 8, produced from each mill heat.
4. Two disc springs of each size produced from each mill heat.

Free ends of cable for restrainer units shall be securely wrapped at each end to prevent separation.
• Bolts, thread locking system and concrete anchorage devices shall conform to the provisions in Section 75-1.03, "Miscellaneous Bridge Metal."

• Unless otherwise specified, steel parts shall conform to the requirements in ASTM Designation: A 36/A 36M. Steel for bearing bars or pins shall conform to the requirements in ASTM Designation: A 36/A 36M or A 576 Grade 1030 (AISI 1030) and shall be other than rimmed or capped steel.

• Pipe sleeves shall be commercial quality welded steel pipe.

• Steel parts shall be galvanized in conformance with the provisions in Section 75-1.05, "Galvanizing." Holes may be drilled after galvanizing provided all holes are repaired as provided in Section 75-1.05.

• Fabrication and welding shall conform to the provisions in Section 75-1.03, "Miscellaneous Bridge Metal." The minimum size of fillet welds shall conform to the requirements in AWS D1.1 except as modified below:

<table>
<thead>
<tr>
<th>Base Metal Thickness of Thicker Part Joined (millimeters)</th>
<th>Minimum Size of Fillet Weld (millimeters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 19 to 38</td>
<td>8</td>
</tr>
<tr>
<td>Over 38 to 57</td>
<td>10</td>
</tr>
<tr>
<td>Over 57 to 150</td>
<td>13</td>
</tr>
<tr>
<td>Over 150</td>
<td>16</td>
</tr>
</tbody>
</table>

• Concrete for filling cable drum units shall conform to the provisions in Section 90-10, "Minor Concrete," or shall be a commercial grade pea gravel mix with not less than 400 kg of cement per cubic meter.

• Existing structural steel paint areas damaged by the Contractor's operations and holes drilled through existing steel members shall be repaired in conformance with the provisions for repair of galvanized surfaces in Section 75-1.05, "Galvanizing," at the Contractor's expense.

• Elastomeric pads shown with restrainer units shall conform to the provisions in Section 51-1.12H, "Elastomeric Bearing Pads," except that the pads may consist of elastomer only regardless of thickness. Laminated reinforcement will not be required.

• Polyvinyl chloride (PVC) pipe shall be commercial quality.

• When shown on the plans, bond breaker on PVC pipe shall consist of a mortar-tight wrapping of plastic sheet or rubber sheet, 0.25-mm minimum thickness, or equal.

• Expanded polystyrene and hardboard shall conform to the provisions in Section 51-1.12D, "Sheet Packing, Preformed Pads and Board Fillers."

• Expansion joint filler shall conform to the provisions in Section 51-1.12C, "Premolded Expansion Joint Fillers."

• Neoprene sheets shown with restrainer units shall conform to the requirements for neoprene in Section 51-1.14, "Waterstops." The neoprene sheets shall be smooth, free from pin holes or surface blemishes, and shall show no evidence of delamination.

• Closed cell expanded neoprene material shall be of commercial quality conforming to the stiffness requirements for Class SC Grade 43E material or firmer as set forth in ASTM Designation: D 1056.

• Each restrainer unit shall consist of the number of cable units shown on the plans.

• Where shown on the plans, the cable shall be covered with a piece of 19-mm inside diameter neoprene tubing having a wall thickness of not less than 3mm. Neoprene tubing shall be held in place with stainless steel hose clamps. Neoprene tubing and hose clamps shall be of commercial quality. Cadmium plated screws furnished with stainless steel clamps will be acceptable.
Appendix C

Copy of the letter sent to Caltrans by Cable Moore, Inc. detailing why the list of approved threadlocking compounds required updating.
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6. REFERENCES


ADDENDUM TO:
“Evaluation of Several Brands of Anaerobic Threadlocking Compounds Used for Nut Retention on the Threaded Rod Ends of Bridge-Joint Restrainer Cables”

On July 27, 2000, two more Anaerobic Threadlocking Compounds, Saf-T-Lok and Pacer, were tested on 1” diameter ASTM A449 hot-dipped galvanized threaded rods with matching ASTM A563, Grade DH nuts. Both compounds passed the minimum breaking torque value of 45 lb-ft or 61 N⋅m and are considered acceptable for use with this particular rod size and type. These two compounds will now be added to the Qualified Products List (QPL) at:


The test results are in Table-1 below. It is important that all traces of oils, debris, and dry lubricants are thoroughly removed from all threaded surfaces prior to application of the primer or adhesives. Also, the “Application Instructions for Caltrans-Approved Anaerobic Threadlocking Systems,” must be followed.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Breaking torque (N⋅m)</th>
<th>Prevailing torque (N⋅m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample number</td>
<td>Avg.</td>
</tr>
<tr>
<td>Saf-T-Lok</td>
<td>151 196 199 175 164</td>
<td>177</td>
</tr>
<tr>
<td>Pacer</td>
<td>118 108 82 113 106</td>
<td>105</td>
</tr>
</tbody>
</table>