

DYWIDAG Circular Structure Repair with Hoop Tendons





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Services for Repair of Circular Structures

Over the years, DSI has accumulated a large amount of experience in installing and helping owners and contractors install repair solutions to their circular structures. Whether it is a tank, a silo or a cylinder pipe, whether the towers are high and difficult to access or the pipe is buried under a high volume traffic artery, DSI has cost-effectively installed strand-based repair solutions. With this background, DSI can provide today a one-step supply and installation solution for hoop tendon repairs.

With a history of dealing with tendons and strands since the 1950s, DSI has been present in almost any kind of tendon installation throughout the USA. The personnel present in the many nationwide DSI offices provide a global approach to the necessities of the American market. In addition, DSI USA benefits from the equipment and



technical resources of a worldwide leader in post-tensioning – DYWIDAG Systems International.

Now with the addition of the know-how of the experts at Lang Tendons, the circular structure repair team has increased in strength and responsiveness.

One particularly helpful feature, for PCCP pipeline owners, is the ability of DSI to install external post-tensioning hoops on pipelines while minimizing the excavation to two trenches. By using external hoops for the repair of PCCP instead of replacing bulky cylinder pipes,

not only is the encumbrance of large cranes and staging areas avoided, the area of excavation, in tight urban spaces, can be minimized and avoid disturbing major traffic arteries or highly encumbered surfaces.

Pipeline or silo owners will find that DSI works in close collaboration with the inspection, monitoring and engineering team on the circular structure repair project to participate in optimizing the repair solution. In effect, integrating the repair team to the management of a given containment asset facilitates the return on investment of its maintenance.



Material for Repair of Circular Structures

Prestressed Concrete Cylinder Pipe (PCCP) pipeline owners faced with potential pipeline ruptures, due to corrosion failures of circumferential prestress wires, can repair them, rather than replacing them, with the economical and efficient POLYSTRAND external hoop tendon system. This method restores the prestress force and keeps PCCP pipelines in service. Lang Tendons, now a subsidiary of DYWIDAG-Systems International specially developed this system, based upon its patent for extrusion coated strand for post tensioned concrete and its strand coupler patent. With this system specifically designed for PCCP pipe, repairs can be easily and quickly installed. It is of great benefit that the pipes do not have to be de-watered or removed, but they are strengthened in-situ once excavated. Only the pipes identified as having bad wires need to be repaired, there is no need to condemn the entire pipeline.

Our specialized strand is an extrusion coated, high tensile strength prestressing strand (ASTM A-416). Each hoop has an ultimate tensile strength of over 58.6 kips. Corrosion protection is assured because the steel is encased in a very high quality corrosion inhibitor, which is then encapsulated by extruding a molten seamless polypropylene (PP) polymer sheath over the strand.

Due to our strand's low coefficient of friction and high force transmission properties, the prestressing force is efficiently transferred along the entire 360-degree pipe circumference.

The 80 mils thick, high strength, virgin polypropylene sheath provides toughness and durability during installation and under load.

A key component of the economical pipe repair system is the SURFACE

LOKCOUPLER™, designed to be used in conjunction with the high force transmission and corrosion resistive properties of the our specialized strand tendons. This coupler system, with corrosive protection features, builds on Lang's experience in the repair of circular tanks and silos for more that 15 years using its patented LOKCOUPLER™. The SURFACE COUPLER is designed to bear on the surface of pipes as small as 48 inches in diameter.



Other couplers, or surface anchors, from the DSI array of post-tensioning accessories increase the range of application of hoop tendons on pipes 36" in diameter to 144" in diameter and larger. In particular, very large diameter structures, in the case of silo and tank repairs, can be done by engineering relay couplers around the circumference of the structure and reduce the overall post-tensioning losses.

The hoop tendon system has been proven since 1997 in a variety of pipeline applications from Arizona to Texas to Massachusetts. On one project alone, over 4,000 hoop tendons were installed

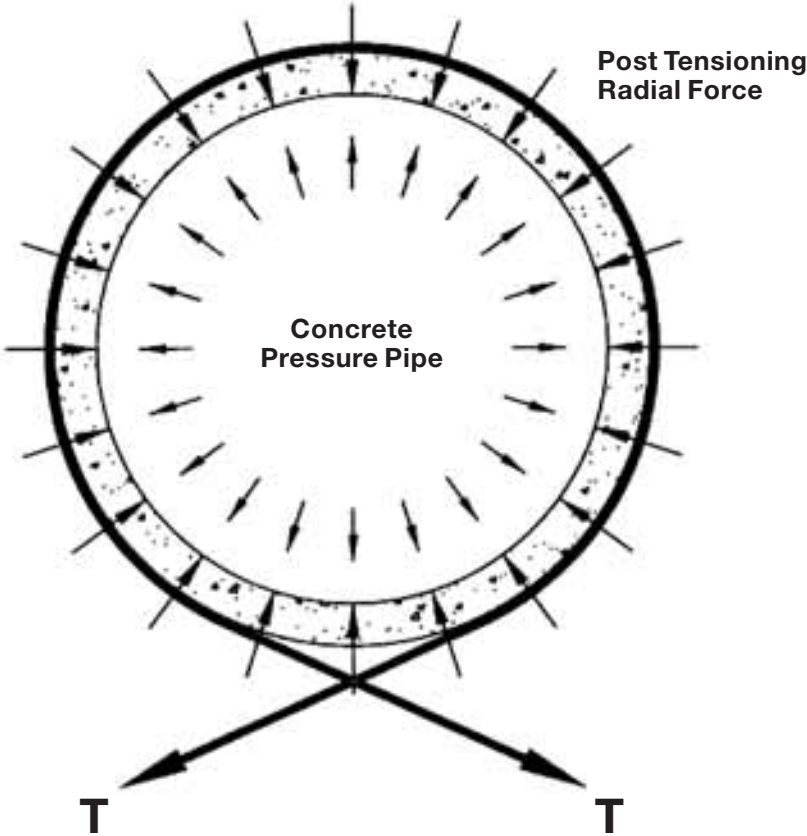
by Arizona Public Service Co. on a water pipeline supplying the Palo Verde Nuclear Generating Station.

A recent addition to the range of application of hoop tendons is the use of Epoxy-Coated Strand instead of regular bare strand in the extruded sheath. The bare strand is subjected to a flow of epoxy, filling the gaps between the wires and adding on the exterior of the tendon a 30 mil epoxy coat. In itself, this strand

can withstand the high strength, durability and coating resistance demands of hoop tendons.

Used in conjunction with the 80 mil coating and corrosion inhibiting grease, the system provides over 4,500 hours of resistance to the ASTM salt fog accelerated corrosion test. This is used in particularly corrosive soils, on pipes submitted externally to chemically aggressive runoffs or simply to reduce what additional cover would be required for impact and corrosion protection.

Radial Force Distribution from Hoop Tendons



- T = Tension in Hoop Tendon
- Pr = Radial Force on Concrete Pipe
- R = Outside Radius of Concrete Pipe
- D = Outside Diameter of Concrete Pipe



$$\begin{aligned} Pr \times D &= 2T \\ Pr \times D/2 &= T \\ Pr \times R &= T \end{aligned}$$

$$Pr = \frac{T}{R}$$



This sketch shows the basic principle of circular structure strengthening with hoop tendons and does not take into account all the loads and parameters that should be included in the design of a strengthening solution. For more information, please contact DSI USA.

Steel Specifications for Polypropylene-Coated Strand PCCP Hoops

For 7-wire Stress Relieved Steel Strand for Prestressed Concrete

| Strand Designation | Grade 264 KSI 67K | | Grade 270 KSI, Ultimate Stress – 270,000 psi | | | |
|--|---------------------------------------|---------------------|--|---------------------|---------------------------|---------------------|
| | 6/10" Compacted Strand ASTM A 779* | | 58K 6/10" ASTM A 416 | | 41K 1/2" ASTM A 416 | |
| ASTM Specification | ASTM A 779* | | ASTM A 416 | | ASTM A 416 | |
| Strand Diameter Nominal | 0.600 in. | 15.2 mm | 0.600 in. | 15.24 mm | 0.500 in. | 12.70 mm |
| Steel Area Nominal | 0.256 sq.in. | 165 mm ² | 0.217 sq.in. | 140 mm ² | 0.153 sq.in. | 101 mm ² |
| Steel Weight/LF | 0.87 #/LF | 1.295 kg/m | .74 #/LF | 1.10 kg/m | 0.52 #/LF | 0.78 kg/m |
| Modulus of Elasticity | 28.5 x 106 psi | 1.96 x 106 bar. | 28.5 x 106 psi | 1.96 x 106 bar. | 28.5 x 106 psi | 1.96 x 106 bar. |
| Minimum Guaranteed Ultimate Tensile Strength (GUTS) | 67.4 kips | 299.8 kN | 58.6 kips | 260.7 kN | 41.3 kips | 183.7 kN |
| Temporary Jacking Force (Max 80% of GUTS) | 53.9 kips | 239.8 kN | 46.9 kips | 208.6 kN | 33.0 kips | 146.8 kN |
| Initial Lockoff Load (70% of GUTS) | 47.2 kips | 210.0 kN | 41.0 kips | 182.4 kN | 28.9 kips | 128.6 kN |
| Design Load (60% of GUTS) | 40.4 kips | 179.7 kN | 35.2 kips | 156.4 kN | 24.8 kips | 110.3 kN |

These data are representative. Mill test certifications of actual values are provided with each order of POLYSTRAND[®].

Conversion Factors

1 in = 25.4 mm
 1 mm = 0.039 in
 1 mm² = 0.0016 in²
 1 in² = 645.16 mm²
 1 kN = 224.8 lbs

Nomenclature

A_{ps} = Area prestress steel, nominal
 F_{pu} = Force, minimum ultimate = Kips (kN)
 f_{pu} = Stress, minimum ultimate = ksi (N/mm²)

*See also British Standard 5896.

External Hoops Stress & Force

As related to pipe O.D. (based on 6/10 inch diameter, 58K strand).

| Pipe I.D. | Pipe O.D. | Tendon Length (Circumference) | Initial After Release Average Stress ² | Long Term Losses ³ | Average | Final Average StressForce |
|----------------|----------------|----------------------------------|---|----------------------------------|---------------|---------------------------------|
| [inches] / [m] | [inches] / [m] | [feet] / [m] | [ksi] / [MPa] | [ksi] / [MPa] | [ksi] / [MPa] | [kip] / [kN] |
| 42 / 1.067 | 48 / 1.219 | 13.5 / 4.11 | 141.9 / 978 | 6.4 / 44.0 | 135.3 / 932 | 29.4 / 130 |
| 48 / 1.219 | 58 / 1.473 | 16.0 / 4.88 | 146.5 / 1,010 | 6.6 / 45.5 | 139.9 / 964 | 30.4 / 135 |
| 54 / 1.372 | 64 / 1.626 | 18.0 / 5.49 | 153.4 / 1,057 | 6.7 / 46.2 | 146.8 / 1,012 | 31.9 / 142 |
| 60 / 1.524 | 71 / 1.803 | 19.5 / 5.94 | 155.2 / 1,070 | 6.7 / 46.2 | 148.6 / 1,024 | 32.2 / 143 |
| 66 / 1.676 | 78 / 1.981 | 21.5 / 6.55 | 159.6 / 1,100 | 6.7 / 46.2 | 152.9 / 1,054 | 33.2 / 148 |
| 72 / 1.829 | 85 / 2.159 | 23.5 / 7.16 | 161.9 / 1,116 | 6.8 / 46.9 | 155.2 / 1,070 | 33.7 / 150 |
| 78 / 1.981 | 92 / 2.339 | 25.0 / 7.62 | 163.4 / 1,126 | 6.9 / 47.6 | 156.5 / 1,079 | 34.0 / 151 |
| 84 / 2.134 | 99 / 2.515 | 27.0 / 8.23 | 165.1 / 1,138 | 7.1 / 49.0 | 158.0 / 1,089 | 34.3 / 153 |
| 90 / 2.286 | 106 / 2.692 | 29.0 / 8.84 | 166.6 / 1,148 | 7.1 / 49.0 | 159.5 / 1,099 | 34.6 / 154 |
| 96 / 2.438 | 111 / 2.819 | 30.0 / 9.14 | 167.3 / 1,153 | 7.1 / 49.0 | 160.2 / 1,105 | 34.8 / 155 |

Notes:

- These values are approximations only. They are derived by a calculation of ADAPT Post-Tensioning Stress Loss & Elongation Program – FELT (Ver. 3.50), assuming stressing from one end only. This model does not exactly describe the behavior using a Surface LOKCOUPLER.
- Nominal cross section average of 58K strand is 0.217 sq.in.
- For existing PCCP, long term losses will be reduced due to the age of the concrete and therefore, negligible concrete creep or shrinkage.

Specifications for Polypropylene-Coated Strand System for PCCP Pipeline or Circular Structure Repairs

1. Scope

This specification is for hoop tendons of corrosion protected 7-wire strand, high tensile strength prestressing steel used to repair PCCP pipe. The hoop tendons shall be extrusion coated strand with polypropylene, as manufactured by DYWIDAG-Systems International, or an approved equal.

2.0 Material

The material used to manufacture the strand shall be as follows:

Prestress Strand

2.1 Steel strand shall be 0.6 inch (15.2 mm) diameter 7-wire prestressing strand. If standard prestress strand with round wires is used, the strand shall meet ASTM A 416 with an ultimate stress of 270 ksi. If made with drawn and compacted wires, the strand shall meet ASTM A 779 or British Standard BS 5896-“Specification for High Tensile Steel Wire and Strand for the Prestressing of Concrete.” The compacted strand steel should have a nominal tensile strength of 1820 N/mm and a characteristic breaking load of 300 kN.

Corrosion Inhibitor

2.2 The organic corrosion inhibitor shall be Visconorust 2889 or equivalent, (which surpasses the corrosion inhibitor standard in ACI Bldg. Code 318, Sec. 18.14.3, and the specification for “Unbonded Single Strand Tendons”, revised July 1993 by the Post-Tensioning Institute.)

The corrosion inhibitor shall have a:

- 2.2.1 Melting point of over 260°C
- 2.2.2 High Reserve Alkalinity of 170 or greater for extended neutralization properties for long term corrosion protection
- 2.2.3 Minimum Specific Gravity of 1.04 (which is greater than water’s 1.0) to increase resistance to moisture encroachment
- 2.2.4 Salt Fog Accelerated Corrosion Test, exceeding 1500 hrs., per ASTM B-117, 5 mils
- 2.2.5 High resistance to microbiological and fungi degradation

Polymer

2.3 Polymer sheathing used for extrusion coating of the strand shall be minimum 80 mils nominal polypropylene (cell classification PP 210 B55542, as defined by ASTM D-4101 or approved equal).

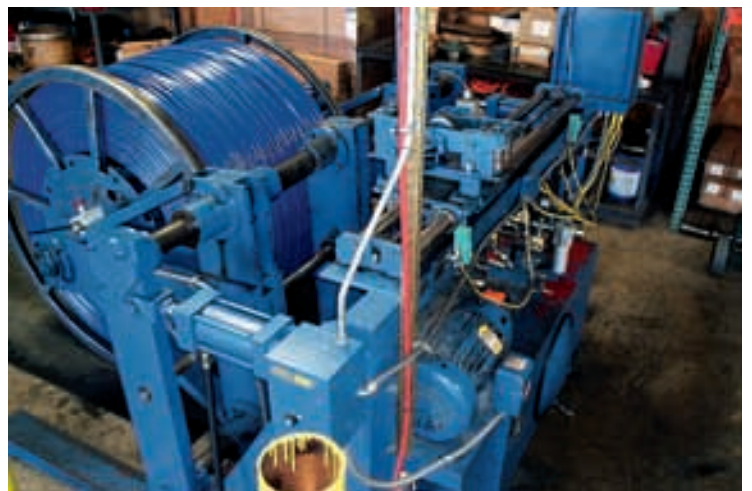
3.0 Corrosion Protection

Corrosion protection shall be as follows:

3.1 The unbonded tendons strand shall be fully coated by corrosion inhibitor and then encapsulated by a seamless polypropylene sheath.

3.1.1 Corrosion inhibitor shall fill all space between strand wires and between the strand and the extruded sheath. The diameter of the corrosion inhibitor film covering the strand shall be 0.005 to 0.010 inches greater than the diameter of the bare strand.

3.1.2 The strand sheath shall have a wall thickness of a nominal 80 mils or 0.08 inches. This sheath shall be hot-melt extruded over the corrosion inhibitor encased strand.



Specifications for Polypropylene-Coated Strand System for PCCP Pipeline or Circular Structure Repairs



4.0 Quality Control

4.1 Manufacturer of the seamless extrusion coated strand shall certify that the requirements of this specification have been satisfied.

4.2. Field inspection shall verify the following:

4.2.1 Full coating with corrosion inhibitor. Determine by visual inspection smoothness of extruded sheath. Reject if the sheath external surface follows the helical lay of the strand wires.

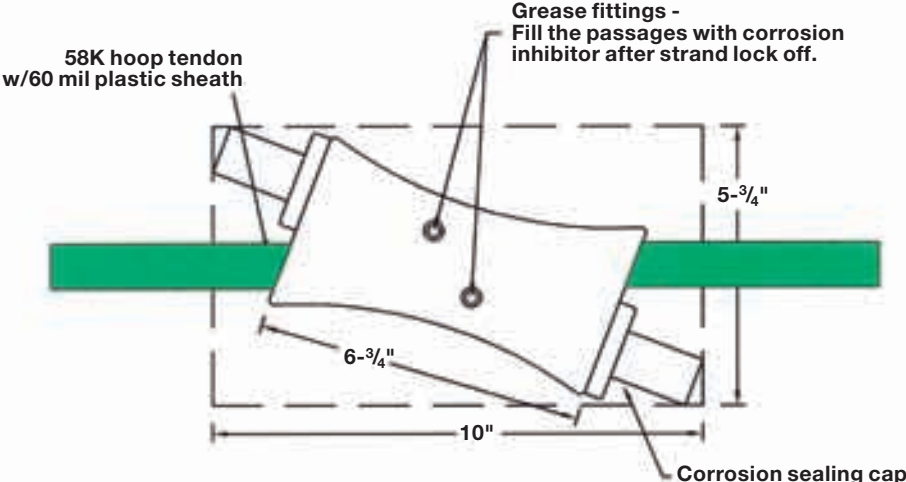
4.2.2 Minimum wall thickness of sheath. Reject if outside diameter of extruded sheath is less than diameter of bare prestressing strand plus 0.010 inches plus two times the specified wall thickness.

4.2.3 Integrity of the sheath. Inspect for presence of corrosion inhibitor that would be visible at a sheath hole, puncture or laceration, since the internal corrosion inhibitor is under a slight positive pressure. Remove corrosion inhibitor and examine sheath damage. Repair sheath in accordance with the recommendation of the manufacturer.

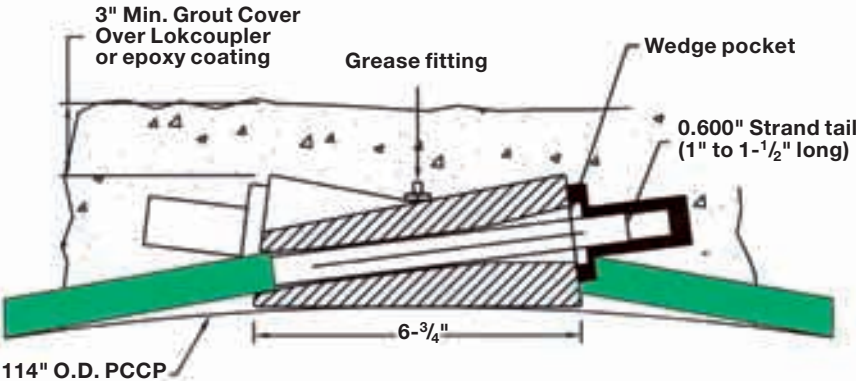


Surface Lokcoupler™ – Nominal Dimensions & Installation Details

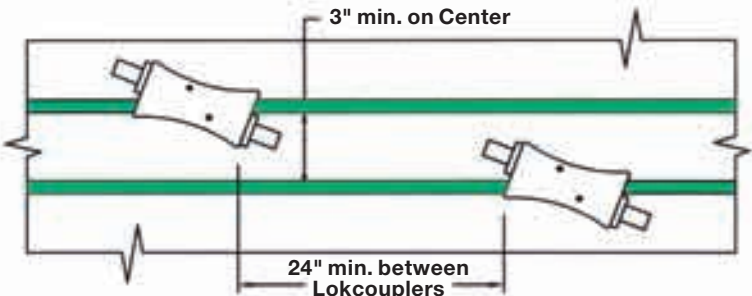
Top View After Stressing



Side View After Stressing



Staggered Arrangement



Comparison of Corrosion Inhibitors for PCCP Tendons

The table below compares corrosion inhibitor used by DSI in its Hoop Tendons for PCCP repair vs. the standards of the Post-Tensioning Institute for unbonded

tendons, Ref. Table 3.2.1, of the Post Tensioning Manual, Fifth Ed. This table shows the superior quality of the PCCP tendon inhibitor, in particular, for the

specific gravity, dropping point, base no., salt fog, soak tests, and water soluble ions.

| PROPERTIES (TYPICAL) | Test Method | PCCP Corrosion Inhibitor | PTI Specifications |
|---|------------------------|--------------------------|--------------------|
| Specific Gravity @ 77°F | – | 1.04 | – |
| Density lbs./gal. | – | 8.7 | – |
| Cone Penetration @ 77°F dmm | ASTM D-217 | 330 | – |
| Dropping Point °F min. | ASTM D-566 | 500 | 300 |
| Flash Point °F min. | ASTM D-92 | 345 | 300 |
| Viscosity @ 210°F cps | – | Thixotropic | – |
| Total Base No. Mg KOH/gm | ASTM D-974 Modified | 190 | – |
| Copper Corrosion Test | ASTM D-130 | 1a | – |
| Rust Preventive Properties of Grease | ASTM D-1743 | 1,1,1 | – |
| Salt Fog @ 100°F hrs. @ 5 mils Accelerated Corrosion Test | ASTM B-117 | 1500 | 1000 |
| Soak Test: Salt Fog 50/50 Immersion, hrs. | ASTM B-117 Modified | 1000 | 720 |
| Oil Separation @ 160°F, max. | FTMS 791B Method 321.2 | 0.5 | 0.5 |
| Water %, max. | ASTM D-95 | 0.1 | 0.1 |
| Water Soluble Ions, ppm max. | | | |
| Chlorides | ASTM D-512 | 2 | 10 |
| Sulfides | APHA 45002 | 2 | 10 |
| Nitrates | ASTM D-992-78 | 4 | 10 |
| Cubic Thermal Exp. | – | 0.0005 | – |
| Sheathing Compatibility | | | |
| Hardness % max. Change | ASTM D-4289 | 10 | 15 |
| Volume % max. Change | ASTM D-4289 | 7 | 10 |
| Tensile Strength % max. Change | ASTM D-638 | 21 | – |
| Application Temp. °F | – | >0 | – |
| | | No melt | |



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