

DYWIDAG-SYSTEMS INTERNATIONAL Circular Structure Repair

POLYSTRAND™ Hoop Tendons

DYWIDAG-SYSTEMS INTERNATIONAL USA, INC.

Post-Tensioning / Reinforcing Business Unit
Repair and Strengthening

POLYSTRAND™ Hoop Tendons INTRODUCTION

Services for Repair of Prestressed Concrete Pipe and Circular Structures

Over the years, DSI, through the Lang and DSI repair activities, 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 provides 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.

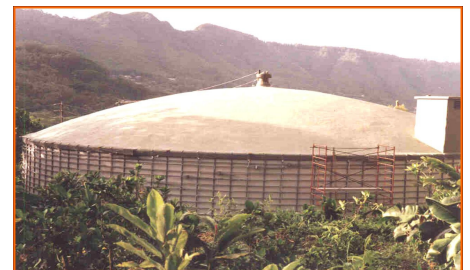
Now with the addition of the know-how of the experts at Lang Tendons, the circular structure repair team has increased in strength and responsiveness.



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.

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POLYSTRAND™ Hoop Tendons INTRODUCTION

Material for Repair of Prestressed Concrete Pipe and 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.

POLYSTRAND 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 POLYSTRAND'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 POLYSTRAND tendons. This coupler system, with corrosive protection features, builds on Lang's experience in the repair of circular tanks and silos for more than 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 POLYSTRAND 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 POLYSTRAND 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.

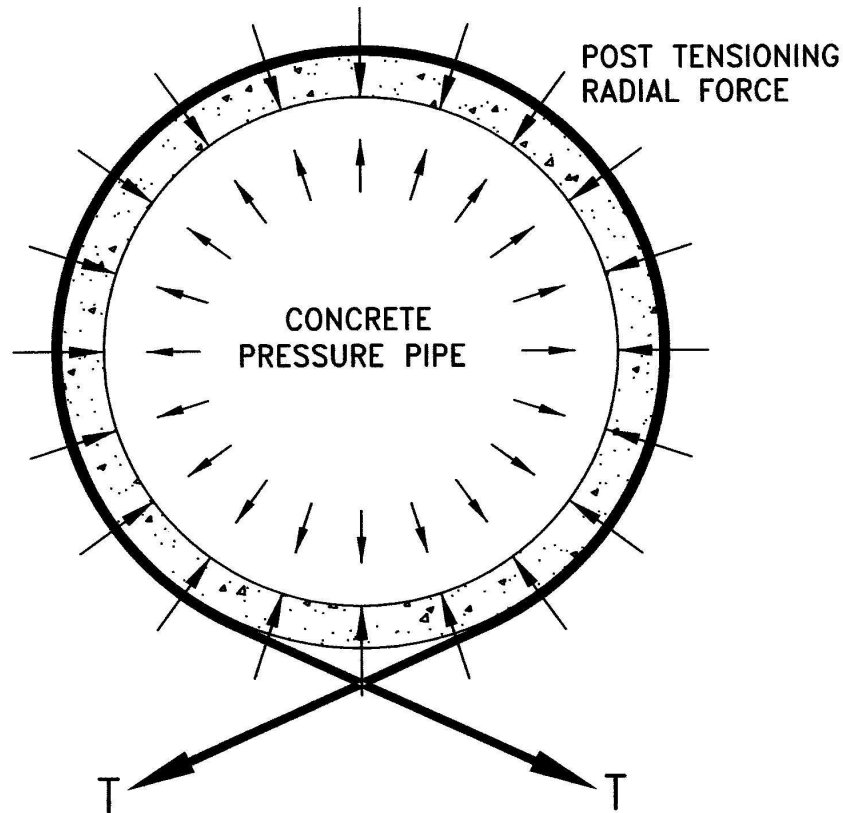
Used in conjunction with the 80 mil coating and corrosion inhibiting grease, the system provides over 4,500 hours of resistance to the ASTM salt fog accelerated corrosion test. This is used in particularly corrosive soils, on pipes submitted externally to chemically aggressive runoffs or simply to reduce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

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POLYSTRAND™ Hoop Tendons
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Radial Force Distribution from POLYSTRAND Hoop Tendon



T = TENSION IN HOOP TENDON
Pr = RADIAL FORCE ON CONCRETE PIPE
R = OUTSIDE RADIUS OF CONCRETE PIPE
D = OUTSIDE DIAMETER OF CONCRETE PIPE

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

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

POLYSTRAND™ Hoop Tendons TECHNICAL

Specifications for POLYSTRAND System for PCCP Pipeline or Circular Structure Repairs

1.0 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 POLYSTRAND extrusion coated strand with polypropylene, as manufactured by DYWIDAG-Systems International, or an approved equal.

2.0 Material

The material used to manufacture POLYSTRAND 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.

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POLYSTRAND™ Hoop Tendons TECHNICAL

Specifications for POLYSTRAND System for PCCP Pipeline 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.



POLYSTRAND™ Hoop Tendons
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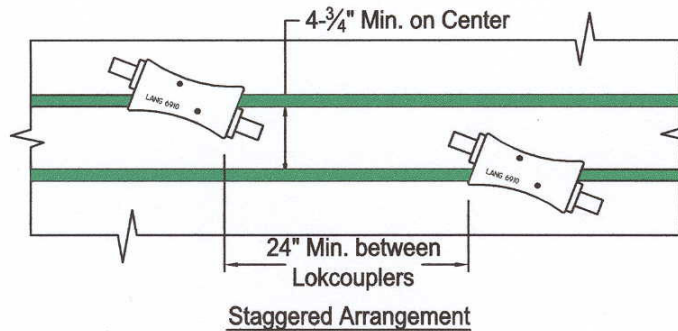
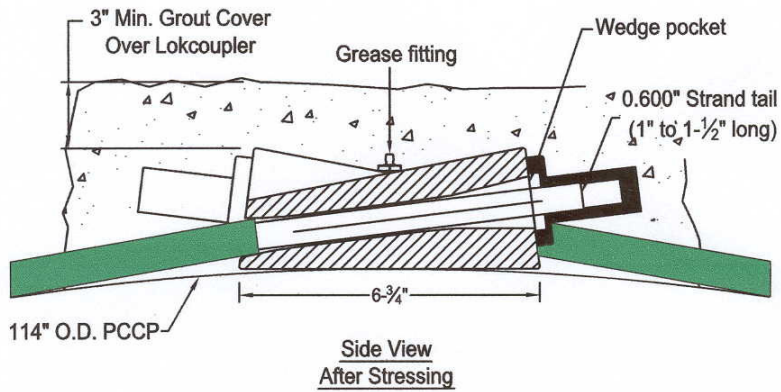
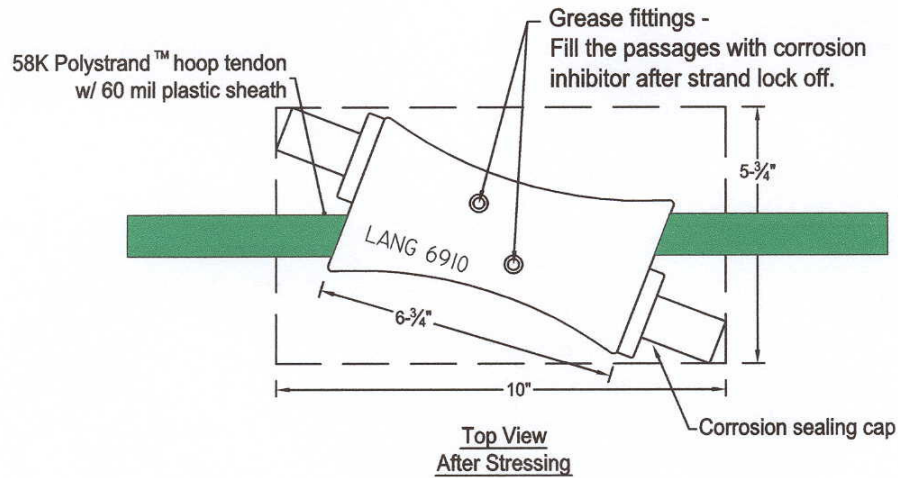
Comparison of Corrosion Inhibitors for PCCP Tendons

The table below compares corrosion inhibitor used by DSI in its POLYSTRAND Hoops 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	30
Application Temp. ° F	-----	>0 No melt	-----

POLYSTRAND™ Hoop Tendons
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SURFACE LOKCOUPLER™ – Nominal Dimensions & Installation Details





**POLYSTRAND™ Hoop Tendons
SPECIFICATIONS**

Steel Specifications for POLYSTRAND PCCP Hoops

For 7-wire Stress Relieved Steel Strand for Prestressed Concrete

Strand Designation ASTM Specification	Grade 264 KSI		Grade 270 KSI, Ultimate Stress – 270,000 psi			
	<u>67K</u> 6/10” Compacted Strand		<u>58K</u> 6/10”		<u>41K</u> 1/2”	
	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 10 ⁶ psi	1.96 x 10 ⁶ bar.	28.5 x 10 ⁶ psi	1.96 x 10 ⁶ bar.	28.5 x 10 ⁶ psi	1.96 x 10 ⁶ 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
 1mm = 0.039 in
 1 mm² = 0.0016 in²
 1 in² = 645.16 mm²
 1kN = 224.8 lbs

Nomenclature
 Aps = Area prestress steel, nominal
 Fpu = Force, minimum ultimate = Kips (kN)
 fpu = Stress, minimum ultimate = ksi (N/mm²)

*See also British Standard 5896.



POLYSTRAND™ Hoop Tendons
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External Hoops Stress & Force

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

Pipe I.D.	Pipe O.D.	Tendon Length (Circumference)	Initial After Release Average Stress ²	Long Term Losses ³	Final Average Stress	Average Force
<u>inches</u>	<u>inches</u>	<u>feet</u>	<u>ksi</u>	<u>ksi</u>	<u>ksi</u>	<u>ksi</u>
42	48	13.5	141.9	6.4	135.3	29.4
48	58	16.0	146.5	6.6	139.9	30.4
54	64	18.0	153.4	6.7	146.8	31.9
60	71	19.5	155.2	6.7	148.6	32.2
66	78	21.5	159.6	6.7	152.9	33.2
72	85	23.5	161.9	6.8	155.2	33.7
78	92	25.0	163.4	6.9	156.5	34.0
84	99	27.0	165.1	7.1	158.0	34.3
90	106	29.0	166.6	7.1	159.5	34.6
96	111	30.0	167.3	7.1	160.2	34.8

Notes:

1. 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.
2. Nominal cross section average of 58K POLYSTRAND is 0.217 sq.in.
3. For existing PCCP, long term losses will be reduced due to the age of the concrete and therefore, negligible concrete creep or shrinkage.



POLYSTRAND™ Hoop Tendons Project References

Representative PCCP Pipeline Repairs 1997-2005

Arizona Public Service Company

Palo Verde Nuclear Station

Estimate 10,000 POLYSTRAND Hoops
on 96 inch I.D. PCCP
Repaired numerous pipe segments on water line to
power plant and plant recirculation line using approx.
40 hoops per pipe segment

Middlesex County Utilities Authority

Sayreville, NJ

331 POLYSTRAND Hoops
on 60"-102" I.D. PCCP
Repaired pipe segments with hoops
4" on center

2004

Washington Suburban Sanitary Commission

Laurel, MD

1,240 POLYSTRAND Hoops
on 96 inch I.D. PCCP
Repaired 28 pipe segments using approx.
46-48 hoops per segment

Tarrant Regional Water District

Fort Worth, TX

80 POLYSTRAND Hoops
on 72 inch I.D. PCCP
Repaired two pipe segments using 40 hoops
per segment

Dominion Generation (VEPCO)

Dumfries, VA

90 POLYSTRAND Hoops
on 120 inch I.D. PCCP
Repaired two pipe segments using 45 hoops
per segment.

Commonwealth of Puerto Rico

Guaynabo, Puerto Rico

4,500 POLYSTRAND Hoops
on 96 inch I.D. PCCP
Repaired over 100 pipe segments using approx.
40 per pipe segment

Northern Colorado Water Conservancy District

Loveland, CO

763 POLYSTRAND and POLYSTRAND HS Hoops
on 96 inch I.D. PCCP
Repaired 17 pipe segments using 32-53 hoops
per segment

Second Repair Project
468 POLYSTRAND Hoops

2004

Massachusetts Water Res. Authority

Stoneham, MA

Emergency repair of 48 inch I.D. PCCP
0.5 inch dia. 41K POLYSTRAND Hoops placed
on leaking 20 foot segment

Constellation Power Source Generation (Former BG&E)

Brandon Shores Power Plant Facility
Baltimore, MD

320 POLYSTRAND Hoops
on 102 inch I.D. PCCP
Repaired eight pipe segments using approx.
40 hoops per segment.



POLYSTRAND™ Hoop Tendons Project References

PCCP Owner/Engineer References

Owners

Arizona Public Service Company

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Fax: 602-393-6736

Washington Suburban Sanitary Commission

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Tarrant Regional Water District

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Brandon Shores Facility
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