DYWIDAG Micropiles

“Electra” Building, San Diego, CA, USA
The historic “Old SDGE Station B” building is located in downtown San Diego. The building was originally built in 1911 to accommodate the boilers and turbines of the San Diego Electrical Railway Company. Later it became the property of the San Diego Gas & Electric Company under whose name it is still known. A builder applied for the permit to build a new 43-storey high-rise building on that site. However, the historically deemed facade with its neo-classical and Art Deco stylistic elements was to be maintained. Therefore, it was decided to build the new high-rise building within the old facade and to integrate the facade into the new project.

For this purpose, the SDGE building was entirely gutted inside, and the facade was elaborately stabilized during the construction. In addition, the load capacity of the foundation soil had to be improved in a sustainable manner for the anticipated loads of the new skyscraper. Following its completion in December 2007, the new nostalgic complex will bear the name of “Electra” — in reference to the former owners of the site — and offer about 250 modern, luxurious apartments with a magnificent view of the harbour and the city of San Diego.

Condon-Johnson & Associates Inc., San Diego, was awarded the contract for the excavation, sheeting and shoring work. To increase the load capacity of the foundation soil, DYWI Drill® Hollow Bar Anchors were used.

DYWI Drill® Hollow Bar Anchors can easily be installed on the construction site under confined space conditions using simple and small dimensioned drilling equipment.

The DYWI Drill® Hollow Bar Anchor System offers the following advantages:

- use of small dimensioned drilling equipment.
- No predrilling need under limited space conditions.
- Simultaneous drilling and grouting in a single operation.

For this landmark project that will exceed any other buildings in San Diego after its completion DSI Long Beach supplied a total of 10,000 ft. DYWI Drill® Hollow Bar Anchors type T76S including hardware accessories such as drill bits and couplers.

**Owner** Bosa Development California II, Inc, British Columbia, Canada
**Main Contractor** Bosa Development California II, Inc, British Columbia, Canada
**Execution** Condon-Johnson & Assoc. Inc., San Diego, CA, USA
**DSI Unit** DSI-LANG, Geotechnical Systems Business Unit, Toughkenamon, PA, USA
**DSI-Services** Supply of about 10,000 ft/3.048 m DYWI Drill® Hollow Bar Anchors type T76S including hardware accessories such as drill bits and couplers
History
Use of micropile (mini pile, reticulated pile, etc.) started in early 1950s in Italy for underpinning applications of historic buildings damaged during World War II. Micropile technology is a reliable pile system that can withstand large capacity axial or lateral loads with minimal disturbance to the existing structures. They became very popular due to their ability to transfer loads efficiently through skin friction and due to their many installation advantages over conventional pile systems.

General Notes
A GEWI® Pile is a drilled and grouted micropile, less than 12 inches in diameter that is centrally reinforced with either one or a group of two or three high tensile strength DYWIDAG THREADBAR®. GEWI® Pile can carry loads up to 300 tons in compression or tension in relatively small boreholes. GEWI® Pile is also a friction pile. The load is transferred by bond from the threadbar to a cement grout body and from there by friction to the surrounding ground. The friction value between grout-ground can be increased by use of post grouting techniques.

Applications
GEWI® Pile applications are influenced by the existing environment and soil conditions and methods of construction. There are two major applications that can be classified.

1. Structural support, directly loaded pile (used most often)
   — Underpinning of existing structures (repair or replacement)
   — Seismic retrofitting
   — New foundations

2. Insitu reinforcement
   — Slope stabilization and earth retension
   — Settlement reduction.

Soil Types
The GEWI® Pile is a foundation element for any ground condition:

— Cohesive Soils:
  For example, clays, silts (up to an untrained shear strength of $Cu \geq 1.45$ psi) do not require additional lateral support.

— Noncohesive Soils:
  For example, sand and gravel

— Rock:
  Ranging from hard clays to granite, with open or closed joints and fissures.

— Permafrost:
  Easy to transport and to install. Ask for DSI grouting instructions.
Advantages and Characteristics

1. Offer a practical and cost-effective solution to costly alternative pile systems as well as a solution to job sites with different access.

2. Continuous Thread
   — DYWIDAG THREADBAR® has a continuous rolled-on pattern of thread-like deformations that allow full load couplers and anchorages to be easily positioned along the pile.
   — The pile length can be segmentally increased allowing access inside low head rooms areas.
   — Coarse thread remains threadable even if dirty or damaged.

3. Easy Installation
   — Compact, lightweight drilling and installation equipment makes GEWI® piles ideal for remote or confined areas such as: steep slopes, wetlands, river pier foundations, basements, beneath overpasses
   — Drill small holes very close to existing walls.

4. Vibration-Free Drilling Method
   — Boreholes can be drilled without damage to adjacent structures.

5. Preloading Capacity
   — Piles can be easily pre-loaded, virtually eliminating long-term settlement of structures

6. Foundation Element for any ground Condition
   — Cohesive soils (clay, silt, sand), non-cohesive soil (sandy gravel, cobbles, boulders), rock
   — Compression and tensile loads, also alternating loads, can be transferred into the underground by skin friction along the grout body.

7. Environmentally Friendly
   — Do not require large access road or drilling platforms
   — Materials are environmentally safe

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DSI's solution for a micropile is the GEWI® Pile
Design Methodology

GEW® Pile design follows currently available methods for micropile, standard pile and earth anchors. As per FHWA-SA-97-070 Manual, minimum recommended design steps are:

1. Review project information in regards to pile layout, loading requirements, access and overhead clearance

2. Review geotechnical data for soil properties, design parameters, corrosion protection requirements, grout-to-ground parameters, bond length, pile spacing for group effects

3. Structural design should include:
   - Anticipated settlement/required stiffness analysis
   - Lateral load pile capacity/ Anticipated lateral displacement
   - Buckling of the pile/soil lateral support

4. Additional structural details such as: case and uncased length, strain/ductility of the steel, transition between case and uncase section, reinforcement splice connections, pile to footing connection, corrosion protection,

5. Load testing program and quality control requirements

![Diagram of GEW® Pile](image1)

![Diagram of Stress-Strain Curve](image2)
Corrosion Protection

**Single Corrosion Protection**

The DYWIDAG THREADBAR® at the core of the pile is surrounded by a cement grout layer of various thickness. In addition to sealing the bar from moisture, the high pH-value of the cement grout passivates the steel surface of the bar, providing further corrosion protection. Under compressive loads, the grout remains firmly bonded to the bar (without cracking), providing good corrosion protection.

Under tensile loads, the bar’s thread deformations create a uniform distribution of fine cracks in the cement grout, the width of which are minimized by the low elongation of the threadbar itself. However, for permanent piles and where the crack width exceeds acceptable levels, double corrosion protection should be used.

**Double Corrosion Protection**

Double corrosion protection is provided by placing the threadbar within a corrugated PVC sleeve and by filling the annulus between the bar and the sleeve with a non-shrink cement grout, preferably in a qualified shop. This pre-grouted threadbar is then assembled, installed and grouted in the same way as the single corrosion protected bar.

Double corrosion protection is recommended for permanent tension piles and piles installed in aggressive media.
Installation of GEWI® Pile

Drilling and Grouting with Casing

In granular soils, the GEWI® Pile is always installed in cased bore holes. Due to the small diameter, these holes can be made using the advanced drill procedures of the anchor technology. The bore holes can be advanced quickly, without vibrations and relatively quiet. Drilling obstacles, such as hard strata, blocks or foundations, can be penetrated without problems. The bore holes can be inclined to any degree, from horizontal to vertical. The rigid casing not only permits straight holes in which the GEWI® Piles can be installed without bending, but also pressure-grouting of the bond length and the shaft of the pile. The figure shows the various phases in the installation of the GEWI® Pile.

Post-grouting

Post-grouting improves the load carrying capacity in cohesive soils by increasing the skin friction. The same post-grouting system, as developed for the DYWIDAG bar anchor, is used for the GEWI® Pile. Through a ring line, with grout valves in the bond length,

Post grouting is done once or repeatedly. The limits for the load transfer capacity is not only determined by the maximum obtainable skin friction, but also by the ability of the soil itself to carry the load.

Note: Post grouting can be performed in multi-stages, 1-stage per 18 hour interval. Post-grout injection pressure should be not exceed 6MPa.

Failed piles can often be recovered to safe design load by additional post-grouting.

Gravity Grouted Cement Grout Body (before Post-Grouting)

Gravity Grout

Corrugated PVC Sheath outer Layer of corrosion protection

GEWI® Bar

Post-grout

Gravity Grouted Cement Grout Body (after Post-Grouting)

Cement Grout Body after Post-Grouting (Enlarged Grout Body)

Cement Grout Body (all pieces)

PVC

Gravity Grout

Post-grout

Line

Post-Grout Lines
Installation References

Lion Gate Hospital

Mini-track mounted drill rig
Installer: Kani Foundation
Technology

Kerrisdale Elementary School

Pile Installation
Contractor: Southwest Contracting
## Bar Properties

### DYWIDAG THREADBAr® Reinforcing Steel ASTM A615 (Grade 75)

<table>
<thead>
<tr>
<th>THREADBAR® Designation</th>
<th>Maximum THREADBAR® Diameter</th>
<th>Yield Stress (fy)</th>
<th>Cross Section Area (As)</th>
<th>Yield Load (fy x As)</th>
<th>Nominal Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[in] [mm]</td>
<td>[ksi] [MPa]</td>
<td>[in²] [mm²]</td>
<td>[kips] [kN]</td>
<td>[lbs/ft] [kg/m]</td>
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<tr>
<td>#11</td>
<td>36 1.61</td>
<td>75 517</td>
<td>1.56 1,006</td>
<td>117.0 520</td>
<td>5.31 7.90</td>
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<td>75 517</td>
<td>2.25 1,452</td>
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<td>75 517</td>
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<td>300.0 1,335</td>
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<td>63 2.72</td>
<td>80 552</td>
<td>4.91 3,168</td>
<td>393.0 1,748</td>
<td>16.91 25.16</td>
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<tr>
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<td>75 3.18</td>
<td>75 517</td>
<td>7.06 4,555</td>
<td>529.5 2,355</td>
<td>24.09 35.85</td>
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<tr>
<td>#28</td>
<td>90 3.68</td>
<td>75 517</td>
<td>9.62 6,207</td>
<td>721.5 3,209</td>
<td>32.79 48.79</td>
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</tbody>
</table>

**Note:** Maximum test load = 90% of the yield load; Mill length = 60'-0" for #6 through #24 bars and 48'-0" for #28 bars

### DYWI Drill® Hollow Bar Properties

<table>
<thead>
<tr>
<th>Bar Designation</th>
<th>Nominal Outer Diameter</th>
<th>Average Yield Stress (fy)</th>
<th>Average Ultimate Tensile Stress (fu)</th>
<th>Average Cross Section Area (As)</th>
<th>Yield Load (fy x As)</th>
<th>Ultimate Load (fu x As)</th>
<th>Nominal Weight</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>[in] [mm]</td>
<td>[ksi] [MPa]</td>
<td>[ksi] [MPa]</td>
<td>[in²] [mm²]</td>
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<td>[kips] [kN]</td>
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<tr>
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<td>2.00 51</td>
<td>106 729</td>
<td>1.17 754</td>
<td>101 450</td>
<td>124 550</td>
<td>3.97 5.90</td>
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<tr>
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<td>112 772</td>
<td>1.32 854</td>
<td>118 525</td>
<td>148 660</td>
<td>4.50 6.70</td>
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<tr>
<td>R51N</td>
<td>2.00 51</td>
<td>112 772</td>
<td>1.61 1,036</td>
<td>142 630</td>
<td>180 800</td>
<td>5.44 8.10</td>
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<tr>
<td>T76N</td>
<td>3.00 76</td>
<td>108 745</td>
<td>3.32 2,145</td>
<td>270 1,200</td>
<td>360 1,600</td>
<td>11.29 16.80</td>
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<tr>
<td>T76S</td>
<td>3.00 76</td>
<td>110 758</td>
<td>3.88 2,504</td>
<td>337 1,500</td>
<td>427 1,900</td>
<td>13.24 19.70</td>
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</table>

**Note:** Maximum allowable, temporary test load is 100% of the yield load. Average cross section area is based on average internal diameter of the bar. The ultimate and yield load capacity are measured values. The ultimate tensile and yield stress are calculated average values. Mill length is 9'-10" (3m). Longer lengths can be special order.

### DYWIDAG THREADBAr® Prestressing Steel ASTM A722 (Grade 150)

<table>
<thead>
<tr>
<th>THREADBAR® Designation</th>
<th>Maximum THREADBAR® Diameter</th>
<th>Ultimate Stress (fu)</th>
<th>Cross Section Area (As)</th>
<th>Ultimate Load (fu x As)</th>
<th>Nominal Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[mm] [in]</td>
<td>[ksi] [MPa]</td>
<td>[in²] [mm²]</td>
<td>[kips] [kN]</td>
<td>[lbs/ft] [kg/m]</td>
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<td>1-1/4&quot;</td>
<td>32 1.44</td>
<td>150 1,034</td>
<td>1.25 806</td>
<td>187.5 834</td>
<td>4.39 6.53</td>
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<tr>
<td>1-3/8&quot;</td>
<td>36 1.63</td>
<td>150 1,034</td>
<td>1.58 1,019</td>
<td>237.0 1,054</td>
<td>5.56 8.27</td>
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<tr>
<td>* 1-3/4&quot;</td>
<td>46 2.01</td>
<td>155 1,069</td>
<td>2.58 1,664</td>
<td>400.0 1,779</td>
<td>9.22 13.72</td>
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<tr>
<td>* 2-1/2&quot;</td>
<td>66 2.79</td>
<td>150 1,034</td>
<td>5.16 3,355</td>
<td>774.0 3,443</td>
<td>18.20 26.36</td>
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<tr>
<td>* 3&quot;</td>
<td>75 3.15</td>
<td>150 1,034</td>
<td>6.85 4,419</td>
<td>1,027.0 4,568</td>
<td>24.09 35.85</td>
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</tbody>
</table>

* Meets the strength requirements of the A 722.

**Note:** Maximum test load = 80% of the ultimate load; Mill length = 60'-0" for 1", 1¼" and 1½" Threadbars and 45'-0" for 1¾", 2½" and 3" bars

### Properties of Multibar GEWI® Piles

<table>
<thead>
<tr>
<th>Bar quantity/size</th>
<th>Yield stress (fy)</th>
<th>Cross Section Area (Aps)</th>
<th>Ultimate Load (Aps x fu)</th>
<th>Yield Load (Aps x fy)</th>
<th>Nominal Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>[mm] [ksi] [MPa]</td>
<td>[in²] [mm²]</td>
<td>[kips] [kN]</td>
<td>[kips] [kN]</td>
<td>[lbs/ft] [kg/m]</td>
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<tr>
<td>3ea #14</td>
<td>3x43</td>
<td>517 [17]</td>
<td>6.75 4,356</td>
<td>675 3,000</td>
<td>22.95 34.14</td>
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<td>517 [75]</td>
<td>12.00 7,743</td>
<td>1,200 5,338</td>
<td>40.80 60.72</td>
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<tr>
<td>3ea #20</td>
<td>3x63</td>
<td>552 [80]</td>
<td>14.73 9,504</td>
<td>1,473 6,552</td>
<td>50.10 74.55</td>
</tr>
</tbody>
</table>

All combinations of sizes up to 3 GEWI® Bars are possible.
DYWIDAG SYSTEMS INTERNATIONAL

Bar Hardware Properties

DYWIDAG THREADBAR® Reinforcing Steel ASTM A615 (Grade 75)

<table>
<thead>
<tr>
<th>THREADBAR® Designation</th>
<th>Hex Nut Length [mm]</th>
<th>Coupler Length [mm]</th>
<th>Coupler Outer Diameter Ø [mm]</th>
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</thead>
<tbody>
<tr>
<td>#11</td>
<td>36</td>
<td>2.89</td>
<td>6.37</td>
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<td>43</td>
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<td>#18</td>
<td>57</td>
<td>4.23</td>
<td>9.35</td>
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<tr>
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<tr>
<td>#28</td>
<td>90</td>
<td>4.80</td>
<td>10.61</td>
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DYWI Drill® Hollow Bar Hardware Properties

<table>
<thead>
<tr>
<th>Bar Size</th>
<th>Coupler Length [mm]</th>
<th>Coupler Diameter [mm]</th>
<th>Hex Nut Length [mm]</th>
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<td>6.30</td>
<td>2.24</td>
<td>2.68</td>
</tr>
<tr>
<td>R51N</td>
<td>7.87</td>
<td>2.48</td>
<td>3.54</td>
</tr>
<tr>
<td>T76N</td>
<td>8.66</td>
<td>3.82</td>
<td>3.15</td>
</tr>
<tr>
<td>T76S</td>
<td>8.66</td>
<td>3.82</td>
<td>3.15</td>
</tr>
</tbody>
</table>

DYWIDAG THREADBAR® Prestressing Steel ASTM A722 (Grade 150)

<table>
<thead>
<tr>
<th>THREADBAR® Designation</th>
<th>Hex Nut Length [mm]</th>
<th>Coupler Length [mm]</th>
<th>Coupler Outer Diameter Ø [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 1/4*</td>
<td>32</td>
<td>2.88</td>
<td>6.75</td>
</tr>
<tr>
<td>1 3/8*</td>
<td>36</td>
<td>3.88</td>
<td>8.75</td>
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<tr>
<td>1 3/4*</td>
<td>46</td>
<td>3.38</td>
<td>7.75</td>
</tr>
<tr>
<td>2 1/2*</td>
<td>66</td>
<td>5.00</td>
<td>10.75</td>
</tr>
<tr>
<td>3*</td>
<td>75</td>
<td>5.00</td>
<td>11.00</td>
</tr>
</tbody>
</table>

Coupler and hexnut develop the full load of the bar ultimate load. Bearing plates are available in any size and are made from steel material conforming to ASTM A36 or ASTM A572 grade 50.

Multibar Assembly

At the Anchorage

- Bearing Plate with Hex Nut
- Spiral Reinforcement
- DYWIDAG THREADBAR® (Tot. 3)

In the Borehole

- Centralizer
- Primary Grout Tube
- Cement Grout
- Post Grout Tube
The GEWI® Splice Coupler, allowing splicing at any point, offers the following advantages:

- Installation of GEWI® Piles under restricted headroom such as for foundation rehabilitations in basements and underneath bridges.
- Short transport lengths, if needed, in case of container or helicopter transport.
- Unlimited extension of the GEWI® Bar, for example, to anchor the cross beam for pile tests.

GEWI® Pile assembly with double corrosion protection (DCP) and high pressure post-grout lines/values. Post-grouting can be performed in one or more stages. Post-grouting will increase bond values between grout body and soil by up to 3 times over conventional gravity grouting.
The safety of a foundation, particularly in low resistance soils, depends largely to what extent the foundation can be tested.

Testing of GEWI® Piles in compression can be facilitated by using adjacent piles as reaction piles. Testing in tension is usually sufficient since the compression capacity of the pile is always slightly higher than the tension capacity.

Settlement or creep of GEWI® Piles under service loads is generally very low — usually less than 5mm. In granular soils, settlements of less than 2mm are common.

Tested piles are not affected by the testing process and can be used as an integral part of the foundation system. Testing of GEWI® Piles is a simple procedure since the jack is axially pulling the centre bar or group of bars.
References

Irving Tissue Weston road plant upgrade; Canada

**Owner** Irving Tissue Corporation, Toronto, Canada

**Consulting Engineers** AMEC Earth & Environmental Limited, Scarborough, Canada

**Piling Contractor** Geo-Foundations Contractors Inc., Bolton, Canada

**DSI Unit** DSI Canada, Eastern Division, Gormley, Ontario, Canada

**DSI Services** Supply of 40 GEWI® Piles, 92 ft/28m long, 57 mm grade 75 bar with double corrosion protection, accessories, expertise and equipment

References

DYWIDAG Technology provides additional seismic event stability for Terminal Building

**Owner** Vancouver International Airport Authority, BC, Canada

**General Contractor** Ledcor Industries Ltd., Vancouver, BC, Canada

**Structural Design** Read Jones Christoffersen Ltd., Vancouver, BC, Canada

**Geotechnical Engineers** Macleod Geotechnical Ltd., North Vancouver, BC, Canada

**Piling Contractor** Kani Foundation Technologies, Richmond, BC, Canada

**DSI Services** Supply of 330 GEWI® Piles with double corrosion protection, total length 59 ft/18 m; Technical support; Rental of testing equipment
References

20 Windmills reinforced with Micropiles, Texas

Owner: General Electric Co., Greenville, South Carolina, USA
Execution: Nicholson Construction and Hayward Baker, USA
DSI Unit: DSI USA, Business Unit Geotechnical Systems, Toughkenamon, PA, USA
DSI Services: Supply of 240 micropiles using 3 GEWI® Bars in lengths of 45 ft / 13.7 m each, © 63.5 grade 80 (St 555/700), supply of slotted spacer plates and bar spacers
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