APPENDIX C

DYNA FORCE® ELASTO-MAGNETIC SENSOR
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FIGURES

DYNA Force® Elasto-Magnetic Sensor (Catalog Cut)  Sheets 1 thru 8
DYNA Force® Elasto-Magnetic Sensor
Penobscott Narrows Bridge and Observatory, Maine, USA
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On many occasions during construction and service life of the structure, it is crucial to know the force in the post-tensioning system. Although there are many methods to measure the tendon force, most of them are cumbersome, expensive, and the accuracy differs depending on the method used. DYWIDAG has been involved in the development, testing and execution of DYNA Force® to measure the force in the tendon. DYNA Force® is being used in cable stay bridges, cable system testing and building structure to measure the force during stressing and to monitor forces during the service life of the structure. DYNA Force® can be used for bare, epoxy-coated and greased-sheathed steel.

DYNA Force® is manufactured based on the theory that the permeability of steel to a magnetic field changes with the stress level in the steel. By measuring the change in a magnetic field the magnitude of the stress in the steel element can be obtained. The DYNA Force® does not alter the characteristics of the tendon other than its magnetization. The permeability is a function of temperature and magnetization, and a calibration process eliminates the impact of these variables. The program takes into consideration the temperature change effect automatically. A portable Power Stress unit is attached to wire leads from the DYNA Force®. This unit will create the magnetic field and then measure the residual value and then convert it to a direct force reading. The accuracy of the force measurement is within 1%. DYNA Force® system is robust, requires no maintenance and has no moving parts. It is composed of sensors and Power Stress unit (read-out box). DYNA Force® is installed over the strand or bar during construction and a zero reading is taken before applying any post-tensioning force. It is expected to have a similar service life as the bridge/building structure. This will allow the owner to regularly monitor the forces in the post-tensioning system in minutes as a part of their inspection procedures without the need for lift-off equipment or other special expensive techniques. This will also avoid the inaccuracies and risks often associated with lift-off readings. One person can do this job.

<table>
<thead>
<tr>
<th>DYNA Force® Type</th>
<th>Strand/Bar</th>
<th>ID [in]</th>
<th>OD [in]</th>
<th>Length [in]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strand DYNA Force®</td>
<td>0.5&quot;</td>
<td>0.71</td>
<td>1.50</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>0.6&quot;</td>
<td>0.78</td>
<td>1.50</td>
<td>5.1</td>
</tr>
<tr>
<td>Bar DYNA Force®</td>
<td>1-1/4&quot; &amp; 1-3/8&quot;</td>
<td>1.70</td>
<td>2.80</td>
<td>6.7</td>
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<tr>
<td></td>
<td>1-3/4&quot;</td>
<td>2.10</td>
<td>3.90</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>2-1/2&quot;</td>
<td>2.85</td>
<td>6.20</td>
<td>12</td>
</tr>
</tbody>
</table>

Note: Dimensions for 2-1/2" bar are preliminary.
Quality Assurance

All DYNA Force® sensors are professionally made in a quality controlled facility. Furthermore, each DYNA Force® is tested and individually packed and numbered at the DSI facility before sending to the job site. Although many tests have been conducted in the development of the DYNA Force®, DSI conducted additional tests to simulate the performance of the system when places within the anchorage zone of stay cables. In these tests DYNA Force® sensors were placed near the center and on the outside of the strand bundle. The loads were applied using a stressing jack and the force was monitored using a very accurate load cell. The load cell readings were compared to the results from the Power Stress unit and very good correlation was obtained.
When a DYNA Force® is installed on a strand/bar, the force in it may be obtained directly by merely attaching the leads from DYNA Force® to a portable Power Stress unit. No other equipment is needed. DYNA Force® sensors have been used in many bridge and building structures for the past several years.

DSI supplied two hundred forty sensors for Waldo cable stay bridge, Maine, USA. Each cable had six sensors and the cable forces at each stage of construction were monitored using these sensors. Periodic lift-off operations were made on the strands with sensors. A good correlation was observed. The bridge is now open to traffic and the forces in any cable can be monitored anytime using these DYNA Force® sensors without any disruption to traffic.
Practical Applications

DSI used DYNA Force® sensors in a fatigue testing of 41-strand cable stay system. Force in each 0.6” dia epoxy coated strand was monitored at various loading stages during two-million fatigue cycles.

DYNA Force® in Fatigue Test of Cable Stay System

DYNA Force® sensors were used in moment resisting frames in a City Office building, California. The tendons were 0.5” diameter greased and sheathed un-bonded strands. DYNA Force® was used to measure the force during stressing and will be used to monitor the forces in each loop tendon especially after earthquake takes place.

DYNA Force® for Seismic Evaluation of Building Structure, California, USA
Details, dimensions and system designs are subject to change without notice.

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