THE BASE ISOLATION OF THE NEW TRIESTE HARBOR LOGISTIC PLATFORM

Mauro SARTORI¹, Giulio CAMOSSI², Ivica ZIVANOVIC³

ABSTRACT

The growing of the goods traffic by shipping in Northern Italy stresses the need of having wide logistic platforms for the management of the goods, organizing their stock, ships docking and link with the main transport links, both routes or railways.

The new investment in Trieste harbor with its irregular plan will cover around 70,000 square meters of the existing bay and will improve the movement of goods from central Europe and Turkey for an estimated yearly turnover of 15 million Euros.

The new logistic platform is 470 meters long and 275 meters wide. It is made by a post-tensioned concrete slab of thickness 50 cm fully base isolates with 850 CE marked curved surface sliders supplied by Freyssinet. The paper describes the seismic isolation solution from calculation of the overall isolation system up to the tests performed on the curved surface sliders as well as the complete package of expansion joints and post-tensioning system provided.

Keywords: Large Platform; Base Isolation; Full Scale Tests

1. INTRODUCTION

The last decades showed a growing of the international goods traffic through Northern Italy, from Europe to middle and far East. This growing is due to the key location of this side of the Country, especially of its harbors when shipping goods from and to Europe. To manage the goods coming from and to be shipped all over the world, wide logistic areas are required to stock them, to dock ships and to connect routes and railways to the sea ways.

Trieste is a town located in the middle of this area, Northern Italy, at the end of the Adriatic Sea, within the Mediterranean Sea. Its location is strategic for the movement of goods and for this reason its harbor is one of the most popular. To improve its capacity of managing the goods traffic, a new huge platform has been built over the water to increase the space available for stocking, docking and links. The platform has also been declared duty-free zone by the Italian government to ease the commercial relationship between international shipping companies.

The new investment in Trieste harbor with its irregular plan will cover around 70,000 square meters of the existing bay and will improve the movement of goods from central Europe and Turkey for an estimated yearly turnover of 15 million Euros. The platform has been constructed by a joint-venture of Italian contractors composed by I.Co.P. s.p.a, Interporto Bologna S.p.a., Cosmo Ambiente s.r.l. and Francesco Parisi S.p.a. The design has been carried out by the Italian design companies Studio Altieri S.p.a. and ALPE Progetti s.r.l.

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2. DESCRIPTION OF THE STRUCTURE AND SEISMIC INPUT

The new logistic platform is 470 meters long and 275 meters wide and it is made by a post-tensioned concrete slab of thickness 50 cm.

It is composed by three main elements:

- The slab (superstructure) which will be the space over which all the harbour activities will take place;
- The seismic isolation system composed by curved surface sliders isolators, on which the superstructure will lay;
- The column-piles drilled into the ground on which the isolators are installed

The superstructure is composed by pre-casted and prestressed concrete beams with rectangular cross section 1.8 m wide and 1 m height and by a post-tensioned concrete slab with thickness 50 cm built on a prestressed concrete self-supporting formwork. The slab has an irregular profile to follow the coast, developing hence the 470 m of the sea front and it has a global surface of 70.000 square meters with a structural gridwork of 10 x 10 square meters.

The natural geological and orographic configuration of the bay when linked to the width of the structure bring to a very different stiffness of the column-piles which can vary over time when the space below the slab is filled by the sea water after completion of the job. In addition, there is a huge variability both in amount and in position of the live loads over the slab which could represent up to 75% of the global load. The column-piles are drilled into the ground characterized by a stratigraphy very different depending on the position and with time, depending as well on the level of filling of the basin. The piles have a diameter of 1270 mm and are composed by a steel cylinder 10 mm thick filled with reinforced concrete.

Between column-piles and the beams supporting the slab, an isolation system is installed to link the two parts of the structure. The isolation system is composed by more than 850 CE marked double surface curved surface sliders able to provide high flexibility and additional structural damping. In addition, the isolation system, as it has been chosen, has various advantages, allowing the reduction of the stiffness variability among piles positioned in different position or drilled into ground with different stratigraphy and avoiding torsional effects.

All the seismic isolators have been designed, manufactured, tested and supplied by Freyssinet Product Company Italia, branch of Freyssinet group on the Italian market, as well as the Freyssinet post-
tensioning system including 750 tons of strand, about 2000 anchorages and 3900 couplers. To conclude the full package of solution for structural engineering which can applied to major projects, Freyssinet Product Company Italia supplied also 1250 m of rubber expansion joint to cover the gap between platform and dry land allowing at the same time the seismic movements without damages to the adjacent structures. This is a great example of the capacity of Freyssinet to provide a reliable complete solution to construction companies and to supply a wide number of devices in a short time, thanks to the big portfolio of products and expertise.

Figure 2: The new logistic platform at Trieste harbor – Structural gridwork

The structure is designed with a nominal lifetime of 100 years and a reference period of 200 years for the seismic actions. The seismic isolation technique allows to limit the structural damage concentrating the displacement and deformation into devices properly installed to absorb the seismic energy and reduce the ground acceleration in case of seismic event through the period shifting and additional damping (Figure 3).

Figure 3: Reduction of seismic acceleration by period shifting and increased damping

The use of an isolation system, thanks to the reduction of the shear seismic force between superstructure and piles, respect to a traditional not isolated structure, shows an increased technical and economic
efficiency when the superstructure is designed to be seismic free. The superstructure is indeed designed in elastic condition, according to the applicable standard, which is the Italian regulation NTC 2008, even for ultimate seismic conditions. This leads to a limited ductility demand to the superstructure since the main deformation is concentrated into the isolation system with a consequent very limited expected damage for the structure after the earthquake.

The design of the structure considers four limit states with reference to the seismic actions, two for service and two ultimates:

- **Operability Limit State (SLO):** After the earthquake, the structure shall not show damages and important breakdowns;
- **Damage Limit State (SLD):** After the earthquake, the structure can show damages that do not represent a risk for people and the structure keep its characteristics of resistance and stiffness for vertical and horizontal loads. The structure is still working even if its content could be out of order
- **Life Safety Limit State (SLV):** The substructure works in elastic field, the superstructure does not present signs of important damages and the isolation system maintains its operability;
- **Collapse Limit State (SLC):** After the earthquake, the structure shows structural damages even if it presents enough safety margin for the vertical loads. The isolation system does not reach the collapse.

Based on the latitude and longitude of the site, the Italian code gives the PGA of the design earthquake for the four limit states. In addition, in the case of the Trieste platform, the reference period of 200 years for the seismic action brings to a return period of 1898 years for the SLV (10% probability of exceedance within 200 years) and a return period of 2475 years for the SLC (5% probability of exceedance within 200 years).

Depending on the location of the site, the ground characteristics and the probability of exceedance of the reference period for the seismic action, the Italian code gives all the parameters to define the response spectra for the four limit states as indicated in the Table 1.

### Table 1: Parameters of the design spectra for the four limit states.

<table>
<thead>
<tr>
<th>Device</th>
<th>SLO</th>
<th>SLD</th>
<th>SLV</th>
<th>SLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_g$</td>
<td>0.060</td>
<td>0.074</td>
<td>0.163</td>
<td>0.177</td>
</tr>
<tr>
<td>$F_0$</td>
<td>2.588</td>
<td>2.560</td>
<td>2.612</td>
<td>2.620</td>
</tr>
<tr>
<td>$T_C$</td>
<td>0.268</td>
<td>0.287</td>
<td>0.355</td>
<td>0.360</td>
</tr>
<tr>
<td>$S_T$</td>
<td>1.600</td>
<td>1.600</td>
<td>1.532</td>
<td>1.490</td>
</tr>
<tr>
<td>$C_C$</td>
<td>1.947</td>
<td>1.895</td>
<td>1.741</td>
<td>1.730</td>
</tr>
<tr>
<td>$q$</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

The above listed parameters allow to define the response spectra for the four limit states as given by the expressions (1) to (4).

\[
0 \leq T < T_B \quad S_e(T) = a_g \cdot S \cdot \left[ 1 + \frac{T}{T_B} \cdot (\eta \cdot F_0 - 1) \right] \quad (1)
\]

\[
T_B \leq T < T_C \quad S_e(T) = a_g \cdot S \cdot \eta \cdot F_0 \quad (2)
\]

\[
T_C \leq T < T_D \quad S_e(T) = a_g \cdot S \cdot \eta \cdot F_0 \cdot \left( \frac{T_C}{T} \right) \quad (3)
\]

\[
T_D \leq T \quad S_e(T) = a_g \cdot S \cdot \eta \cdot F_0 \cdot \left( \frac{T_C \cdot T_D}{T^2} \right) \quad (4)
\]
Where:

- \( a_g \) is the design ground acceleration,
- \( S = SS \cdot ST \) is the soil factor.
- \( \eta = \sqrt{\frac{10}{5 + \xi}} \) is the damping correction factor.
- \( \xi \) is the viscous damping.
- \( F_0 \) is the amplification factor.
- \( T_C = C_C \cdot T_C^* \) is the upper limit of the period of the constant spectral acceleration.
- \( T_B = T_C / 3 \) is the lower limit of the period of the constant spectral acceleration.
- \( T_D = 4 \cdot \frac{a_g}{g} + 1.6 \) is the value defining the beginning of the constant displacement response range of the spectrum.

The response spectra of acceleration and displacement for the four limit states are graphically represented in Figure 4.

![Response spectra](image)

**Figure 4: Response spectra for the four limit states**

3. THE ISOLATION SYSTEM

3.1. SEISMIC ANALYSIS

In order to respect the four above mentioned limit states, the final choice for the isolation system foresees curved surface sliders with double sliding surfaces, as in Figure 5, with higher durability with respect to other types of isolators and less sensible to different load configurations.
Figure 5: The isolation system composed by double concave surface sliders

The time-history analysis has been carried out using 7 couples of accelerograms chosen from 7 natural accelerograms properly scaled and adapted to the input spectra described in the previous section. Data and results are gathered in the Table 2 and Figure 6 and 7 below.

<table>
<thead>
<tr>
<th>ID</th>
<th>Station ID</th>
<th>Earthquake Name</th>
<th>Date</th>
<th>Mw</th>
<th>Fault</th>
<th>Epicent Mech</th>
<th>Dist [km]</th>
<th>PGA_X [m/s²]</th>
<th>PGA_Y [m/s²]</th>
<th>PGV_X [m/s²]</th>
<th>PGV_Y [m/s²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>149</td>
<td>ROLC</td>
<td>Christchurch</td>
<td>2011</td>
<td>6</td>
<td>reverse</td>
<td>reverse</td>
<td>29,44</td>
<td>0,456</td>
<td>0,450</td>
<td>0,046</td>
<td>0,063</td>
</tr>
<tr>
<td>30</td>
<td>IWT021</td>
<td>N Iwate Prefecture</td>
<td>1998</td>
<td>5,9</td>
<td>reverse</td>
<td>reverse</td>
<td>19,32</td>
<td>0,405</td>
<td>0,367</td>
<td>0,045</td>
<td>0,035</td>
</tr>
<tr>
<td>83</td>
<td>ST_3644_5</td>
<td>Parkfield</td>
<td>2004</td>
<td>6</td>
<td>strike–slip</td>
<td>strike–slip</td>
<td>15,23</td>
<td>1,386</td>
<td>2,24</td>
<td>0,229</td>
<td>0,184</td>
</tr>
<tr>
<td>133</td>
<td>MODE</td>
<td>EMILIA Pianura Padana NW</td>
<td>2012</td>
<td>6</td>
<td>reverse</td>
<td>reverse</td>
<td>26,82</td>
<td>0,439</td>
<td>0,216</td>
<td>0,037</td>
<td>0,031</td>
</tr>
<tr>
<td>27</td>
<td>KGS010</td>
<td>Kagoshima Prefecture</td>
<td>1997</td>
<td>6</td>
<td>strike–slip</td>
<td>strike–slip</td>
<td>26,81</td>
<td>1,89</td>
<td>2,055</td>
<td>0,212</td>
<td>0,230</td>
</tr>
<tr>
<td>81</td>
<td>AI_013_CER</td>
<td>Duzce 2</td>
<td>2000</td>
<td>6</td>
<td>normal</td>
<td>reverse</td>
<td>15,23</td>
<td>0,629</td>
<td>0,623</td>
<td>0,061</td>
<td>0,079</td>
</tr>
</tbody>
</table>
Figure 6: Accelerogram selected (up) and scaled (down).

Figure 7: Average spectrum after scaling

The analysis has been carried out using the commercial software SAP 2000 where the column-piles have been modelized through linear links fixed at the base while the curved surface sliders have been modelized through non-linear links with the properties shown in the Figure 8.

The diagrams in Figure 9 show the results of the dynamic analysis using the 7 accelerograms. 5 check points have been selected to monitor the displacements of the column-piers and isolators.
Figure 8: Modelling on SAP 2000: Structure and properties.

Figure 9: Modelling on SAP 2000: Results of the dynamic analysis

The above described time-history analysis of the platform including the model of the double curved surface sliders as described in 3.1 and subjected to seismic inputs given by natural accelerograms properly brought to the characteristics of the isolators given in Table 3.
### Table 3: Isolator design characteristics

<table>
<thead>
<tr>
<th>Data</th>
<th>Mark</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Isolator Displacement</td>
<td>$d_{E}$</td>
<td>0.20 m</td>
</tr>
<tr>
<td>Maximum Vertical non-seismic load - ULS</td>
<td>$N_{gd\text{ ULS}}$</td>
<td>116000 kN</td>
</tr>
<tr>
<td>Maximum Vertical non-seismic load - SLS</td>
<td>$N_{gd\text{ SLS}}$</td>
<td>8000 kN</td>
</tr>
<tr>
<td>Minimum Seismic Vertical Load</td>
<td>$N_{gd,\text{min}}$</td>
<td>1900 kN</td>
</tr>
<tr>
<td>Maximum Seismic Vertical Load</td>
<td>$N_{gd,\text{max}}$</td>
<td>8000 kN</td>
</tr>
<tr>
<td>Maximum Horizontal Load</td>
<td>$V_{ed}$</td>
<td>531 kN</td>
</tr>
<tr>
<td>Equivalent radius</td>
<td>$R_{eq}$</td>
<td>8.7 m</td>
</tr>
<tr>
<td>Dynamic Friction Coefficient</td>
<td>$\mu_{din}$</td>
<td>4%</td>
</tr>
<tr>
<td>Isolation Period</td>
<td>$T_0$</td>
<td>5.91 s</td>
</tr>
<tr>
<td>Maximum Design Velocity</td>
<td>$v_{ED}$</td>
<td>0.244 m/s</td>
</tr>
</tbody>
</table>

#### 3.2. DESCRIPTION OF THE CURVED SURFACE SLIDERS

The basic components of the double curved surface slider are shown here below in Figure 10:

![Double curved surface slider typical section](image)

**Figure 10:** Double curved surface slider typical section

Where:
1. Top sliding plate
2. Primary sliding surface
3. Sliding material
4. Median plate
5. Secondary sliding surface
6. Bottom plate

The choice of the double concave surface sliders with two identical sliding surfaces allows to reduce the plan dimensions of the device, which is a great benefit for the limited space available for the installation. These devices are characterized by the fact that the displacement is shared by the same ratio on the two upper and lower sliding surfaces, as in Figure 11, limiting in the same time the eccentricity of the vertical load on the column-piles, or in other words, the P-Δ effect.
Their main characteristics of the double curved surface sliders are the following:

- They allow the relative displacement of the structure with respect to the substructure following one or two spherical surfaces.
- The equivalent radius of the device mainly determines the natural period of the structure.
- The friction coefficient of the sliding surfaces mainly determines the equivalent viscous damping of the isolation system.
- The natural period is independent from the mass of the structure.
- They are self-centring after a seismic event.

As it is well known, curved surface sliders follow the physical law of the pendulum to act as a harmonic oscillator placed between the structure and the foundation suitable to increase the natural period of the structure.

Disregarding the friction, the movement between the two main surfaces corresponds to the movement of a pendulum with period $T$ equal to:

$$T = 2\pi \sqrt{\frac{R}{g}}$$

(5)

$R$ being the equivalent radius of the device.

If the friction component of the horizontal force is also considered, the effective period $T_{\text{eff}}$ is then calculated as:

$$T_{\text{eff}} = 2\pi \sqrt{\frac{V_D}{K_{\text{eff}} g}}$$

(6)

With $K_{\text{eff}}$ the effective stiffness of the sliding pendulum for the design displacement:

$$K_{\text{eff}} = \frac{V_D}{R} + \mu \frac{V_D}{D_D}$$

(7)

In the expressions (6) and (7) $V_D$ is the dead vertical load and $D_D$ is the design displacement.

The double curved surface sliders for Trieste Platform (Figure 12) have been designed by Freyssinet, manufactured, tested and supplied by Freyssinet Product Company Italia and they are all provided with CE mark, which is nowadays mandatory within CEN countries.
Particular care has been considered for the corrosion protection of the isolators due to the very severe environmental conditions. As previously mentioned, the isolators are installed on top of the column-piles drilled into the sea bottom of the bay, hence at the end of the construction the sea water will lay just below the isolation level. Even if a protection against waves is installed on the sea front and so the isolators are not subjected to water splashes, the salinity of the water very close to the devices makes the environment very aggressive. To protect all the steel elements, a corrosion protection according to class C5M-H of EN 12944 has been applied, which includes a 4 layers metallic and epoxy paint applied with a high quality level checked by inspections and tests to ensure the desired level of reliability. In addition, to avoid any contamination of the internal elements, a hermetic cover has been installed all around the device. Finally, but not for importance, all the anchor bolt heads are covered by plastic caps filled with grease to increase the durability of the hot dip galvanized bolts.

Figure 12: Double curved surface slider for Trieste Platform with hermetic cover

3.3. TESTS ON CURVED SURFACE SLIDERS

The CE mark is the final evidence given by an independent Notified Body who certifies the Constancy of Performances through audits aimed to verify the quality process and that the performances of the isolators correspond to those assumed at design stage. According to the harmonized standard for anti-seismic devices EN 15129, this is obtained by performing Type Tests on prototypes full scale and by Factory Production Control (FPC) tests to verify on a percentage of the mass production the Constancy of Performances.

Type Tests have been performed at Eucentre (European center for training and research in earthquake engineering) in Pavia, Italy, on two devices following a severe protocol aimed to identify the main characteristics of the isolator in term of vertical and horizontal stiffness and damping at different levels of displacement and velocities and at different vertical loads. The protocol, as Table 4, is following the indications given in the EN 15129 for Type Test of Curved Surface Sliders.
Table 4: Type Test Protocol

<table>
<thead>
<tr>
<th>test #</th>
<th>test name</th>
<th>label</th>
<th>main dof</th>
<th>Amplitude</th>
<th>max velocity</th>
<th>frequency</th>
<th>load shape</th>
<th>vert load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>[mm]</td>
<td>[mm/s]</td>
<td>[Hz]</td>
<td></td>
<td>[kN]</td>
</tr>
<tr>
<td>1</td>
<td>Pre-test</td>
<td>vert</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>8000</td>
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<tr>
<td>2</td>
<td>Load bearing capacity</td>
<td>vert</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16000</td>
</tr>
<tr>
<td>3</td>
<td>Frictional resistance force test</td>
<td>long</td>
<td></td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>loading ramp</td>
<td>8000</td>
</tr>
<tr>
<td>4</td>
<td>Service condition test</td>
<td>S</td>
<td>long</td>
<td>45</td>
<td>5</td>
<td>0.02</td>
<td>sine</td>
<td>8000</td>
</tr>
<tr>
<td>5</td>
<td>Benchmark</td>
<td>P1</td>
<td>long</td>
<td>145</td>
<td>50</td>
<td>0.05</td>
<td>sine</td>
<td>8000</td>
</tr>
<tr>
<td>6</td>
<td>Dynamic test D1</td>
<td>D1</td>
<td>long</td>
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<td>257</td>
<td>1.13</td>
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<tr>
<td>7</td>
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<td>0.05</td>
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<td>8000</td>
</tr>
</tbody>
</table>

Factory Production Control tests have been performed both at Isolab (Freyssinet testing facility) in Montebello della Battaglia, Italy and at Sismalab, Crispiano, Italy, as Table 5:

Table 5: FPC Test Protocol

<table>
<thead>
<tr>
<th>test #</th>
<th>test name</th>
<th>label</th>
<th>main dof</th>
<th>Ampl. [mm]</th>
<th>max vel [mm/s]</th>
<th>freq [Hz]</th>
<th>load shape</th>
<th>vert load [kN]</th>
<th>cycles [#]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Load bearing capacity</td>
<td>vert</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>16000</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Frictional resistance force test</td>
<td>long</td>
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<td>-</td>
<td>0.1</td>
<td>-</td>
<td>loading ramp</td>
<td>8000</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
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<td>P1</td>
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<td>50</td>
<td>0.0549</td>
<td>sine</td>
<td>8000</td>
<td>3</td>
</tr>
</tbody>
</table>

Tests at Isolab were performed on the new 70 MN testing bench able to test devices up to 70.000 kN static vertical load and up to 20.000 kN static horizontal load. The testing bench is also able to develop a vertical dynamic force up to 18.000 kN and a horizontal dynamic force up to 5.000 kN with a maximum stroke of 1.000 mm up to a velocity of 1.000 mm/s. The testing bench is shown in the Figure 13.

The main figures of test results are summarized in the table 6 where the behavior of the curved surface slider is compared to the theoretical in term of dynamic friction, maximum horizontal force and energy dissipated for the test displacement dbd.
Table 6: summary of test results

<table>
<thead>
<tr>
<th></th>
<th>Dynamic Friction [%]</th>
<th>Maximum Horizontal Force [kN]</th>
<th>Energy Dissipated [kNm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>4</td>
<td>453</td>
<td>185.6</td>
</tr>
<tr>
<td>Experimental</td>
<td>3.9</td>
<td>415</td>
<td>179</td>
</tr>
<tr>
<td>Deviation</td>
<td>-2.5%</td>
<td>-8.4%</td>
<td>-3.6%</td>
</tr>
</tbody>
</table>

Figure 13: 70 MN Testing Bench at ISOLAB

Figure 14: Type Test at EUCENTRE
4. POST-TENSIONING SYSTEM AND EXPANSION JOINTS

The construction method chosen for this major job foresees to build the platform at different steps. At every step, a square section of the whole platform with dimension 3 x 3 square meters is casted. Each of these sections is then post-tensioned to the adjacent elements already manufactured. The full post-tensioning system, including 750 tons of strand, about 2000 anchorages and 3900 couplers needed to create the structural continuity of the whole platform. The anchor system, shown in Figures 16 to 19, has been developed by Freyssinet group fulfilling the requirements given into the main international standard and they are provided by European Technical Assessment (ETA) and CE mark. All the elements have been designed in order to minimize their size, so that the recess into the concrete to install them is minimized consequently and the tension system is optimized to facilitate the tension operations and to reduce the steel reinforcement, geometrical interferences and efficiency of the post-tensioning system.

Figure 16: Active Anchor – C Range Series
Figure 17: Multi-Strand Couplers – CC Series

Figure 18: Fixed Anchor – F Range Series

Figure 19: Anchor – Installation on site
The platform, as every wide structure, develops deformation in every direction due to reversible actions, like the environmental temperature. Moreover, in case of earthquake, the isolation system requires a high movement capacity of the whole structure. In order to cover this need, along the full perimeter of the platform 1250 m long, an expansion joint line is installed.

A special type of expansion joint was installed, able to cover the gap between two adjacent spans even during seismic events, as in Figure 20. The joint is composed of reinforced rubber with a bridge plate to ensure the continuity above the gap also during the seismic event. The reinforcing metal profiles made of steel are completely inserted and vulcanized to the rubber. This process is the suitable solution to ensure efficient protection against corrosion and allows a longer lifetime to the product. The rubber compound, too, has been intentionally specifically formulated to resist to the components as oil, grease, petrol, salt and sand, without besides, suffering premature ageing phenomena due to sun rays, salt and snow. It works like a classic rubber expansion joints for service movement absorbing it by rubber deformation. During the earthquake, it is able to resist to much higher deformation, thanks to the wide bridge plate vulcanized in the central part of the rubber.

![Figure 20: Section of the expansion joint](image)

5. CONCLUSIONS

To solve the need of improving the capacity of the Trieste harbor a new duty-free, huge platform of 70,000 square meters has been built covering an existing bay. This investment will help the stocking of good transiting through the future main hub at the end of Adriatic Sea and will allow the docking of big ships as well as the link with the main roads and railways.

The logistic platform is a 50 cm thick post-tensioned concrete slab supported and isolated by more than 850 double curved surface sliders installed on steel-concrete column-piles drilled directly into the sea bottom.

Thanks to Freyssinet portfolio, joining and expertise of the Freyssinet Group, a complete solution is provided with specific technologies as applied to this major project has been provided from design level up to test and installation on site.

Curved surface sliders used in the isolation system are described together with the seismic performance and test performed to validate the behavior.

This shows how, nowadays, an integrated solution is important to grant a high level of reliability and quality of the products respecting at the same time the always tight construction schedules.
6. REFERENCES


European Committee for Standardization (CEN), 2009, EN 15129, Anti-Seismic Devices.
