Engineering solution of an Automatic Test Equipment Pylons Inclinometer Monitoring System (ATE PIMS) during construction phase of the cable-stayed bridge over Golden Horn Bay in Vladivostok

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Hong Kong
Motor highways were built for Asia-Pacific Economic Cooperation Summit 2012

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The bridges of Vladivostok

- Cable-stayed bridge over Golden Horn Bay, main bridge span L=730 m
- Cable-stayed bridge to the Russky Island across the Eastern Bosphorus strait, main bridge span L=1104 m
- Low-level bridge De-Freez-Sedanka, L=4000 m

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The bridges of Vladivostok
Municipal authority used temporally wood desk boarding instead of bridge, which were put on bay ice in winter.
Pedestrian crossing of Golden Horn Bay

The temporary wood desk boarding was disposed in spring
Construction phase of the cable-stayed bridge over Golden Horn Bay, Vladivostok

Bridge Description

• Overall length 1 387,09 m
• Total bridge span 2.1 km
• Width of span 30.6 м
• Width of carriageway 28.50 m
• Height of pylon 226.25 m
• Main spans 737.00 m
• Height of spans 64.00 m
• Seismic resistance 8-point
• Cables 192 pieces
• Construction budget - 670 000 000 $
• General designer - Joint Stock Company «Institute Giprostroymost» SPB
• General contractor -- Joint Stock Company Pacific bridge engineering Khabarovsk

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crane hook
Complexity of the surveying of the construction process of unique and unordinary bridges
Problems of using manual of GNSS technologies

- computational complexity
- A lot of manual work
- necessity open space
- Necessity manual supervision
- Impossible measurement down mounting level
- Possibility comprehensive automation

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Bridge steel core

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Traditional surveying technologies using only totalstations and GNSS periodical observations don’t provide a good measurement rate, synchronization and data adequacy to supervise pylons during the construction phase.
Working procedures

In addition the solar radiation significantly affects the heating of the surface of pylon; furthermore is accompanied by wind gusts.

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The crane load and works for installation also influenced on pylons tension. The pylons move in elliptic curve, which is modulating by solar, wind and construction work.

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Pylon movement mechanics

Movement in a ellipse

solar radiation  
Wind  
Crane load

proper weight
Using automatic Test Equipment Pylons Inclinometer monitoring system (ATE PIMS)
Key benefits

• Measurement in online mode
• Collection, communication and routing of data
• Saving and archiving a database
• Analyzing and visualization of data
• Alarm mode
• Inquiry processing
• Decision-making system
Environment and loads

- Wind loads
- Crane loads
- Construction sequence
- Solar radiation
- Vertical Movement from self-weight
Equipment options for ATE PIMS

Total stations
GNSS receivers (GNSS sensors)
Accelerometers
NZL
X-Y Inclinometers
Digital temperature sensors
Weather station

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Equipment options for ATE PIMS

Weather station Viasala

Wind speed 0 ... 60 m/s
Direction 0..360
Air temperature -52° C..60° C
Barometric pressure 600 ... 1100 hPa
Rainfall
Relative humidity

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Equipment options for ATE PIMS

Leica NIVEL 220

Overview
- Two-axis high precision sensor
- Measuring range ±3 mrad
- High precision and resolution of 0.004 mrad
- Short measuring time of 300 ms
- Long-term stability
- Real-time data

Inboard serial interface RS-485 bus (NIVEL220)

Precise information about inclination displacements

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Equipment options for ATE PIMS

Temperature sensor STS

- Measuring range: 
  - °C

  - °C

- Accuracy: ± %FS
  - %

Pressure range

- Range: 0.5 ..2 Bar

- Accuracy: ± %FS
  - %

- ( 1 mBar)

Inboard serial interface RS-232

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Dimensions mentioned at numerator design size at denominator as-build size
Option equipments for ATE PIMS

Digital 3 axis accelerometer

- Measurement range: ± 2 g
- Digital data representation: 16 bit
- Device resolution:
  - X, Y axis: 60 μg (Bandwidth = 10 Hz)
  - Z axis: 250 μg
Software options for ATE PIMS

• GeoMoS Monitor
• GeoMoS Analyzer
• MeteoData- collection, processing, WEB imaging, integration to GeoMoS
• WEB GeoMoS - WEB imaging date at smartphone, IPad
• Frequency analyzer software
Monitoring site disposition

Main pylon №8

Main pylon №9

Meteo station

Project office

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Waiting for the last (lock) section of span
Equipment placement

Thermo equipment

Inclinometer Leica 220 equipment
The following measuring devices were installed:

- 12 inclinometers Nivel Leica 220 - at Level 60 m, 130 m, and 175 m
- 32 temperature sensors - at skin surface reinforced concrete pylon wall at Level 3 m, 60 m, 130 m, 175 m
- 1 weather station - at block span crane Level 75 m
- Communication and uninterruptible power supply was made in anti-vandal version.
Output results Inclination
Output results
temperature sensor
Output results
Inclination

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Output results
Inclination

~1.3 mrad x 175 m = ~225 mm
Output results
Meteodata

www.meteomost.ru
Output results: How do it works?

Inclination Nivel (Level, X, Y, T, t_i)

surface temperature (Level, T, t_i)

Wind (speed, direction, ait, T, t_i)

Internal frequency (Level, f_i, amplitude, t_i)

Manual Survey

GNSS data (X, Y, Z, t_i)
TPS data (X, Y, Z, t_i)

ATE PIMS

Computation: New coordinate t_{i+1}, Level i+1. Determinate shift (ΔX, ΔY, ΔZ, t_{i+1})

Working procedures:
- Designer
  - Stake out the coordinate of core and reinforced concrete wall
- Surveyor
  - Working procedures:
    - Survey main coordinate
    - Surveyor
- Builder
  - Working procedures:
    - Assembly core and fabricated metals, formwork, pour concrete, concrete hardening, stripping formwork

Next Level
Cross-section of main pylons

reinforced concrete wall pylon

Butt unit axes

Un-1

Un-2

cable stay axes

k1

k2

k3

k4

k51

k52

k50

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Output results

Internal (resonant) frequency displacement

Hz

frequency $f_{x1}$

Hz

frequency $f_{y2}$

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Monitoring for regular maintenance
second step of project

<table>
<thead>
<tr>
<th>Equipment</th>
<th>First step</th>
<th>Second step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference station GNSS GR10</td>
<td>1 pcs.</td>
<td>1 pcs.</td>
</tr>
<tr>
<td>Monitoring receiver GMX902 GG</td>
<td>5 pcs.</td>
<td>5 pcs.</td>
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<tr>
<td>Weather station Vaisalla WTX 520</td>
<td>3 pcs.</td>
<td>1 pcs.</td>
</tr>
<tr>
<td>Inclinometer Nivel 220</td>
<td>12 pcs.</td>
<td>12 pcs.</td>
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<tr>
<td>Seismograph station</td>
<td>1 pcs.</td>
<td>1 pcs.</td>
</tr>
<tr>
<td>Thermo sensor STS DTM</td>
<td>32 pcs.</td>
<td>32 pcs.</td>
</tr>
<tr>
<td>Concrete strain transducer</td>
<td>16 pcs.</td>
<td>4 pcs.</td>
</tr>
<tr>
<td>Metallic strain transducer</td>
<td>8 pcs.</td>
<td>4 pcs.</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>22 pcs.</td>
<td>4 pcs.</td>
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Nice morning view at the bridge

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Thank you for your attention!

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