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Engineering Geodesy Consultancy

5 March, 2014

XXV International Federation of Surveyors Congress, Kuala Lumpur, Malaysia, 16 – 21 June 2014

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Introducing GeoSensing as the Integration of Geodetic and Geotechnical Monitoring Techniques to contribute on Deformation Modeling

Joel van Cranenbroeck and Partners

Beyond East & West GeoSensing Community

A Solution is an answer to a Problem

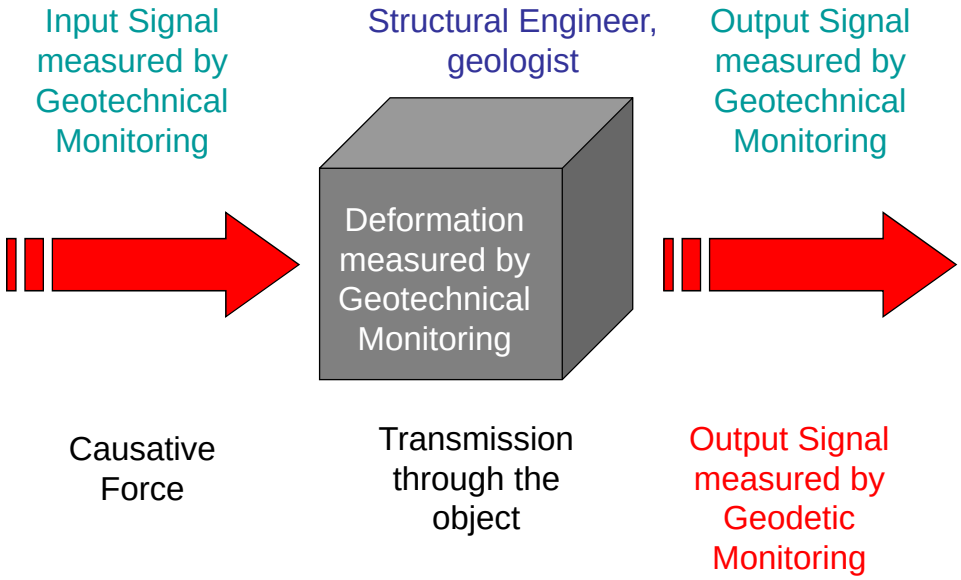
Every geosensors (instrument) on a project should be selected and placed to assist with answering a specific question : if there is no question, there should be no instrumentation.

John Dunnicliff – Geotechnical Instrumentation for Monitoring Field Performance (ISBN 0-471-00546-0 WILEY-INTERSCIENCE)

To define a Monitoring Solution we need to know …

- What is the problem ?
- Number of monitoring point
- Where are located the points
- Accuracy, Precision, Reliability ?
- Magnitude of the displacement ?
- How many data (recording rate) ?
- How the analyse will be done ?
- How to present the results ?
- How to build and produce a deformation model ?

Deformations, Deflections, Mouvements



City Life Project, Milano in Italy

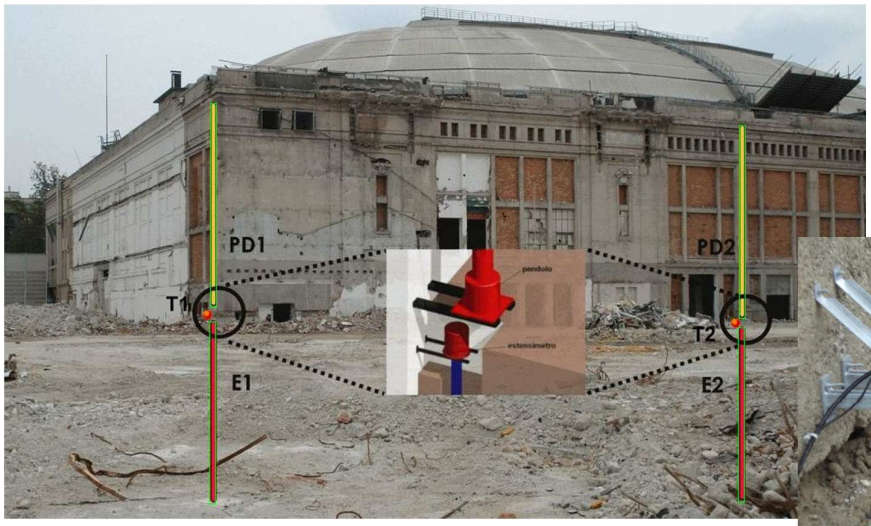
Rehabilitation of the exhibition area of Milan

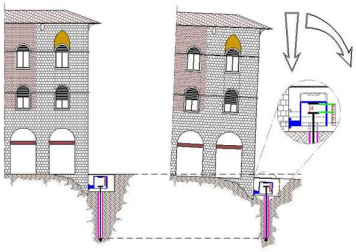
Monitoring system for the building near the construction site.

Extensometer and TPS + Prisms

City Life – building monitoring

Geotechnical Sensors

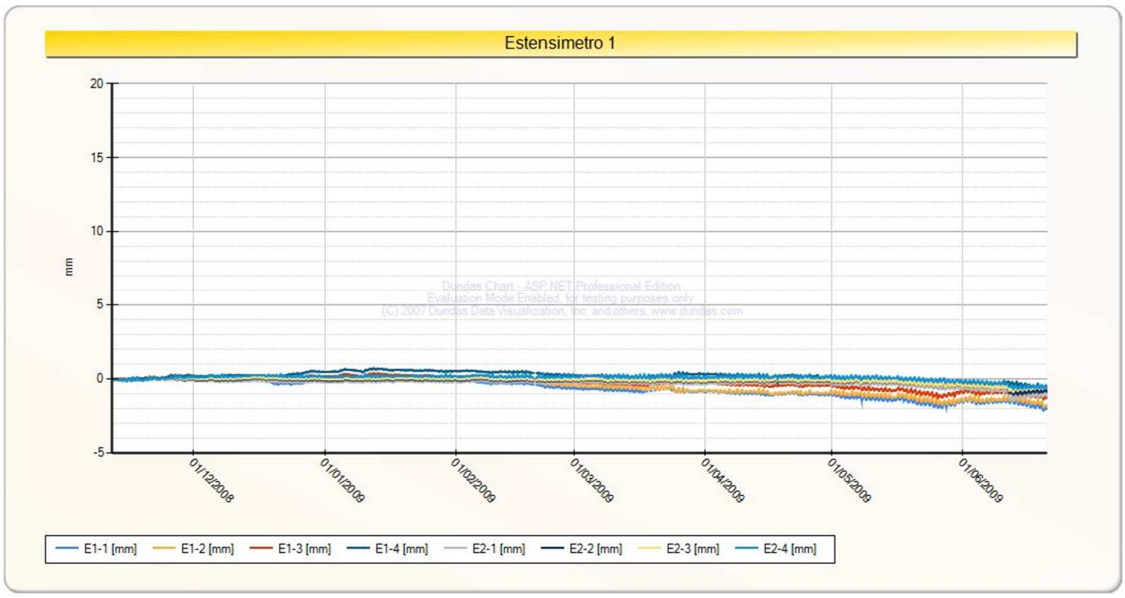




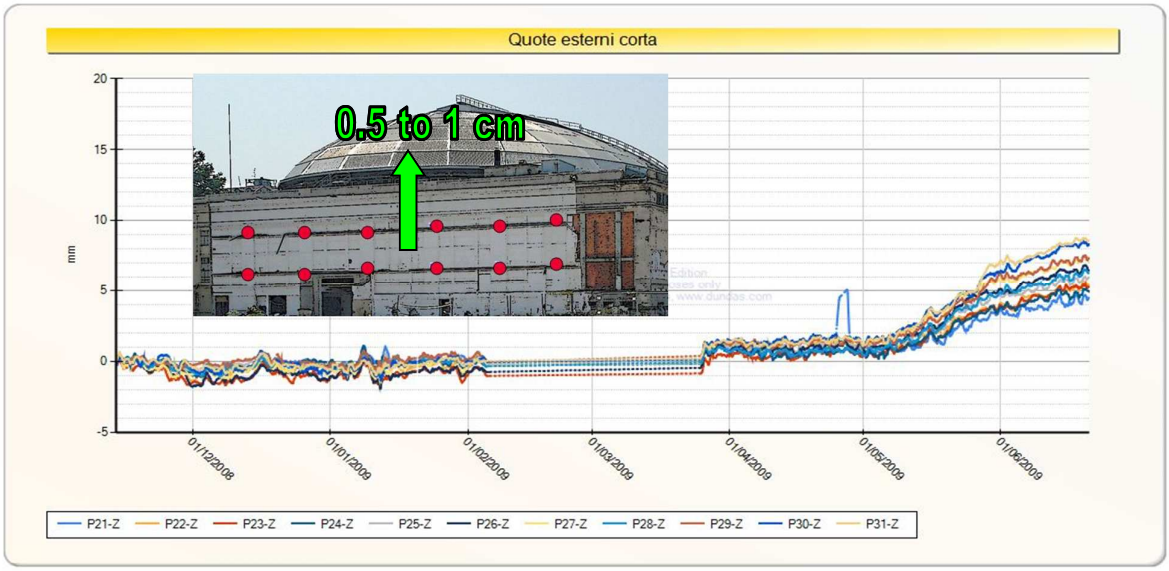
Geodetic Sensor

Geodetic sensor

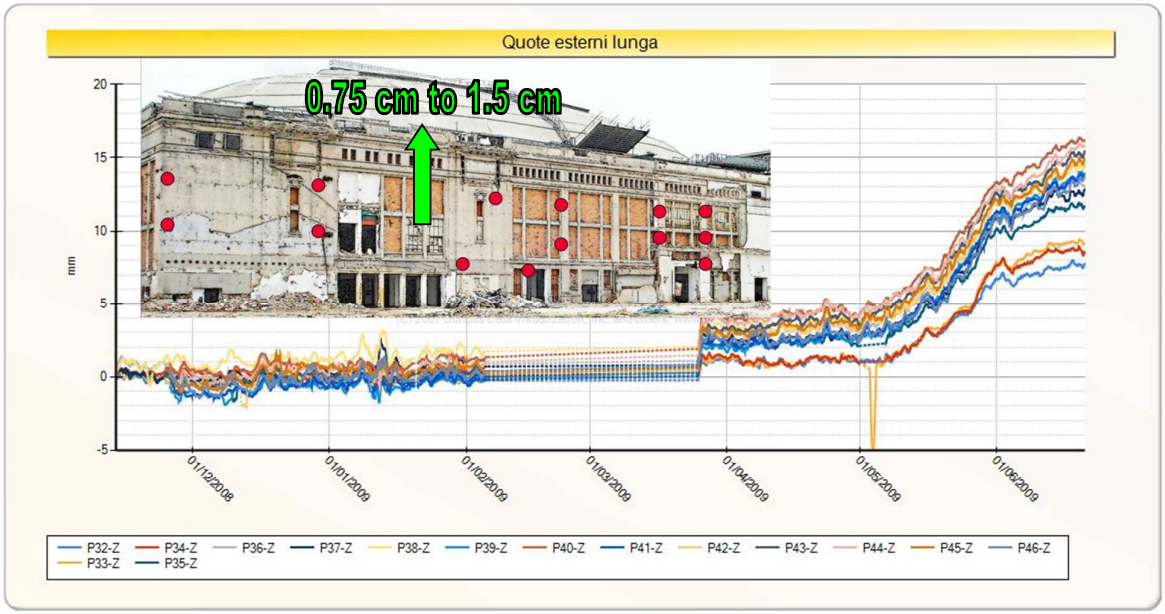
Extensometers Results – No movements



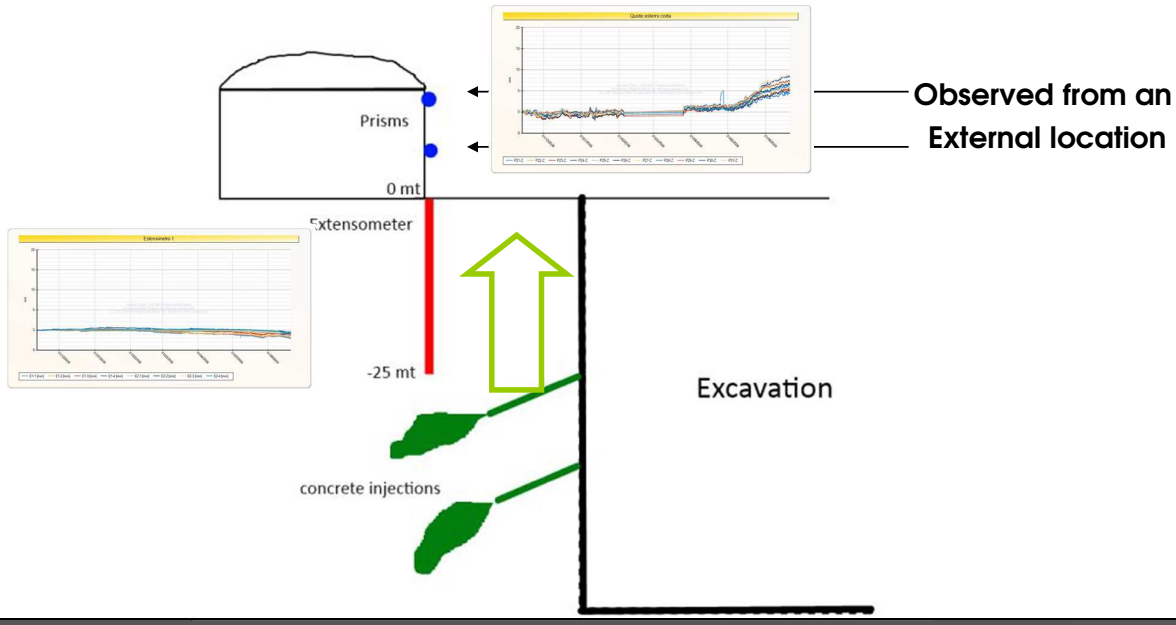
Automatic Total Station Results Differential movement



Automatic Total Station Results
Differential movement

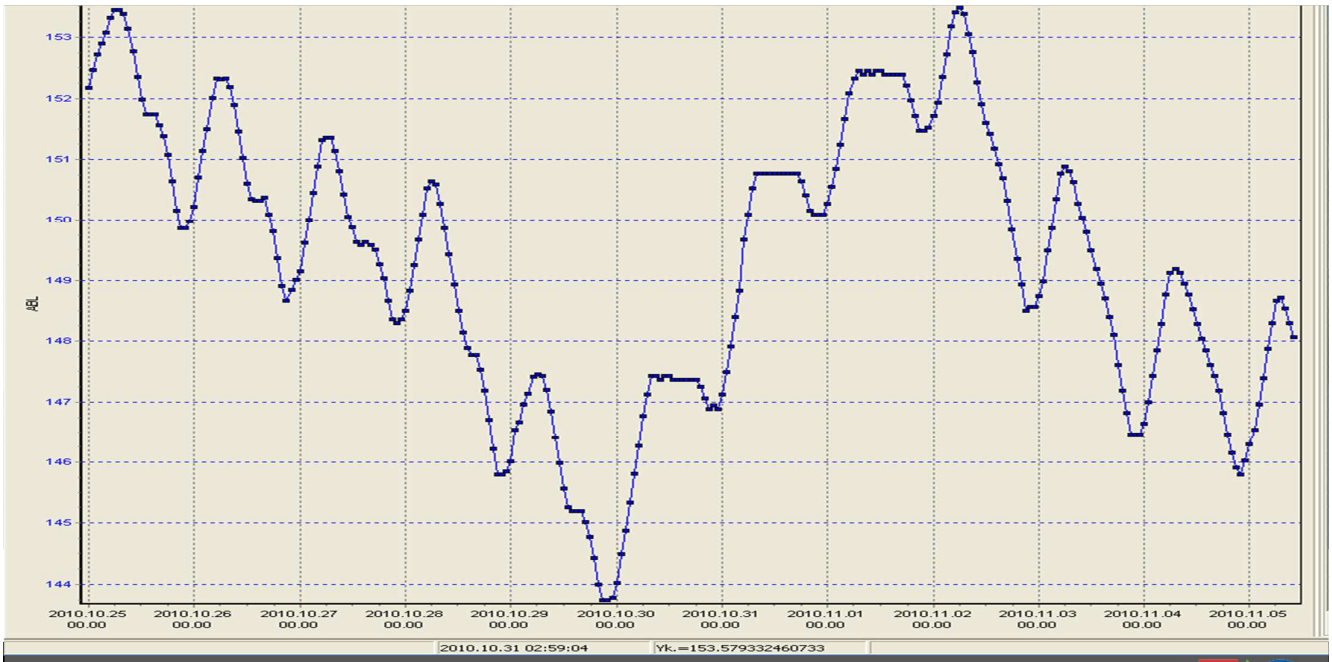


City Life – What happened?



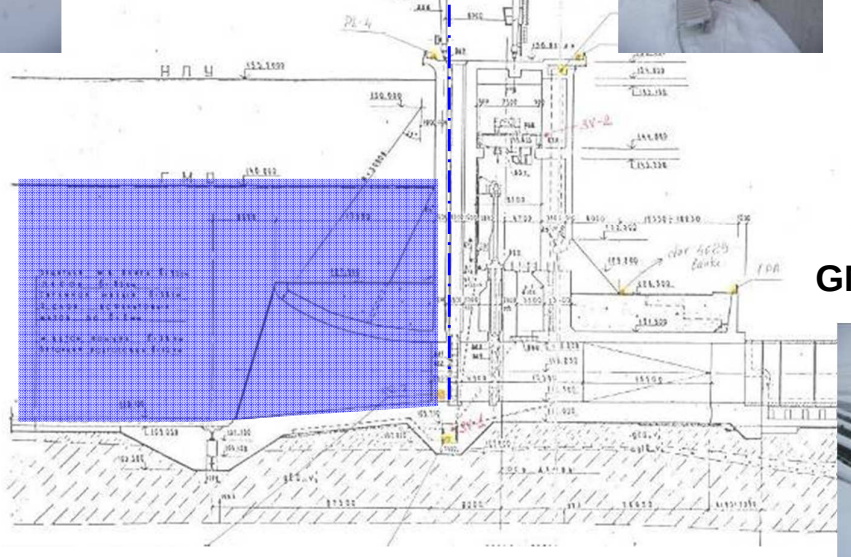
Kruonio HAE
Dam Water Variations on Upper Reservoir

Geodetic Monitoring must be 24/7 … or the investment will be lost having no “results” !



GMX2 **0.0 mm**

GMX3 **0.0 mm**

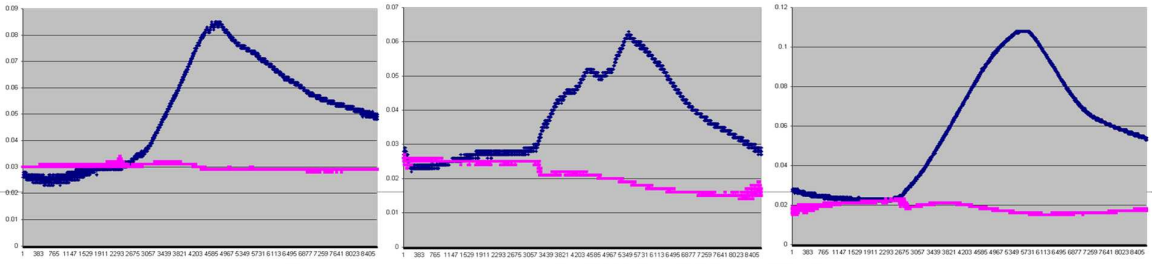


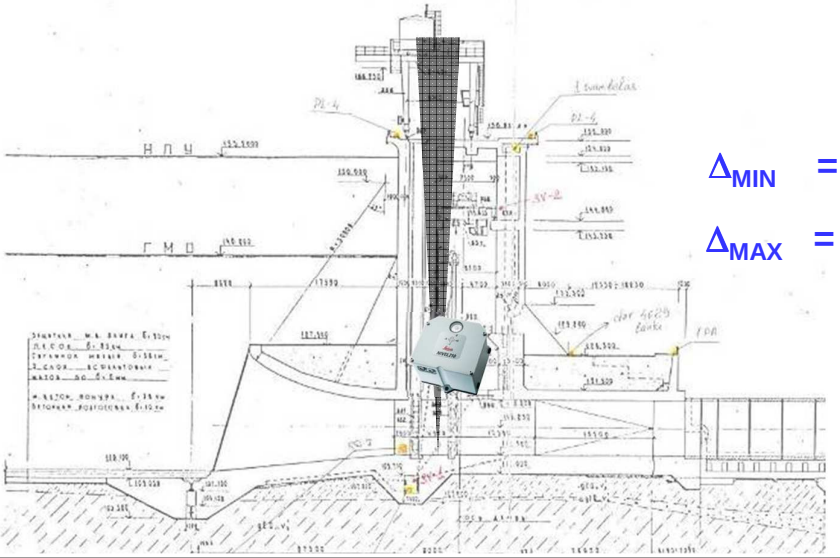
GMX1 **+0.7 mm**

GMX2 +3.6 mm

GMX3 +3.4 mm

GMX1 0.0 mm





Δ_{MIN} = 0.0 mm

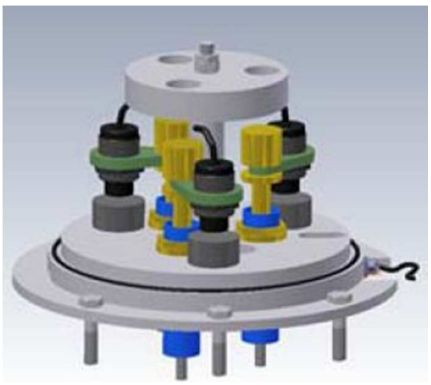
Δ_{MAX} = + 3.2 mm

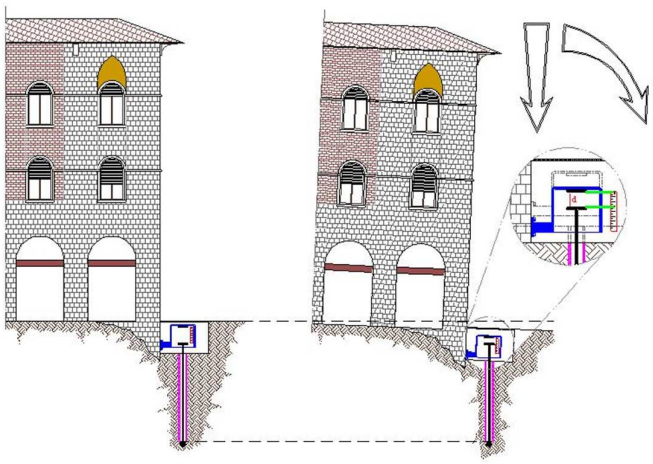
Building Settlement Monitoring

Automatic Levelling system for monitoring the raft settlement (foundation level) 24/7 with sub-millimetre accuracy

Foundations Surveying and Monitoring Traditional methods

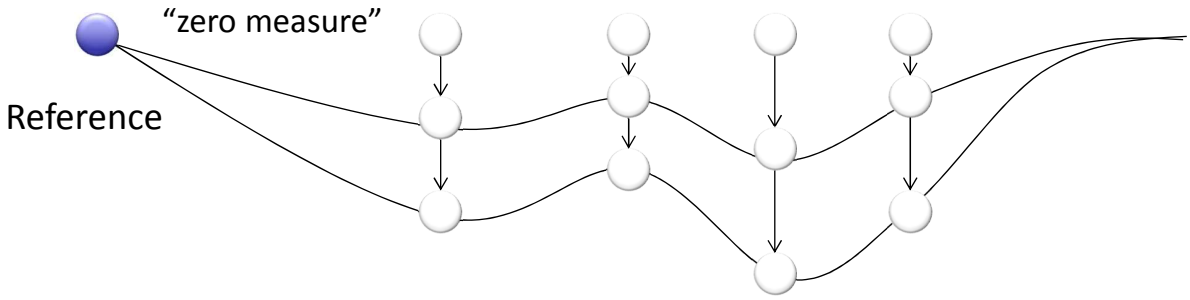
Extensometers, Rod,Fiber





Vertical displacements at submillimeter accuracy level

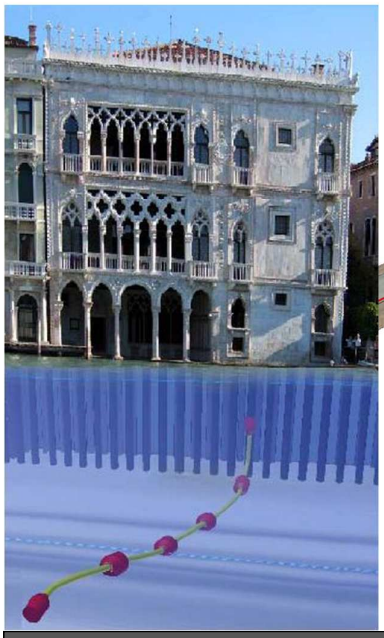
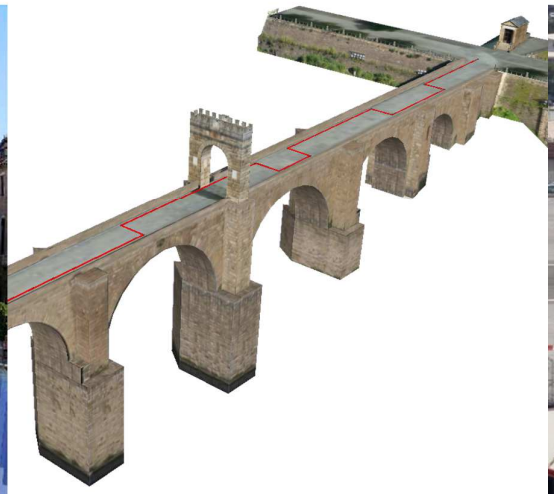
Automatic profile gauge is designed and developed to detect and measure settlement over time, referenced against a bench marked level.



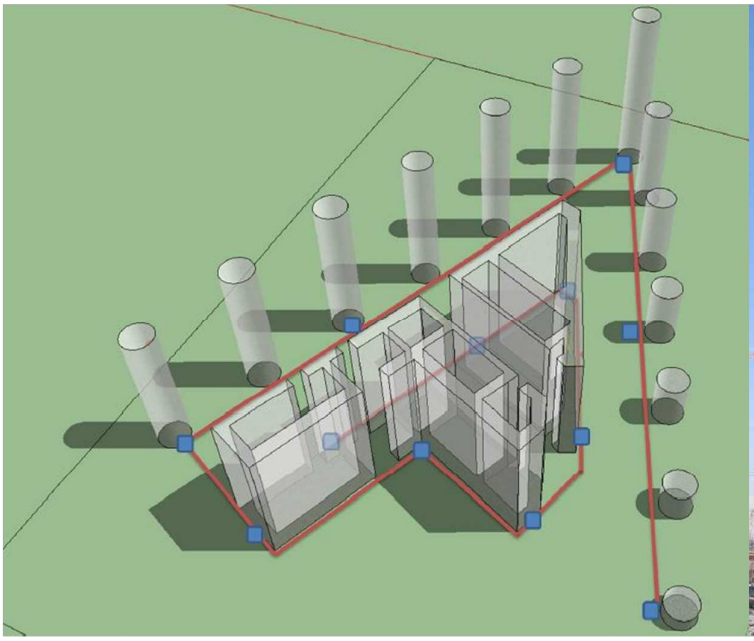
The measure is obtained by reading the pressure of a special fluid contained in a pipe. In particular, the displacement between two sensors is proportional to the pressure difference.

Hydro-Static Levelling System

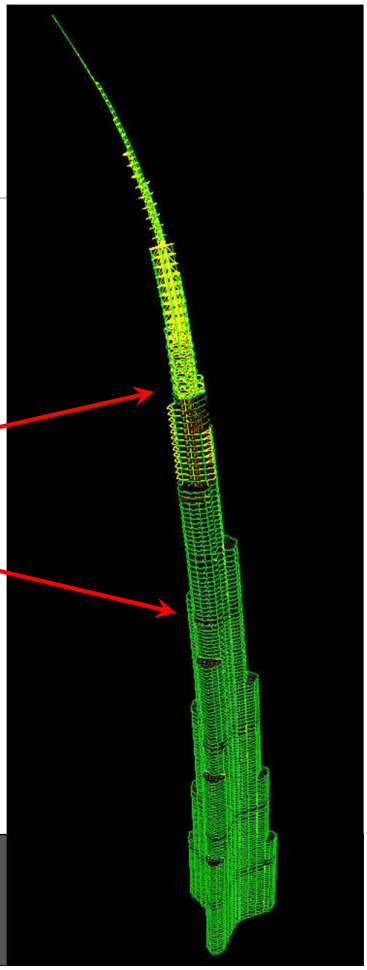
Bridges, Historical Buildings, Airport Runaway


Building in Construction



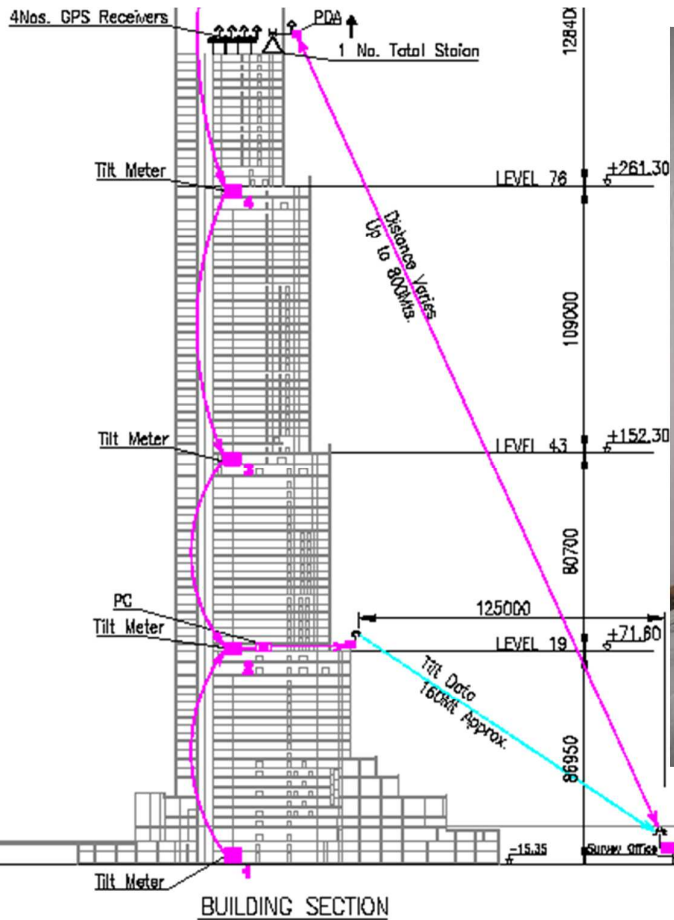

Structural Brief
Movement Control



- Horizontal Movement by Wind

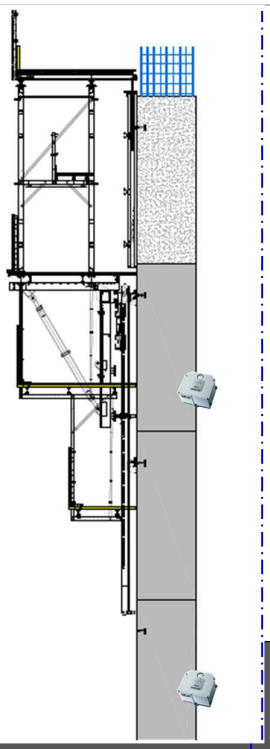
Location	Height	Movement
Office (L153)	569.7 m	125 cm
APT (L108)	375.3 m	54 cm

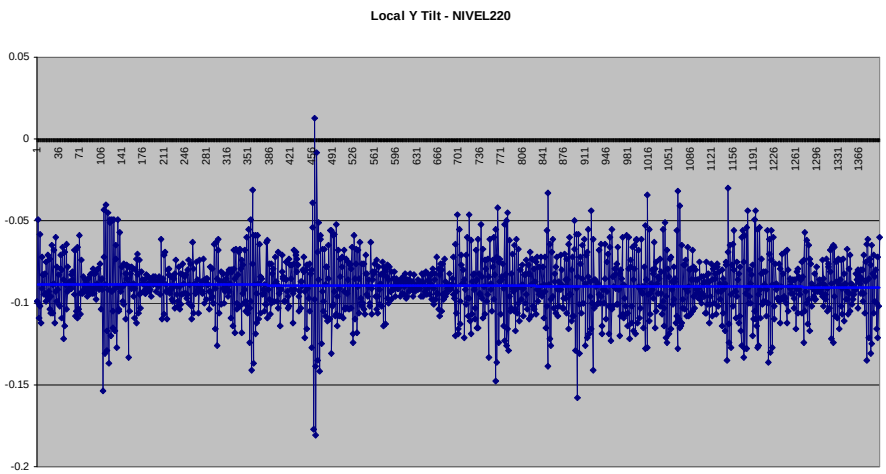
- Vertical Movement by Self-weight
  - Column Shortening : 65 cm
    (KLCC : 60 cm)



Precise Dual Axis Inclinometers provide continuously information about the tilts

...





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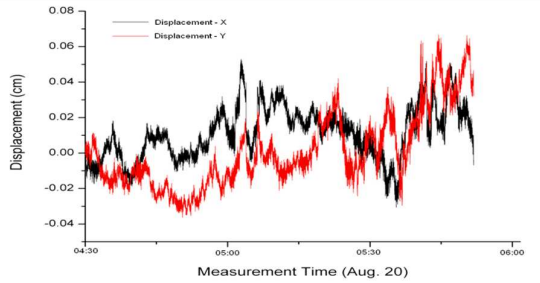
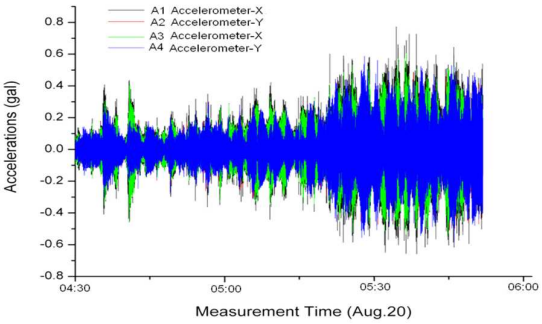
IFC 2 TOWER HONG KONG

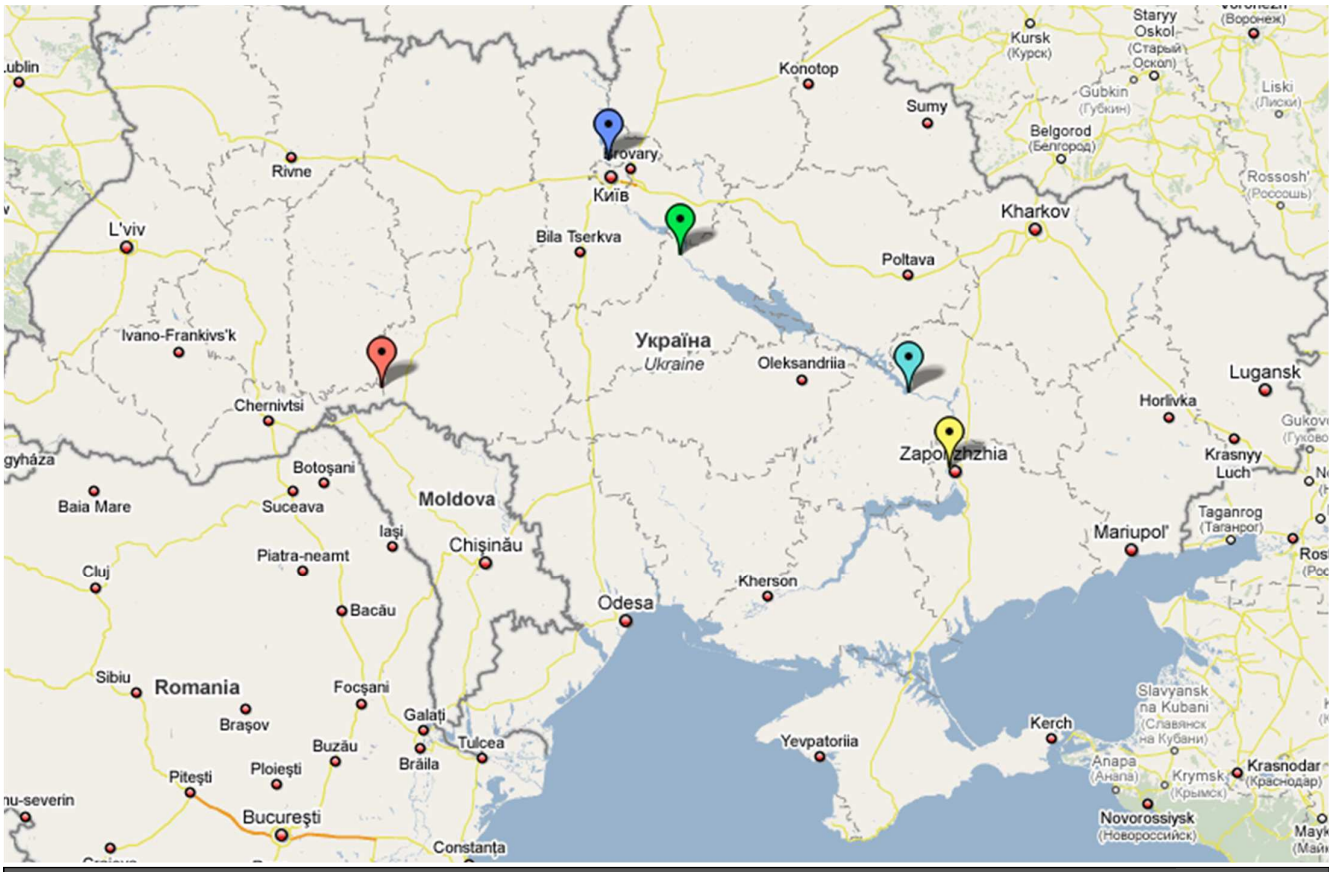




4 x Hydro Power Plants in UKRAINE

Kaniv HPP *Dniprodzerzhynsk HPP* *Dnipro HPP* *Dnister HPP*

CGEOS is acting in that project as sub-contractor for design, configuration, tuning, commissioning and acceptance operations.



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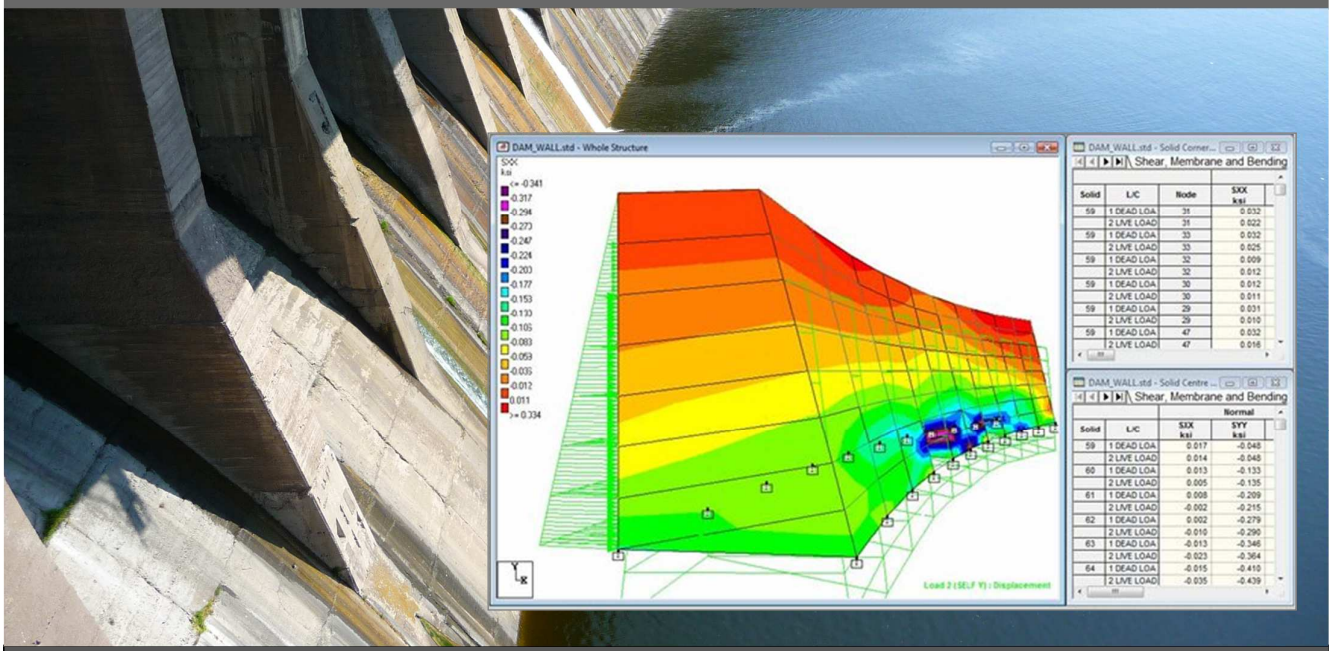
Hydro Power Plant



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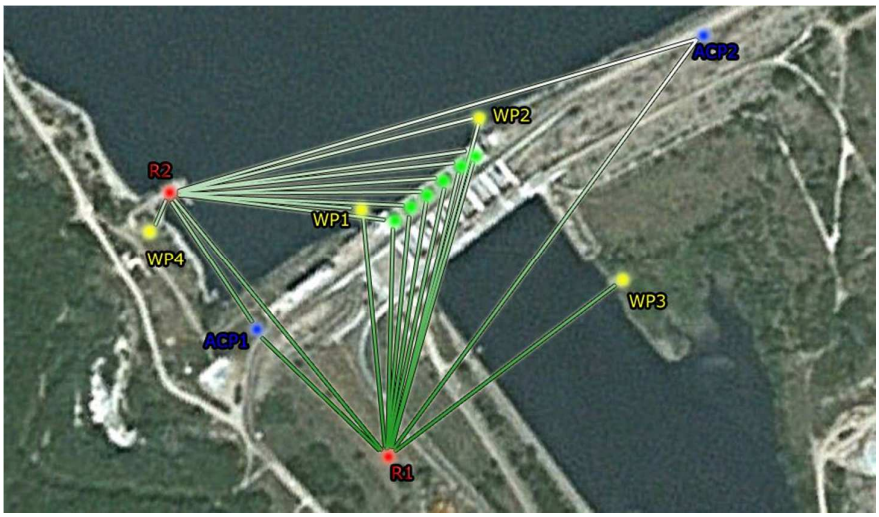
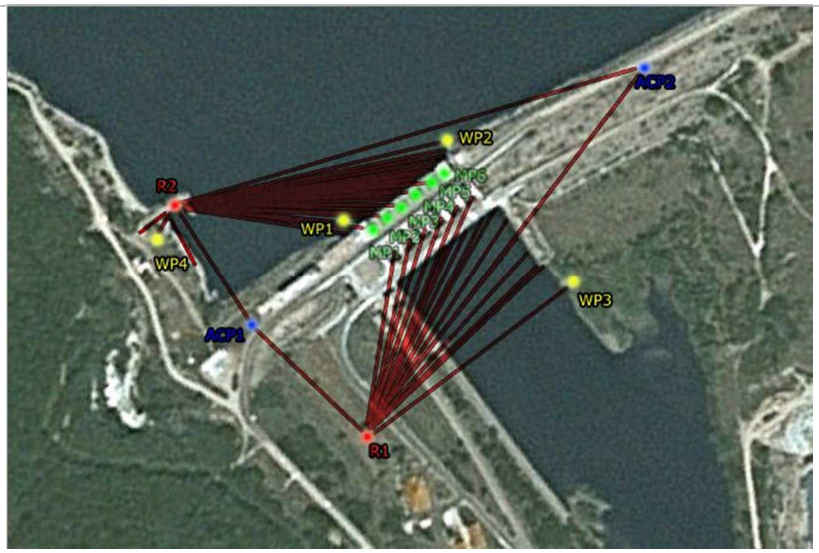
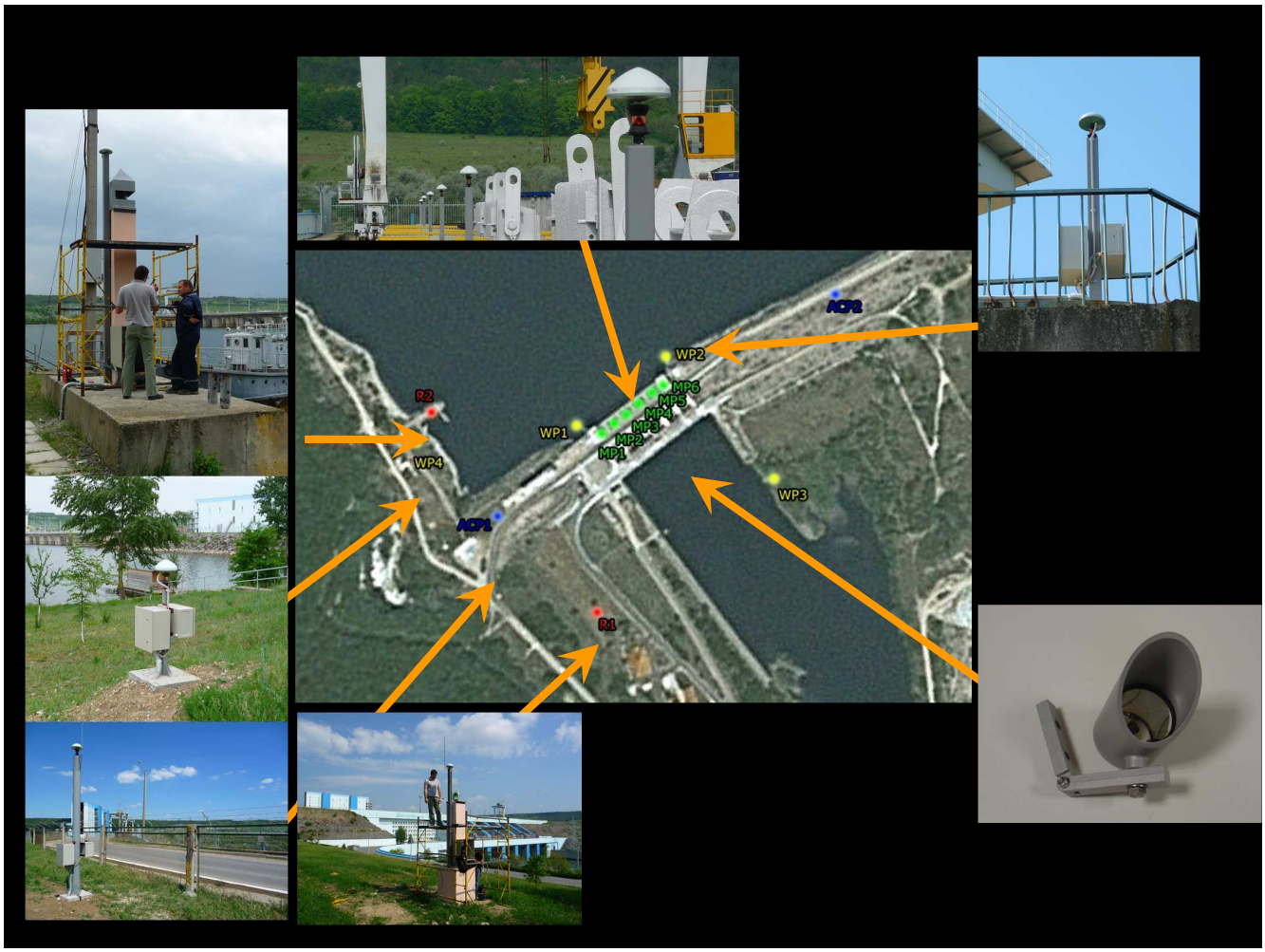
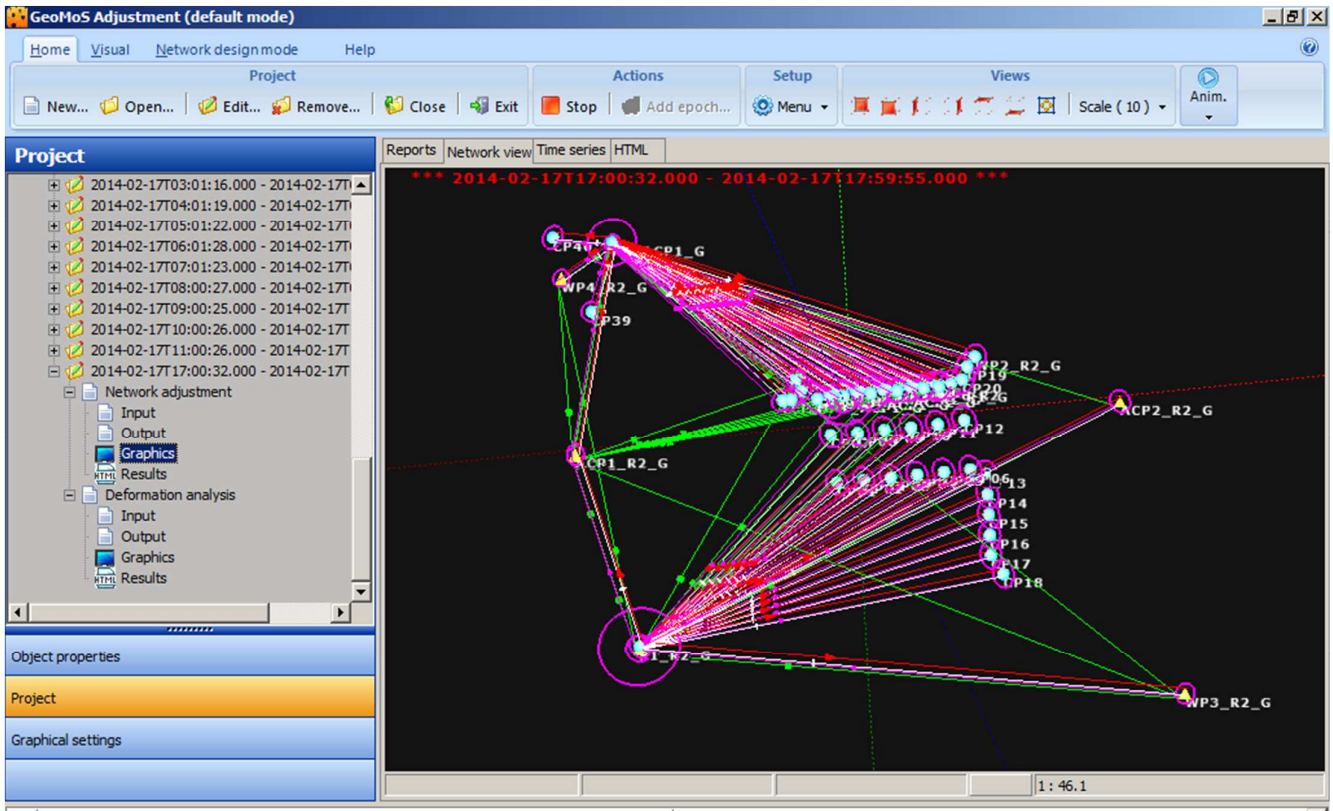
GNSS Deformation Network

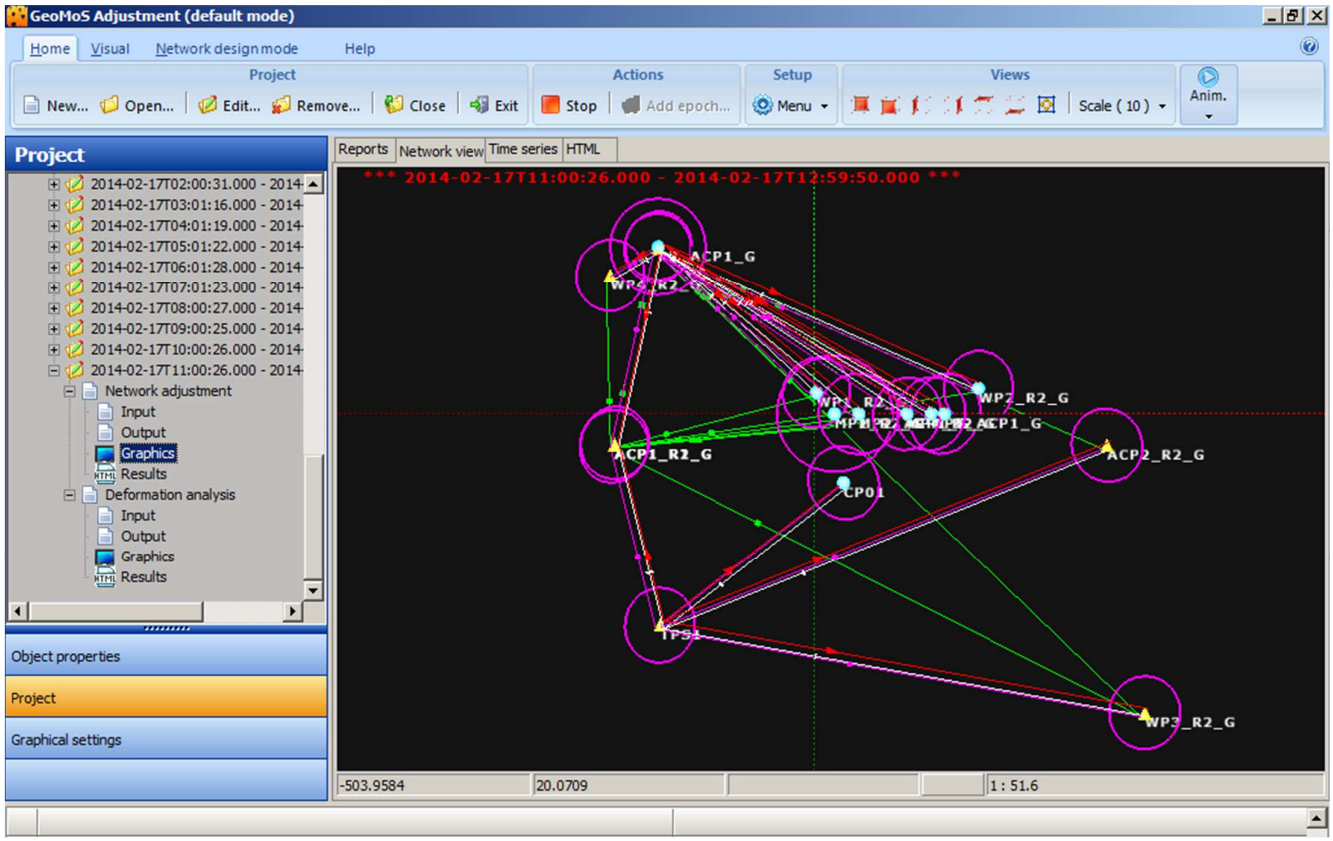


TPS Deformation Network

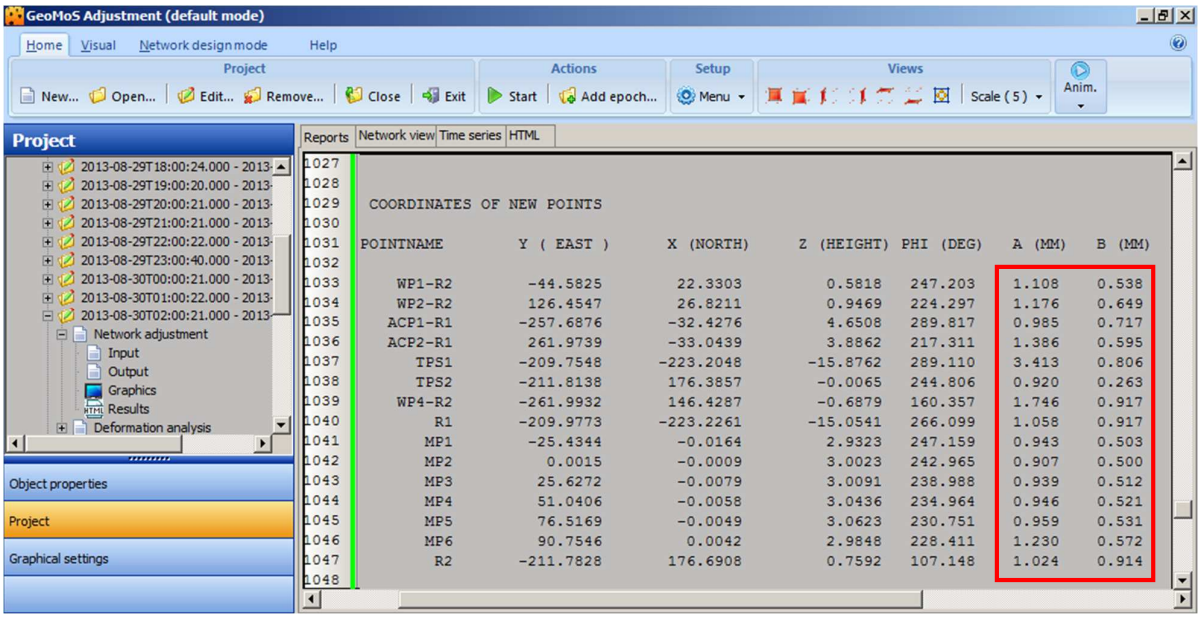



ACP2
WP2
MP6
MP5
MP4
MP3
MP2
MP1
R2
WP1
WP4
WP3
ACP1
R1


GeoMoS Adjustment (default mode)
Home
Visual
Network design mode
Help
Project
New...
Open...
Edit...
Remove...
Close
Exit
Actions
Stop
Add epoch...
Setup
Menu
Views
Scale (10)
Anim.
Project
Reports
Network view
Time series
HTML
*** 2014-02-17T17:00:32.000 - 2014-02-17T17:59:55.000 ***
Network adjustment
Input
Output
Graphics
Results
Deformation analysis
Input
Output
Graphics
Results
Object properties
Project
Graphical settings
ACP2_R2_G
CP1_R2_G
WP3_R2_G
1 : 46.1
Outlier found, but left unchanged due to decreasing redundancy
R2__



σ = 1 mm



COORDINATES OF NEW POINTS

POINTNAME	Y (EAST)	X (NORTH)	Z (HEIGHT)	PHI (DEG)	A (MM)	B (MM)
WP1-R2	-44.5825	22.3303	0.5818	247.203	1.108	0.538
WP2-R2	126.4547	26.8211	0.9469	224.297	1.176	0.649
ACP1-R1	-257.6876	-32.4276	4.6508	289.817	0.985	0.717
ACP2-R1	261.9739	-33.0439	3.8862	217.311	1.386	0.595
TPS1	-209.7548	-223.2048	-15.8762	289.110	3.413	0.806
TPS2	-211.8138	176.3857	-0.0065	244.806	0.920	0.263
WP4-R2	-261.9932	146.4287	-0.6879	160.357	1.746	0.917
R1	-209.9773	-223.2261	-15.0541	266.099	1.058	0.917
MP1	-25.4344	-0.0164	2.9323	247.159	0.943	0.503
MP2	0.0015	-0.0009	3.0023	242.965	0.907	0.500
MP3	25.6272	-0.0079	3.0091	238.988	0.939	0.512
MP4	51.0406	-0.0058	3.0436	234.964	0.946	0.521
MP5	76.5169	-0.0049	3.0623	230.751	0.959	0.531
MP6	90.7546	0.0042	2.9848	228.411	1.230	0.572
R2	-211.7828	176.6908	0.7592	107.148	1.024	0.914

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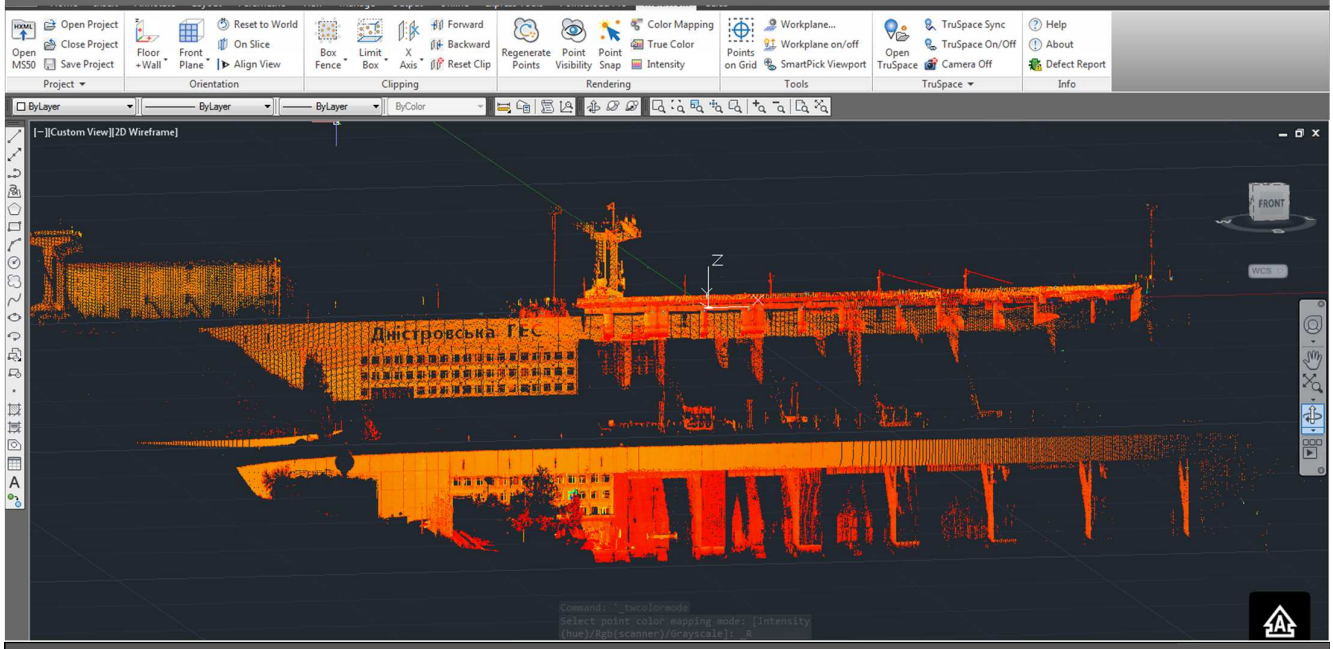
DNIESTER UHE HPP



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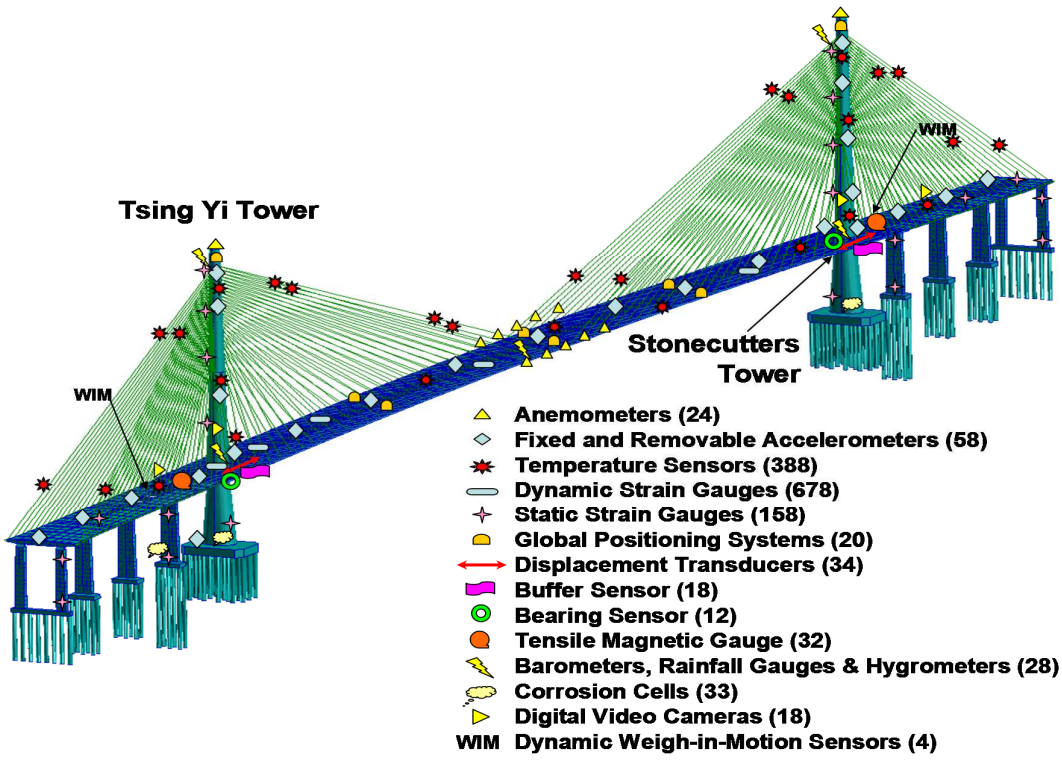
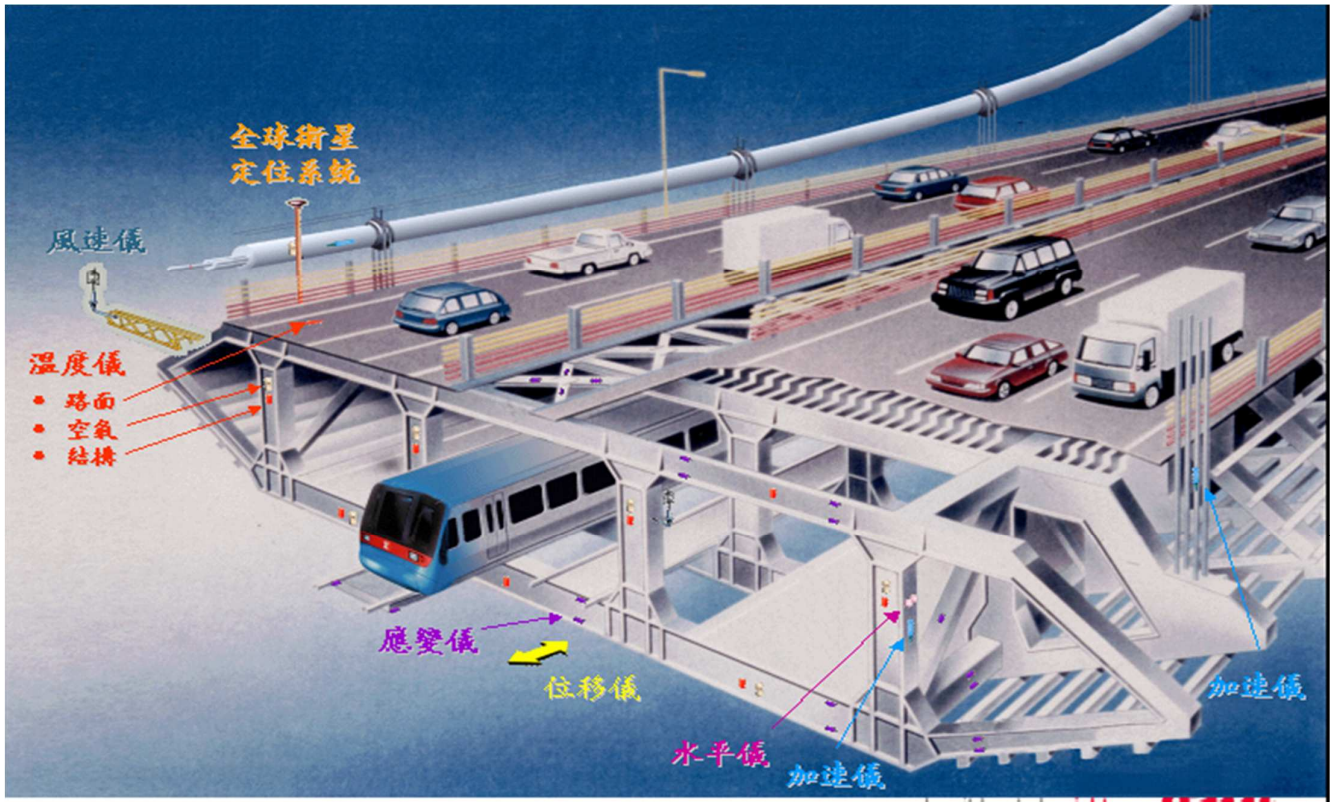
Stone Cutter Bridge – Kowloon HK


Tsing Yi Tower
WIM
WIM
Stonecutters Tower
Anemometers (24)
Fixed and Removable Accelerometers (58)
Temperature Sensors (388)
Dynamic Strain Gauges (678)
Static Strain Gauges (158)
Global Positioning Systems (20)
Displacement Transducers (34)
Buffer Sensor (18)
Bearing Sensor (12)
Tensile Magnetic Gauge (32)
Barometers, Rainfall Gauges & Hygrometers (28)
Corrosion Cells (33)
Digital Video Cameras (18)
WIM Dynamic Weigh-in-Motion Sensors (4)


全球衛星
定位系統
風速儀
溫度儀
路面
空氣
結構
應變儀
位移儀
水平儀
加速儀
加速儀

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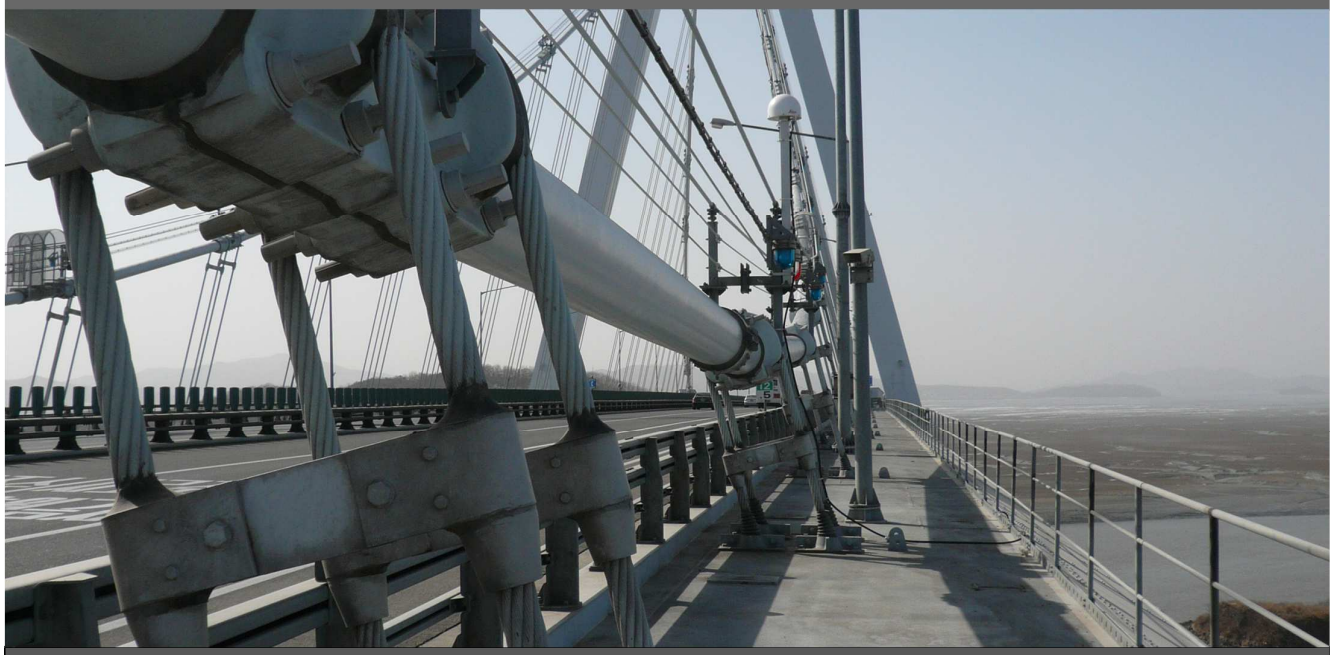
Yeong Jong Bridge KR



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Control Centre

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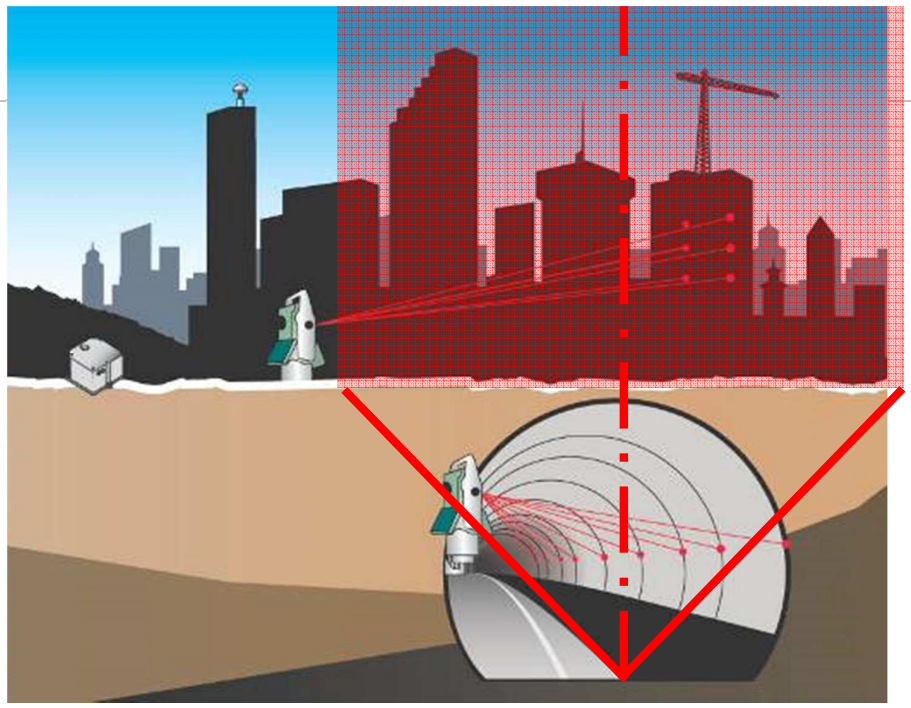
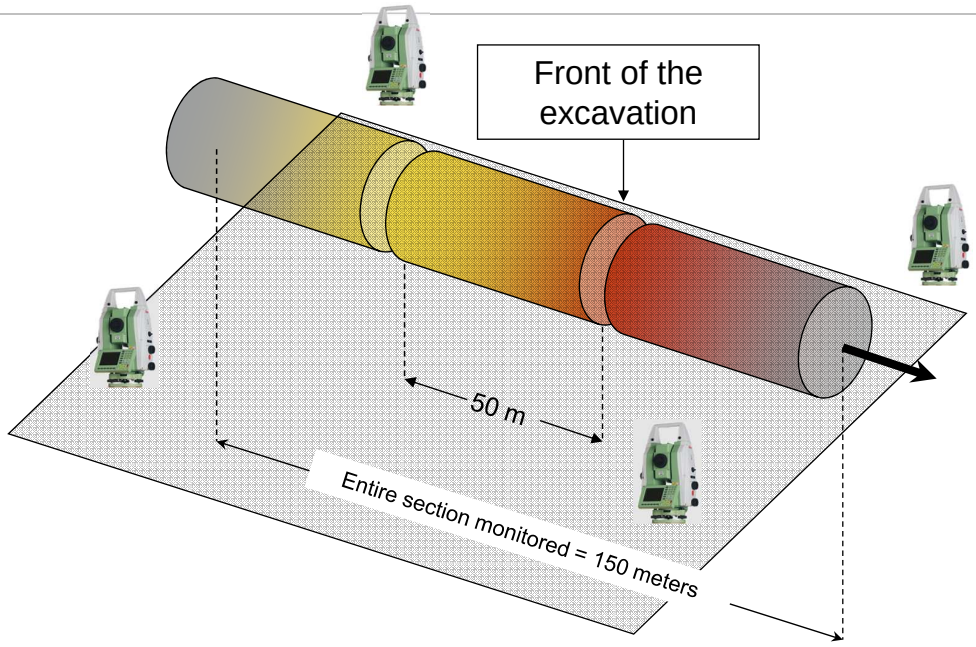
Risk Management by Geodetic Monitoring



When excavation is conducted to lead underground connections such tunnels and galleries the ground level is subject to subsidence impacting the infrastructures like buildings, bridges, pipe lines and roads…

Therefore a monitoring system is requested to control the risk on the influence area's.

Intelligent Deployment of Total Station



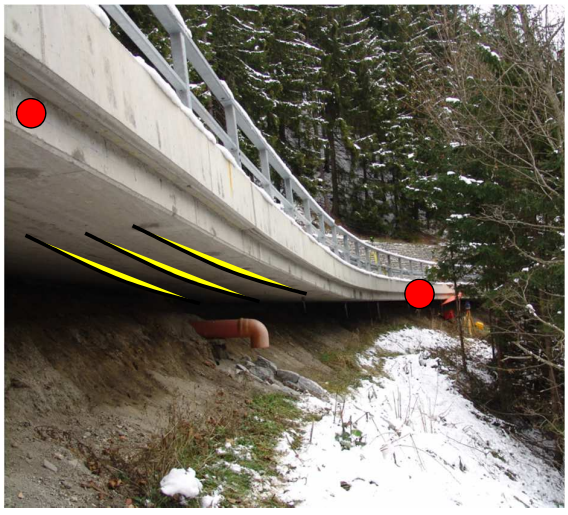
Traditional Analysis
Internal and external Measurements

Standard analysis model

$$\mathbf{y} + \mathbf{e} = \mathbf{A} \cdot \xi \qquad \Sigma_{yy} = \sigma_0 \cdot \mathbf{V}_{yy}$$

$$\begin{bmatrix} \mathbf{y}_R \\ \mathbf{y}_d \\ \mathbf{y}_L \end{bmatrix} + \mathbf{e} = \begin{bmatrix} \mathbf{A}_R \\ \mathbf{A}_d \\ \mathbf{A}_L \end{bmatrix} \cdot \begin{bmatrix} \hat{\mathbf{x}} \\ \hat{\mathbf{L}} \end{bmatrix}$$

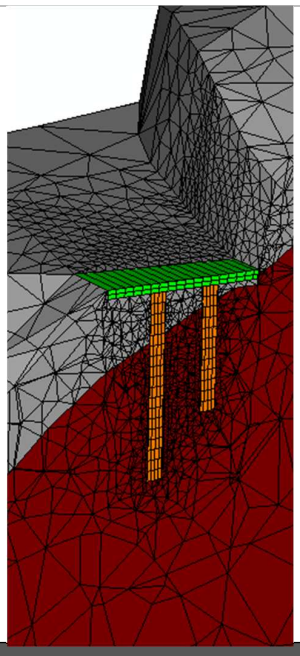
$$\mathbf{N} = \mathbf{A}^T \cdot \mathbf{V}_{yy}^{-1} \cdot \mathbf{A} = \begin{bmatrix} \mathbf{N}_{xx} & \\ & \mathbf{N}_{LL} \end{bmatrix}$$

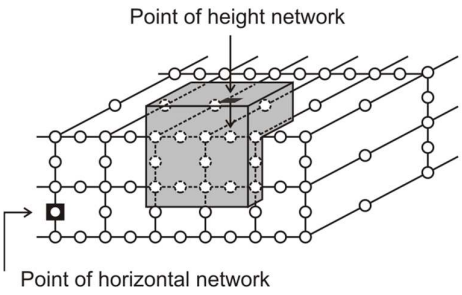


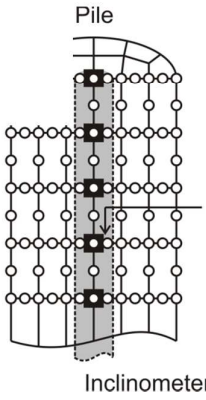
Result

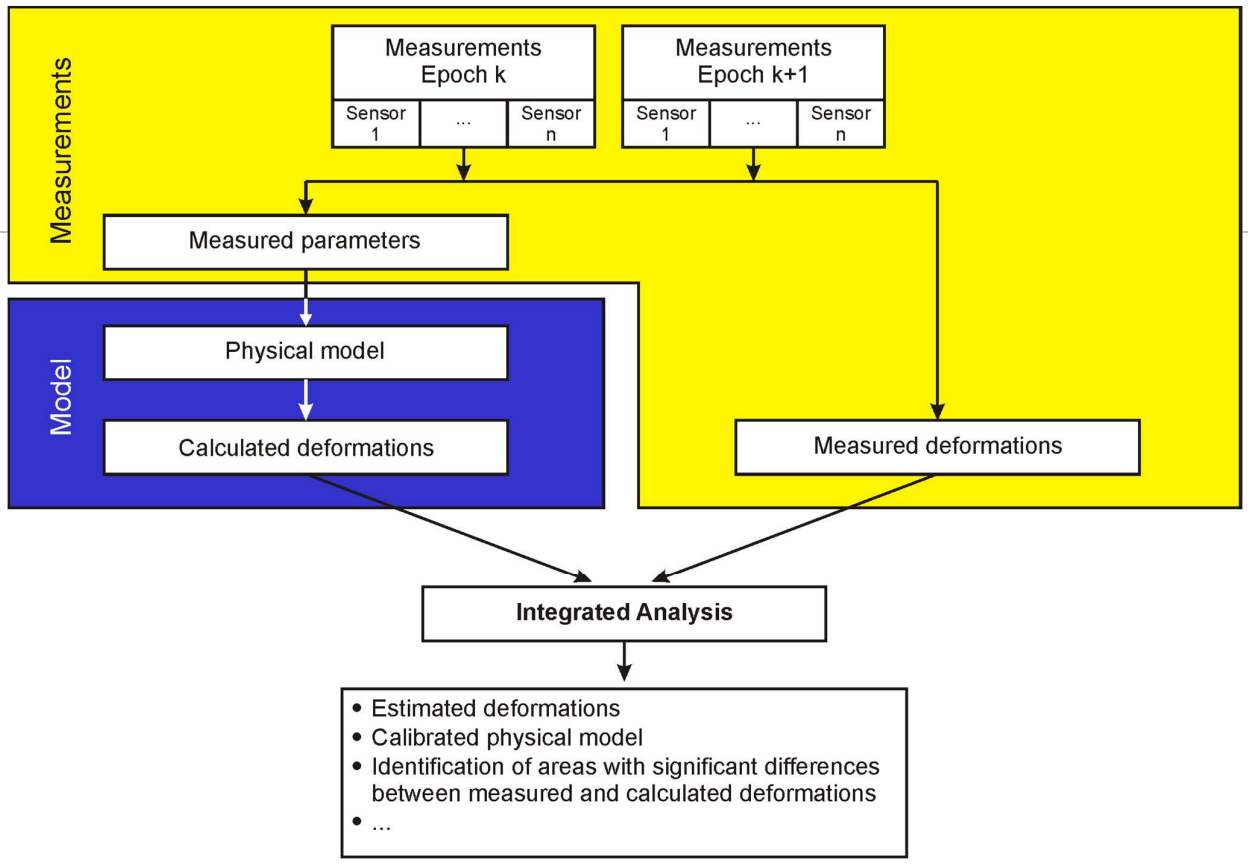
- Normal equation system collapses
- Global deformation behaviour cannot be assessed

Integrated Analysis and Physical Model









Conclusions

- Review the Monitoring principles
- Geodetic + Geotechnical = Geosensors
- Buildings, foundations, Dams, Bridges, …
- Design is very important and must consider an a priori deformation model …
- Integrated Analysis (measurement and models) …
- There is always many solutions but only few are elegant !
- There is a call to talk between Geodesists and Geotechnical Engineers …

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Thank you so much !

Creativity and passion will refresh Engineering Geodesy and Surveying in the 21st Century by GEOSENSING the World

Beyond East & West Geosensing Community

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