

ONLINE SAFETY MONITORING OF UNDERGROUND METRO LINES DURING CONSTRUCTION

1 INTRODUCTION

The mass rapid transit system (MRTS) forms the very backbone of the transportation infrastructure of a bustling metropolitan city anywhere in the world and the underground metro is a vital constituent of (even synonymous to) a MRTS. Underground metro projects generally have a comprehensive geotechnical and structural instrumentation and monitoring program, more so during the construction phases, when there are populations, buildings or other structures of interest in the vicinity of the underground construction activities for the safety purposes. Instrumentation monitoring in general, is carried out at strategic locations selected along the entire length of the underground metro tunnel alignments and stations. Its scope **includes integrating the instrumentation monitoring data from multiple tunnels, underground stations and structures within zone of influence, to provide an accurate model of ground movements**

2 UNDERGROUND METRO CONSTRUCTION METHODOLOGIES

The underground metro corridor construction work is carried out basically by two methodologies: Cut and cover and Tunneling (bored/NATM). Though tunneling is costlier than cut and cover methodology, it is a feasible solution for underground track alignments below critical buildings and densely populated areas of a city. The bored tunnelling is generally carried out with the help of a shield machine i.e. either tunnel boring machine (TBM) or earth pressure balanced machine (EPBM). For construction of underground stations, cut and cover method with either top down or bottom-up approach is used. All construction works are carried out in a manner which ensures minimum ground movement.

3 ROLE OF INSTRUMENTATION

The purpose of monitoring using geotechnical instrumentation is as follows:

- **Safety of buildings and utilities:** To provide early warning through regular or continuous monitoring for any excessive and undue ground movements affecting any structure/utilities within the zone of influence of excavations or tunnels. This allows for implementation of preventive remedial actions well within time.
- **Design verification:** To provide settlement, deflection and deformation data for the verification of initial design of the permanent structures and the temporary works supporting the excavation.
- **Construction control:** To monitor that the parameters such as total settlement, differential settlement, angular distortions, wall lateral movements, earth pressure, strut load, bottom heave etc. are within allowable limits. If exceeded construction methodology might be changed as a remedial measure. Thus, monitoring provides confidence in the construction process. Monitoring of ground water level is done confirming that the dewatering drawdown is in accordance with the statutory body's stipulations.
- **Long term monitoring for safety:** It is essential to periodically monitor condition of the underground structures to ensure its maintenance. The main factors affecting the performance are steel corrosion, degradation of concrete with age, undue settlement and change in the loading pattern due to increase in passenger traffic with time. Sometimes, a future construction activity in the vicinity of metro can affect the metro structure. In such cases, the instruments installed for long term monitoring give very important data.

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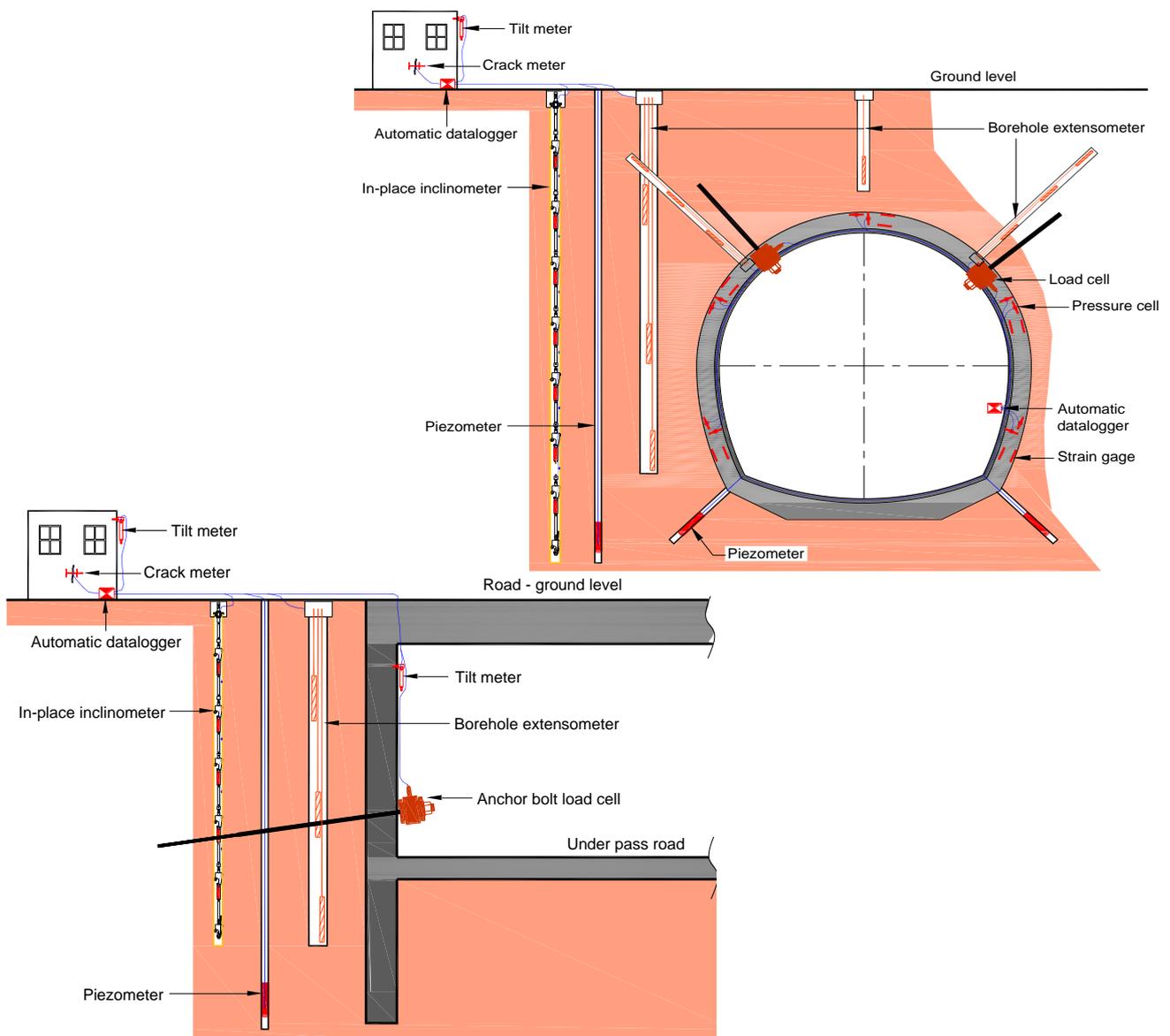
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4 MONITORING SOLUTIONS FOR UNDERGROUND METROS

- A. **Pre/post construction condition (dilapidation) survey** of structures and utilities within zone of influence of construction.
- B. A basic **online web based data monitoring solution** offered by Encardio-rite that can be used for any type of underground metro construction essentially consists of the following:
1. Encardio-rite model EAN-52M vertical **in-place inclinometer** system with several biaxial probes (with integral SDI-12 protocol) mounted vertically in a borehole for continuously monitoring sub-surface lateral movements.
 2. Encardio-rite model EPP-30V vibrating wire **piezometer** (with model ESVI-01-01 or ESVI-10VB SDI-12 interface box) for monitoring sub surface pore pressure variations.
 3. Encardio-rite model EDS-70V vibrating wire type **multiple point borehole extensometer** (with ESVI-01-04 SDI-12 interface box) for monitoring sub-surface settlement and lateral movement at specified depths.
 4. Encardio-rite model EAN-92M-B or EAN-93M-B **biaxial tilt meter** (with integral SDI-12 protocol) mounted at one or more locations on the buildings within zone of influence to record changes in tilt.
 5. Encardio-rite model EDJ-40V vibrating wire **crack meter** (with ESVI-01-01 SDI-12 interface box) for monitoring displacement/opening of cracks in buildings/structures.
 6. Encardio-rite model ELC-30S/ELC-30SH resistive strain gage type **centre hole load cell** (with ESBI-10 SDI-12 interface box) for monitoring tension in anchors. Model ELC-210S/ELC-150SH resistive strain gage type **strut load cell** for monitoring loads on struts.



7. Encardio-rite model ESC-30V vibrating wire **shotcrete pressure cell** or model EPS-30V vibrating wire **concrete pressure cell** (with ESVI-01-01 SDI-12 interface box) for monitoring radial and tangential stress in shotcrete lining or concrete pre-cast segments
8. Encardio-rite model EDS-20V-E/EDS-20V-AW vibrating wire **strain gages** (with ESVI-01-01 SDI-12 interface box) for monitoring strains in D-wall or concrete pre-cast segments
9. Encardio-rite model ESDL-30 **data logger** for the above mentioned sensors, with integral GSM/GPRS modem for storing and transmitting data to a server. For details refer to data sheet 1216-15 datalogger for SDI-12 interface sensors
10. Encardio-rite **Online Web Data Monitoring Service (WDMS)** that provides data online (with alarms) to authorised users at different locations, on their computer/laptops. More details are given in section 3.

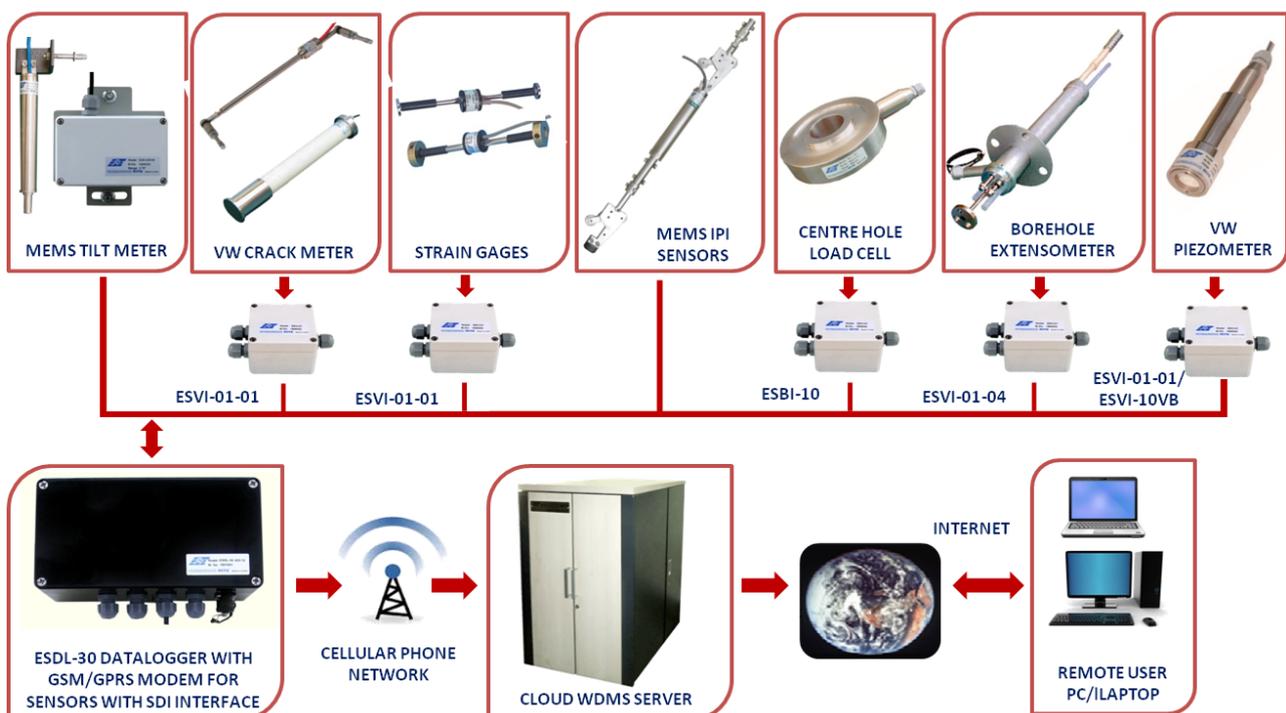
NOTE: Data retrieval from datalogger is also possible by directly downloading it on a laptop.

5 PUBLIC CLOUD BASED WEB DATA MONITORING SERVICE (WDMS)

The heart of the online structural monitoring instrumentation system is a Public Cloud Based Web Data Monitoring Service offered by Encardio-rite for retrieving data from the ESDL-30 SDI-12 data logger, archiving the data in a SQL database, processing the data and presenting the processed data in tabular and most suitable graphical forms for easy interpretation of the logged data. The tables and graphs related to any site or sites can be accessed by authorized personnel who can login to their site using the supplied login ID and access password from anywhere in the world over the internet. No special software is needed for accessing the user sites as the information can be viewed using most standard and popular web browsers like Microsoft Internet Explorer, Mozilla Firefox, Google Chrome etc.

Data from Encardio-rite cloud based web monitoring service can be accessed from just about any type of device that supports a standard web browser like a desktop or laptop PC, Tablet, smart phone or most other mobile computing devices.

A graphic like a map, ground plan or a photograph is put on the opening screen marked with position of installed sensor/sensors represented as square dots. As soon as the mouse pointer is brought over any sensor location the corresponding sensor details like sensor identification Tag, last recorded sensor reading, and the values of the programmed alert levels pop up in a box. If any one of the alarm level is exceeded the sensor location turns to a red dot. Clicking the pop up table with the mouse brings up an associated data window where the sensor data can be seen either as a table or as a graph.



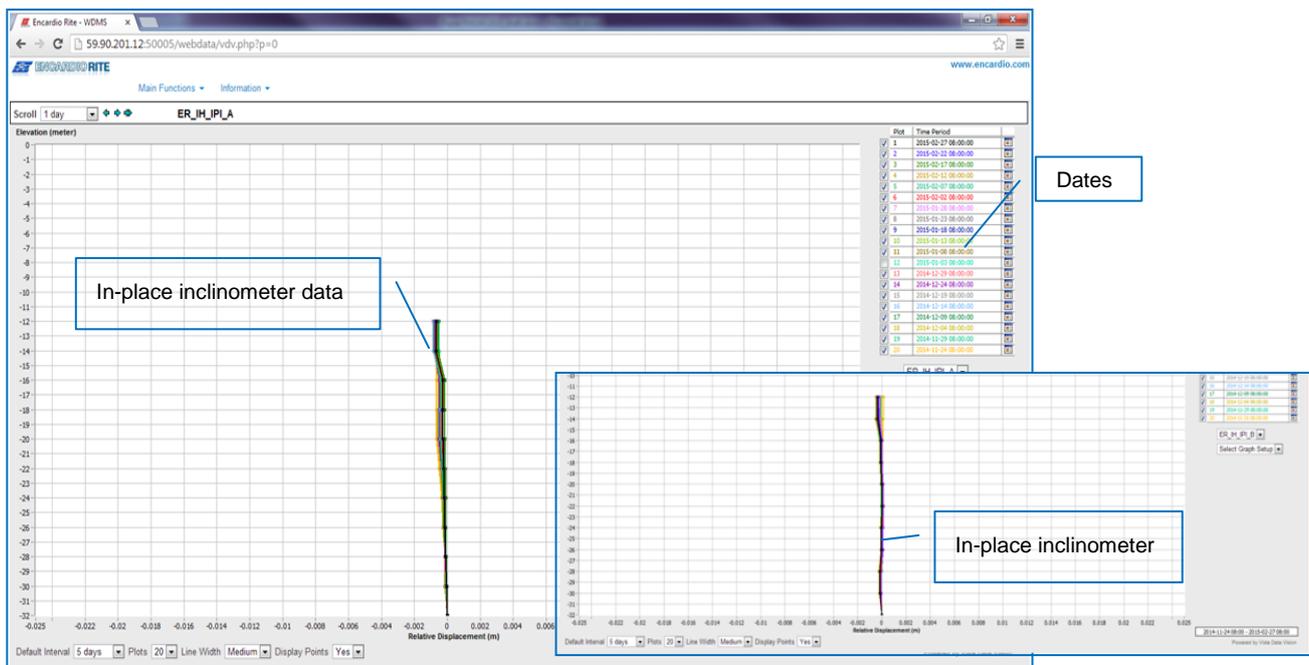
Site administrators can set two alarm limits which are generally considered as “alert level” and “evacuate level”. Other users can only view the data and alarm status but cannot make any changes.

The WDMS can also be programmed to send SMS alert messages or e-mail to selected users as soon as any sensor data crosses its predefined alarm levels, either while going above or going below the alarm level. It can also be programmed to send the health status of the system to selected users.

The web browser interface is very simple to use and intuitive. A user who is only interested in viewing the data and reports will take just a few minutes to get familiar with the operation of the system.

Encardio-rite cloud services work on a rental model. User has to pay a small setup fee for first time and then a monthly rental has to be paid for accessing the data over the cloud as long as required.

NOTE: Data retrieval is also possible by directly downloading it on a laptop.



6 Conclusions

The data observed from the geotechnical and structural instrumentation describe above plays a vital role in providing verification of design assumptions, manage the construction in a safe and controlled manner, safeguarding existing adjacent buildings and other facilities and monitoring long term behaviour of underground and ground structures.

During the earlier design stages, specific instrumentation requirements are generally assessed and incorporated into the design. Specific ground and groundwater conditions, construction methodology and the location and sensitivity of adjacent existing structures have to be given due consideration in selecting a suitable instrumentation and monitoring system. The programme for implementation of instrumentation requires advance planning. The procurement, installation and initialization of instrumentation require sufficient time to enable base readings to be taken, in most cases, before any construction activity commence within the zone of influence. There is no substitute or shortcuts for getting reliable and meaningful data from the instruments, so both the instruments and the manpower deployed for installation, monitoring and maintenance of instruments have to be top-notch.