

AGS(HK) Seminar - Tunnelling - Selected Topics

Instrumentation for Tunnelling

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13 June 2009

Presentation Outline

- Practical Aspects of Tunnelling Instrumentation
- Managing, Interpretation and Reporting Instrumentation and Monitoring Data
- Share Instrumentation Examples

Tunnelling in an Urban Environment



Instrumentation Objectives and Limitations

- Monitor performance of tunnelling relative to design predictions
- Monitor structural limits of existing utilities and structures
- Provides a mechanism to warn of behaviour trends
- May not always reflect unanticipated behaviour
- A tool to quantify risk level (ie. not an absolute limit)
- Not a substitute for bad design or taking unnecessary risks

Instrumentation Design

- sufficient coverage of structures and utilities
- optimise the value of instrumentation information



instruments along
“test sections” to easily
facilitate comparison of
measured vs predicted

Underground Obstructions

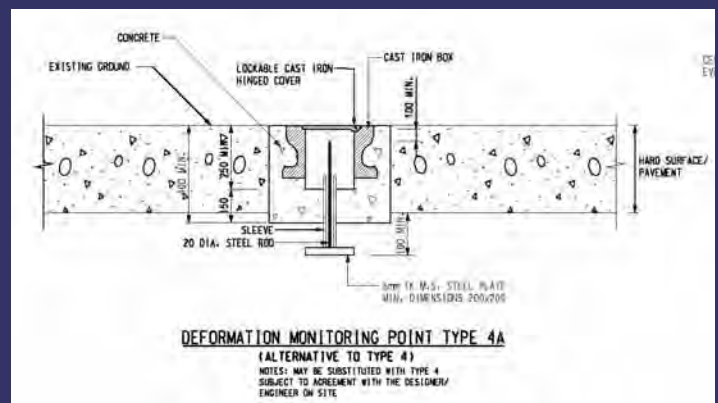
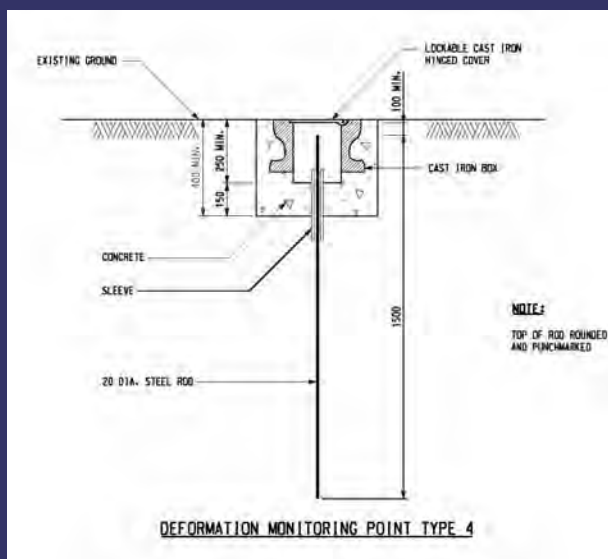
- underground obstructions in public roads
- instrumentation locations need to be flexible



utilities & concrete surround obstructions

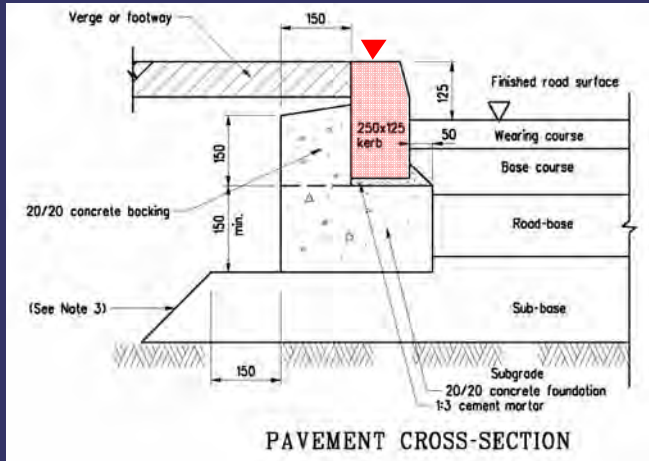
Alternative Installation Details

alternative installation details to suit site conditions



Alternative Ground Monitoring

- Survey nail on kerbstone
– alternative to installing rod type settlement marker



best location to reflect ground settlement below road pavement



Alternative Utility Monitoring

- Survey nail in manhole rim
– alternative to installing on deep utilities



best alternative to reflect utility settlement

Third Party Structures

- instruments on private structures
- access to private areas



Real-time Instrumentation

- requires electrical supply & internet access
- wifi / GSM mobile modem



Safety on Public Roads

- installations in roads – requires TTM
- finding utilities – accuracy of as-built information



Safety on Public Roads

- surveying in live traffic to be avoided



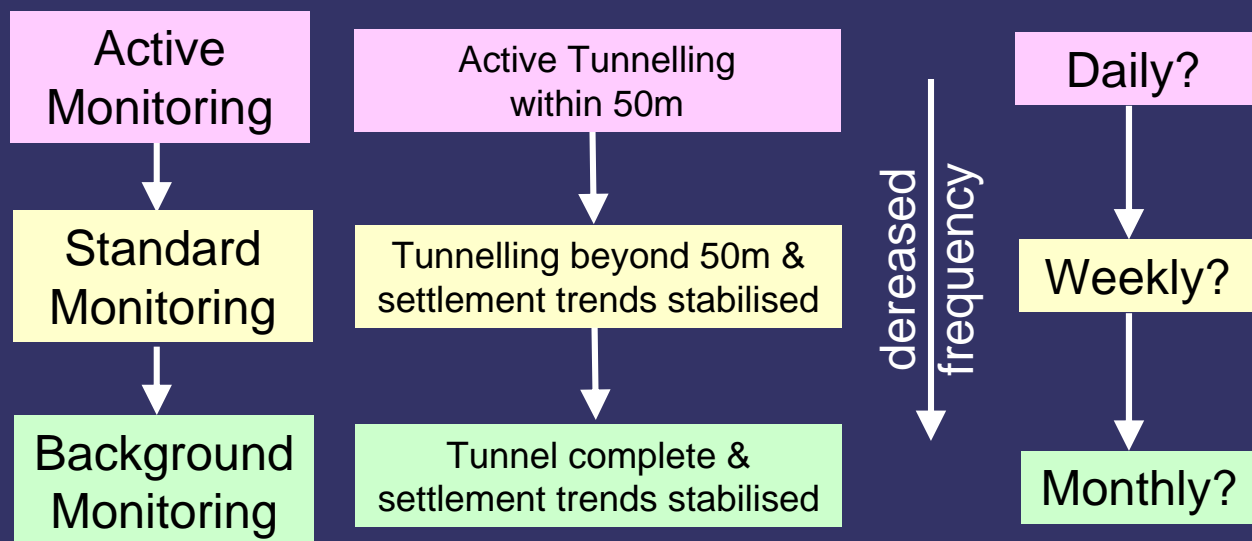
Baseline Monitoring

TABLE 1. BASELINE MONITORING PERIODS

INSTRUMENT TYPE	BASELINE MONITORING PERIOD
ADMS, VIBRATING WIRE STRAIN GAUGES AND SEISMOGRAPHS IN MTRCL TUNNELS	AT LEAST 14 DAYS PRIOR TO ACTIVE CONSTRUCTION ACTIVITIES WITHIN THE ZONE OF INFLUENCE.
TARGET PRISMS (PRM), TILT METERS / TILT SENSORS (TS), DEFORMATION MONITORING POINTS (DMP), UTILITY MONITORING POINTS (UMP), CRACK GAUGES (TT) AND SURFACE MOUNTED VIBRATING WIRE STRAIN GAUGES (VWVG)	AT LEAST 7 DAYS PRIOR TO ACTIVE CONSTRUCTION WORKS WITHIN THE ZONE OF INFLUENCE
PIEZOMETERS AND STANDPIPE PIEZOMETERS (PZ, VPZ), OBSERVATION WELLS	AT LEAST 7 DAYS PRIOR TO ACTIVE CONSTRUCTION WORKS WITHIN THE ZONE OF INFLUENCE
INCLINOMETERS (INC), MAGNETIC PROBE EXTENSOMETERS (MPX)	AT LEAST 7 DAYS PRIOR TO ACTIVE CONSTRUCTION WORKS WITHIN THE ZONE OF INFLUENCE
IN-PLACE INCLINOMETERS (IVI, IHI), INCLINOMETERS (INC), MAGNETIC PROBE EXTENSOMETERS (MPX)	
VIBRATING WIRE STRAIN GAUGES (VWVG) ON STRUTS SUPPORTING EXCAVATION	
SEISMOGRAPHS (SMG)	
OTHER INSTRUMENTS	

- clearly define length of baseline monitoring required before active construction works
- clearly identify milestones for installation (eg. before tunnelling commencement, after completion of permanent structure, or after diversion of utilities, etc)

Monitoring Frequency



Trigger Levels and Generalised Plan of Action

Upon Reaching Alert

2. IF AN ALERT LEVEL IS REACHED, THE FOLLOWING PROCEDURE WILL BE FOLLOWED:
- NOTIFY THE RSE AND KCRC IMMEDIATELY;
 - UPON DETECTING THAT AN ALERT LEVEL HAS BEEN REACHED, SUBMIT A BRIEF REPORT DESCRIBING THE WORKS BEING UNDERTAKEN IN THE VICINITY OF THE INSTRUMENT;
 - PROPOSE A SUITABLE PLAN OF ACTION SUCH AS THE INSTALLATION OF ADDITIONAL INSTRUMENTS AND/OR INCREASE THE MONITORING FREQUENCY;
 - WITHIN 7 DAYS, SUBMIT A REPORT TO REVIEW DIFFERENTIAL DEFORMATIONS, ASSESSMENT OF THE LIGHT OF THE RELEVANT CONSTRUCTION ACTIVITIES BASED ON THE TRENDS IN THE MONITORING DATA;
 - WITHIN 7 DAYS, SUBMIT A DETAILED PLAN OF ACTION DESCRIBING THE MEASURES TO BE TAKEN IN THE TRIGGER LEVEL BEING ATTAINED;
 - MAKE PREPARATIONS FOR IMPLEMENTING THE ACTION IN ACCORDANCE WITH THE AGREED DETAILED PLAN OF ACTION.

Upon Reaching Action

3. IF AN ACTION LEVEL IS REACHED, THE FOLLOWING PROCEDURE WILL BE FOLLOWED:
- NOTIFY THE RSE AND KCRC IMMEDIATELY;
 - UNDERTAKE A JOINT INSPECTION OF THE WORKS WITH THE RSE AND/OR KCRC;
 - IMPLEMENT THE ACTION LEVEL TRIGGER ACTIONS AS APPROPRIATE SO THAT THE ALARM LEVEL IS NOT REACHED IN ACCORDANCE WITH THE DETAILED PLAN OF ACTION;
 - UPON EXCEEDING AN ACTION LEVEL, DEVISE AND IMPLEMENT THE MEASURES TO BE TAKEN IN THE EVENT OF AN ACTION LEVEL BEING ATTAINED;
 - MEET WITH THE RSE AND/OR KCRC TO DISCUSS THE EFFECTIVENESS OF THE TRIGGER LEVEL ACTION;
 - IMPLEMENT AGREED ACTIONS TO UNDERTAKE AND AVOID REACHING THE ALARM LEVEL;
 - WITHIN 7 DAYS, SUBMIT AN UPDATED REPORT TO INCLUDING DIFFERENTIAL DEFORMATIONS, ASSESSED MONITORED ELEMENTS IN LIGHT OF THE RELEVANT PREDICTION OF FURTHER MOVEMENTS BASED ON THE DATA UP TO DATE;

Upon Reaching Alarm

4. IF AN ALARM LEVEL IS REACHED, THE FOLLOWING PROCEDURE WILL BE FOLLOWED:
- REVIEW NEED TO SUSPEND ACTIVE CONSTRUCTION WORKS WITHIN THE INFLUENCE ZONE OF THE INSTRUMENT;
 - NOTIFY THE RSE AND KCRC IMMEDIATELY;
 - UNDERTAKE A JOINT INSPECTION OF THE WORKS WITH THE RSE AND KCRC;
 - IMPLEMENT EMERGENCY TRIGGER ACTION BASED ON THE EMERGENCY PLAN REVIEWED WITHOUT OBJECTION BY THE RSE AND KCRC;
 - WITHIN 3 DAYS, PROVIDE A COMPLETE REPORT TO EXAMINE THE CONSTRUCTION METHOD AND REVIEW THE DEFORMATION AND GROUND RESPONSE HISTORY AND THE TRIGGER ACTIONS ADOPTED RELATED TO THE CONSTRUCTION ACTIVITIES. THE WORKS MAY ONLY RECOMMENCE AFTER AFTER A REMEDIAL PROPOSAL HAS BEEN SUBMITTED AND AGREED WITH THE RSE & KCRC.
 - PROPOSE AN ALARM2 VALUE TO ENSURE THAT THERE IS A FURTHER RESPONSE LEVEL IN PLACE IN THE EVENT THAT MOVEMENTS PROGRESS BEYOND THE ALARM LEVEL. IF NECESSARY, THE DESIGNER WILL PROVIDE A DESIGN ASSESSMENT OF THE GROUND, STRUCTURE OR UTILITY WHICH JUSTIFIES THE MAGNITUDE OF ALARM2 RESPONSE VALUE PROPOSED.

Hong Kong
Alert / Action / Alarm

Singapore
Alert / Work Suspension Level

Detailed Plan of Action

Gammon
AAA Exceedance Plan of Action (KPA)
Form No. 0006

Contract No. X084358
Tunnel Project

To: TS Supervising Engineer
Cc: Construction Manager
RSE
RSE
Chief
HyD

Cause for Issuance of Plan of Action

Date: 17 January 2019
Location of Instrument: T&D Vialat Bridge No. 3115

Instrument No.	Trigger	Status of Instrument
1014	Alert	OK (in use)
1015	Action	OK (in use)
1016	Alarm	OK (in use)

General Information and Observations:
Instruments found incorrect for resonant nature at Vialat Bridge No. 3115 as noted above.

Other observations are as follows:
• The instruments at T&D No. 3115 (Photo 1) disturbed suitably between 2:00pm and 3:00pm on 16 and 17/01/2019 during their removal & installation at No. 3115. The 1016 was slightly lower (please refer monitoring records attached).

The possible causes of the above 3 days may include:
• Trenching at the east side of pier AC may have caused sideways movement of the pier pile cap.

Detailed Plan of Action (DPA) and Emergency Plan of Action (EPA)

I. Contact Details of Key Personnel:
T&M Construction Manager
(Tel: 3224 0100)
Instrumentation and Monitoring Manager
(Tel: 3224 2111)

J. Contractor's Proposed Actions:
By (date) of this form and with a Daily Summary of Alerts to be submitted through the instrumentation database.

K. Contractor's Proposed Actions:
DPA Upon Exceedance of the Alert Level:
1. Notify TS Supervising Engineer, RSE, RSE, Chief, HyD & Designer.
2. Discuss in the regular instrumentation review meeting.
3. Carry out regular site inspection and closely watch trends in settlement.

Gammon
AAA Exceedance Plan of Action (KPA)
Form No. 0006

Contract No. X084358
Tunnel Project

Detailed Plan of Action (DPA) and Emergency Plan of Action (EPA)

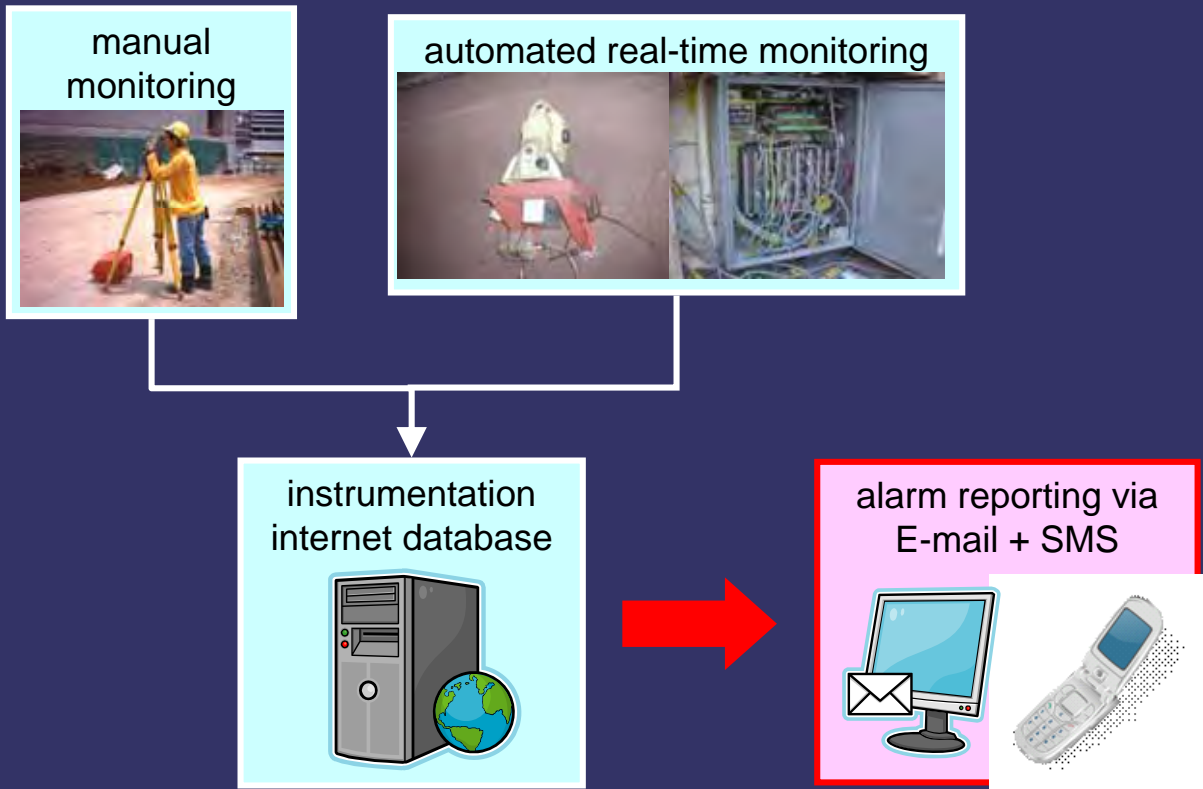
DPA Upon Exceedance of the Action Level:
Notify TS Supervising Engineer, RSE, RSE, Chief, HyD & Designer.
Carry out a detailed site inspection.
Site inspection was carried out on 17/01/2019 and on installation of instrument on 18/01/2019 and on installation of instrument on 19/01/2019.

Works can be continued
Works cannot be continued

TS Supervising Engineer's comments on L&V response actions:
• Contractor's CH4 & EPA Agreed
• The Contractor should also carry out remedial program of monitoring of movement of pile cap.

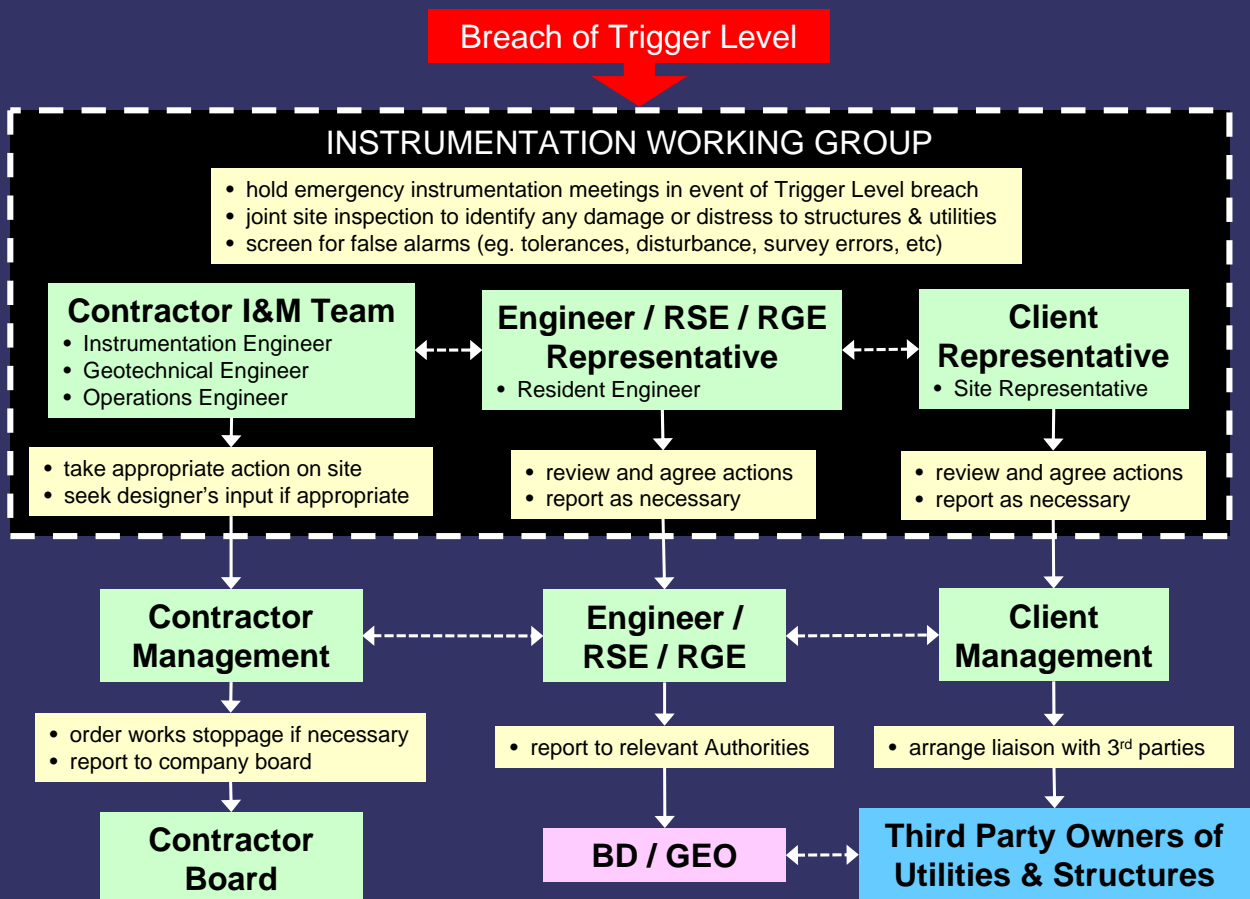
- upon exceedance of trigger level provide detailed plan of action based on actual site situation and monitoring trends
- may require Designer's input

Alarm Reporting



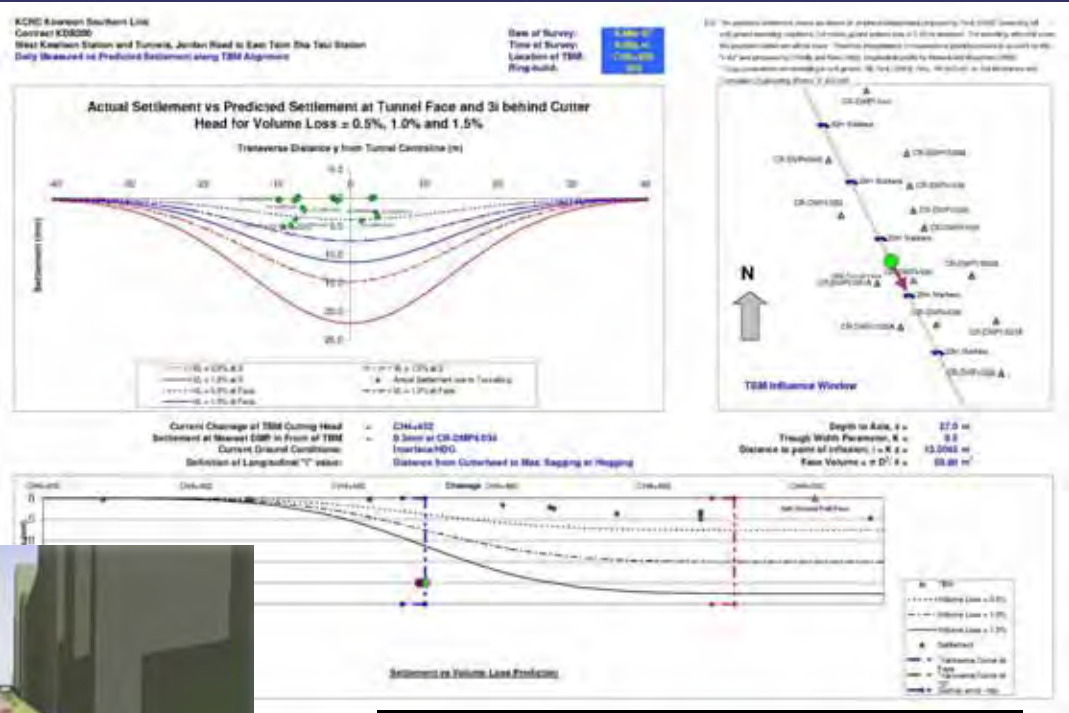
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Exceedance Management



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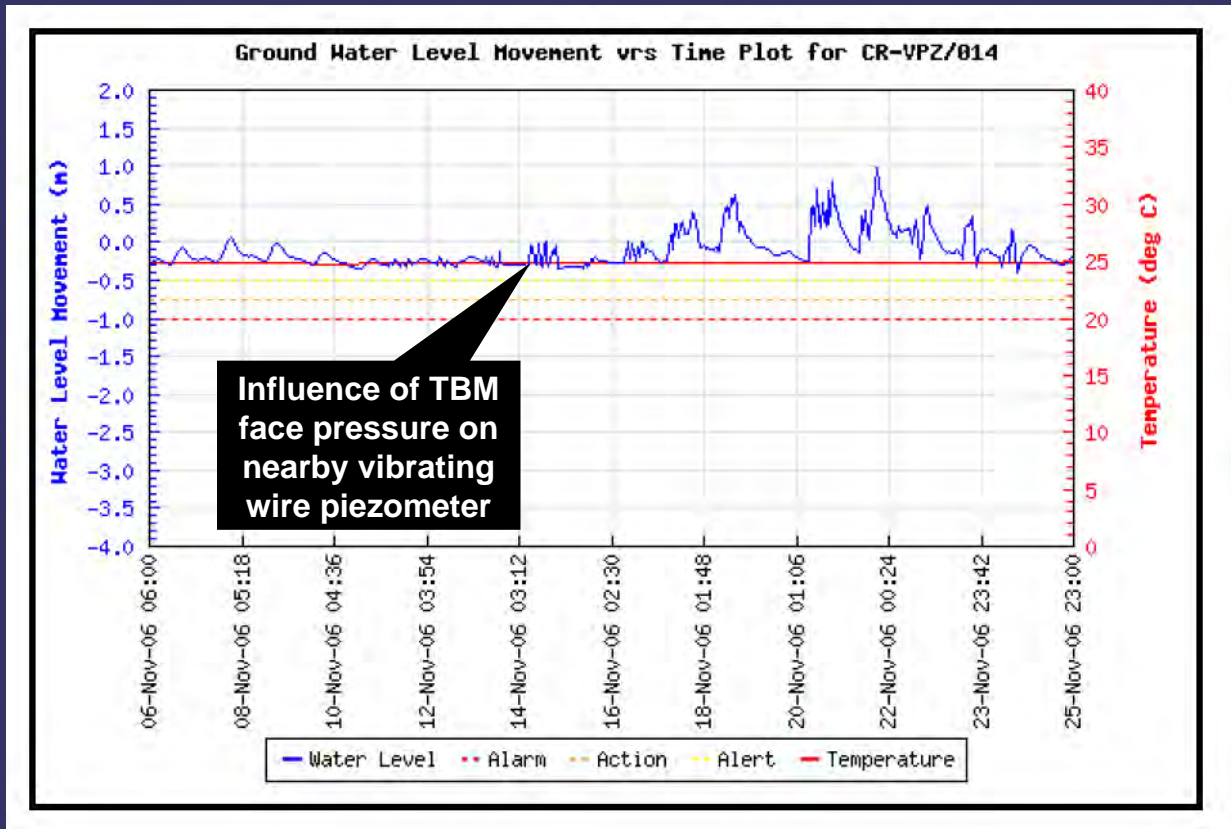
Tracking Performance



- daily updating of measured vs predicted settlement data
- plotted against predicted settlement for varied volume loss

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TBM effect on porewater pressure

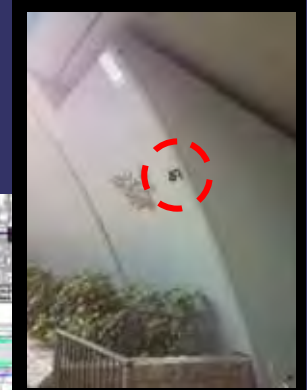
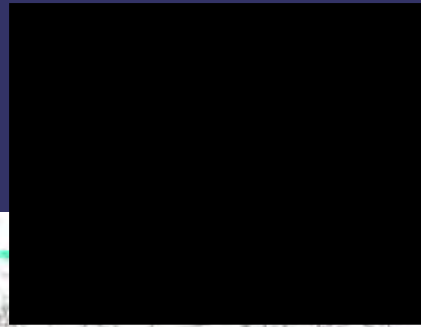


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Monitoring of a Highway Bridge



view of bridge structure



target prisms



ADMS KEY ISSUES

- cycle time
- traffic obstructions
- sight lines
- alternative tilt sensors

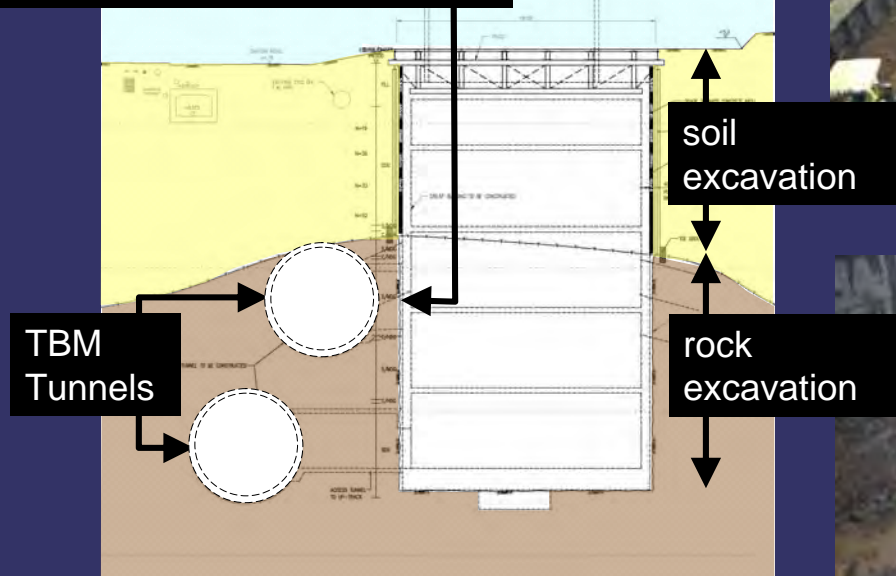


EL tilt sensors on bridge soffit

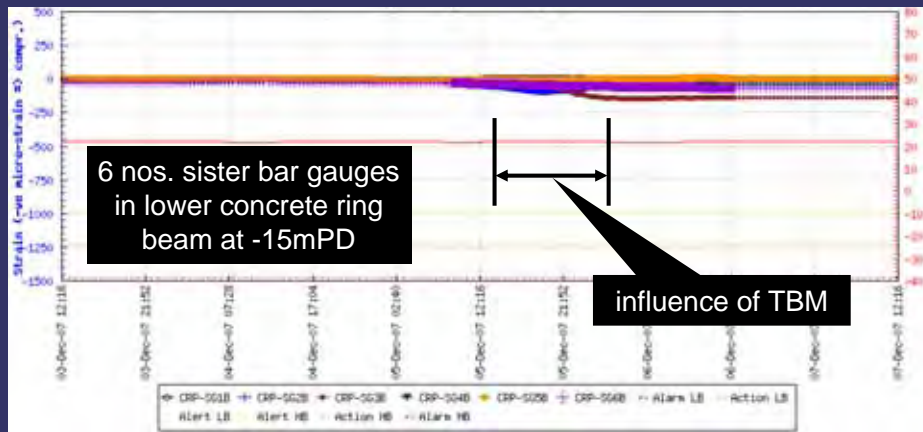
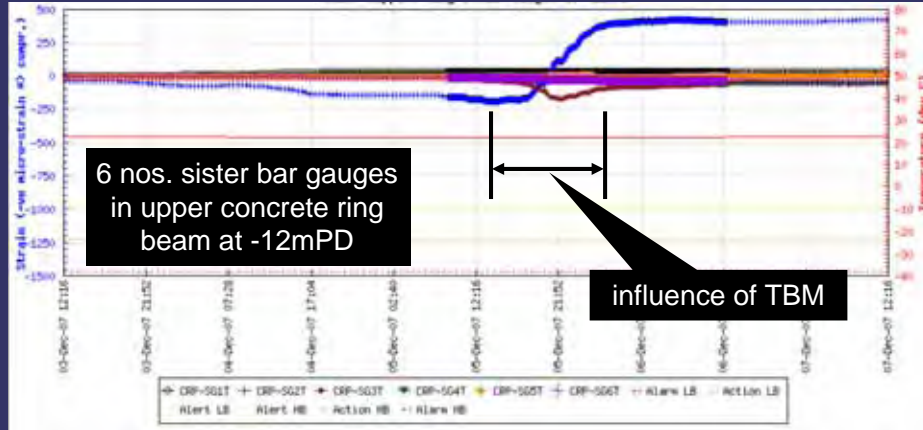
TBM Drive Adjacent to Shaft Excavation



sister bar embedded in concrete ring beam

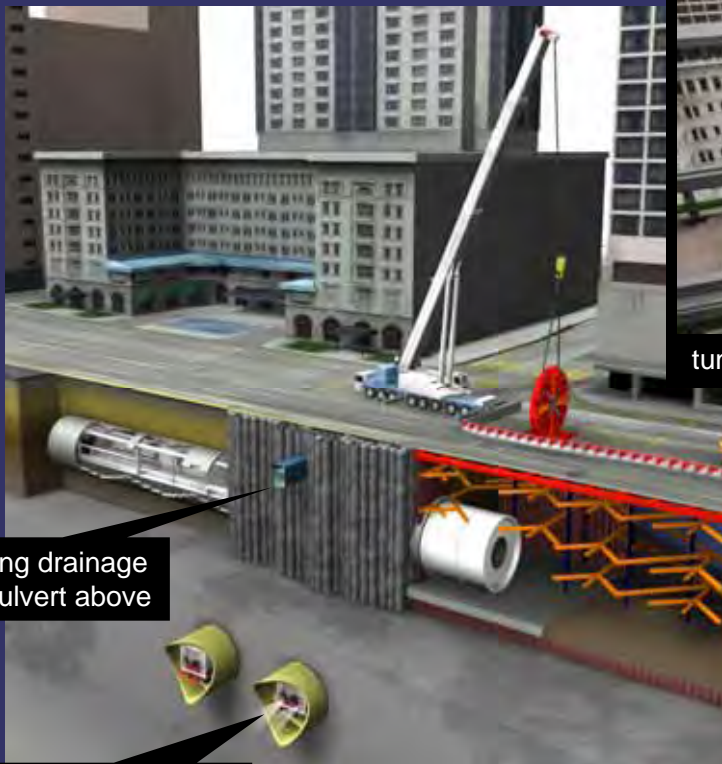


TBM Drive Adjacent to Shaft Excavation



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Tunnel Crossing



existing drainage box culvert above

<2m separation to existing running tunnels



tunnel crossing below busy traffic intersection



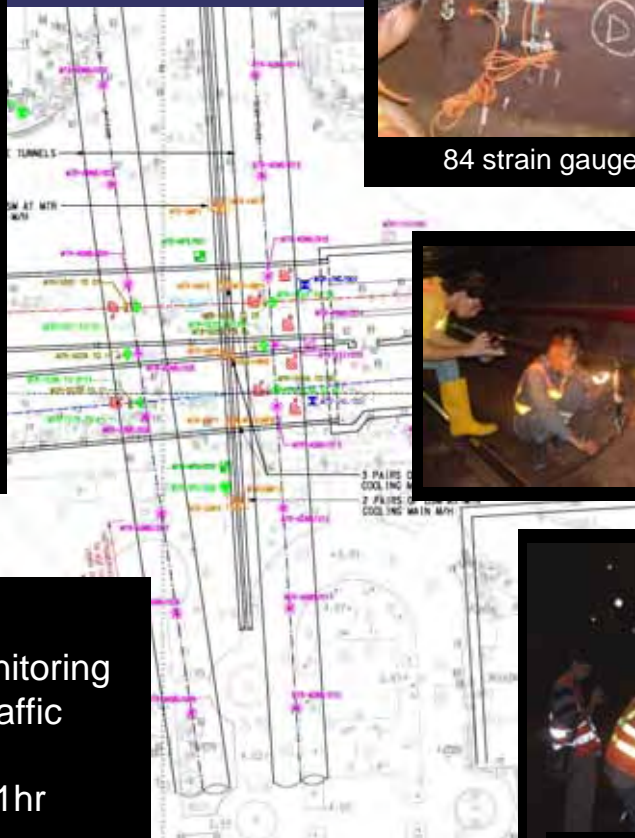
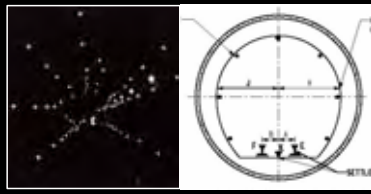
TBM breakthrough

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Tunnel Crossing



ADMS + 126 nos. prisms



84 strain gauges + seismographs



tape extensometers



manual level & offset

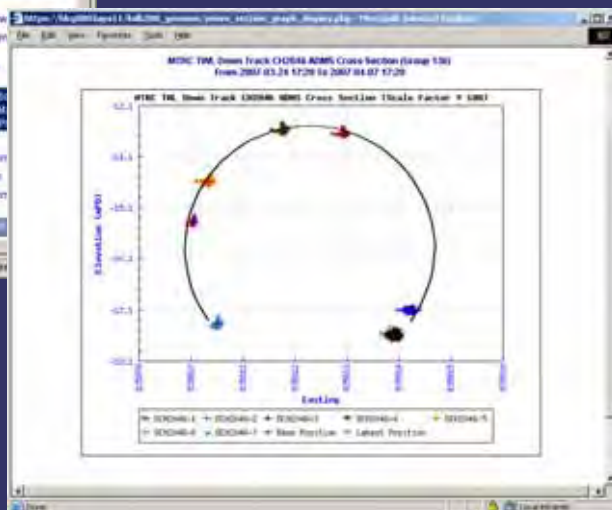
KEY ISSUES

- remote real-time monitoring
- access during non-traffic hours only
- ADMS cycle time of 1hr

Instrumentation Database

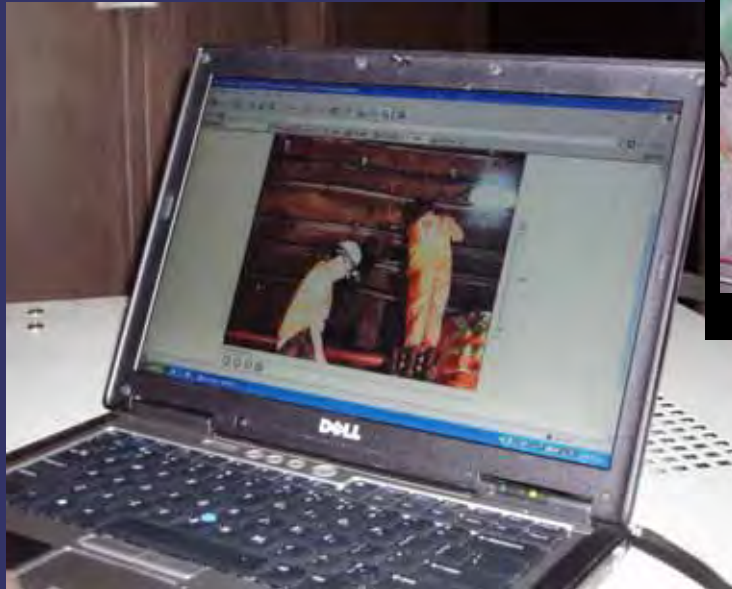


- map interface
- settlement contours
- real-time automated notifications
- PDF reports generated on the fly
- customisable interface



VMS – Visual Monitoring System

VMS inside running tunnels



remote operated camera unit

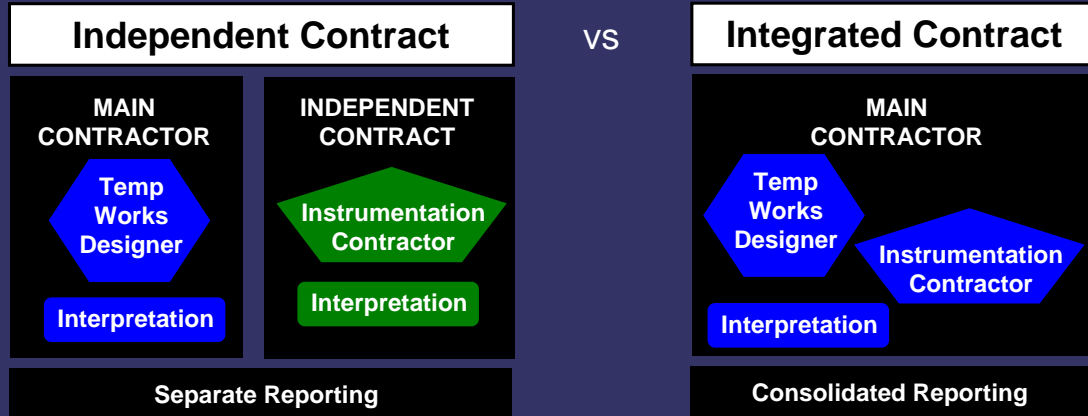
Features

- visual aid during inaccessible hours
- remote operated pan & zoom functions
- added sense of security

Webcam Time Lapse

A screenshot of the GEOMON web interface. The browser address bar shows the URL: https://geomon1.gammonconstruction.com/kdb200_geomon/input_index.php - Microsoft Internet Explorer. The page features logos for Link 200 Joint Venture, Galfour Beatty, KCR (九廣鐵路), and GEOMON. A navigation menu includes HOME, REPORTS, ALARMS, DATA INPUT, ADMINISTRATION, UPDATE MAP, and ABOUT. The main content area is split into two panels: on the left, a live webcam feed labeled 'CAM_002' showing a construction site with 'ATW' and 'NO.001' overlaid; on the right, a map view with red arrows and green dots indicating camera locations. The footer contains the text: © Gammon Construction Ltd • Last Change: 2006-08-28 by jaf.

Instrumentation Procurement



- perceived removal of conflict of interest ?
- more conservative ?
- single instrumentation contractor for multiple construction contracts
- interpretation by separate parties with differing opinions

- cheaper cost
- designer familiar with predicted behaviour
- co-ordinated actions / interpretations
- beware if wrong team
- with right people, the integrated approach can be more efficient

Thank You