Reclamation Ground Settlement Monitoring by using GPS and other Technologies at Shenzhen Airport

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– where it has to be right

Background

- **Current reclamation practices**
  - Dredging – environmentally unfriendly
  - Surcharging with Prefabricated Vertical Drains – time consuming
- **We need to strengthen soft marine clay in a friendly way, however**
- **Compaction, deep compaction, blasting – environmentally unfriendly**
- **Deep cement and lime mixing, grouting and thermal modification – costly**
- **Electro-osmosis – ineffective**

– where it has to be right

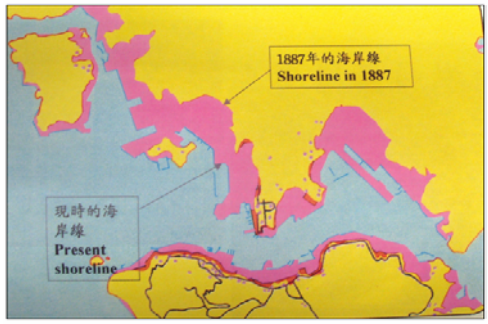
Background

Objectives of this research

- To study technical feasibility of **offshore vacuum preloading** (under water for at least 2 – 3m), to see possibility of adopting existing approaches from onshore vacuum preloading (shallow water, usually 1m or less) to offshore vacuum preloading
- To study consolidation mechanism and representative stress path in vacuum preloaded clay
- Investigate new techniques for achieving the objectives above and using GPS & other technologies in monitoring ground settlement in this approach

– where it has to be right

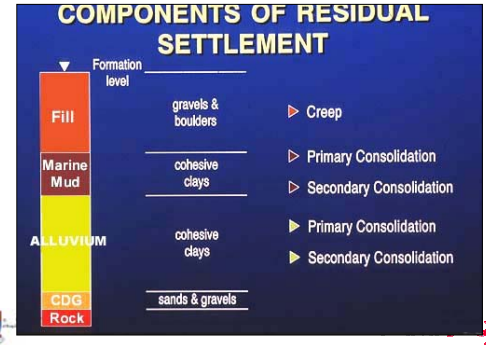
Hong Kong has a Long History in Reclaiming Land



– where it has to be right

Example of a Reclamation Project in Hong Kong

Major Factor to be Considered in Reclamation: Settlement of Soft Marine Mud (Clay)



Two Conventional Methods in dealing with Settlement, by:

1. Removing the Soft Marine Mud (Clay) by Dredging and replacing it by Sand Fill

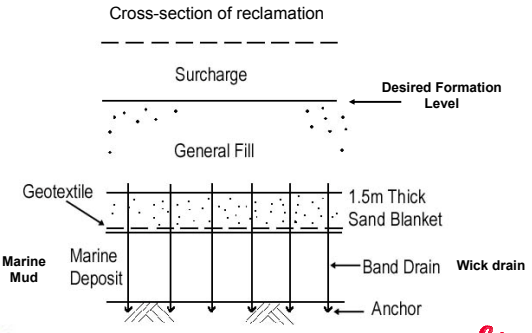
2. Expelling water in the Soft Marine Mud (Clay) by Installing **Vertical Wick Drains** and **Pre-compressing it with heavy load** (Pre-consolidation Process or Surcharging)

Disadvantages of Dredging

- ❖ Adverse environmental impact to the marine ecology during the dredging process
- ❖ Adverse environment impact to the nearby residents
- ❖ Disposal of large volumes of marine mud (Diminishing of dumping ground)
- ❖ Unnecessary large consume natural resources – The more is dredged, the more is the volume of sand required for filling. The more is the sand required for filling, the more dredging is required for sand borrowing.

Mud plumes from dredging

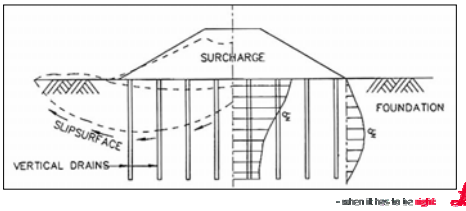
Pre-consolidation Process or Surcharging



Placing of Surcharge and wait for Consolidation to complete

Disadvantages of Pre-consolidation Process

- Cost of Wick Drains is high
- Construction and removal time of surcharge is **more than 2 years**
- Large volume of sand is required to be moved on and off site
- Possible failure if surcharge is constructed too fast
- Quality of wick drains is difficult to control



Set up a Project – and its principle objectives

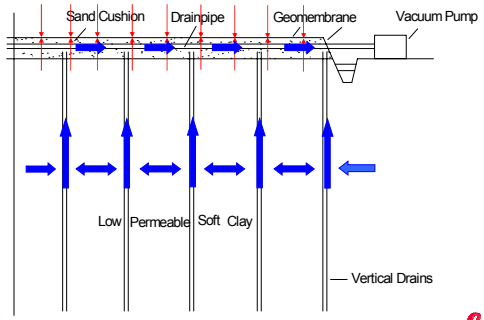
- To investigate a practical **"offshore" vacuum suction technique that could replace conventional dredging** such that environmental problems related to reclamation could be completely eliminated
- To establish **rational design** and **construction guidelines** for improving the strength of soft marine clay in Hong Kong
- To demonstrate the feasibility of the technique in Hong Kong waters by conducting and monitoring **large-scale field tests**
- Introduce **GPS in the monitoring** task and **compare** the result against conventional manual leveling & geotechnical sensor measuring method.

Previous "Onshore" Vacuum Preloading Technique applied in Tianjin (□□) and Qiandao (□□) Harbor Area (shallow water)

Site visits with Tianjin University (□□□□) and Ocean University of China (□□□□□□) in August 2003

Test Site – an area close to Shenzhen Airport

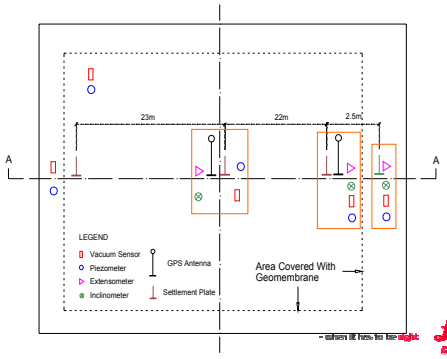
Setup vacuum preloading



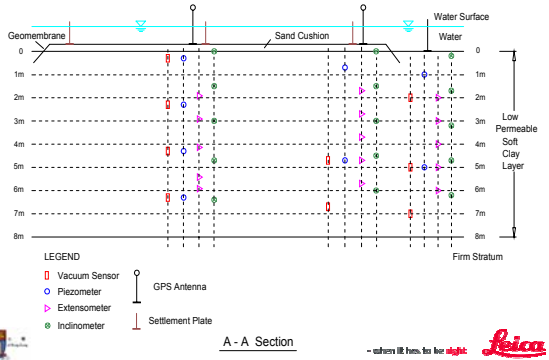
Test Site – apply vacuum suction and installed instruments

Test Site – Apply vacuum suction over water

Installation of instruments: Monitoring Program

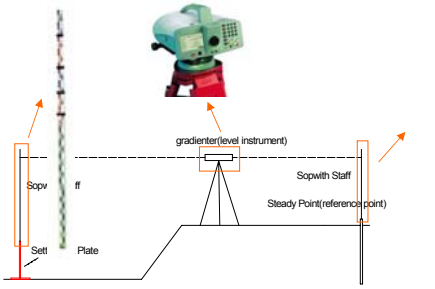


Vertical section of instrumentation installation



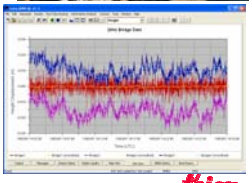
A - A Section

Settlement monitoring by conventional manual leveling



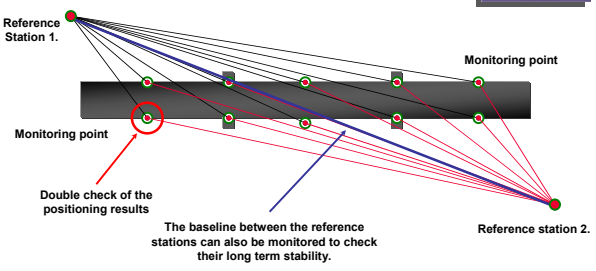
Settlement Monitoring by GPS – WHY ?

- Absolute 3D coordinates measurement including height
- All weather operation
- high measurement rate – up to 20Hz is possible
- Real-time result presentation
- synchronized measurement – provide timing for other sensors
- Good for area that is difficult to access regularly
- can measure over long baselines
- low maintenance and a long service life



Advanced GPS Monitoring Principle

Real-time / Post-processing is possible



Selecting the ideal GPS monitoring receiver

GMX901 vs GMX902 vs GRX1200 GG Pro

Select the GMX901 when you need:

- Lowest cost, single frequency
- 12 channels L1
- 1Hz data rate
- Post processing, short baselines (<10km)

Select the GMX902 when you need:

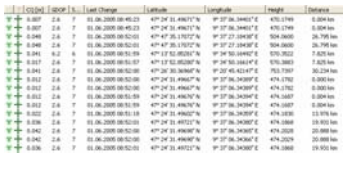
- Low cost, dual frequency, PPS
- 12 channels L1 + L2
- High speed (20Hz)
- Real time, long baselines

Select the GRX1200 GG Pro when you need:

- 72 channels GPS + GLONASS
- High speed (20Hz)
- Onboard logging, web interface

GPS Monitoring Solutions

GPS Management and Processing Software



Leica GPS Spider v2.0 Positioning is the most flexible application software for managing GPS receivers and centrally processing all combination of baselines at high rates (up to 20Hz) with the highest accuracy in both real time and post-processing.

- The results are streamed out through serial ports, TCP-IP ports, files or to an SQL database in various formats like the well known NMEA format for interfacing with analysis software.
- RINEX files can be generated from the real time data stream or by periodical downloading for post processing, archive or in-depth studies of multi-path effects and other investigations.

GPS Monitoring Result Analysis

High Speed Analysis

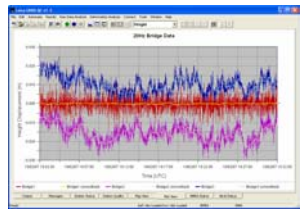
- Data input from NMEA GGA , GGQ and LLQ data stream, files and Spider Post Processing database
- High speed (20Hz) data and graphing of data from serial and TCP/IP

Limit Checks and Messaging

- Three levels of absolute limit checks for each of longitudinal, transverse, height, 2D and 3D displacement
- Messaging (email, SMS, external applications)

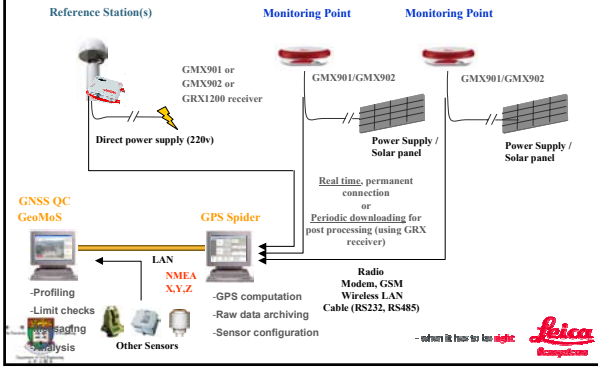
Site Assessment

- Quality check of raw GPS observations
- Multipath and SNR analysis



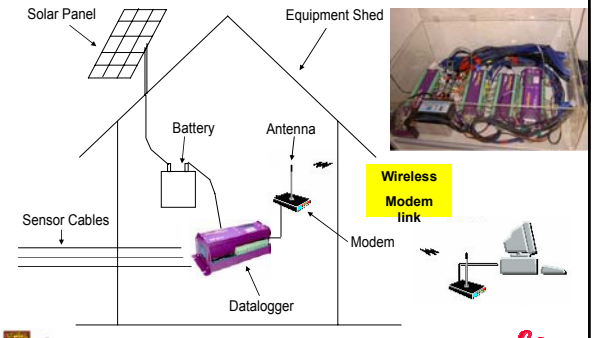
The Plot View tab showing a real time graph of height displacement for three NMEA data streams output by Leica GPS Spider Positioning Products

Advanced GPS Processing with GPS Spider

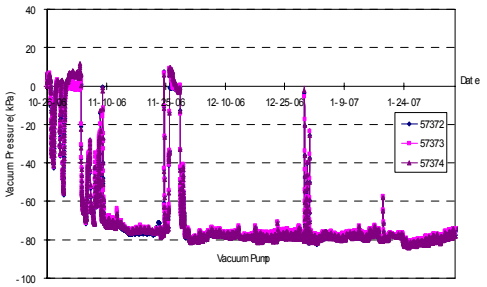


GPS receivers operation – overcame problem of manual leveling in inaccessible areas

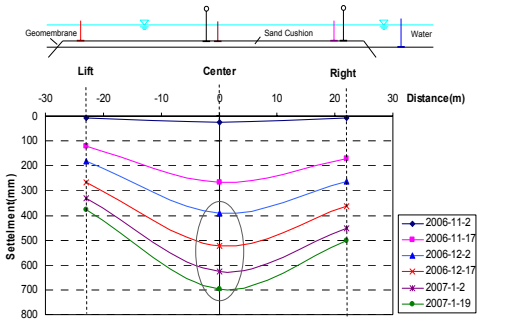
Data Collection and Remote Data Transfer



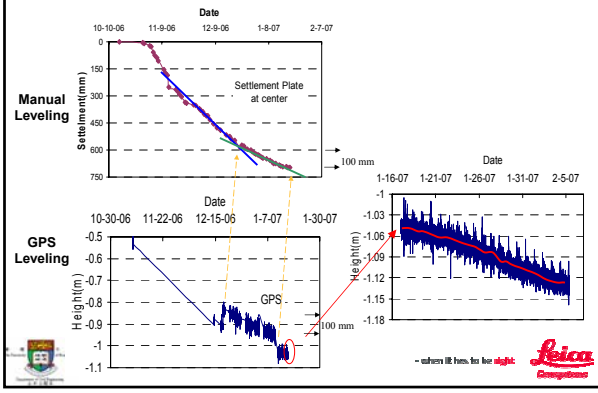
Results: vacuum pumps



Results: Surface Settlement



Results: Leveling vs GPS measurement



Summary

- ❖ Full-scale fully instrumented field test has shown that offshore vacuum preloading is feasible.
- ❖ GPS monitoring result agreed very well with the conventional leveling measurement.
- ❖ GPS proves to be operating in all weather condition and suitable in operating in difficult access location.
- ❖ Remote wireless instrumentation and GPS provided movement measurements in inaccessible areas.

Many Thanks for Your Attention.