THE DEFORMATION STUDY OF HIGH BUILDING USING RTK-GPS : A FIRST EXPERIENCE IN MALAYSIA

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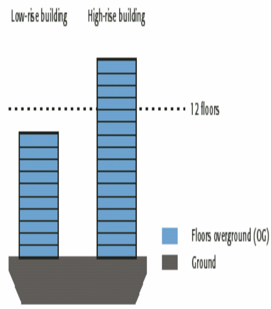
INTRODUCTION

- A high-rise building is defined as a building 35 meters or greater in height, which is divided at regular intervals into occupiable levels, and require the use of a system of mechanical vertical transportation such as elevators
- The most important safety factor for high buildings is the building's need to withstand the lateral forces imposed by strong winds and potential ground movements, e.g. earthquake,tsunami, etc



Defined by the Public Works Ministry, Malaysia

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- Nowadays, one of the prime tasks is to adopt quantitative and accurate building inspection (monitoring) methods to ensure the safety of it's
- Furthermore, aging of our national high buildings inventory and the fact that all of them are carrying loads have significantly increased the need over the past few years to monitor high building performance.
- The geodetic terrestrial data (total station, levelling, CRDP, and the satellite data system through the GPS technology is capable of giving deformation conditions of large engineering structures (Dams, Building, bridges, etc).

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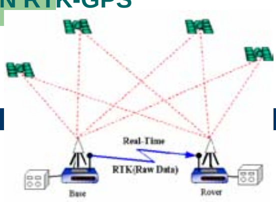
- The terrestrial methods, however would be time consuming and costly when applied to the monitoring of larger survey networks, network geometry dependent, and need site intervisibility condition.
- In contrast, the GPS technology can measure directly the position coordinates in which relative displacements can be measured at rates of 10Hz and higher.
- This provides a great opportunity to monitor, in real time, the displacement or deformation behavior of the structures under different loading conditions and implement 'alarm notification' procedures.

REVIEW ON RTK-GPS



- This approach is a differential positioning technique that uses known coordinates of a reference station occupied by one 'base' receiver to determine coordinates of unknown points visited by a 'rover' receiver.
- The technique employs carrier phase measurements, and processing is carried out in real time, giving computed coordinates at reasonable accuracies.
- To process the data in real time, the reference station coordinates and measurements are transmitted to the rover via data links.

THE EXPERIMENT

- The experiment is done at Sarawak Business Tower (build in 1991) which is strategically located at Johore Bahru, Johore Malaysia. It is one of the tallest building in the Southern region.
- The State of Johore has no seismic loading provision but a 'distant earthquakes' (or tsunami) from Sumatra & Java (Indonesian) and wind loading from the Malacca Straits has usually been considered as the major form of lateral loading on the building.
- Built to withstand earthquake of up to 7.0 Ritcher scale, the building's structure is consisted of 30 storey tower with vertical elevators. The tower houses some government offices, commercial offices, department stores, shops and restaurants.

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- In our experiments, we had used dual frequency GPS receivers Leica System 500 with RTK facilities.
- The RTK-GPS monitoring campaign has been carried out for Sarawak Business Tower on 21 December 2004 until 23 December 2004.
- One control station (B1) is being established using static GPS from 1st. order GPS station (DSMM) and VRS station for RTK measurements.
- One monitoring point (R1) have been identified and surveyed (placed on the roof top corner of the building).

The Control Point, B1

Control Station for RTK experiment

LEICA System 500

The Monitoring Station, R1

RESULTS & ANALYSIS

Table below shows the result adjustment of the data observation for coordinate transfer from geodetic reference stations to control station (base station for RTK measurement) - B1.

Point Name	Latitude	N error	Longitude	E error	Height	h error
B1	1°27'45.14692"N	0.004m	103°46'26.01444"E	0.007m	11.261m	0.011m
J416	1°27'42.54339"N	0.000m	103°46'24.05429"E	0.000m	11.297m	0.000m
JHJY	1°32'12.55948"N	0.000m	103°47'47.47728"E	0.000m	38.560m	0.000m

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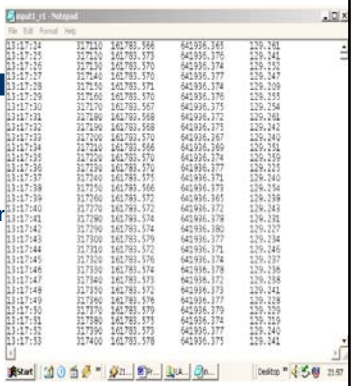
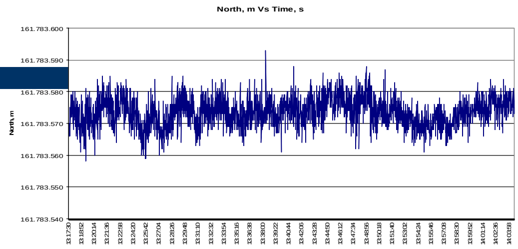


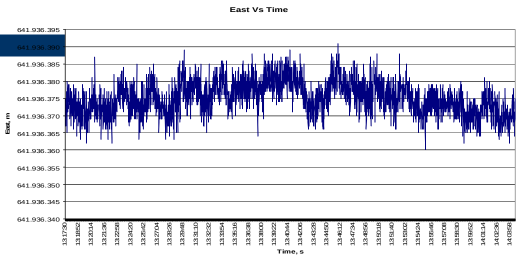
The figure shows the data observation (in local coordinates) of continuous RTK for Base 1 (B1) and Rover 1 (R1) using Leica System 500 with 1 second sampling rate with AT502 (Normal) Antenna.

The Dynamic Variation For Monitoring Point R1 – (N_{RSO} local coordinates)



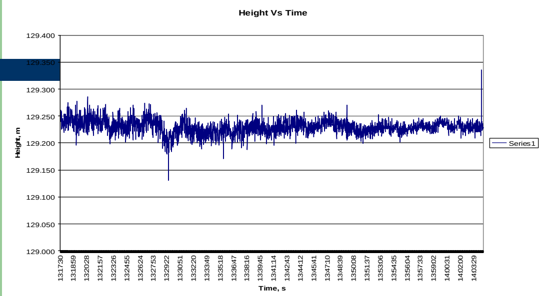
- The attainable precision of position for the monitoring point R1 is within 1cm. However, few 'spikes' is occurred during the measurements. This may due to the shading and diffraction effects caused by helipad platform on the building and/or the multipath which mainly came from nearby buildings (e.g.hotels)

The Dynamic Variation For Monitoring Point R1 - E_{RSO} local coordinates



- The attainable accuracy is quite similar to northing component.

The Dynamic Variation For Monitoring Point R1 – Ellipsoid Height



As expected, the attainable precision of vertical for the monitoring point is about 2-3x the horizontal components.

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- A Kalman Filter program had been developed using Matlab version 6.1 for building structural monitoring analysis.
- The main input is coordinate,variance-covariance matrices for every position/epoch => filtering and predicted process => perform statistical test => graphical outputs
- Each filtering step in the program takes five observations (5seconds) into account to discard the irrelevant data (loss of lock).
- The structural monitoring analysis is performed in three dimensions: north, east, and height.

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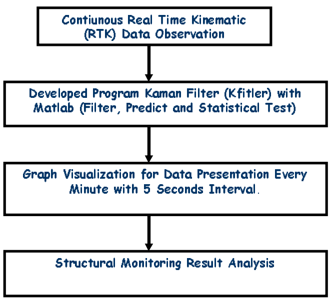
- The program generated an output file which contained single point test of three analysis components (north, east, and height).
- If all statistical test of all three components are smaller than t-table, then it can be considered as no deformation.
- If any of the three components has values larger than t-table, there are some displacements the point.

Flow Chart of Stage Analysis



SOME EXAMPLE OF THE Kfilter PROGRAM

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... Cont...
...
%% Input Data : Coordinate & Variance Covariance    For RTK method..............................
for  i = 1 : bil(1,1);
SumXX = SumXX + XX(i);
SumYY = SumYY +  YY(i);
SumHH = SumHH + HH(i);

   if limit == t;
   MX = SumXX/t;
   MY = SumYY/t;
   MH = SumHH/t;
   Xi = [MX
       MY
       MH];
   % Variance covariance for each position ..........every epochs
    Wi = [0.01    0   0
          0    0.01   0
          0    0   0.02];
    % Process Filtering & predicted start...............
    X1= M*X;    %predicted position
    CX1 = M*Cx*M'+Cy;   %Variance Covariance predicted
    G = CX1 *A'*inv(A*CX1*A'+Wi);   %Compute G matrix
    Fx = X1 + G*(Xi - A*X1);    %Compute final state vector
FCX=(I-G*A)*CX1;          %Computer final variance covariace state vector.

   % Process STOP here...............................
   % Process Statistic Test..........start............
   %d = Xi - A*X1;
   %Qd=Wi + A*CX1*A';
   % Ho : E[dk+1]= 0, H1 : E[dk+1] =/ 0. If Ho is true, the computed results are accetable.
   % (Yalcinkaya, 2003) ==> Local Test.... Not gross errors inside the data!
   ............
   .........  cont...
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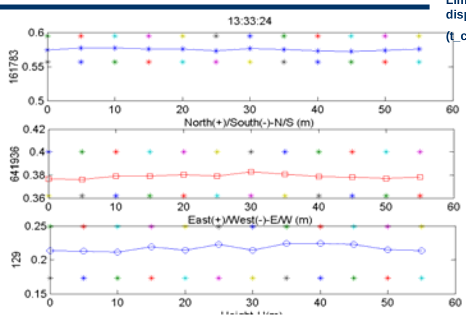
Structural Monitoring Analysis

*** Graphical outputs**

Limitation of displacement (t_comp)



Example of Deformation Report

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--------------Single Point Test------------------

Difference	t-calculate	t-table	Result
-0.002	0.20	1.96	Stable
0.000	0.04	1.96	Stable
-0.001	0.07	1.96	Stable

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--------------Single Point Test------------------

Difference	t-calculate	t-table	Result
0.002	0.18	1.96	Stable
0.004	0.42	1.96	Stable
-0.003	0.14	1.96	Stable

Conclusion

- **Our experimental data demonstrate the real time capability of continuous RTK-GPS monitoring to determine the safety behavior of the building.**

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- **Our next experiment is to do some GPS observations after Tsunami disaster strike Acheh (Indonesian) and the West Malaysian coastal areas (on 26 Disember 2004)**
- **Something to be considered : our 1st. Order GPS network has moved from approx.7cm – 20cm after the tsunami disaster !!**

THANK YOU