TS 19.5 Deformation Measurements and Analysis II

Assessment Of Satellite Based And Terrestrial Measurement Techniques In Monitoring Vertical Deformations

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Content of Presentation

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INTRODUCTION AND BACKGROUND - 1

To determine the deformations of an object or an area that is figured out by the points of geodetic network for this aim is included in the main interests of the geodesy science. After starting to use Global Positioning System (GPS) with geodetic aims in the world wide, this satellite based positioning system has also become a dominant technique in deformation measurements branch of geodesy. GPS measurement technique satisfies the needed accuracy for deformation measurements in 2D positioning but it seems that this very technologic measurement system can not be sufficient in vertical component (heights) as well as the 2D coordinates. Because of this, GPS measurements are needed to support by another conventional technique, which is precise levelling technique

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INTRODUCTION AND BACKGROUND - 2

The aim of this study is analyzing the vertical deformations of an engineering structure using GPS and Levelling measurements data. During the analysis, three different approaches were applied. In the first and second approaches, height differences from precise levelling measurements (ΔH) and from GPS measurements (Δh) were used in the analyzing algorithm separately, but in the third approach the combination of height differences (Δh and ΔH) were used in the deformation analyzing procedure. In combining process of two observables groups (Δh and ΔH), Helmert Variance Component Estimation Technique is used during the determining the weights of observables as the stochastic part of the model.

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THEORY OF DEFORMATION ANALYSIS - 1

In general, the deformation analysis is managed in three steps in geodetic networks.

In the first step, the measurements, which were carried out in the measurement epochs, are adjusted separately according to free adjustment method

In the second step, global test procedure is carried out

After determining a group of stabile points as the results of global test, the next step starts

In the third step, the deformation points are handled one by one and it is inspected that if their positions are changed or not

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Deformation Analysis with Levelling Measurements

To test the changes of heights in points of a control network, The network is adjusted separately using these measurement groups. During these calculations, free network adjustment method is used. In the calculations, outliers are eliminated and calculations repeated.

The second step of analysis is global test. With this test, it is determined if there is any vertical displacement in a point or a group of point in the interval.

In the next step, the deformation points are handled one by one and it is inspected that if their positions are changed or not

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Deformation Analysis with GPS Derived Height Differences

Determining vertical deformations using GPS derived height differences is based on the same calculation algorithm as deformation analysis with precise levelling data .

In the algorithm, the ellipsoidal height differences (dh_{ij}), which were derived from the GPS baseline solutions, are used as measurements.

Also, the stochastic information of measurements comes from the GPS baseline solutions.

Combined Deformation Analysis - 1

In this approach, height differences, derived from both measuring techniques, are used together and deformation analysis is applied according to results of evaluation of combined data groups. A very important point that the both measurements groups derived from both techniques do not have the same accuracy. And so, the stochastic information between these measurements groups relative to each other has to be derived.

In this study, for computing the weights of both measurement groups derived from GPS measurements and levelling measurements respectively, Helmert Variance Component Estimation (HVCE) Technique have been used.

Combined Deformation Analysis - 2

Variance analysis technique has an increased importance especially after satellite based measurement techniques have become widely used in geodetic applications.

Because, satellite based measurements and terrestrial measurements are used together with in a same project to serve the same purpose.

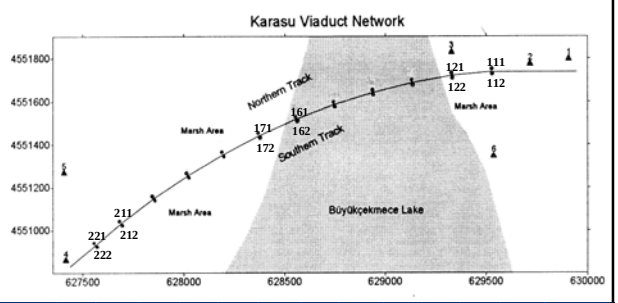
However, with this aim, when combining these measurements is necessary, the correlation between them and different weights of each measurement group causes problems in the computation algorithms. Because of that it is difficult to put together the measurements, which doesn't have the same accuracy.

NUMERICAL EXAMPLE - Definition of the Study

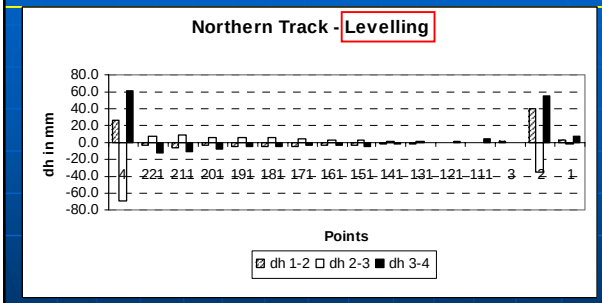
In this study, the vertical deformations of highway viaduct, Karasu, were investigated using GPS measurements data and precise levelling data. As the longest viaduct of Turkey (2160m), Karasu is located in the west of Istanbul in one part of the European Transit Motorway and the viaduct cross over the lake and piers of the building are in the water.

During the measurements the used control network had 6 reference points and all these points were set around the viaduct and on the building of the viaduct, there are 24 deformation points, which were located on the piers of the viaduct (in the next slide)

The configuration of the geodetic network

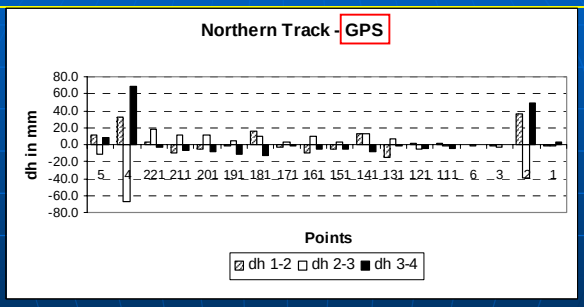


Evaluating of Deformation Analysis Approach - 1



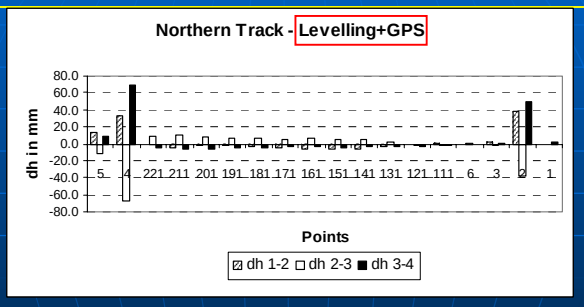
Height differences between consecutive epochs in the northern track

Evaluating of Deformation Analysis Approach - 2



Height differences between consecutive epochs in the northern track

Evaluating of Deformation Analysis Approach - 3



Height differences between consecutive epochs in the northern track

Interpreting of the Results - 1

As it is mentioned previously, the deformation analysis was carried out into three approaches. At first data from both measurement techniques were processed for each epoch separately. Thus, the results from independent solutions for each epoch were compared. This was necessary for getting information about the quality of data, revealing possible inherent problems and to get apriori information about instable points and by this way to determine a suitable strategy for analysis.

Interpreting of the Results - 2

As the result of this preparation process, it was seen that precise levelling measurements made very beneficial support to GPS measurements. Because by the help of levelling, it is become possible to check the heights from GPS measurements and antenna heights problems occurred during GPS sessions were able to be clarified. This is very considerable contribution of levelling measurements to GPS measurements in deformations monitoring .

Interpreting of the Results - 3

In general meaning, the results of these three deformation analysis calculations are confirmed each other. In the results of them, it is surprisingly found that the maximum height changes were in point 2 and point 4, which were assumed as stabile at the beginning of the study and their constructions are pillar.

In the third approach, as a result of the Helmert Variance Component Estimation it was computed that the weight of height differences from levelling equals to 30 times over of the weight of GPS derived height differences. This result was reached in the third iteration step.

Interpreting of the Results - 4

As the graphics of the first, the second and the third approaches are compared, it is seen that the results of the third approach is closer to the first approach. This similarity shows that it is not reliable enough to use GPS measurements without special precautions for the GPS error sources, such as multipath, atmospheric effects, antenna height problems etc., in vertical deformation analysis of engineering structures. So, as the result of this study, it is suggested to support GPS technique with levelling measurements in monitoring vertical deformations .

Interpreting of the Results - 5

However, at a first glance, it was surprising to found deformations in point 2 and point 4 that had been chosen as reference points, after geological and geophysical investigations, the origin of these results was captured. According to that the area is a marsh area that this characteristic might widen also underneath of these two reference points, 2 and 4. The uppermost soil layer in the region is not seemed to be stabile and the foundations of the constructions of the reference points are not founded as deep as the piers of the viaduct and so they are affected by the environmental conditions easily .

CONCLUSION AND REMARKS - 1

The main motivation was testing the performance of GPS as a satellite based precise positioning system in determining vertical deformations as being aware of geometrical weakness of this system and error sources affects its vertical positioning accuracy. To determine the performance of it, the results of analysis of the data derived from GPS are compared with the results of analysis of precise levelling measurements.

CONCLUSION AND REMARKS - 2

As the first remark, GPS measurement technique can be used for determining vertical deformations with some special precautions for eliminating GPS error sources.

These include using forced centering mechanisms to avoid centering errors, using special equipments for precision antenna height readings, using special antenna types to avoid multipath effects etc.

Also, during the data processes it is necessary to clear the cycle slips from the data, and to consider insufficiencies of the used tropospheric and ionospheric models .

CONCLUSION AND REMARKS - 3

However, even though these precautions, to provide better results in vertical deformation analysis, GPS measurements have to be supported with Precise Levelling measurements.

It was seen that precise levelling technique gives more successful and reliable results according to GPS technique in determination of vertical deformations, while the first and the second analysis approaches were compared each other.

And using the combination of GPS measurement technique and precise levelling technique gives better results than using just GPS measurement technique as it can be seen in the third deformation approach .

CONCLUSION AND REMARKS - 4

Hence, using the combination of levelling measurements and GPS measurements together in deformation analysis algorithm gives better and more reliable results in vertical deformation analysis.

And on the other hand, levelling provides an opportunity to check antenna heights errors and by this way it helps to increases the quality of GPS data, and according to this, using levelling measurements as an auxiliary technique during the deformation measurements in addition to GPS is also be beneficial for the 2D deformation analysis with GPS measurements .

Thank you for your attention . . .