Modern Height Determination Techniques and Comparison of Accuracies

Ayhan CEYLAN, Cevat INAL, Ismail SANLIOGLU
Turkey

The Egyptian Committee of Surveying and Mapping (ECSM) · Egyptian Survey Authority (ESA) · International Federation of Surveyors (FIG) · Global Spatial Data Infrastructure (GSDI)

PRESENTATION PLAN

1. Introduction
2. Definition and Analysis of the Height Determination Techniques
3. Numerical Application
4. Conclusions

Introduction

Nowadays, not only in academic studies but also in engineering works it is run into problems of determination of height differences between points or the height of points.

- Surveying of levelling networks
- Vertical applications, maintenance and control measurements of big structures like bridge, dam, very tall buildings, and tower.
- Determination of vertical crustal movements
- Motorway, railway, sewer and pipeline measurements.

In this study, accuracies of height determination techniques have been compared with each other according to used instrument, and measurement method

Definition and Analysis of The Height Determination Techniques

Geodetic methods for determining of heights or height differences:

according to used surveying instruments and applied measurement method

- Geometric Levelling
- Trigonometric Levelling
  - Unidirectional trigonometric levelling
  - Leap-Frog (jumped) trigonometric levelling
  - Reciprocal trigonometric levelling
- GPS/Levelling

Definition and Analysis of The Height Determination Techniques

Geometric Levelling

1. using level and hold vertical rods
2. very difficult on the rough ground and sensitive to regular or irregular model errors
3. To eliminate or reduce model errors stemmed from instrumental and outer surroundings, the preventative measures must be taken , such as:
   a. using Schwartz or Red pants methods
   b. applying appropriate measurement methods
   c. taking equal backward and forward observation range

Definition and Analysis of The Height Determination Techniques

Geometric Levelling

d. the round trip surveying,
e. following BFFB (backward forward forward backward) or FBBF (forward backward backward forward) observation order
f. surveying calibration in lab and
g. surveying additional parameters such as pressure, temperature and time at the survey moment

Definition and Analysis of The Height Determination Techniques

Nowadays, also motorized geometric levelling applications have been done by establishing survey hardware on the land vehicle, thus successful results have been obtained. According to geometric levelling, the advantages of the motorized levelling may be summarized as below;

- Improve 40-60% in production velocity
- Decrease errors connected to time
- More observation ray, thus decreasing asymmetric refraction error
- More accuracy

Definition and Analysis of The Height Determination Techniques

Geometric Levelling

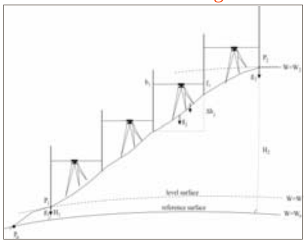

Figure 2. The survey model of the geometric levelling

Definition and Analysis of The Height Determination Techniques

Unidirectional Trigonometric Levelling

$$\Delta h_{ij} = \left(S_{ij} . \cos Z_{ij}\right) + \left(\frac{S_{ij}^2}{2R_m} . \sin^2 Z_{ij}\right) - S_{ij} . \left(\varepsilon_{ij} + dZ_{r}\right)\left(\sin Z_{ij}\right)$$

Fonksiyonel model of the unidirectional trigonometric levelling

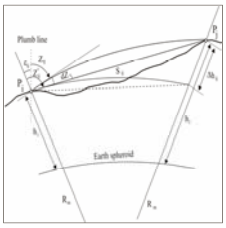

Figure 3. Survey model of the unidirectional trigonometric levelling

Definition and Analysis of The Height Determination Techniques

Reciprocal Trigonometric Levelling

$$\Delta h_{ij} = \frac{1}{2}\left(\begin{array}{l} S_{ij} . \left(\cos Z_{ij} - \cos Z_{ji}\right) + \frac{S_{ij}^2}{2R_m}\left(\sin^2 Z_{ij} - \sin^2 Z_{ji}\right) - \\ S_{ij} . \left(\varepsilon_{ij} + dZ_{r_i}\right) \sin Z_{ij} + S_{ij} . \left(\varepsilon_{ji} + dZ_{r_j}\right) \sin Z_{ji} \end{array}\right)$$

Fonksiyonel model of the reciprocal trigonometric levelling

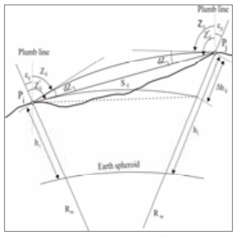

Figure 4. Survey model of the reciprocal trigonometric levelling

Definition and Analysis of The Height Determination Techniques

Leap-Frog (jumped) trigonometric levelling

$$\Delta h_{ij} = \left(S_{kj} . \cos Z_{kj} - S_{ki} . \cos Z_{ki}\right) + \frac{1}{2R_m}\left(S_{kj}^2 . \sin^2 Z_{kj} - S_{ki}^2 . \sin^2 Z_{ki}\right) - S_{kj}\left(\varepsilon_{kj} + dZ_{r_j}\right)\left(\sin Z_{kj}\right) + S_{ki}\left(\varepsilon_{ki} + dZ_{r_i}\right)\left(\sin Z_{ki}\right)$$

Fonksiyonel model of the Leap-Frog (jumped) trigonometric levelling

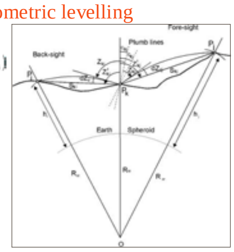

Figure 5. Survey model of the Leap-Frog (jumped) trigonometric levelling

Definition and Analysis of The Height Determination Techniques

GPS / Levelling

The ellipsoidal heights obtained by GPS are not directly used for practical surveying. The ellipsoidal height has to be transformed to orthometric height, which is distance measured along the plumb line between the geoid and a point on the Earth's surface and taken positive upward from the geoid.

Definition and Analysis of The Height Determination Techniques

GPS / Levelling

h = H + N

h: ellipsoidal height
H: orthometric height
N: geoid height

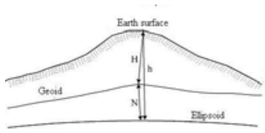

Figure 6. Relationship between ellipsoidal height and orthometric height

NUMERICAL APPLICATION

Definition of the Study Area and Area Surveys

A levelling line with 11 points that are 50m spaced on the same line, was established throughout east-west direction in Alaeddin Keykubat Campus area of Selcuk University with the aim of searching accuracies which are obtained by geometric levelling, trigonometric levelling, GPS/levelling using the most recent and advanced technological equipments

The measurements were performed independently from each other as combinations with different equipments all the way through line. The fifty-five height differences among points were computed.

NUMERICAL APPLICATION

Definition of the Study Area and Area Surveys

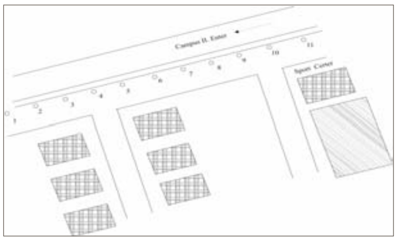

Figure 7. Levelling line

NUMERICAL APPLICATION

Used Equipments in Geometric Levelling

1. First equipment has one Wild N3 precision level and two invar rods that are divided to two-party and three meter in length.
2. Second equipment has one Sokkia B2 automatic level and two wooden rods that are three meters in length.
3. Third equipment has one Sokkia SDL30 digital level and two bar coded aluminum rod that is five meter in length. All rules that must be taken into consideration were carried out carefully in the geometric levelling surveys.

NUMERICAL APPLICATION

Used Equipments in Trigonometric Levelling

1. First equipment has one Topcon GTS 701 electronic total station, Wild T2 theodolite, five prisms, and target table.
2. Second equipment has one Topcon GTS701 total station, five prisms, and target table.
   In the trigonometric levelling with first equipment, the distances among the points were measured by using Topcon GTS701 total station and the vertical angles were reciprocally measured by using Wild T2 theodolite as four series. The heights of instrument, prisms, and target tables were measured in mm level. Both distances and vertical angles were measured by using Topcon GTS701 total station in the trigonometric levelling with the second equipment.

NUMERICAL APPLICATION

Used Equipments in GPS Levelling

Five Leica GPS receiver and set were used in GPS surveys. The GPS surveys were realized by using static method with 30 minutes sessions. GPS data were processed by SKI 2.3 GPS software after downloading to computer. The ellipsoidal heights were obtained in conclusion of the processing. Geoid heights were taken from study made beforehand at the same area

NUMERICAL APPLICATION

Processing of Surveys

The height differences of precise levelling were assumed as true values in computation of the accuracies of measurements that were made by every one of the equipment. By means of ε true errors, root mean square errors (RMSE) of height differences were computed as follows

$$m = \mp\sqrt{\frac{[\varepsilon\varepsilon]}{n}}$$

n : the number of measurements.

NUMERICAL APPLICATION

Processing of Surveys

The root mean square errors computed according to different measurement methods, different equipments, and their measurement times.

Levelling method	Equipment	RMSE (mm)	Total Time (Hour)
Geometric Levelling	SOKKIA B2 Automatic Level and Wooden Rods	±3.7	31
	SOKKIA SDL 30M Digital Level and Bar coded Rods	±2.0	18
Trigonometric Levelling	WILD T2 Theodolite TOPCON GTS 701 Total Station	±16.4	25
	TOPCON GTS 701 Total Station	±14.7	17
GPS/ Levelling	LEICA 9500 GPS receiver and set	±18.8	5

CONCLUSIONS

When table 3 and the results of the present written sources are investigated, questions of which levelling method must be carried out and in which occupation may be answered as follows:

- If there is a geoid information at levelling in rural area in which density of point is so low and in which shadow area is not formed because of tree, etc., the GPS/levelling method must be chosen. In the opposite situations, the geometric levelling method with digital level or the trigonometric levelling method with total station may be chosen.

CONCLUSIONS

- It is appropriate to choose the geometric levelling with digital level or the trigonometric levelling with total station at levelling in urban area or semi-urban area in which density of point is so high.
- If the deformation surveys are carried out in big structures as bridge, dam, GPS receivers may be used for observations on condition that they are not far from the reference points. In addition, the precision levelling method should be chosen by using digital level with invar rods or optic-mechanic level in type of these deformation surveys.

CONCLUSIONS

- In construction projects as highway, railway, smoothing area, the GPS/levelling, the trigonometric levelling with total station, the geometric levelling with digital level, and laser level may be chosen respectively.

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