ГОДИШНИК НА УНИВЕРСИТЕТА ПО АРХИТЕКТУРА, СТРОИТЕЛСТВО И ГЕОДЕЗИЯ СОФИЯ

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DISCREPANCIES AND MISCLOSURES IN THE THIRD LEVELLING OF BULGARIA

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Keywords: *precise levelling, errors, discrepancies, differences, misclosures*

ABSTRACT

In order to investigate the expediency of the allowable differences between both independent measurements among bench marks in the sections, lines and loops of our First Order Levelling Net, the data of the Third Levelling of Bulgaria have been analyzed.

Using simple graphical visualization techniques is made an attempt at clarifying of the relationship between the length of the sections, lines and loops and the accumulated discrepancies in the measured elevations and misclosures, respectively.

Analyzing the above-mentioned data, a heteroscedasticity of the distribution of the discrepancies is detected.

1. Introduction

Despite developing of GNSS measurements the First Order Levelling still leaves the most accurate method for vertical measurements [1]. Based on this fact the method is commonly applied for monitoring of the Earth's crust [2 – 5], tectonic investigations [6], monitoring of vertical movements of constructions [7 – 8], etc. Owing to the importance of this approach there are strict recommendations and prescriptions on how measurements have to be executed [9 – 11]. Differences in territory, relief, economic and political environment, development of the levelling equipment [12], etc. reflect on the methodology of execution of the precise levelling. Consequently, each country has different criteria of the allowable discrepancies in the levelling sections and lines and acceptable misclosures in the levelling loops. According to [9] the allowable difference between both forward and backward measurements of the elevation between two bench marks in the sections, lines and loops in Canada can be given by equation (1).

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$$|D| \le 3mm\sqrt{L}\,, \tag{1}$$

where L is the levelling distance between two bench marks in the sections, lines or loops in km.

Based on the previous experience the authors of [9] have remarked that 16% of the measurements in the sections, lines and loops can't meet the above requirement and must be relevelled.

The limit (1) is also used in the first order levelling in Russia [10] when the number of the stations in the measured sections are less than 15 per km. In order to avoid rejecting measurements in the mountain areas, [10] define additional looser criterion in these cases when the number of the stations in the measured sections are greater than 15 – (2).

$$|D| \le 4mm\sqrt{L}\,. \tag{2}$$

This fact is a small step ahead in differencing the mountain crossing lines from these ones which pass through a flat terrain.

The Old Bulgarian instruction [13] defined the allowable discrepancies of the sections, lines and loops by equations (3), (4) and (5), respectively.

$$|d| \le 1,5mm\sqrt{l}\,. \tag{3}$$

$$|D| \le 2,25mm\sqrt{L}\,. \tag{4}$$

$$|W| \le 1,5mm\sqrt{F}\,. \tag{5}$$

In equations (3)-(5) l, L and F are the levelling distances between two bench marks in the sections, lines and loops in km, respectively.

Without any consideration equations (3)–(5) have been added in [11]. Due to this fact the criticism [14] seems to be reasonable.

The first goal of this article is to support those part of the conclusions which were made in [14] concerning the vertical control with utilizing of simple graphical visualizations.

The second one is to illustrate some lows of heaping up of the discrepancies and misclosures of the Third Levelling of Bulgaria /1975 – 1985 year/ [15].

2. Discrepancies in the sections

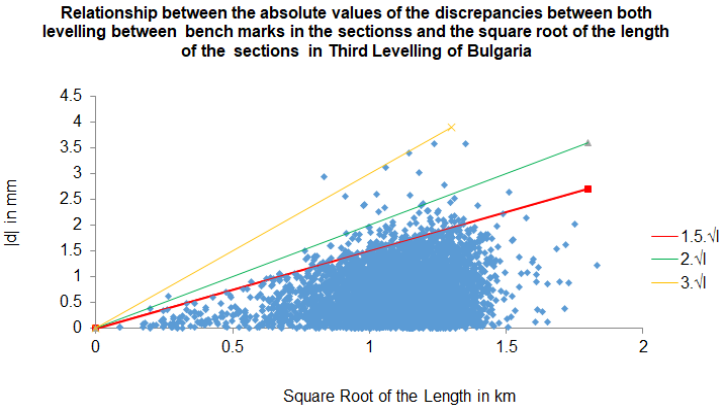

Fig. 1. Discrepancies in the sections

Looking at Fig. 1 one can see that:

A. The limit of the differences between both forward and backward measurements of the section elevations given by (3) is too ambitious. What is more, this criterion can't be meet in those sections which contain routes with huge elevations as were shown in [16].

B. The second limit, which is pictured in green in Fig. 1 and is close to (4) seems more reasonable than (3). It is obvious that only 15 out of 4573 sections don't meet it.

C. The third limit, which is pictured in yellow and given by (1), was not satisfied only in one section. Despite being appropriate in the mountain regions this criterion is too loose in the main part of the sections.

D. The spread of the discrepancies in the analyzed **4573** sections is triangle shaped along the square root of the length. This fact clearly shows a presence of a heteroscedasticity and raise a question about relationship between section discrepancies and the square root of the length of sections. Furthermore, the question about appropriate weights of the section elevations seems to be more a rule of the thumb than a proven scientific fact.

3. Discrepancies in the lines

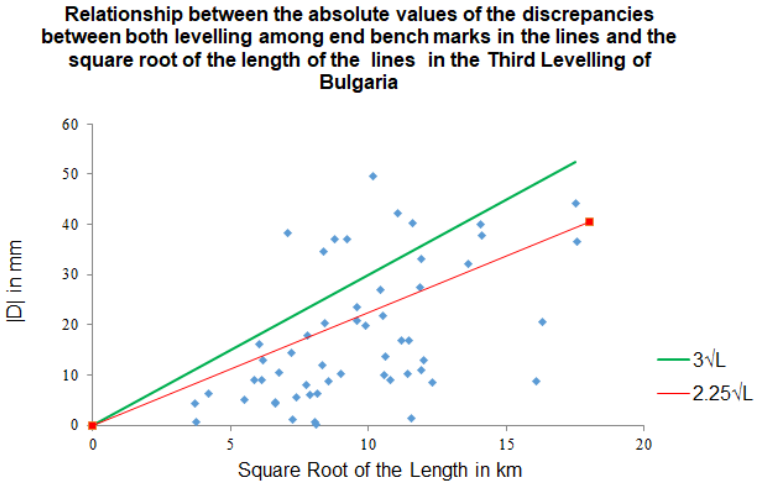

Fig. 2. Discrepancies in the lines

Looking at Fig. 2 it is obvious that:

A. The limit of the differences between both forward and backward measurements of the line elevations given by (4) is too ambitious. One can count that 18 out of 55 lines or 33% of all lines in the Third Levelling of Bulgaria weren't able to satisfy this requirement.

B. The limit given by (1), which is pictured in green in Fig. 2 seems more reasonable than (4). The limit (1) wasn't met only in 7 out of 55 lines and again those are mainly mountain crossing lines.

C. The spread of the discrepancies in the analyzed **55** lines is triangle shaped along the square root of the length of the lines. This fact clearly shows a presence of a heteroscedasticity and raises a question about relationship between line discrepancies and the square root of the length of the lines. Furthermore, the question about appropriate weights of the line elevations of the Third Levelling of Bulgaria doesn't seem to meet the classic theory. Analyzing the Second Levelling of Bulgaria and one third part of the Second Levelling of Finland [16] has been shown that there is a stronger relationship between the discrepancies |D| in the lines and the accumulated absolute elevations ∑|h| along the lines than between |D| and the square root of their length.

4. Misclosures of the loops

The misclosures of the loops produced in the Third Levelling of Bulgaria are pictured in fig. 3. It is important to say that the analyzed misclosures don't contain a gravimetric correction. Thus, they are raw misclosures.

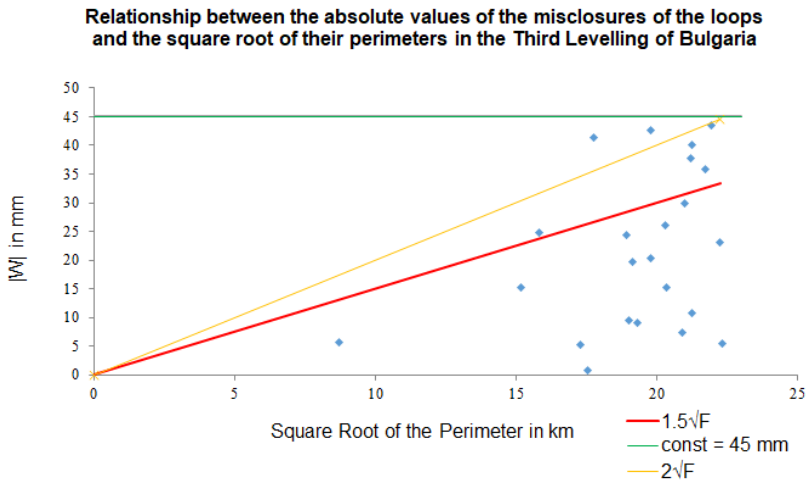

Fig. 3. Misclosures in the loops

Looking at Fig. 3 can be seen that:

A. The limit of the differences between both forward and backward measurements of the line elevations given by (5) is both ambitious and unreasonable. One can count that 7 out of 23 loops or 23% of all loops in the Third Levelling of Bulgaria weren't able to satisfy (5).

B. According to Fig. 3, if the coefficient of 1,5 in (5) had been replaced to 2 only about 10% of the loops would not satisfy the limit.

C. As mentioned above the limit (5) is unreasonable owing to the fact that the misclosures are column shaped where upper band is close to 45 mm. Looking at Fig. 3 one can see that the spread of the misclosures seems to be more similar to a noise than a trend.

Fig. 3 clearly shows that the misclosures of the loops are not function of their lengths. One strong argument in this direction is the misclosure of the ring loop which is only 2,85 mm but the length of the loop is 2550,18 km.

5. Let put all things together

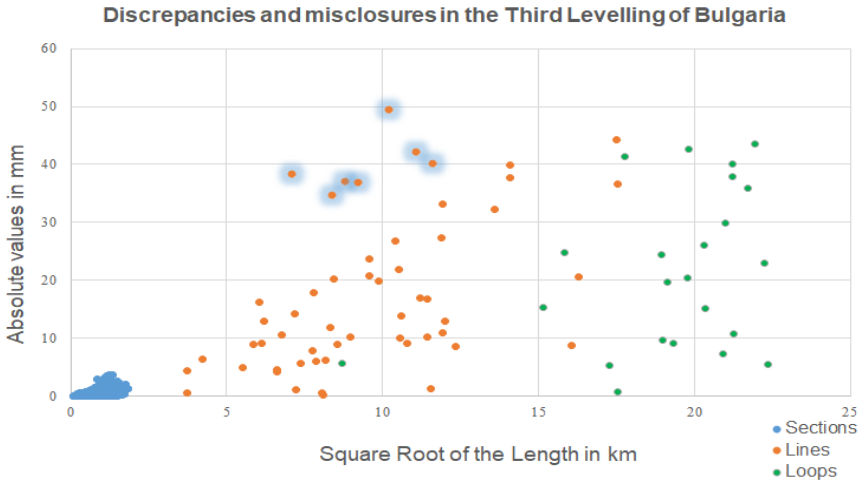

Fig. 4. Discrepancies and Misclosures

Fig. 4 gives a general point of view about the lows of accumulation of the discrepancies and misclosures in the Third Levelling of Bulgaria. It is easy to see that:

A. The errors are trapezium shaped. This fact implies of a presence of a heteroscedasticity along the sections, lines and loops. Therefore, the limits (1)–(5) may not be the best ones.

B. The discrepancies in the mountain crossing lines / marked outliers / are equal or greater than the greatest misclosure in the loops even though their length is 2 – 3 times shorter than the perimeters of the loops. This fact clearly shows that the classic theory about the lows of accumulation of levelling errors in our country should be revised [16].

C. Up to 200 km the lines have systematic heaping of discrepancies but after this length there is some compensation which leads to the fact that the misclosures of the loops can't leap over some value. According to Fig. 4 this value is approximately equal to the discrepancy of the line with the greatest length.

6. Conclusion

We cannot solve our problems with the same thinking we used when we created them [17]. This Einstein's thought is fully relevant concerning the precise levelling in Bulgaria. It needs further investigations to define more appropriate vertical control limits than (3)–(5), which according to Fig. 1 – Fig. 4 are not suitable for the territory of Bulgaria. It needs

different thinking in order to understand the lows of accumulation of the errors in the precise levelling as a whole and based on this knowledge to produce relevant vertical control criteria.

To be this possible the levelling data [15] have to be digitized in an open file format and to be easily acceptable [18] by analyzers for further investigations.

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НЕСЪОТВЕТСТВИЯ И НЕСЪВПАДЕНИЯ ПРИ ТРЕТАТА НИВЕЛАЦИЯ НА БЪЛГАРИЯ

В. Цветков[1]

Ключови думи: *прецизна нивелация, грешки*

РЕЗЮМЕ

С цел изследване на състоятелността на допустимите разлики между двете независими противоположни измервания на превишенията между реперите в нивелачните секции, линии и полигони са анализирани данните от третото измерване на първокласната нивелачна мрежа на Р България.

Като се използват опростени графични техники за визуализация, е направен опит да се изясни връзката между дължините на нивелачните секции, линии и полигони и натрупаните разлики в измерените превишения и несъвпадения.

Установена е нарастваща неуспоредност в разсейването на изследваните разлики с нарастване на пронивелираните разстояния.

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