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ACCURACY OF HEIGHT MEASUREMENTS FOR LEVELLING ACROSS WIDE WATER BODIES

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Key words: leveling, leveling mark, optical leveler.

Introduction

The study aim is to carry out measurements across the river Lielupe applying geometric leveling, trigonometric leveling and global positioning methods. As the end result the effectiveness of each method are evaluated and each method quality parameters are compared. To achieve this objective, the following main tasks where set:

– Geometric leveling, using the device for precise leveling rod reading for long distances;
– Trigonometric leveling with 2’’ total station;
– Elevation determination with the global positioning;
– First order control leveling.

Carrying out geometric leveling in Latvia territory has to take into account the terrain and specific hydrological layout. While working at Latvia leveling core network design, the new lines were planned primarily by the existing leveling lines. The new leveling lines in some locations were planned by locations where Class I leveling were not performed [1; 2].

According to the developed plan, Latvia leveling core network field measurements were performed from the year 2000 to year 2010. At the time period from year 2000 to year 2005 precise leveling works were organized and executed by the State Land Service. In the following period – from year 2006 to year 2010 these works were continued and successfully completed by the Latvian Geospatial Information Agency experts [3].

Carrying out class I leveling, had to perform precise leveling across wide water bodies, such as Lielupe, Daugava, Venta. Not always at the place of planned leveling work site nearby were bridges to make measurements from one geodetic sing to another, as well as carrying out leveling to the nearest bridges associated with the additional use of resources and the overall precision reduction of leveling network. Consequently, it had to determine the elevation from one river bank to other using existing methods. This leveling was performed using a digital leveler DiNi 12 or optical leveler Ni 002 with bar leveling rods. However, at distances larger than 200 m, the existing measurement method did not provide sufficient certainty of results. Taking into account gained experience, was working on the accessories that make the elevation determination with a higher certainty. After quite extensive experimental measurements, the work was a success. In the Latvian Patent Board in year 2012 was approved patent no. 14529 “Accessory and method for precise leveling bar leveling rod reading in long distance”. This device applied performing Class I leveling at very symbolic place – at the creek of river Daugava.

The reason for the research was debates of Latvian land surveyors, for the possible best, most efficient method of measuring the elevation across the wide water bodies.

Looking at earlier fulfilled Class I leveling across wide water bodies, it can be concluded that they were fulfilled using only geometric leveling method.

There is a certain accessory for precision leveling rod reading in long distance, which was used in the Soviet Union and now in Russia. It consists of plate strengthened on leveling rod, which depicts horizontal stripes, which width and location depends on the measurement distance (Fig. 2) [4]. During the measurements, the plate is moved up and down on leveling rod and plate’s stripe is directed in leveler’s sight plane by observer team, from the opposite shore.

Plate position on leveling rod in this case is determined by reading the scale against the leveling rod plate index. Use of such accessory is associated with a considerable time and leveling rod scale reading for the index is not accurate. There is certain accessory that in use is similar to the previous mentioned, but it has on a black background depicted white circle instead of wide stripes on a plate (Fig. 3). Such a device was used in precision leveling in Latvia last century’s 30-ies [1]. However, the circle setting in leveler’s sight plane is less accurate than the stripes.

There is also certain accessory for leveling rod reading for range of 200 meters, with a single 5 mm wide strip mounted on leveling rod so that stripes index, which coincides with the axis of the stripes, coincide with leveling rod, and stripe in locate the micrometer range (Fig. 4) [5].

The use of such device over longer distances is hard to implement when the micrometer scale reading is close to the beginning or the end, because in greater distances there are more likely reading fluctuations due to external factors.

Since so far there is not dealt with complex leveling methods in Latvia, than it was decided to determine the elevation between two fixed benchmarks by different methods.

Materials and Methods

Leveling was performed in Jelgava city, located 35 km south of the capital city Riga (Fig. 5). This is due to the fact that in this city is located Latvia University of Agriculture. In this university since last century’s 30-ies the research is carried out, in relation to the precise leveling and has accumulated extensive experience in this field.

As the bench marks were chosen point “Pālis” from class I leveling network and on the other side of river Lielupe – bench mark 001 which is located on right coast of river Lielupe, in front of the main building of Latvia University of Agriculture. The distance between points is 333 m (Fig. 6).

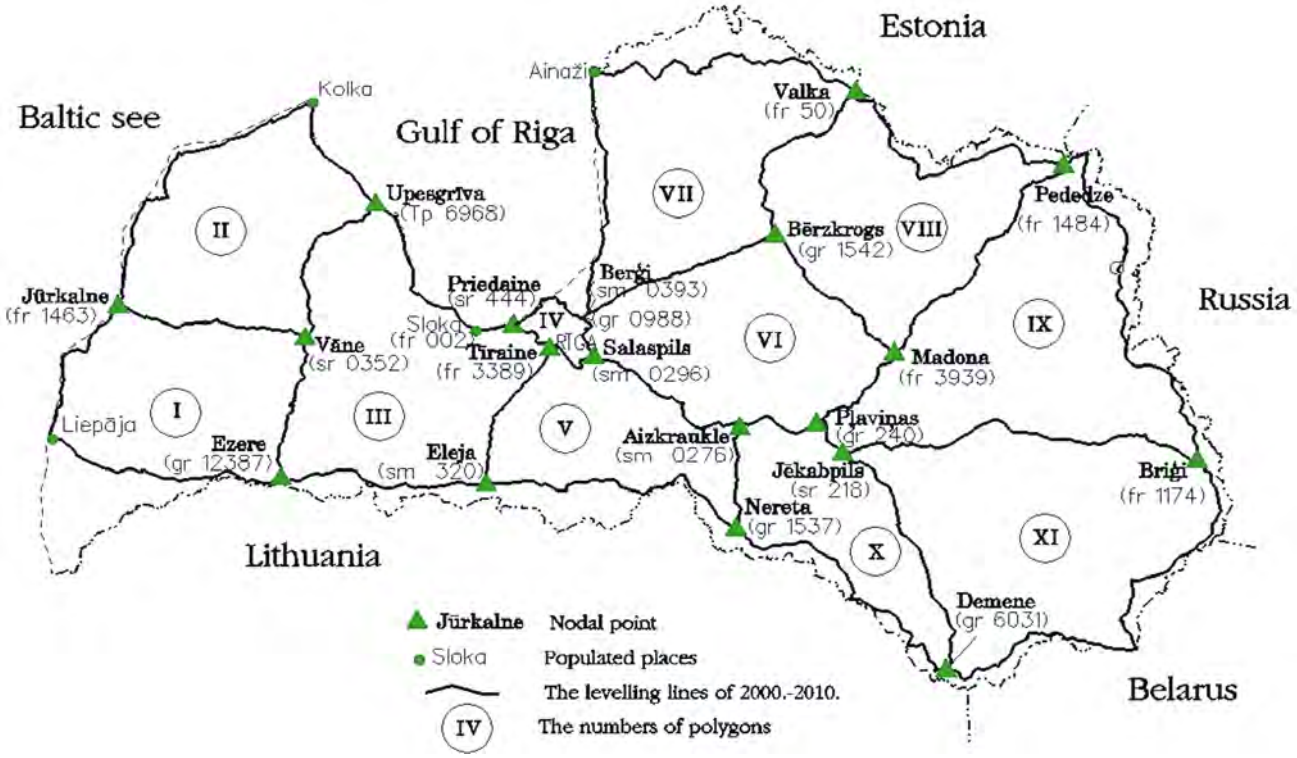

Fig. 1. Scheme of first order leveling network

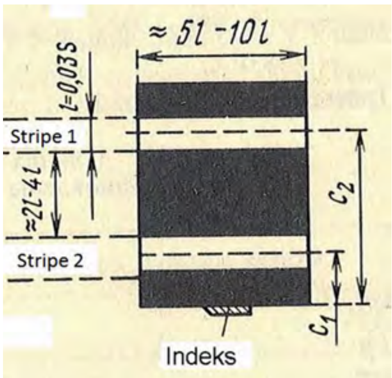

Fig. 2. Scheme of leveling rod plate

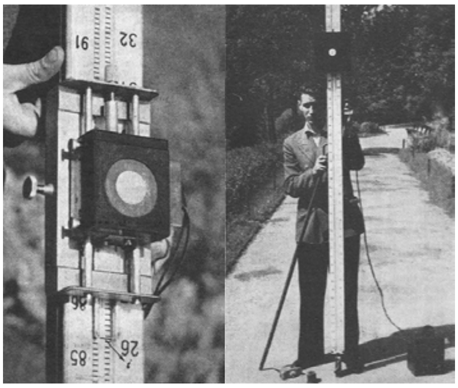

Fig. 3. Leveling rod with circle plate

Fig. 4. Leveling rod with single stripe plate

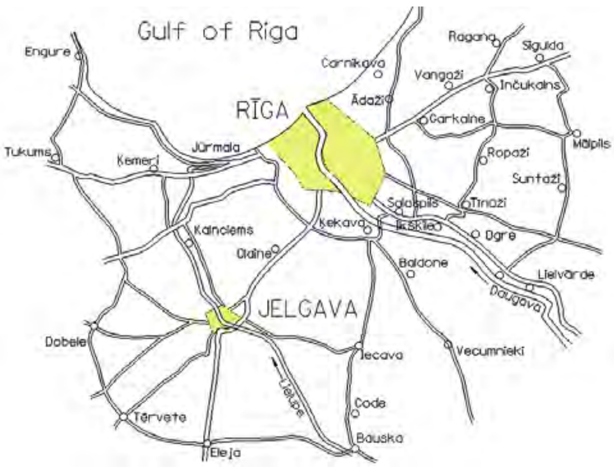

Fig. 5. Location of Jelgava city

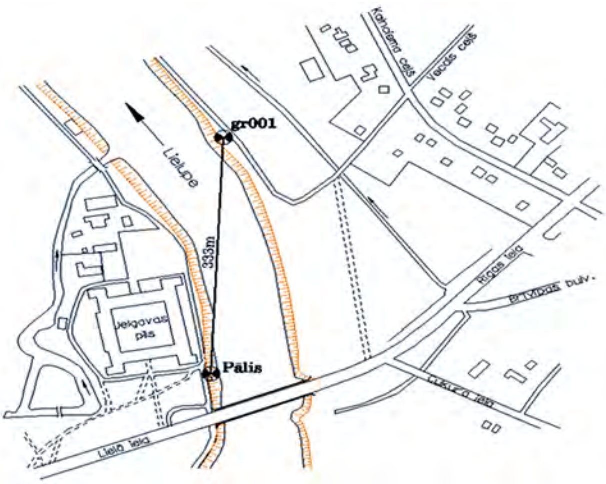

Fig. 6. Location of points

Fig. 7. Leveling mark and optical leveler Ni 002

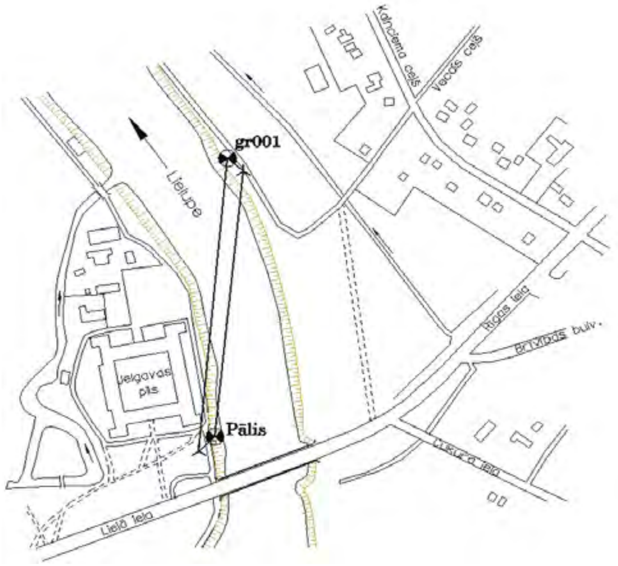

Fig. 8. Principle of measurements with Ni 002

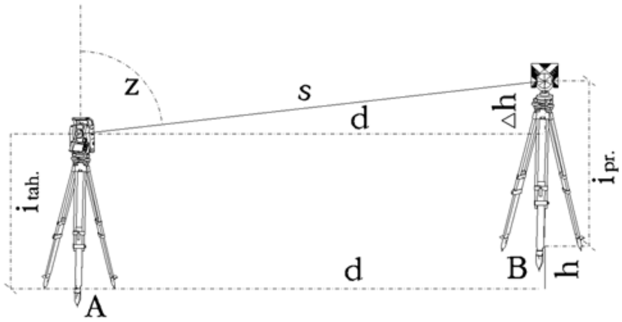

Fig. 9. 2'' total station and principles of measurement:
d – horisontal length; z – zenith angle;
I $_{tah}$., I $_{pr.}$ – instrument and prism height;
h – point's B elevation above piont A

For leveling directly across the river Lielupe were used optical leveler Ni002 from ZEISS and new type leveling mark strengthened on leveling rod (Fig. 7) [6; 7].

Leveler was located 13 m away from the bench mark. Taking measurements to the far leveling rod [8] which is located across the river, the mark is fitted and secured so that the leveler's cloth average horizontal stripe is located on one of the new type leveling mark stripes (Fig. 8).

On each coast were performed six half-techniques of observation to the other cost. Six time observations were made from each bank of river Lielupe.

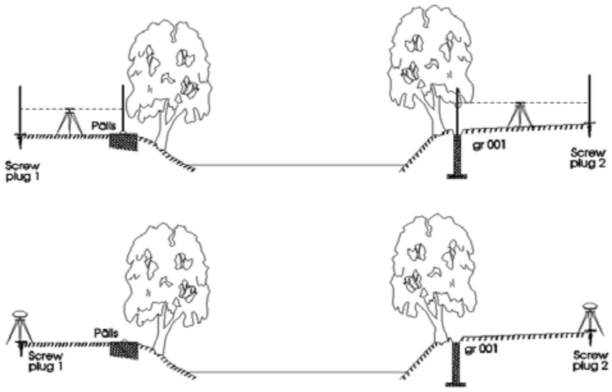

Fig. 10. GNSS measuring steps

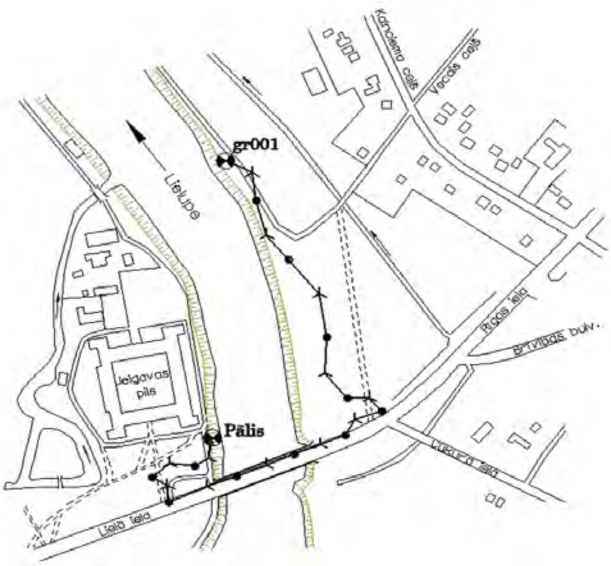

Fig. 11. Leveling line for leveling with DiNi 12

For elevation determination with trigonometric method total station Trimble M3 with 2" accuracy was used. In measuring process total station was on one bank of river and prism on another bank of river. After 12 observations, total station and prism were change places. In figure 9 can see the principle of trigonometric leveling.

In research the elevation also was determined with the global positioning. But the horizon in both ground benchmark places are covered from tries. Therefore for measurement time was fixed temporary points – screw plugs, in left and right bank of river (Fig. 10).

At first was carried out first order leveling from geodetic points to screw plugs. Than were carried out GNSS measuring on screw plugs. Measurements were performed with two Trimble R8 instrument sets. The time of measurement session was two hour long. After that, were carried out elevation and precision calculations between both geodetic points.

For the obtained elevation values control the first order leveling was carried out. Leveling was performed with digital leveler DiNi 12, measuring "forward" and "back" between the both geodetic signs [2]. For elevation determination was used two 3 m long bar code leveling rods. Leveling line was directed over the bridge (Fig. 11).

Carrying out leveling, leveling rods were placed on plugs driven into the ground. In leveling across the bridge in mini road cover were reinforced dowels, on which were placed leveling rods. Leveling was performed according the instruction, and maximum length of sight – 40 m.

Results and Discussion

Elevation determination between the ground signs, using the techniques mentioned above, was performed with the highest care and precision. For the final results of each method, the value of standard deviation was calculated. It is necessary to characterize the accuracy of elevations in measuring process. Obtained results shows what is each specific method's measurement accuracy. This should be taken into account to select the most optimal elevation determination methods for leveling across wide water bodies.

In process of elevation determination between geodetic signs on both banks of the river, the complicated measurement process was using global positioning. Since foliage of the trees on both banks of the river, in close proximity of benchmarks hid complete satellite signal, than in distance of 30 m from the benchmarks were installed temporary signs – screw plugs. Global positioning measurements at first were performed to the screw plugs. Then was determined elevation between the screw plugs and geodetic signs. After performance of abovementioned measurements, was calculated elevation value between the geodetic signs Pālis and gr001. Calculated elevations are shown in table 1. For each elevation determination method also was calculated the measurement standard deviation.

The elevation determination final results, obtained with: optical leveler Ni002 and new type leveling mark, strengthened on leveling rod; trigonometric leveling with 2'' total station; First order control leveling with DiNi 12 and elevation determination with the global positioning, shown in table 2. Summarizing elevation value, obtained with global positioning, there are shown calculated elevations in the direction Pālis – gr 001. Carrying out global positioning measurements on both geodetic points, simultaneously there are no "forward" and "back" measurements. Analyzing obtained results at first look at elevation difference between "forward" and "back" measurements.

Table 1

Leveling results with GNSS

Elevation determination direction	Calculated elevation, m	Elevation determination method	Standard deviation, mm
Screw plug 1 – Screw plug 2	- 0,1570	Trimble R8	3,0
Pālis – Screw plug 1	+ 0,28092	Ni 002	0,1
gr 001 – Screw plug 2	+ 0,31952	Ni 002	0,1
Pālis – gr 001	- 0,1956	Calculation	3,0

Table 2

Leveling results

Method of elevation Determination Pālis – gr 001	Leveling direction	Measured elevation, m	Elevation difference, mm	Calculated elevation, m	Adjusted elevation value standard deviation, mm
Geometric leveling Zeiss Ni 002	Forward Pālis – gr 001	-0,19205	1,68	-0,19289	0,04
	Back gr 001 – Pālis	+0,19373			
Trigonometric leveling Trimble M3	Forward Pālis – gr 001	- 0,1880	8,6	-0,1923	1,1
	Back gr 001 – Pālis	+ 0,1966			
Geometric leveling Trimble DiNi 12	Forward Pālis – gr 001	-0,19264	0,54	-0,19291	0,13
	Back gr 001 – Pālis	+0,19318			
Global positioning Trimble R8	Pālis – gr 001	–	–	-0,1956	3,0

It can be seen that the largest elevation difference by direction is in trigonometric leveling. Carrying out leveling with length of sight 333 m, elevation difference in leveling lines is 1.68 mm, which taking into account the length of sight is a very good result. Smallest elevation difference, according to elevation values in "forward" and "back" measurements, between the geodetic signs, achieved by DiNi 12.

However, given the estimated standard deviations of measurements, it is concluded that the most accurate measurements performed by geometric leveling with Ni 002, using the device for precise leveling rod reading for long distance. This has been achieved largely due to in leveling process used mark, its precise index matching with leveling rod stripe; as well as clearly visible angled bisector matching with one of the mark lines.

The fact that standard deviation value in leveling with DiNi 12 is larger than with Ni 002 performed measurements, explained that leveling had to cross a bridge. Even though, across the bridge leveled "forward" and "back" directions, respectively, in the morning and evening, and taking into account the ongoing micro movements, it gave the impact on the overall accuracy. This situation illustrates leveling network overall accuracy decrease risks, if for river crossing should perform additional Class I leveling to reach the bridge and get to a geodetic sing, which is located on the other side of the river. As well as additional leveling increases the overall project performance costs.

As can be seen, by obtained results (Table 2.), into height transfer good results can be achieved using trigonometric leveling. The calculated standard deviation, to specific measurements, show that the use of trigonometric leveling can provide Class III geometric leveling requirements. In Latvia Class III leveling standard deviation value is set 3,0 mm/km. Consequently, to ensure the leveling jobs at measurements cross wide water bodies, they can be carried out with a theodolite which certainty is 2”. Such a combination of leveling methods is possible for leveling network densification works. Assessing with global positioning obtained measurements accuracy value, it can be concluded that the height transfer with such method can provide only technical leveling requirements. However, the use of this method for height transfer cross wide water bodies requires additional research.

Conclusions

1. The most precise results are obtained by geometric leveling.
2. Comparing DiNi 12 with Ni 002 the highest accuracy was obtained by leveling directly across the water body.
3. Trigonometric leveling provides class III leveling requirements.
4. Leveling with global positioning provides requirements of technical leveling.
5. By direct leveling, time and resources are saved and the accuracy of the measured leveling network is increased.

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Точність вимірів висот через широкі водні перешкоди

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Мета роботи – встановити точність визначення перевищень при використанні методів геометричного, тригонометричного нівелювання, а також користуючись методами ГНСС. У ході роботи визначені точностні показники отриманих перевищень при використанні кожного з вищеназваних методів і проведено порівняння отриманих точностних показників. Під час проведення робіт дотримувалися вимоги, встановлені для виконання нівелювання мережі 1 класу, в роботі на мостах користувалися нівеліром Dini12. Для прямих вимірів користувались нівеліром ZEISS Ni002 із застосуванням нівелірних марок для поліпшення прочитування вимірювань. На основі порівняння отриманих середніх квадратичних помилок вимірювань дійшли висновку, що найточніші результати вимірів отримані з використанням системи ZEISS Ni002. Метод значно покращує загальну точність результатів нівелювання і скорочує витрати на виконання робіт (зокрема грошові) – вилучаючи досі існуючу необхідність шукати обхідні маршрути нівелювання для вимірювань, що пересікають значні водні перешкоди.

Точность измерений высот через широкие водные преграды

А. Целмс, А. Раткевичс, А. Брантс, Е. Кауранеис

Цель работы – установить точность определения превышений при использовании методов геометрической, тригонометрической нивелировки а также пользуясь методами ГНСС. В ходе работы определены точностные показатели полученных превышений при использовании каждого из вышеназванных методов и проведено сравнение полученных точностных показателей. При проведении работ соблюдались требования, установленные для выполнения нивелировки сети 1 класса, в работе на мостах пользовались нивелиром DiNi12.

Для прямых измерений пользовались нивелиром ZEISS Ni002 с применением нивелирных марок для улучшения считывания измерений. На основе сравнения полученных средних квадратических ошибок измерений пришли к выводу, что самые точные результаты измерений получены с использованием системы ZEISS Ni002. Метод значительно улучшает общую точность результатов нивелировки и сокращает затраты на выполнение работ (в том числе денежные) – исключая до сих пор существовавшую необходимость искать обходные маршруты нивелировки для измерений, пересекающих значительные водные преграды.

Accuracy of height measurements for leveling across wide water bodies

A. Celms, A. Ratkevičs, A. Brants, E. Kauranens

The objective is to carry out measurements across the river Lielupe applying geometric leveling, trigonometric leveling and global positioning methods. As the end result the effectiveness of each method are evaluated and each method quality parameters are compared. Elevation between the ground marks were measured with the digital leveler DiNi12, according to Class I leveling requirements. For leveling directly across the river Lielupe were used optical leveler Zeiss Ni002 and new type leveling mark strengthened on leveling rod. Given the estimated standard deviation of the measurements, it is concluded that the most accurate measurements performed by geometric leveling with leveling system Zeiss Ni 002. This method significantly increases the overall accuracy of the leveling network, as well as reduces costs without carrying out additional leveling.