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VERTICAL DATUMS OF LEVELLING NETWORKS IN SLOVENIA

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Abstract

The author presents vertical datums of levelling networks in Slovenia (Austro-Hungarian levelling, I. and II. levelling of great accuracy) and problems arising when defining the vertical datum of the Austro-Hungarian levelling.
Keywords: *levelling network, medium sea level, Slovenia, surface reference plane, vertical datum*

1. INTRODUCTION

In defining altitudes of points it is of vital importance to determine in advance a comparative surface from which heights of points above sea level are calculated. Thus the vertical datum of a levelling network is given by the medium sea level in a certain time span defined as a surface reference plane. The medium sea level is defined on the basis of results of yearlong observations of the sea level oscillation by tide gauges represented by the arithmetic mean of the sea level at one point of a sea shore in a longer time span. The medium sea level is not constant neither at the same point at different time periods nor at different places of the sea shore. The medium sea level variance is a result of a constant oscillation of the sea level due to various causes.

Periodic oscillations of the medium sea level are the result of the attractive force of the Sun, Moon, and Earth. Irregular oscillations of the medium sea level are due to activities of wind, atmospheric pressure, differences in temperature and quantity of salt in the sea water. Greater influence on oscillation of the medium sea level have periodic influences e.g. the medium sea level oscillates more or less periodically. To obtain reliable data on medium sea level which is represented by the vertical datum of a levelling network constant observations of oscillation of the sea level are needed for at least 18,6 years due to nodes of Lunar trajectory.

2. NORMAL BENCH MARK

According to agreement the altitude of the medium sea level e.g. the surface reference plane equals zero. The position of the reference surface plane is defined by a vertical distance form the so called normal bench mark which is stabilized on an area regarded as geologically stabile one (Stefanović 1955).

2.1 Connection of the Austro-Hungarian levelling network to a normal bench mark

The normal bench mark for connection of the Austro-Hungarian levelling network to the surface reference plane is the bench mark at the Sartorio pier in Trieste, Italy. The height of the normal bench mark in Trieste was calculated by dr. Farolfi. The altitude of the normal bench mark was determined on the basis of one year observations of the oscillation of the level of the Adriatic Sea in 1875 and the result is 3,352 ± 0,01 m. The tide gauge on the Trieste pier was set up in 1869 yet the first data on the Adriatic Sea level registration for 1875 were published in 1877. In Austro-Hungarian monarchy the height of the normal bench mark was defined on the basis of one year observations because the wish in Europe in those years was to connect medium levels of the Medierranean with the north seas, and to determine a unique normal bench mark for the whole of Europe. As it was found out that the medium level of the Mediterranean is for 13 cm lower from the medium level of the north seas it was decided not to determine a unique normal bench mark for the whole of Europe but each country should keep its normal bench mark (Zeger 1986).

As early as 1904 Sterneck was the first to doubt the reliability of the reference surface plane determination beeing gathered only on the basis of a single year registration of oscillation of the sea level. So he compared heights of the basic bench marks of tide gauges in Trieste, Pula and Dubrovnik which were defined on the basis of yearlong observations of sea level oscillation and on the basis of the Austro-Hungarian levelling network integration. To be able to compare heights of basic bench marks of tide gauges he defined the height of the normal bench mark in Trieste anew for 1901. He defined the medium sea level on the basis of data of registration of the sea level oscillation for the period 1875-1879 (without 1877) and from 1901-1904. The new defined altitude of the normal bench mark equaled 3,2621 ± 0,0099 m. For both heights of the normal bench mark stands they were not defined on the basis of uninterrupted observations of the sea level oscillation (at least 18,6 years). In addition both data differ as to the position of the surface reference plane for 8,99 cm. According to Sterneck's calculations the old Austro-Hungarian altitudes of bench marks do not refer to the medium level of the Adriatic Sea in Trieste but to a comparative level surface which is 8,99 cm lower than the surface reference plane defined on the basis of eight years of observations of oscillations of the Adriatic Sea level (Zeger 1986).

The problem of defining a vertical datum of the Austro-Hungarian levelling network was also dealt with other surveyors and geophysicists. The professional literature gives also the following values of the position of the comparative surface as to the reference surface plane which should be taken for the vertical datum of the Austro-Hungarian levelling network:

- 8,93 cm – this value was determined by Kasumović by the aid of observing oscillation sea level at Bakar and refers to the year 1933 (Kasumović 1950).
- 10,57 cm – the value was obtained from data Kasumović published later and they also refer to the tide gauge in Bakar and year 1933. The two mentioned data differ since Kasumović defined the medium sea level for 1933 by taking the tide gauge constant defined for 1948.

- 13,83 cm – the value was calculated by Bilajbegović from observations of the sea level oscillations in Bakar for 1971.
- 18,5 cm – this value was defined by Istituto Talassografico Trieste from observations of the tide gauge in Trieste for 1969 (Bilajbegović, Marchesini 1991).

The question bound to arise is how comes to differences among medium levels defined by individual observers. Inspecting the above mentioned data we notice the individual values were defined at different tide gauges (Bakar, Trieste) and for different years (1901, 1933, 1969, 1971). Bilajbegović explained the differences among the mentioned values by the difference between linear trends of oscillation of the medium sea level in Trieste and Bakar. In addition in 1991 he published that the medium sea level in Trieste was defined too low – for 6,056 cm (Bilajbegović, Marchesini 1991). The mentioned value was defined on the basis of observations of the oscillations of the sea level in the tide gauge in Bakar and data of levelling between the basic bench mark of the tide gauge in Bakar and the normal bench mark in Trieste.

2.2 Connection of the I. levelling of great accuracy (I. NVN) to normal bench mark

When surveying and adjusting the levelling network of the I. NVN on the territory of the ex Socialist Federative Republic of Yugoslavia there was no stabilized normal bench mark. So the altitudes of the I. NVN were connected to the normal bench mark of the Austro-Hungarian levelling which means we have the same vertical datum for the Austro-Hungarian levelling network and the network of the I. NVN.

2.3 Defining the vertical datum of the II. levelling of great accuracy (II. NVN)

The levelling II. NVN network was first connected to the normal bench mark, which was stabilized on the territory of the ex Socialist Federative Republic of Yugoslavia. The normal bench mark was stabilized at a geologically stabile area in the main part of the ex Yugoslavia (city of Maglaj). On the east coast of the Adriatic Sea there are seven tide gauges. The oldest are the tide gauges in Bakar and Split (in the port), set up in 1929. After the second world war tide gauges were set up in Split at the Cape Marjan (1952), Dubrovnik (1954), Rovinj (1955), Koper (1962) and Bar (1964). Table 1 shows data on the uninterrupted registration of the sea level oscillation for individual tide gauges till 1989 and data on including tide gauges into the levelling of great accuracy.

Table 1

Tide gauge in	*Uninterrupted registration since*	*Year of including tide gauge into levelling of great accuracy*
Koper	*1962*	*1964, 1972*
Rovinj	*1955*	*1957, 1964, 1972*
Bakar	*1954*	*1957, 1964/65, 1970/72*
Split – the port	*1954*	*1957, 1964/65, 1970/72*
Split – Marjan	*1954*	*1957, 1962/63*
Dubrovnik	*1954*	*1957, 1962/63, 1970/71*
Bar	*1965*	*no available data*

The vertical datum of the II. NVN e.g. the medium sea level on individual tide gauges are defined for 3.7.1971, from data of the registration of the sea level oscillation from 1962,2 till 1980,8. On all tide gauges except the one in Bar the medium sea level was defined on the basis of a registration of sea level oscillation for one whole period – 18,6 years (Bilajbegović et al. 1989).

In 1962 and 1963 the normal bench mark in Maglaj was connected by a precise levelling with tide gauges in Split and Dubrovnik. Later also other tide gauges were connected by a precise levelling (1964-1965) and they were included into the surveying of the II. NVN. Into the II. NVN surveying only the tide gauge in Bar was not included as the basic bench mark of the tide gauge was not connected with the levelling network of the II. NVN. The altitude of a normal bench mark is determined by a mutual adjustment of the measured altitude differences among tide gauges and the normal bench mark from 1962/63, 1970-1973, and by altitude differences among the basic bench marks of tide gauges determined from tide gauges observations.

3. CONCLUSION

Altitudes of points, used in Slovenia, are given on the basis of a vertical datum of the Austro-Hungarian levelling network. These altitudes are determined from the survey of the I. NVN and connections of levelling networks of lower orders to bench marks of the I. NVN. If we are to decide for a new NVN survey on the territory of Slovenia the most suitable area for stabilization of the normal bench mark has to be chosen and decision has to be taken as to which basic bench marks of tide gauges the normal bench mark and with it the NVN network is to be connected. There is the tide gauge in Koper yet it remains to be checked whether it is in accordance with standards and regulations about registration of the sea level and data on a constant monitoring sea level changes. In my opinion the vertical datum of the new NVN network ought to be defined also on the basis of observing the sea level oscilations on tide gauges set up in Rovinj, Bakar and Triest. Naturally this should be discussed with appropriate offices in Italy and Croatia.

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