

4.3.11. NATIONAL GRAVITY SYSTEM OF BULGARIA AND ITS IMPLEMENTATION

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4.3.11.1. Introduction

The problems related to the using of the gravity have become significantly important and they have been intensively studied and applied mainly in the field of the Earth sciences and particularly in geodesy. That concerns the works on determination of the world, regional and local geoids, establishment of height and other reference systems, establishment of regional and local gravity networks, geodynamic investigations and many other problems and applications. An intensive international cooperation is established within the Europe. The solution of these problems in the particular countries is also important together with the common European and regional problems. In this respect the establishment of the unified gravity network of absolute gravity stations in Bulgaria is of great interest.

The works accomplished on the establishment of the contemporary gravity system of Bulgaria (NGSB) have been outlined. The necessity and preconditions for establishment of the NGSB, concept, project and development of a network of absolute gravity stations on the territory of Bulgaria have been grounded. Part of the network stations are permanent GPS stations with determined normal heights. A network of new six absolute gravity stations has been established and respective connections to the suitable points from the basic national gravity network and to benchmarks from the national leveling network I-st (II-nd) order have been realized. The normal heights of the benchmarks of the new gravity stations have been determined (with collaboration of the Federal Agency for Standardization and Geodesy, Austria). The gravity values of the new gravity stations and respective differences - $\Delta g_{\text{abs-basic}} [mGal]$ with respect to the suitable points of the basic national gravity network. Local gravity and leveling networks surrounding the absolute stations have been established. Standards have been established on the base of the UNIGRACE and the realized network of absolute gravity stations. They are reliable base for a contemporary national gravity system. A possibility for reproducing of the unit from the International System (SI) of the national standard of the Republic of Bulgaria has been ensured and more exactly, for the gravity "g" through the established gravity station at the State Agency for Metrology and Technical Control, respectively National Centre of Metrology. The results have a many-side national importance both for the Earth sciences and for a number of applications in the country as well as for the integration of the Bulgarian geodesy to the world geodesy.

4.3.11.2. Necessity of national gravity system of Bulgaria

The problem of establishment of a modern National Gravity System (NGS) of Bulgaria is extremely important due to continuously development and improvement of science, integration in Europe and the World, and the necessity of decision of a number of national, regional and global aspects of geodesy and the other Earth sciences,

determination of local and European geoid and other scientific and practical aspects. It is particularly related to the establishment of the Unified European Gravity Network 2002 - UEGN2002. The main reason for development and introducing of a National Gravity System is that the new system should be based on European/international standards which actually are the ground in realisation of the international project for Unification of the Gravity Systems of the Countries from Central and Eastern Europe–UNIGRACE. National Gravity System of Bulgaria is a base for decision of present-day and future national problems of geodesy and geophysics as a development of a unified gravity system and network, for introduction of Bulgarian Geodetic System 2000, for determination of sea-level variations, local geoid of Bulgaria etc. The system concerns the European integration of Bulgaria and determination of the European geoid.

The accomplished up-to-now absolute gravity determinations are obtained on the other lower level of scientific and technical development. The new system of the country is grounded on the base of the contemporary achievements and possibilities in this field. It is also based on a present-day analysis of the already established similar systems in Europe, on the purpose of unification and establishment of combined European gravity, height and space system and network, and European geoid. The establishment of the national system is based on European and international standards and on the international collaboration within the realisation of two projects presented below.

4.3.11.3. International project “unification of the gravity systems of the countries from central and Eastern Europe”

General information

International project “Unification of the Gravity Systems of the Countries from Central and Eastern Europe” - UNIGRACE is realised as a project of the European Commission - INCO/COPERNICUS Program and later on within the Ministry of Education and Science of Bulgaria (MES).

Trough the unification of the gravity systems of the countries from Central and Eastern Europe the differences between the systems in this region are overcome. A network of absolute gravity stations is established (Fig. 4.3.11.1.). Each of the stations is connected with the national gravity network of the respective country by precise relative measurements and surrounding small local gravity networks are established. The absolute gravity measurements are carried out with 5 ballistic gravimeters of different type, delivered by the participating EC countries, calibrated before and after measurements in Sevr, France.

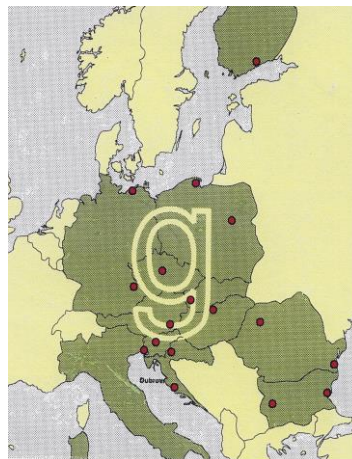


Fig. 4.3.11.1. UNIGRACE Network

Realization of UNIGRACE on the territory of the country

Three absolute gravity stations – Sofia, Plana and Varna were established in 1998 in cooperation with the Austrian Federal Agency for Calibration and Geodesy - BEV, Austria (Fig. 4.3.11.2).



Fig. 4.3.11.2. Location of the gravity stations

Connections between absolute gravity stations and national gravity network, special national traverse for gravimeter calibration, tide gauges at the Black Sea coast and EUVN stations are realised. Absolute gravity values, gradients and the accuracy of the stations are determined from the combined processing of two measurement campaigns on the territory of Bulgaria. The accuracy of 10^{-9} for the absolute determinations is achieved. Repeated gravity measurements of the stations Sofia and Plana were carried out using absolute gravimeter ZZG and relative measurements of the surrounding small networks using relative gravimeter LCR – G986 in 2001. A team from the Institute of Geodesy and Geodetic Astronomy of the Warsaw University of Technology accomplished the measurements. The results from the absolute gravity determinations are shown in Table 4.3.11.1.

Table 4.3.11.1. Results from the absolute gravity determinations

Station name Code	Dimension	Sofia OBG SOFIA	Sofia OBG SOFIA	Plana OBG PLANA	Plana OBG PLANA	Varna OBG VARNA
Country		Bulgaria	Bulgaria	Bulgaria	Bulgaria	Bulgaria
Instrument name		JILA g-6	ZZG	JILA g-6	ZZG	JILA g-6
Date of occupation		9/15/98	4/1/01	9/18/98	4/5/01	9/22/98

Latitude	$^{\circ}N$	42.6670	42.670	42.4764	42.480	43.2033
Longitude	$^{\circ}E$	23.2000	23.280	23.4253	23.430	27.9239
Height	m	607.711	607.711	1230.000	1230.000	6.000
Height system		BG	BG	BG	BG	BG
Used gradient for final reprocessing	$\mu m s^{-2} m^{-1}$	-3.268	-3.076	-3.063	-3.063	-3.035
Instrument reference height	m	0.840	0.360	0.840	0.360	0.840
Gradient at ref. height of ZZG - 80 cm	$\mu m s^{-2} m^{-1}$		-3.076		-3.123	
Groundwater correction	$0,01 \mu m s^{-2}$					
Gravity at instrument reference height	$0,01 \mu m s^{-2}$	980,240,323.0	980,240,531.6	980,074,182.7	980,074,331.9	980,470,513.4
Gravity at 1 m	$0,01 \mu m s^{-2}$	980,240,270.7	980,240,334.7	980,074,133.7	980,074,133.2	980,470,464.8
Gravity at 1 m +gw corr.	$0,01 \mu m s^{-2}$	980,240,270.7	980,240,334.7	980,074,133.7	980,074,133,2	980,470,464.8
Gravity at benchmark (0 m)	$0,01 \mu m s^{-2}$	980,240,597.5	980,240,642.3	980,074,440.0	980,074,339.5	980,470,768.3
Mean drop standard deviation	$0,01 \mu m s^{-2}$	31.4	159.0	5.6	36.0	83.8
Set standard deviation	$0,01 \mu m s^{-2}$	5.6	6.0	3.0	1.0	6.9
Number of drops		6909	812	6612	1883	8351
Number of sets		40	1	38	4	36
Used tidal model		Wenzel	Wenzel	Wenzel	Wenzel	Wenzel

4.3.11.4. Project and establishment of new absolute gravity stations on the territory of the country

- **Preconditions and concept**

Development of the National Gravity System of Bulgaria was realised later on within the Project “National Gravity System – Analysis and Development” of the National Council (NC) “Scientific Investigations” (SI) of MES and it is continuation, development and further realisation of UNIGRACE in Bulgaria.

The Project is based on the proposed concept for establishment of a network of absolute stations on the territory of the country after analyzing the present-day development of geodetic networks, international projects within the IAG, EUREF, ECGN, CERGOP-2, already achieved results through the UNIGRACE in the country, existing conditions and preconditions in Bulgaria, ongoing international projects with Bulgarian participation, realisation of international collaboration. National standards and regulations updated and adopted in the recent time are taken into consideration in the formulation of the concept as well as the necessity for development of all geodetic works in the country. It is possible now to have a national standard for g by the State Agency of Metrology and Technical Control, respectively National Center of Metrology (NCM). It is also very important for the reproduction of the international system SI units of the national standard of Republic of Bulgaria. Statements and concept for complex consideration and establishment of the basic networks of the country and European ones are integrated. That means all stations or part of them should be presented as an element of the combined geodetic networks especially in the establishing of the gravity

system of the country which should be based on the network of absolute gravity stations.

- **Project**

The project of the new absolute stations is shown in Fig. 4.3.11.3 and presented in section 4.3.10 of this monograph. Part of the stations are existing absolute stations of the UNIGRACE project with precise determined heights of the benchmarks which are referred to the Amsterdam tide gauge and transformed into EVRS. This includes Varna absolute station, which is already a permanent GNSS station of the CERGOP-2 project (VARN) (Fig. 4.3.11.3.). The new station Rozhen is also a CERGOP-2 permanent station (ROZH) with precise determined height.

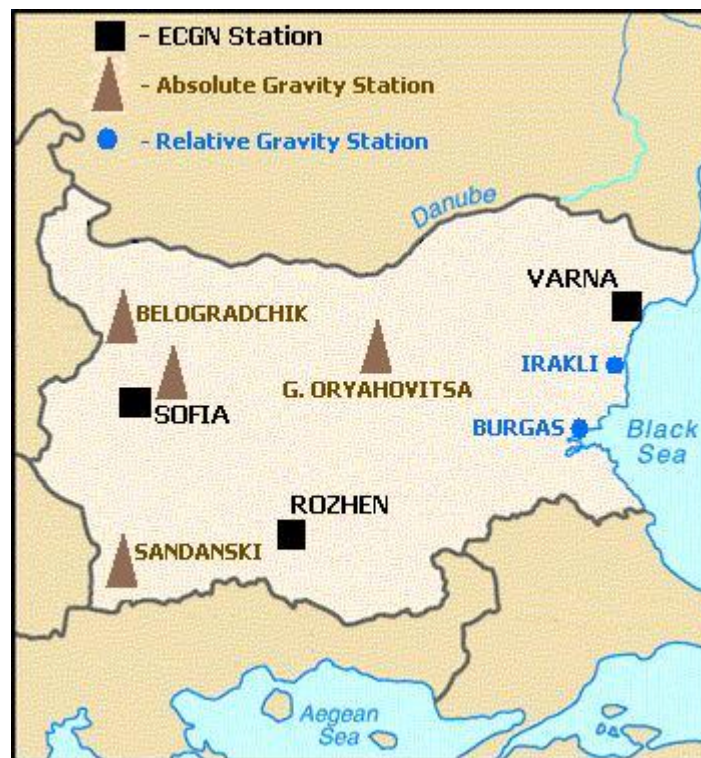


Fig. 4.3.11.3. Gravity and Combined stations

- **Realization of the project and results**

The absolute measurements were carried out during the period 13 -24.09.2004. The absolute gravimeter JILA 6 (FF), drop mode of BEV was used. Relative measurements were carried out as well with LCR-D51. The measured g are referred to the height of 84 cm and they can be reduced to the floor height using average values of the gradients. The results from the absolute measurements and other data are given in the section 4.3.10 of this monograph.

Connection of the absolute stations with the basic gravity and national levelling networks of Bulgaria.

The realized connections of the absolute stations with the basic gravity network of the country are shown in Fig. 4.3.11.4. and main results are presented in Table 4.3.11.5.

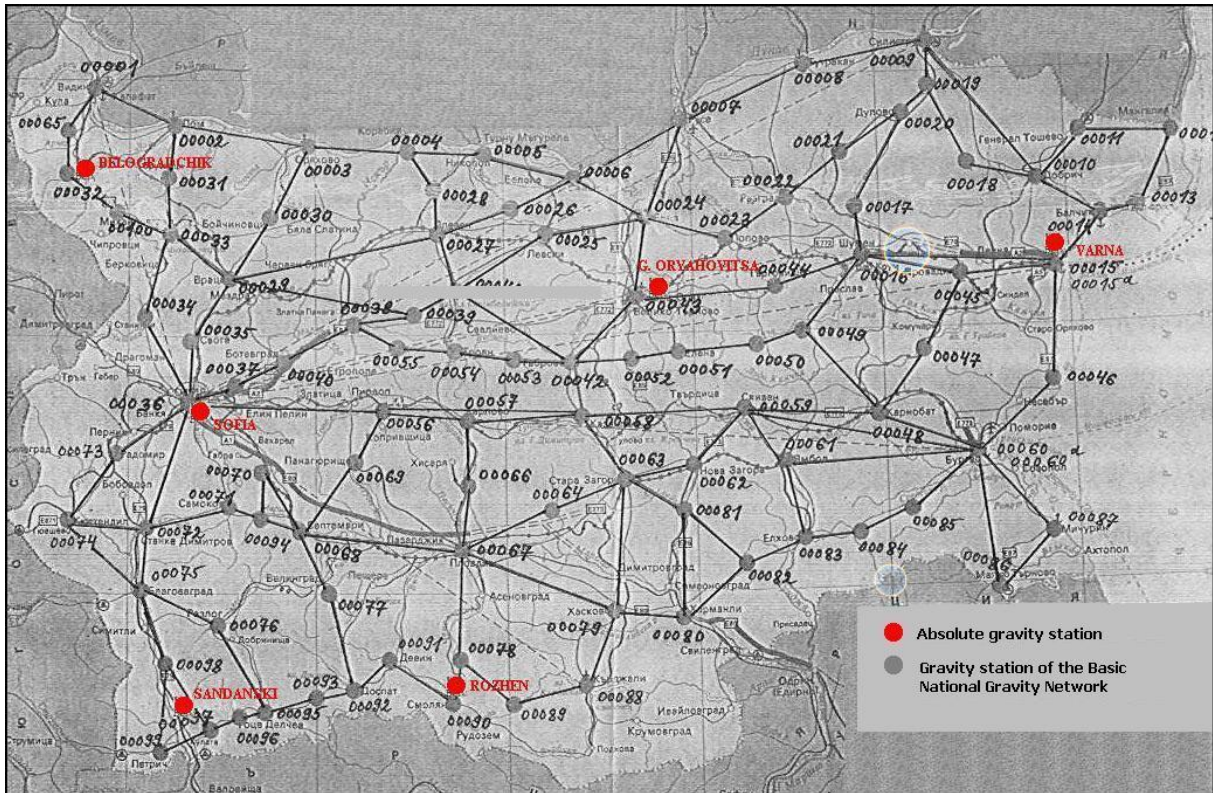


Fig. 4.3.11.4. Absolute stations and Basic Gravity Network

Table 4.3.11.5. Heights of the absolute gravity stations and differences $\Delta g_{\text{abs-ref}}$ between absolute stations and basic gravity network stations

Absolute station			Basic gravity network station		$\Delta g_{\text{abs-ref}}$ mGal
No	Location Settlement	Height m	No	Settlement	
101	Observatory Belogradchik	606.034	100	Prevala	-5.810
102	Municipality Gorna Oryahovitsa	153.943	43	Gorna Oryahovitsa	1.146
103	Open-air theatre Sandanski	250.940	97	Melnik	37.342
104	NAO "Rozhen" Rozhen	172.910	90	Pamporovo	-28.694
105	NCM Sofia	572.112	37	Yana station	-14.681

4.3.11.5. Conclusions and suggestions

A network of absolute gravity stations with a possibly highest order of accuracy is established in Bulgaria as a result of the activities within the framework of an effective international collaboration. The network is connected with the unified gravity network of the countries from Central and Eastern Europe and it will be a component of the Unified European Gravity Network 2002. At the same time three of the stations are also

stations of the European Combined Geodetic Network and two of them are CERGOP-2 permanent stations. Bulgaria is integrated in Europe and the World with the established network of absolute gravity stations together with other networks and systems of the country. In that way preconditions for determination of a national and European geoid become available. Standards made available through the UNIGRACE and the established network of absolute gravity stations are reliable base for transition to a uniform and contemporary national gravity system. The existing basic gravity network is connected to a reliable base and it is being reduced to the new National Gravity System of Bulgaria. All works accomplished in the field of geodesy and the other Earth sciences should be done on the base of NGS of Bulgaria. The achieved results up to now on the base of a successful bilateral collaboration with the Austrian colleagues and the international collaboration are of significant importance for the country as it takes an equivalent place within the European space.

4.3.11.6. References

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