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Measurement of gravitational acceleration values at the calibration laboratories in Korea

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Abstract

The most important conversion factor between mass and force is the value g of the acceleration due to gravity. This can be measured with an absolute or relative gravimeter. It depends on the latitude and height above sea level. Values of g at many calibration laboratories in Korea are measured with a relative gravimeter, Model G manufactured by La Coste & Romberg in USA. To improve the measurement performance of the gravimeter, we attached an optical magnifying system instead of microscope eyepiece, which consists of CCD camera and LCD display. This optical system showed to be sufficiently convenient and accurate to provide a practical alternative to the traditional microscopic eyepiece. The observed value of g spans a range of 0.03% between the northernmost and the southernmost calibration laboratory in Korea. In this paper, the improved performance and the detailed gravity measurement results are given.

Keywords: *Gravity, acceleration, gravimeter, calibration*

1. Introduction

The acceleration of gravity is a quantity which varies from place to place and which also, at any given place, varies with time. Its value is of interest to a wide field of physical sciences: metrology, geophysics and geodesy. In metrology, the gravitational acceleration influences the measurement of force or of any physical quantity involving a force. Thus the standard unit of electrical current, the ampere, is obtained by comparing the force acting between two current-carrying coils with the weight of a known mass in the gravitational field. Consequently, all the quantities derived from the ampere are dependent on the value of g. Another force-related quantity is pressure, which is involved in the realization of fixed points in the International Temperature Scale. Since the accuracy of the measure of g influences the accuracy of the standard units, it is not surprising that the great effort has been done in standards laboratories. For metrological purposes, g is regarded as a local physical constant. However, it is necessary to measure it at every metrological sites for the reasons stated above. Geophysics and geodesy are mainly interested in variations in gravity which changes with locations and, at a given location, with time. Temporal gravity variations may be caused by mass displacement, density variations, surface deformations and variation in the motion of the Earth.

2. Apparatus

Gravity measurements were performed using relative gravity meter. In principle, a relative gravity meter is simply a sensitive weighing device. The force on the test mass changes with variations in the gravitational field, and these small changes in gravity are detected by noting the corresponding small variations in weight. The detection of differences in gravity of the order of 10^{-7} m/s^2 is possible.

The La Coste-Romberg (L&R) relative gravity meter is a long period seismograph which utilizes a ‘zero length’ spring. This spring is characterized by a stress-strain curve that is a straight line passing through the origin. Thus the initial length, corresponding to zero force, is zero. For this kind of spring the force is directly proportional to the length of the spring. In practice, a spring of zero length is in compression before its coils are separated by stretching. As a result of this feature the L&R gravity meter can be adjusted, theoretically, to have an infinite period. The gravity meter used in this experiment is model G, which has a worldwide range of 0.07 m/s^2 (=7000 mGal, 1 mGal=10^{-5} m/s^2) with resolution of 10^{-7} m/s^2 (=0.01 mGal). Its drift rate is one of the most critical aspects of a spring-type gravimeter, depends greatly on the age of the meter, the means and the manner of transportation, and on environmental conditions. Our instrument has a drift of 0.28 mGal/month. The factory provides accurate calibration tables, but to gain the highest accuracy, the sources of systematic errors have to be studied extensively. Each meter has its characteristic reading line. Our reading line is 2.6.

To minimize the backlash and slack in the gears, we approached from left to right by turning clockwise of the nulling dial in every measurement. Figure 1 is a photo of relative gravimeter which is used in this measurement. Microscope eyepiece is replaced by optical system which consists of CCD camera and lenses.

The focus of the lens system is adjustable. While looking the CCD camera, move it up or down until a good focus is found. The image of the crosshair in the microscope is magnified and observed by CCD camera. Figure 2 shows a program which is developed for the calculation of tidal force. This tidal force is added or removed from the measured value to get the average gravity value at the target site.

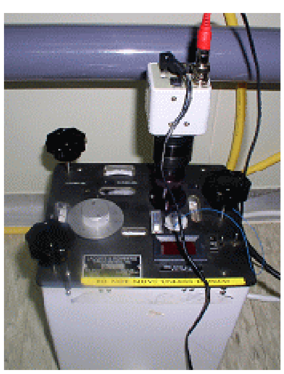


Figure 1. The L & R Gravimeter.

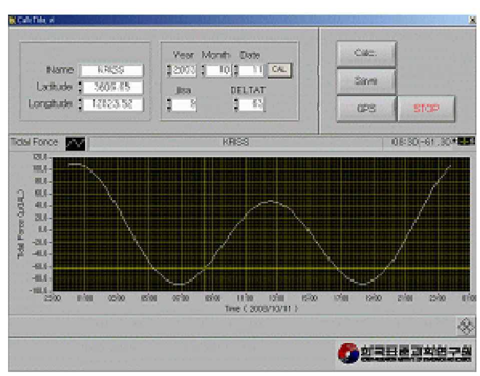


Figure 2. Program for the calculation of tidal force.

3. Gravity observations

Measurements have been performed at the most calibration laboratories in Korea with a relative gravity meter. Before starting the measurement, the gravity meter was checked for reliability by comparing two gravity sites measured by absolute method before. This experiment showed that measurements can be made with accuracy better than ± 0.1 mGal (0.1 ppm). Table 1 shows the results of this measurement.

Table 1. Observations at two sites of known gravity value.

	Absolute Measurement (known), m/s^2	Relative Measurement (unknown), m/s^2	Remarks
KRISS Force Lab.	9.798 299 8	9.798 299 8 (reference)	NIM(China) gravimeter
NGI	9.799 187 8	9.799 188 0	FG5 (Japan, NGI)
Gravity Difference	0.000 888 0	0.000 888 2	= 0.02 ppm

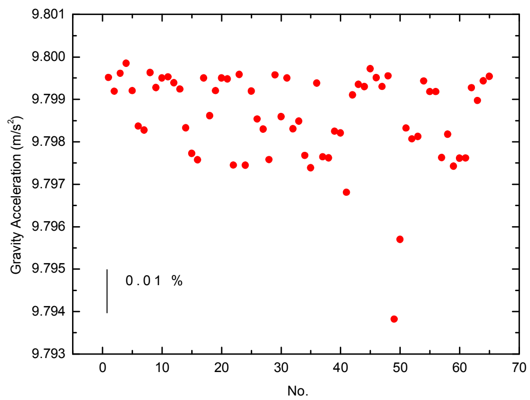
From 2002 to date, the gravitational acceleration was measured at about 80 calibration laboratories with this apparatus. Table 2 lists the values of gravitational acceleration of part of calibration laboratories performed in this period.

Table 2. Some gravity values of calibration laboratories.

No.	Gravitational acceleration, m/s^2	Location
1	9.799 503	Seoul, KTL
2	9.799 196	Kyungki, Soowon, Wise-Control
3	9.799 381	Kangwon, Choonchun, SMBA
4	9.799 365	Kyungki, Yangjoo, CAS
5	9.798 315	Daejeon, KRISS Pressure Lab.
6	9.798 318	Kyungbook, koomi, LG-ITS
7	9.797 451	Kwangjoo, Kia Motors
8	9.797 615	Pusan, Air Force 9341
9	9.796 808	Jeju, SMBA

Figure 3 shows the distribution of gravity values measured at the calibration laboratories. Most of these values lie between 9.797 m/s^2 and 9.800 m/s^2. Maximum gravity value is 9.799848 m/s^2 obtained at the Seoul City Gas. Minimum value is 9.796808 m/s^2 measured at the Jeju site of Small and Medium Business Administration. The difference between these two sites is 0.00304 m/s^2 (= 0.03 %). Further data were obtained at the 1100 m hill of the Hallasan. The value is 9.793822 m/s^2. Therefore, the gravity value of the top of Mt. Hallasan (1950 m) is estimated about 9.791297 m/s^2, if we apply a nominal gravity gradient value of

0.3mGal/m. Figure 4 shows the gravity distribution to compare the gravity values of the North Pole and the equator to show the position in the global point of view.



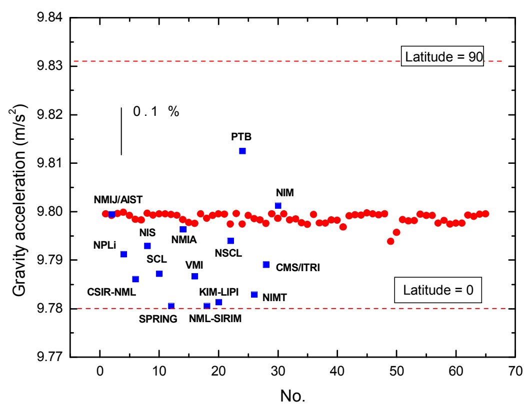


Figure 3. Gravity distribution in Korea. Figure 4. Gravity values in the global view.

4. Conclusion

From 2002 to date, measurements of gravitational acceleration have been carried out at the calibration laboratories in Korea. Most of gravity values are lied on between 9.797 m/s^2 and 9.800 m/s^2. Maximum gravity value was 9.799848 m/s^2 at the Il-san city and minimum value was 9.796808 m/s^2 at the Jeju city. The difference between these two sites is 0.00304m/s^2 which corresponds to 0.03% of the gravitational acceleration value.

5. References

[1] La Coste and Romberg Inc., *Instruction manual*, 1997
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