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Korea Geodetic Framework for Sustainable Development

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Summary

Since the satellite technology has been developed and widely used, the reference system is trended to the world reference system which basically leads to one common system and frame. All geoinformation based on one common system could support to solve many global scientific problems such as climate, environmental, and natural disasters. For this reason, the geodetic datum of Korea is superseded by the new Korean Geodetic Datum 2002 (KGD2002) from January 1, 2007. In order to improve the accuracy of geodetic datum in Korea, the VLBI station and the united control points (UCP) have been established. Subsequently, the hierarchy of national control points was reorganized. Also, to overcome geoid model in Korea separated by inland and ocean, the precise geoid model is being developed using all available land, ship-borne and airborne gravity data in Korea. In this report, the current status and future plans of geodetic frame in Korea for sustainable development is explained in detail.

1. Introduction

The rapid development of the satellite technology as well as the Information Technology accelerates the concept of the one earth. In other words, all geoinformation is considered based on one common system and frame which is defined by physical properties and behaviorof the earth. Furthermore, exchange of information is much faster and easier so that the common problems such as the climate, environment, and natural disaster could be predicted, mitigated, and/or solved. Obviously, GNSS especially GPS played a major role in these innovative changes. The capability of the continuous precise positioning of GNSShas been rapidly adopted over the world and now it is considered as a main system for numerous engineering and scientific data acquisition and analysis. The advantage of the GNSS system would be more increased if the coordinate system and frame corresponds to those being used by the system.

After experiencing rather dynamic changes over the past 60 years, the geodetic frame of Korea at present is well established using the state of art space geodetic technology such as VLBI and GNSS. The world geodetic system is adopted and a network of the newly designed national control point called unified control point is established over the entire country with regular spacing of 10 Km. In this report, the geodetic frame of the Korea is described. Starting from the brief history, the current status of geodetic frame including horizontal and vertical network as well as geoid is explained in detail with the hierarchy and accuracy. With the plans of the future development, a few suggestions are given for the geodetic network of Asian-pacific area.

2. Brief History of Geodetic Network in Korea

2.1. Horizontal Network

The Korean horizontal network has been developed mainly in four phases; KTN1910, KTN1957, KTN1987, and KGD2002. The first Korean Triangulation Network (KTN) in Korea is established in 1910 for the purpose of constructing 1:50,000 topographic maps. It was conducted by the Bureau of Land Survey with the cooperation of the Japanese Military Land Survey. The main technique applied for the most of the survey in KTN1910 was the triangulation, so the accuracy was relatively poor. During this project, 34,444 geodetic control points were established along the Korean Peninsula. Among them, 16,089 were situated in South Korea. It should be noted that the establishment of the network was accomplished by connecting with the Japanese geodetic network, instead of defining a national geodetic datum at this time so the Tokyo datum has been adopted in Korea.

Due to Korean War broke out in 1950 more than 65% of the triangulation points together with the raw data in KTN1910 was destroyed. To reconstruct the country, the government initiated the emergency recovery project for the triangulation points and produced KTN1957. The main purpose of this project was to provide the control points for the national reconstruction, so the rapidness rather than the accuracy and evenness of the network was emphasized. Obviously, this rapid construction of the network aggravated the degradation of the accuracy and the unevenness of the network.

In 1975, the Korean National Geographic Information Institute (NGII) initiated the first Precision Geodetic Network Campaign (PGNC). Mainly the first and second order triangulation points are recovered with the data on approximately 1,200 points obtained for ten years (1975-1994). For 3rd and 4th order control points, the second PGNC was initiated in 1987. Total 4972 points are observed with EDM from 1987 to 1998 and 737 points are observed with GPS from 1997-1998. The instruments used in this campaign other than GPS were Range Master (1976~1978), Range Master*(1979~1989), and G-6000 (1990~1994). In addition, the vertical angles from both ends are measured simultaneously with Wild T3.The trilateration technique was used in the first and second survey, and the network adjustment with those data was performed to publish KTN1987.

For better utilization of the recent satellite technology and following the trend of the coordinate system in worldwide, the KGD 2002 (Korean Geodetic Datum 2002) based on a world geodetic system, is being constructed. The reference epoch of KGD2002 is the 0 hour January 1, 2002 and the adjustment is carried out based on the coordinates of VLBI and GPS stations. That is, after fixing the coordinate of the origin with VLBI observation, the 1st order GPS CORS stations are adjusted. Then the coordinates of 2nd, 3rd order control points are successively adjusted. Through this hierarchical approach, the coordinate frame is gradually changed from ITRF1994 to ITRF2000, and the reference epoch is also changed from 1995.10.29 to 2002.0. In addition to the loss and destruction of the control points as described before, the Korean datum had major problem of projection on to geoid not on to an ellipsoid. Since Korea has not developed the precise geoid model, the measured distances and angles were projected using the orthometric height not the ellipsoidal height. In the development of KGD 2002, the projection of the horizontal distance on to the GRS 80 ellipsoid was performed. Although EGM96 was used for the projection, this provided better realization of the horizontal position than before.

2.2 Vertical Network

To establish the Korean height standard, tidal observation was carried out from 1911 to 1914 at Chungjin, Wonsan, Mokpo, and Jinnampo by the Bureau of Land Survey with the cooperation of the Japanese Military Land Survey. From 1912, the first order levelling was performed in the route of Pusan-Mokpo and Wonsan-Jinnampo. Total 1,931 BMs (Bench Mark) were established and 5,657km round observations were carried out for four years (1912-1916). Subsequently, Japanese Military Land Survey tried to link the Korean original BM of Wonsan to Chinese original BM of Manchuria in order to debouch into China. The attempt, however, is failed because approximately 70% of BM was destroyed at that time and circumstance forced them to conduct new first order levelling using existing BM. However, these results of levelling are not exist at present.

After 1945, Korean National Geographic Information Institute (NGII) initiated the first geodetic levelling for the purpose of recovering and expanding the vertical network and observing the diastrophism. The 1st order nationwide levelling and linking with the main automatic tide-gauge station (Incheon, Kunsan, Mokpo, Yeosu, Iksan, Ulsan, Mukho) were performed from 1974 to middle of 1980's.

In 1987, NGII initiated the first order vertical network adjustment on the basis of the 1st order vertical data which were obtained during 1974~1986 for the purpose of adjusting precision vertical points to standard which unified throughout the country. At the same time, the 2nd order vertical network adjustment was initiated on the basis of the 2nd order vertical data which were obtained during 1960~1987.

In 2006, the 1st and 2nd order vertical adjustment was initiated on the basis on the 1st and 2nd order vertical point data which were obtained during 2000~ 2005 and 1st order vertical point data which were observed in 2006 for the new KGD2002.

3. Current Status and Development

3.1. Korean Geodetic Datum and Origin

According to the revision of the Survey Act, the geodetic datum of Korea is superseded by the new Korean Geodetic Datum 2002 (KGD2002) from January 1, 2007. KGD2002 is a world geodetic system which is compliant with the International Terrestrial Reference System (ITRS). For the reference surface of the horizontal location, GRS80 is selected as the new reference ellipsoid replacing the old Bessel ellipsoid. The rationale for this change of establishing new datum is to keep pace with international trends, to fully utilize the recent satellite technology and to construct the spatial data infrastructure which is compatible worldwide. The comparison of the Korean geodetic datum in Korean 1985 Datum and KGD 2002 is shown in Table 1.

Table 1. The comparison of the Korean geodetic datum

	Koran 1985 Datum	**KGD 2002**
Ellipsoid	Bessel 1841	Land : GRS 1980 / Sea : WGS 1984
Epoch and Frame	Korean 1985 (Tokyo Datum)	ITRF 2000 (Epoch 2002.0)
Projection	TM (Transverse Mercator)	TM (Transverse Mercator)

The origin of the Korean horizontal datum was established in 1985 and is located in the NGII, Suwon city. Before 1985, the coordinates of the horizontal origin based on Tokyo datum was used. Precise Astronomical observation was determined the horizontal position of the origin from 1981 to 1985. WGD(World Geodetic Datum) coordinates for the origin are calculated based on VLBI(Very Long Baseline Interferometry) measurement in June, 2002. The history of the coordinates of horizontal origin is shown in Table 2.

Table 2. The history of the coordinates of horizontal origin

	1910 ~ 1984 **Tokyo datum**	**1985 ~ 2001** **Based on Astro. Survey**	**2002 ~** **Based on VLBI**
Latitude	N 35˚ 39' 17.5148''	N 37˚ 16' 31.9034''	N 37˚ 16' 33.3659''
Longitude	E 139˚ 44' 40.5020''	E 127˚ 03' 05.1451''	E 127˚ 03' 14.8913''

The origin of the Korean vertical datum has been determined from MSL by averaging the ebb and flow of the tide of Incheon Bay in 1963 and is located in the campus of Inha Technical College, Incheon city. The height is 26.6871m and it was observed by NGII from February 28 to March 11 in 1964 based on the Inchon vertical origin which was established in 1917 by the Bureau of Land Survey of Japan.

3.2. National Control Point

NCP(National Control Point) is a measured point providing basic position information for national base map and land development. The control point in Korea based on the Surveying law is consisted of 8 types: Satellite control point, Unified control point, Triangle point, Benchmark, Gravity point, Magnetic Point, Hydrographic point and Territorial base point. Among above, the NCP is the one which is determined by NGII(National Geographic Information Institute) of Korea. The hierarchy of NCP is shown in Figure 1.

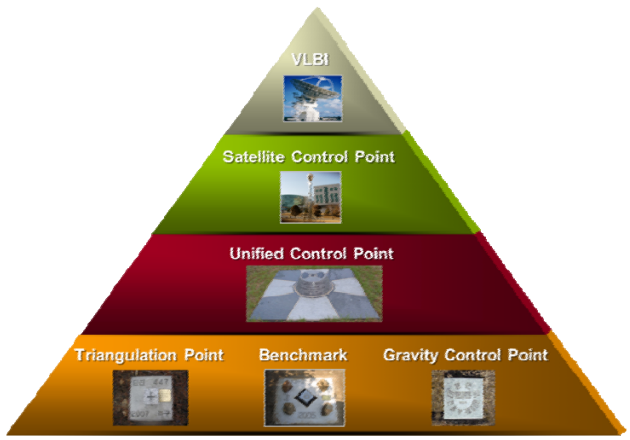

Figure 1. The hierarchy of national control points in Korea

VLBI

Very Long Baseline Interferometry (VLBI) is a system of astronomical interferometry used in geodesy. It allows observations of the coordinate and Earth Orientation Parameters (EOP) with high precision by measuring the time differences between the arrivals of radio waves at separate antennas.

The geodetic VLBI system in Korea was designed in 2007 and the construction of the observation center was begun in 2009. In 2012, the test is completed and is scheduled to begin full-scale observations. Korea geodetic VLBI station (Figure 2) is located in Sejong City, Chungnam province. It is equipped with 22M diameter antenna on the site of 35,000 ㎡with a two story building of the processing center.

Figure 2. Geodetic VLBI station with facilities in Sejong city

The observed results from VLBI will be used to build and maintain the national geodetic datum with high precision. Four ground-combined pillars as reference points were installed around the antenna, which is facility for local-tie connecting ground control points in conjunction with GNSS system. Geodetic VLBI in Korea has the goal of supporting research for the geophysical field associated with the national control point management, intercontinental crustal precision survey, and Earth Orientation Parameters (EOP).

In 2011, there are 28 geodetic VLBI stations, 6 correlation processing centers, 29 analysis centers in 15 countries around the world that joined International VLBI Services for Geodesy and Astrometry(IVS). To join IVS Network Station, NGII announced the current status and future plan of Korea geodetic VLBI station at the 7th Annual Meeting of IVS in March, 2012. The Korea geodetic VLBI station was formally approved from IVS and the test observations were performed successfully in February 2012.

Satellite Control Point (GNSS CORS)

Currently, 103 GNSS CORS are being operated by various institutes/centers in Korea. Among them, 45 stations are operated by NGII whose mission is to provide the coordinates of the national control points. The GNSS CORS of NGII have been operated since March 1995 to investigate the crustal motion of Korea and its vicinity so that precise position could be determined. The stations are equipped with TRIMBLE dual frequency receivers and the data is processed by Bernese which determines the position of GNSS receivers with precision about 20ppb and 60 ppb for horizontal and vertical, respectively. The CORS observation is made on 1 second data interval, but the 30 seconds data is opened to public. Figure 3 shows the current configuration of GNSS CORS network in NGII. The coordinates of the GNSS CORS in KGD 2002 were determined on the epoch of 2002.0 by processing five days of observation from the end of year 2001 to the beginning of year 2002 using Bernese. Now, the GNSS CORS of NGII is served as the first order control points in KGD 2002.

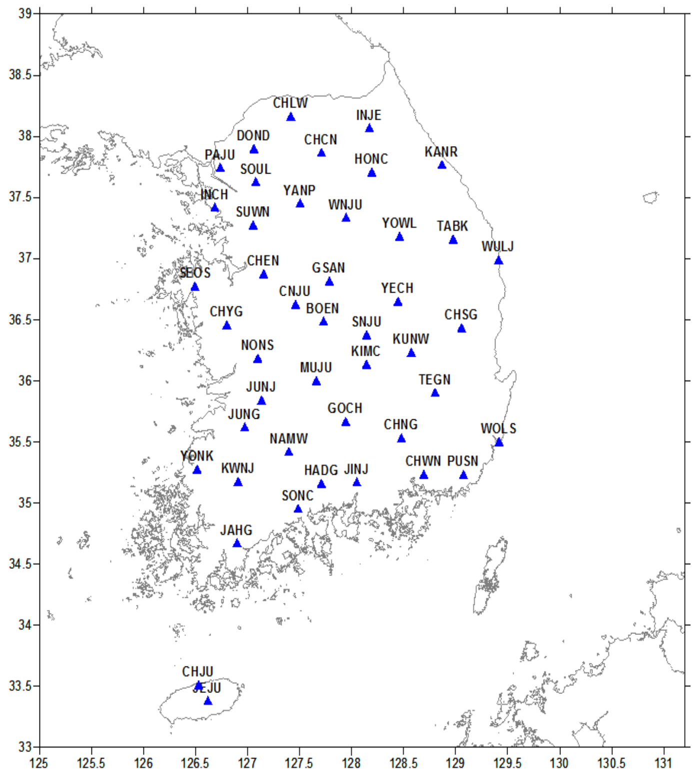

Figure 3. GNSS CORS Network managed by NGII

Unified Control Point

One of the dominant changes in Korean geodetic network is the activities on the establishment of the unified control points. The unified control points are observed, processed and maintained in three-dimensional way. This control point provides the geodetic coordinates, orthometric height and the gravity value. The main reason for this is to fully utilize the satellite positioning technology and to establish the complete compatibility in worldwide coordinate system. On top of that, scientific and engineering data being provided at the same point with accurate spatial information is expected to enhance research quality so that more detailed analysis on physical phenomena could be performed. Figure 4 shows a unified control point established by NGII at Suwon City Hall. The dimension of the marker at the base plate is 1.5m x 1.5m and the diameter and the diameter of the central marker is 40cm. Since 2008, 1195 points have been installed, and cover whole country with 10 km x 10 km spacing.

Figure 4. Unified Control Point

Triangulation Point, Benchmark and Gravity Control Point

According to the revision of the Survey Act in 2009, the triangulation pointscategorized as four orders before were merged into one and connected to the unified control points. Currently, the number of the triangulation points is 16,412 with the spacing of 2.5 ~ 5km. It is decided that the triangulation points will be maintained rather conservatively based on the necessities.

The Korean vertical network is categorized as the first order and the second order with spacing of 4 km and 2 km, respectively. Korean 1st order vertical network consists of 1141 BMs and 36 routes, with total length 3,342. The 2nd order vertical network consists of sixteen leveling loops with total length of 7,863 km; ten loops are encircled by 1st order leveling routes and six loops are bordered by a 1st order leveling routes (Figure 5).

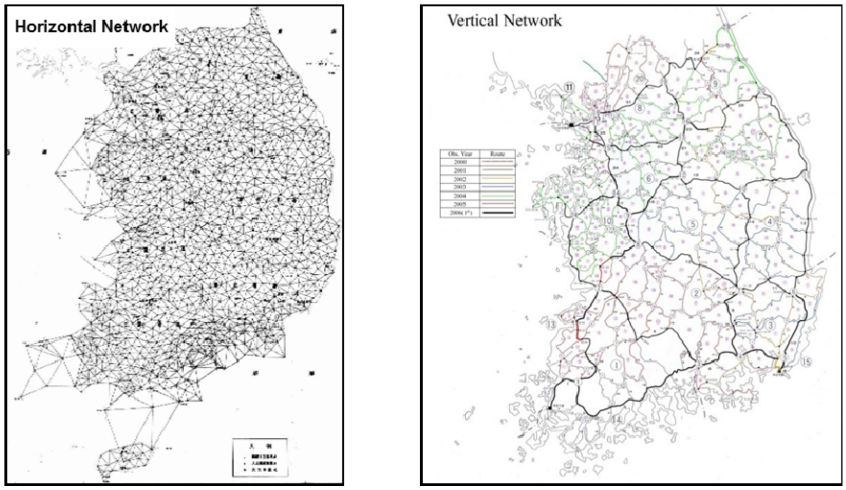

Figure 5. Overview of Horizontal and Vertical Network

The gravity control points consist of absolute and relative gravity points. Currently, 10 absolute gravity points (Figure 6) has been established by the measurement of FG-5 absolute gravimeter.Over the country, total of 8,171 gravity points have been established in Korea.

Point	Abs. Gravity	Year
Suwon	979918.775	2009
Gangneung	979982.612	2010
Daegu	979808.018	2009
Gwangju	979746.827	2009
Daejeon	979831.351	2010
Changwon	979756.618	2010
Jeju	979562.665	2010
Pohang	979858.066	2010
Taebaek	979767.977	2010
Dokdo	980032.966	2010

Figure 6. Absolute gravity points in Korea

3.3. Geoid Model

Previously, the Korean geoid models have been developed separately for inland and ocean by NGII and KHOA(Korean Hydrographic and Oceanographic Administration), respectively. However, the GMK09(Geoid Model Korea 2009) developed by NGII showed big difference at the coast, and the NORI05 constructed by KHOA showed significant bias compared to GPS/Leveling of UCPs due to problems on the gravity data. To overcome the problems, new land gravity data has been obtained by NGII since 2008, and the ship-borne gravity data is being reprocessed by KHOA. Also, the study to construct new geoid model covering whole Korean peninsula has been started in 2011. In 2011, the geoid model has been updated for inland based on the new land gravity data obtained since 2008 and DNSC08 altimeter data. The precision of the gravimetric geoid model is 6.81cm and the degree of fit of hybrid geoid model is 3.56cm. In next three years, the precise geoid model will be constructed using all available land, ship-borne and airborne gravity data in Korea. The goal of the precision is about 1-2 cm in plain area and 3-5 cm in mountainous area.

4. Future Development

The current plans of the future development in next five years for geodetic frame of Korea are listed as below.

a. Full operation of VLBI

- VLBI test operation in conjunction with VLBI of Japan (2012)
- Participate the international joint observation in conjunction with IVS network stations(29 stations in 16 countries, 2013)
- Update the product of control pointsbased on VLBI results (2017)

b. Development of Precision geoid at the level of cm

- Measuring ellipsoidal heights at gravity pointsof coastal area and benchmark for updating hybrid geoid model (~ 2014)
- Develop the precision geoid model using all available gravity data (2014)

c. Establishment of sub-UCP in spacing of 3km

- Establish 7,000 united control points covering whole country with 3 km spacing (~2017)

d. Three dimensional positioning of bench mark (~2016)

e. Establish a new absolute gravity station for improving the functions of VLBI station (2013)

In addition to the above listed works, the adoption of SLR and various system improvements, for example, the adoption of dynamic geodetic datum are under consideration in long term plan as well.

5. Conclusion and Suggestion

In this report, the status of Korean geodetic frame is described with brief history and some future plans. At present, Korea has a stable and accurate geodetic frame based on the world geodetic system. The state of art VLBI system, well established GPS CORS, and newly deployed unified control point provide more efficient and accurate environment of data acquisition not only the position but also the gravity. In next five years, the geodetic frame of Korea will be more accurate by denser control points and precision geoid.

With current technology, the geodetic frame could support many global scientific problems such as climate, environmental, and natural disasters. To do this, a couple of works are necessary in future geodetic frame. These are the adoption of world geodetic system and the unification of the height system. Considering the efficiency of the GNSS system and connection to the other nations, the adoption of world geodetic system on which the most of the geoinformation is expressed and analyzed is the most important prerequisite. Furthermore, the unification of the vertical system is necessary to analyze the physical behavior of the earth and even for a mega construction like long bridge or undersea tunnel. Therefore, it is suggested that a detailed plans for conducting above works should be established based on the cooperation of member states of UN-GGIM.