Analysis of National Vertical Datum Using Tidal Gauge Bench Mark in KOREA

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Key words : Tidal Bench Mark(TBM), Local Mean Sea Level(LMSL), Incheon Mean Sea Level(IMSL), Geoid Model, Sea Level Slope

SUMMARY

Necessity of connection between ocean and land height system for coastal development and disaster prevention has been increased due to sea-level rising occurred by recent global warming and more frequently happened natural disasters than before. There is a rising interest in the ocean and land height system. Standards of vertical datum of ocean and land are different, they are used for different purposes. This study analyses local mean sea level which decides vertical datum of ocean, geometric heights on Incheon Mean Sea Level(IMSL) and national geoid model which decides vertical datum of land using 20 points of TGBM(2013). The result of the comparison between local mean sea level and geometric height national geoid model, there are three points in total 20 points shows residuals over 10cm. These are mainly due to inflow of rivers, relocation of Tidal Gauge Station, or change of local mean sea level based on topographical changes brought harbor constructions.

This study examined possibilies of connection between ocean and land vertical datum standards. In order to connect those two, increasement of connected survey data for ocean and land heights, managed and shared vertical datum by Korea Hydrographic and Oceanographic Administration and National Geographic Information Institute, are required. More accurate vertical height standards would take an important role in efficient and economic coastal development and preventing disasters.

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1. BACKGROUND AND OBJECTIVES

National Vertical Reference Systems have different many different vertical datums according to various purposes. In South Korea, the Incheon Mean Sea Level (IMSL) is used as the land vertical datum. Meanwhile the Datum Level (DL), Local Mean Sea Level (LMSL), and Approximate Higher High Water (AHHW) are used for sea (Navigation chart) vertical datum.

Nowadays, connecting sea and land vertical datums is becoming an important issue as development of the coastal and island area is activated. If the vertical datums of sea and land are not linked, not only public safety could be at stake, but also economic efficiency would be reduced. It will be also helpful to determine the height of breakwater and bridge which would secure for the safety of construction work at coastal areas.

There are various vertical datums in Korea. Korea Hydrographic and Oceanographic Administration (KOHA) has been trying to connect land and sea vertical datums. KOHA created precise leveling between TGBM (tidal gauge bench mark) and BM (bench mark), and developed the precision geoid.

In this research a comparative analysis was carried out using local MSL used to determine sea vertical datum, Incheon MSL used to determine the land vertical datum and Geometry height of KNgeoid(Korean National), using 20 points of TGBM(Tidal Gauge Bench Mark) which are mounted in 2013.

2. METHODOLOGY AND RESULTS

2.1 Tidal Gauge Bench Mark

TGBM is included in the national reference point. The purpose of TGBM is to measure the height and water level. TGBM is located around tidal stations.

Korea Hydrographic and Oceanographic Administration (KHOA) has installed 48 TGBM points from 2012 to 2013. TGBM can provide information about LMSL, IMSL, LDL (Local Datum Level), longitude, latitude, ellipsoid height, geoid height, etc.

TGBM	GPS Survey	BM – TGBM Leveling	Gravity measurement

Figure 1. Tidal Gauge Bench Mark (TGBM) Surveying

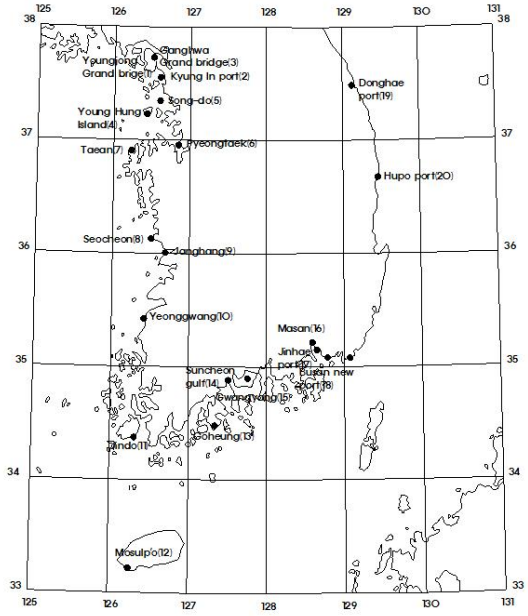

Figure 2. TGBM Installation Area(2013)

Table 1. TGBM Installation Area(2013)

No.	Designation	No.	Designation	No.	Designation	No.	Designation
1	Youngjong Grand bridge	6	Pyeongtaek	11	Jin-do	16	Masan
2	Kyung In port	7	Taean	12	Mosulp'o	17	Jinhae port
3	Ganghwa Grand bridge	8	Seocheon	13	Goheung	18	Busan new port
4	YoungHung Island	9	Janghang	14	Suncheon gulf	19	Donghae port

5	Song-do	10	Yeonggwang	15	Gwangyang	20	Hupo port

2.2 TGBM Data Processing

In this research, GPS coordinates are estimated using the Bernese 5.0 software. The Bernese version 5.0 is selected as main data processing software. It provides several unique data processing tools Which are useful to handling a huge number of GPS measurements (Gendt et al., 2005). LMSL Geometry height was calculated using short-term tidal observations. In addition, IMSL Geometry height was calculated using precise leveling between TGBM and BM. Geometry height was calculated using the KNgeoid13. KNgeiod13 was developed in the National Geographic Information Institute (NGII). The result is the same as in the table below.

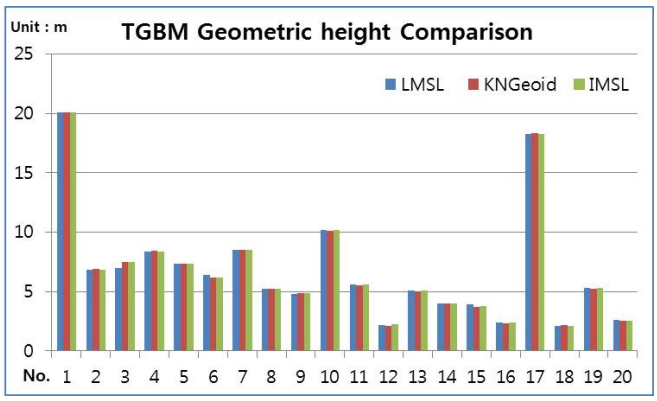

Figure 3. Comparison of Geometric Height

Table 2. Comparison of Geometric Height

TGBM No.	LMSL Geometric Height(m)	KNGeoid Geometric Height(m)	IMSL Geometric Height(m))
01 Youngjong bridge	20.0751	20.1001	20.0570
02 Kyung In port	6.8427	6.8673	6.8248
03 Ganghwa bridge	6.9764	7.4931	7.4986
04 YoungHung-do	8.3725	8.4344	8.3468
05 Song-do	7.3208	7.3445	7.3117
06 Pyeongtaek	6.3969	6.2013	6.1917
07 Taean	8.5236	8.4858	8.4979
08 Seocheon	5.2594	5.1938	5.2534
09 Janghang	4.8058	4.8811	4.8737
10 Yeonggwang	10.1607	10.1228	10.1447
11 Jin-do	5.5872	5.5112	5.5605
12 Mosulp'o	2.1464	2.0731	2.2666
13 Goheung	5.1113	5.0116	5.0749
14 Suncheon gulf	3.9605	3.9564	3.9754
15 Gwangyang	3.9521	3.7203	3.8017

16 Masan	2.4239	2.3408	2.3814
17 Jinhae port	18.2389	18.3384	18.2779
18 Busan new port	2.0887	2.1675	2.1168
19 Donghae port	5.3022	5.2629	5.2961
20 Hupo port	2.5989	2.5670	2.5108

2.3 Geometric height comparison result

Three geometry heights have equal trend. In case of geoid geometry height as synthetic geoid corrected by GPS/Leveling record, it was almost matched with land standard IMSL. As a result of checking the LMSL gap with TGBM Geometry height that using geoid model in standard geometry height. The differences between TGBM Geometry height and geoid model in standard geometry height, the maximum residual was –51.67cm at Ganghwa bridge, and the minimum residual was 0.14cm at Suncheon bay. Ganghwa bridge(-51.67cm), Pyeongtaek(19.56cm), Gwangyang(23.18cm) are shown residual over 10cm. Residual standard 10cm is set based on the marine(navigation) chart, whose standard of water level is also 10cm.

In 2013, the average gap in 20 points TGBM of KNgeoid between LMSL was 0.35cm, and standard deviation was 14.93cm. The average gap except points which had residual over 10cm was 0.94cm, and standard deviation was 6.31cm. Harbor construction work(landfill) in Gwangyang, inflow of the Han river at Ganghwa bridge, movement of tide station and harbor construction work around Pyeongtaek are cause the residual, so there need to field survey and record management in tide stations.

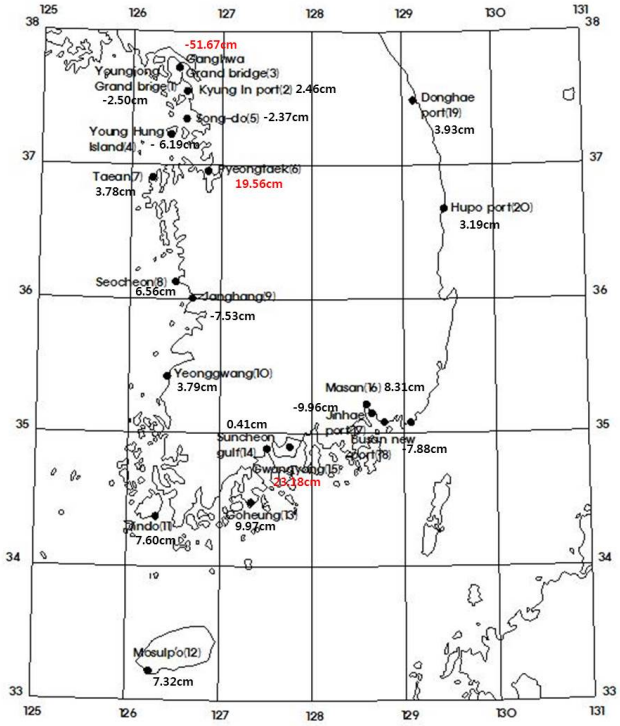

Figure 4. Compare LMSL and Geoid

2.4 Sea Level Slope of Korean coast

Comparing geometry height of LMSL to IMSL is related to Sea Level Slope. Sea Level Slope is calculated the differences between LMSL of TGBM by the MSL of each regions and IMSL by geodetic surveying-levelling network. As the result of the analysis of differences between TGBM's IMSL and LMSL in 2012 ~ 2013, the Sea Level Slope in Korea was getting higher to move from the West sea to the East sea, the South sea (Table 3). To verify the calculated Sea Level Slope, the land / the ocean height connection service in National Geographic Information Institute and the paper related with Sea Level Slope in the Korean ocean are used

Previous paper quoted the result of paper which named 'The Sea level Slopes along the Korean Peninsular Coast Based on the First Order Levelling Net in Korea', was released in 1993. The reason for selecting this as a comparison paper was not much proposed Sea Level Slop of the Korea ocean in field of domestic surveying. According to above paper, Mokpo's Sea Level Slope was 17cm based on Inchon MSL but in this research was 3.1cm. Also in case of the East Sea, Ulsan and Mukho's average Sea Level Slope was 2cm, but in this research

was average 12.7cm. The reason of the differential occurred with previous research was in 1993, the result of LMSL using tide and network adjustment of land bench mark was more low accuracy than present land leveling net and LMSL calculation method.

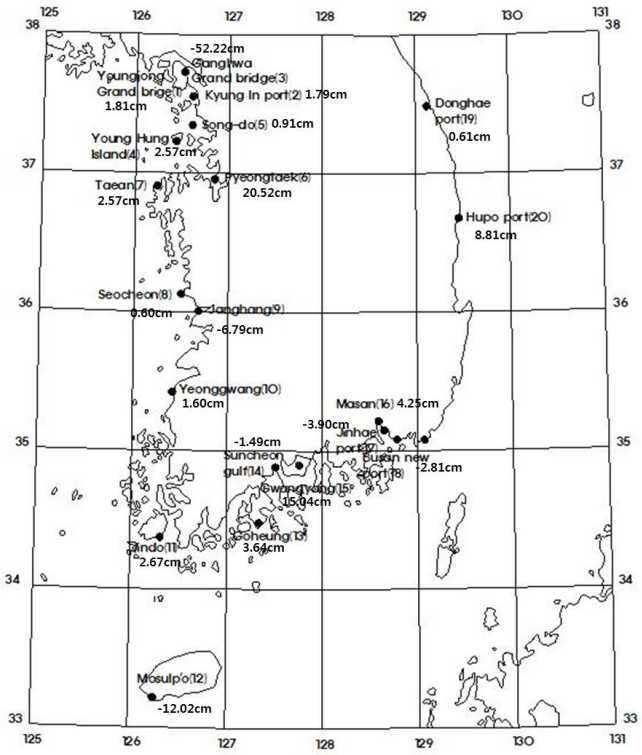

Figure 5. Sea Level Slope of Korean coast(2013)

Table 3. Sea Level Slope of Korea coast by TGBM

Sea Level Slope	Western Sea	Southern Sea	East Sea
Mean(cm)	**-0.34**	**5.01**	**12.58**
Standard Deviation(cm)	**13.64**	**6.46**	**7.55**

3. CONCLUDING REMARKS

As a result of comparison geometry height of geoid model and LMSL using TGBM, there were residual 10cm under at 17 points and over 10cm at 3 points of total 20 points. The points that have residual over 10cm are occurred residual caused by LMSL movement where are influenced by inflow of rivers, relocation of tide station and harbor construction work.

The difference between LMSL and IMSL is defined Sea Level Slope, in Korea, Sea Level Slope is getting higher from the West sea to the South sea and East sea. As a result of

comparing previous paper, there occurred differential and this result had accuracy problem of tidal observation and land leveling net when that paper was released in Korea. The reason why these result occurred is that the determination of LMSL has influenced by physical properties as coast terrain when tidal observation.

This study examined possibilities of connection between ocean and land vertical datum by using TGBM. So from now on, connecting survey of the ocean and land will be implemented continuously to accurate connection with the ocean and land vertical datum. There are many reasons where the gap was occurred, so the record management of TGBM and Tide stations will be processed to figure out the reason. Also these record data have important role in development and prevent of the ocean as base line data.

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