16th World Conference on Earthquake, 16WCEE 2017

Santiago Chile, January 9th to 13th 2017

Paper N° 1605 (Abstract ID)

Registration Code: S-T1463336266

Korean Liquefaction Hazard Map in Real Time

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Abstract

Recently, earthquake hazards have been more unpredictable and severe. Thus many countries have tried to make a special seismic defense system including domestic liquefaction hazard maps. Several countries drew the liquefaction hazard map for metropolitan area under the specific acceleration. Korea also has tries to establish the earthquake and tsunami defense system based on the GIS for several years but there are some troubles to set up and verify a reasonable system because there was few earthquake hazard data in Korea. Nevertheless, Korea kept going to set up and upgrade National Disaster Prevention System. It was thought that liquefaction and land sliding hazard maps were necessary to make the earthquake prevention effectively.

In Korea, a domestic liquefaction assessment can obtain reliable prediction results for seismic design of facilities along with the site response analysis function in case of site amplification. This method is good for a seismic design of a new facility. However, it will take much time in building a national defense system to deal with a lot of data. Thus, it is proper to apply the site amplification coefficients in the macro liquefaction hazard mapping instead of site response analysis.

In this study, we have carried out the liquefaction potential assessment using geotechnical information of 110,000 boreholes in Korea. In the assessment, we determined soil type using average shear wave velocity and we carried out the simplified liquefaction potential assessment using site amplification coefficients. In special, we developed an Excel spreadsheet to calculate the liquefaction potential index automatically. The Excel spreadsheet includes soil classification, the simplified liquefaction assessment, and calculation liquefaction potential index at a position of GIS map. Also, we calculated liquefaction potential indexes using the developed Excel spreadsheet and liquefaction hazard maps against desirable earthquakes with maximum accelerations ranged from 0.06g to 0.38g were drawn.

Also, to develop the real time hazard map, we investigated the relationship between liquefaction potential indexes and accelerations at every point on the map. In the GIS map, we used 2Km by 2Km cell unit for possible to connect with NEDP in Korea. For its verification, Hongsung Earthquake, Odae Mountain Earthquake which occurred in Korea and two artificial earthquakes in Paju and Yangsan were simulated. As a result, real time liquefaction hazard maps for whole country were drawn.

Finally, we drew two kinds of liquefaction hazard maps in this study. One is the liquefaction hazard map under the same acceleration and the other is the virtual liquefaction hazard map to consider the possible earthquake generation under real time. All maps were drawn successfully. From this research, it was found that this mapping method for macro liquefaction hazard map would be effective. Also, it can give a good countermeasure in the moderate seismic countries like Korea..

Keywords: metropolitan area; real time hazard map; liquefaction potential index, National Earthquake Disaster Prevention

1. Introduction

In 1960, the largest earthquake in the world occurred in Chile. After then, 3 times earthquakes over magnitude 8 has occurred. However, the damage has shown a tendency to decrease gradually. The decrease of hazard is a good example to show that the earthquake damage can be reduced with prevention. Also, two years ago, an earthquake occurred in Napa, the United States, there was a performance to predict earthquakes before 8 seconds. 8 seconds is a very short time, but it is very encouraging in that the evacuation effort and a little bit more time to reduce the damage for only 8 seconds.

As above, many countries have tried to prevent earthquake hazards such as liquefaction and land-sliding. Currently, Korea is also making a lot of efforts to establish and advance the system for earthquake disaster prevention at national level.

This study conducted the two sub-researches in order to create a real-time liquefaction hazard map using the whole boreholes' information over 100,000 sites. One is to draw a liquefaction hazard map by liquefaction potential index under an earthquake acceleration. At that time, we calculated the index, LPI with summation of safety factors from evaluated by liquefaction potential assessment program in order to process a large quantity of site data in the whole boreholes' information of Korea. Also, we drew continuously several liquefaction hazard maps for each acceleration based on the interval of 0.04g from 0.06g to 0.38g. The other is to real time liquefaction hazard maps using proposed a relational formula between LPI and each acceleration as to those individual coordinates in the unit of cell on the map through the correlation. Finally, this research created real-time liquefaction hazard maps at magnitude 6.5 for 4 artificial earthquakes' event. In the real time liquefaction hazard simulation, 4 epicentres' situations were selected in Hongsung, Mt.Odae, Paju, and Yangsan.

2. Macro Liquefactin Hazard Map under a Maximum Earthquake Acceleration

To draw macro liquefaction hazard map, this study utilized Liquefaction Potential Index (LPI) proposed by Iwasaki [1] in relation to the liquefaction evaluation for each site acceleration. Using LPI, this study placed priority on the creation of a liquefaction hazard map for each site acceleration as to the metropolitan areas. In case of Korea, for domestic liquefaction evaluation, the standard penetration test results and the assessment method for simplified liquefaction potential are commonly used.

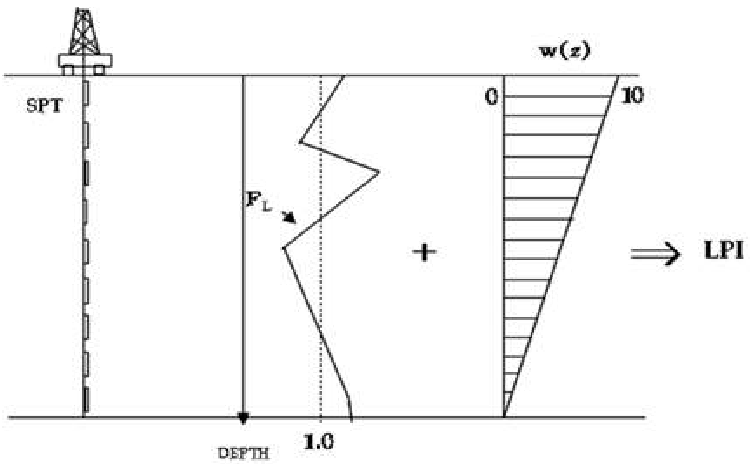


Fig. 1 – Calculation procedure of LPI at a site [2]

Fig. 2 uses the stage 3 prediction method to perform liquefaction preliminary evaluation and simplified evaluation based on site investigation data. Using safety factor for liquefaction potential each boring depths, the liquefaction potential indexes, LPIs are calculated to be used on the map. And this method is appropriate for drawing a liquefaction hazard map for wide area used. The used site investigation data are data on over 110,000 boreholes in metropolitan area obtained from Integrated DB Center of National Geotechnical Information of Korea Institute of Construction Technology. In the DB data, coordinates and standard penetration test results were used.

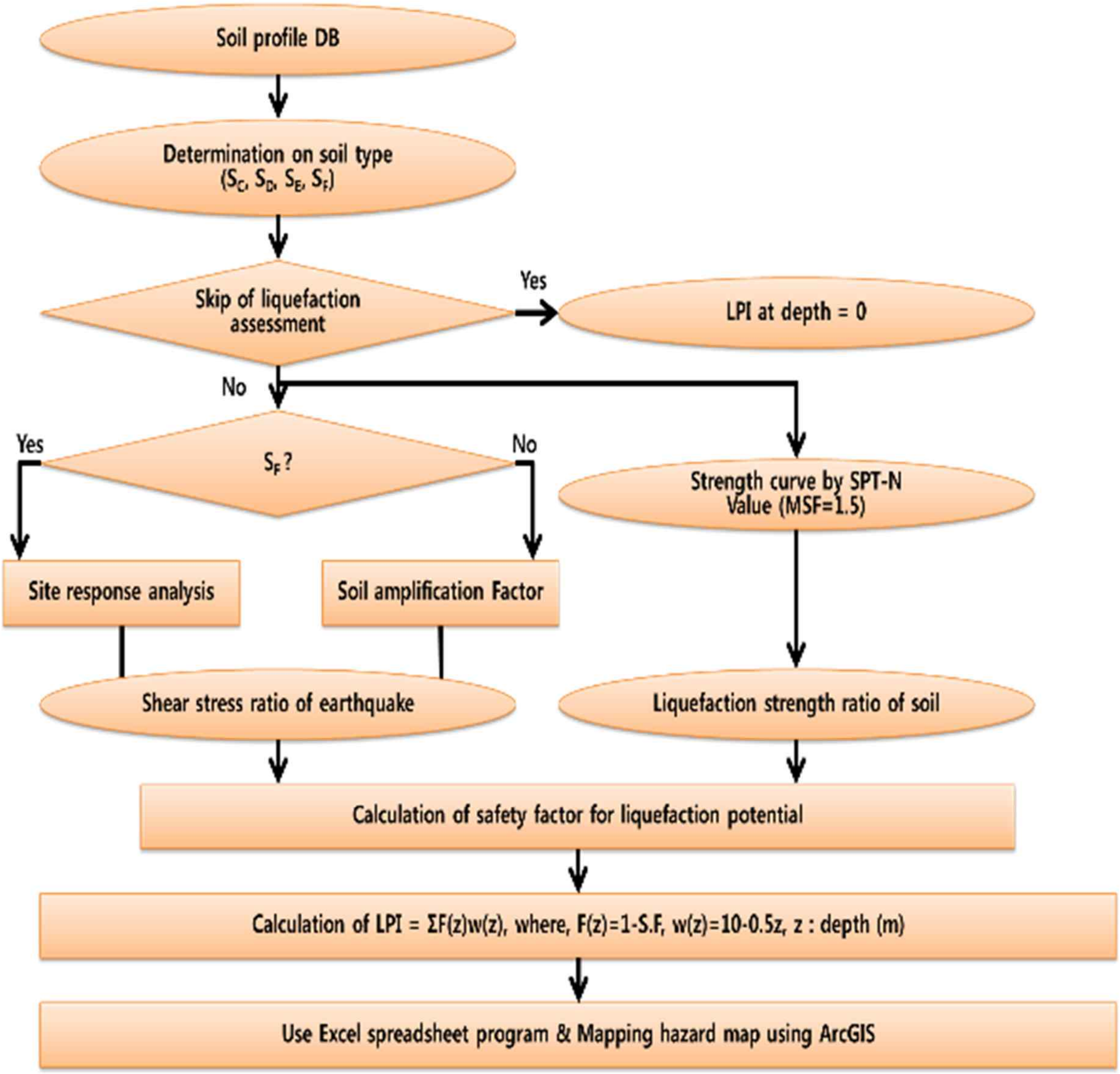


Fig. 2 – Analytical procedure for Korean liquefaction hazard map [2]

When calculating the shear stress ratio by the earthquake, Korea supplemented carrying out site response analysis. But, this simple evaluation is used for estimate the possibility of liquefaction occurrence of existing facilities or new one instead of making liquefaction hazard map. If using this method to perform the creation of the liquefaction hazard map in macro area, it takes much time to analyze site amplification. As an example, Integrated DB Center of National Geotechnical Information, above-mentioned, possesses about 110,000 information of ground borehole. If running site response analysis for liquefaction hazard map based on information, it will require about 50,000 hours to analyze. In this study, we applied amplification coefficients according to the soil type used in Euro-code.

To process approximately 110,000 data, this study conducted the liquefaction evaluation by developing a liquefaction evaluation program using the amplification coefficients for each site that could reduce the time taken for liquefaction evaluation. Fig. 3 shows the liquefaction evaluation program developed in Excel.

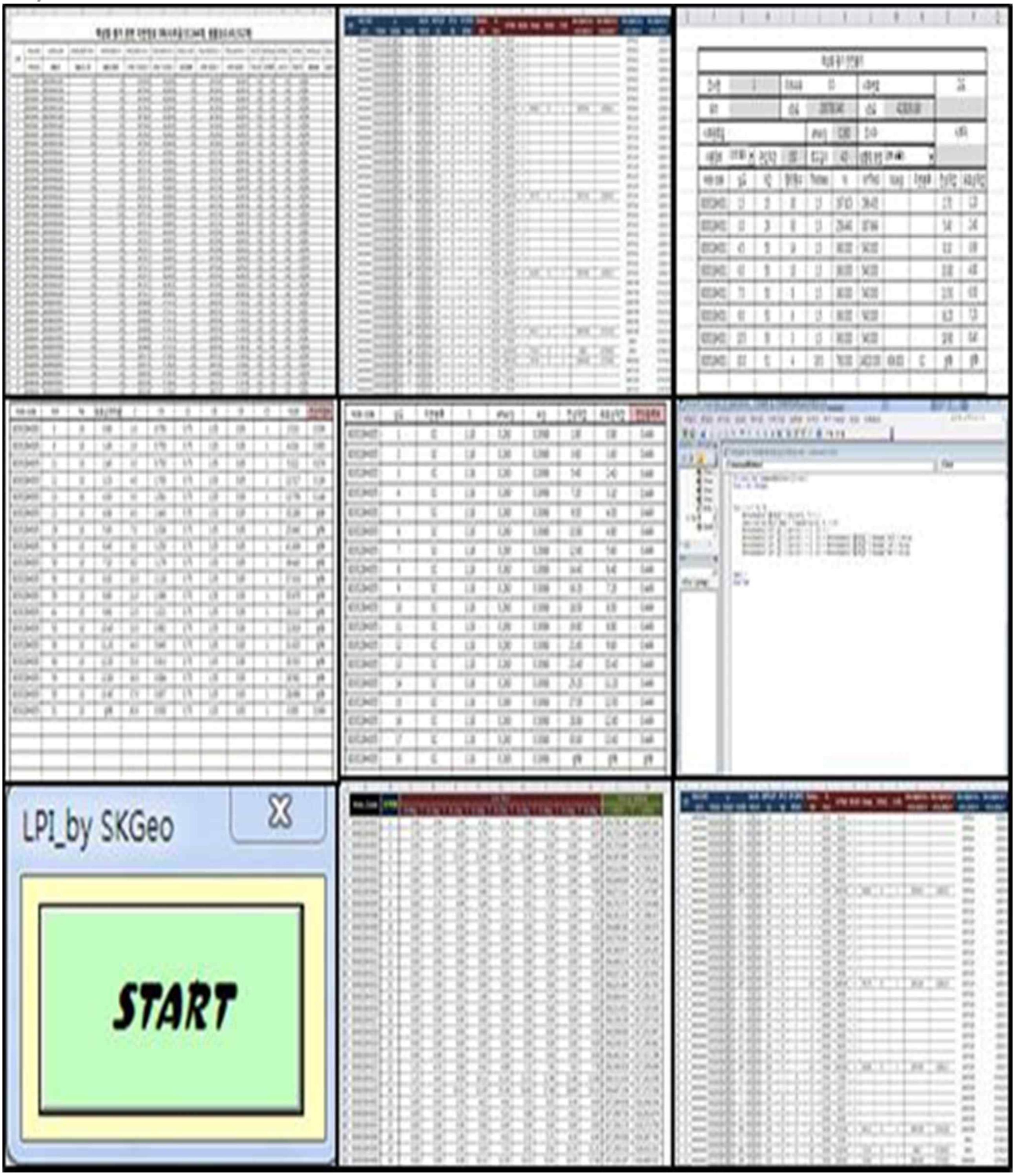
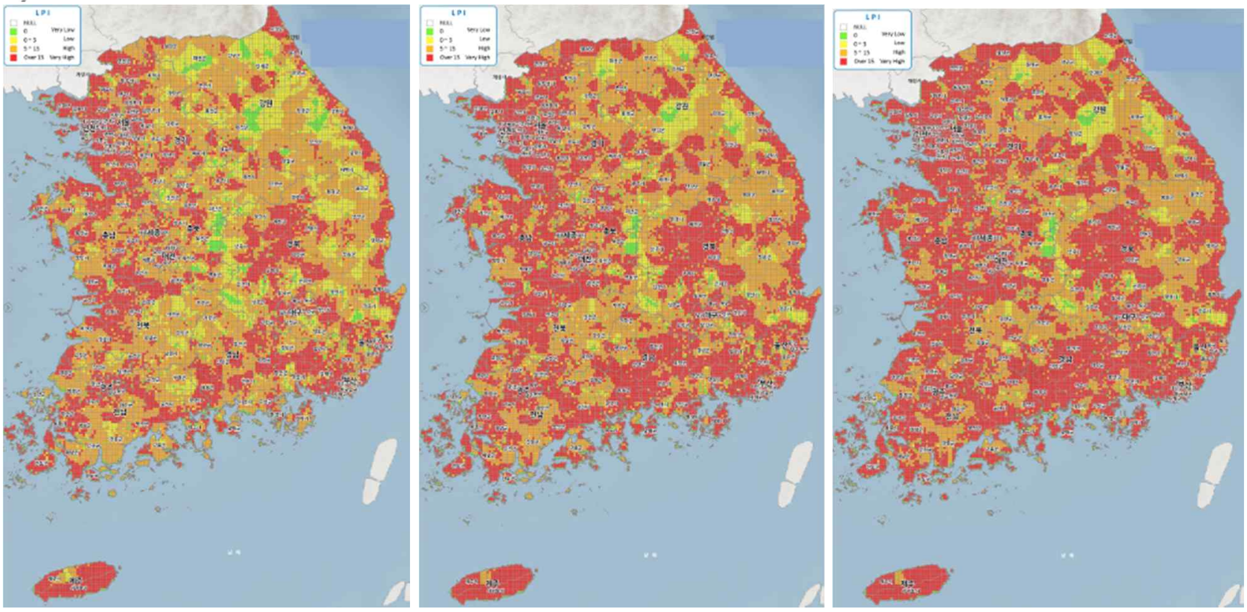


Fig. 3 – Liquefaction evaluation program in Excel [3]

Using this Excel program, we could calculate all LPIs under 9 maximum earthquake accelerations. As a result, we could draw liquefaction hazard maps with Kriging interpolating technique as below.



(a) PGA_0.14g (b) PGA_0.22g (c) PGA_0.30g

Fig. 4 – Liquefaction evaluation program in Excel [4]

3. Liquefaction Hazard Maps in Real time

Using all data for the above hazard maps, we can draw a liquefaction hazard map in real time. Fig. 4 shows a procedure of drawing liquefaction hazard map in real time briefly.

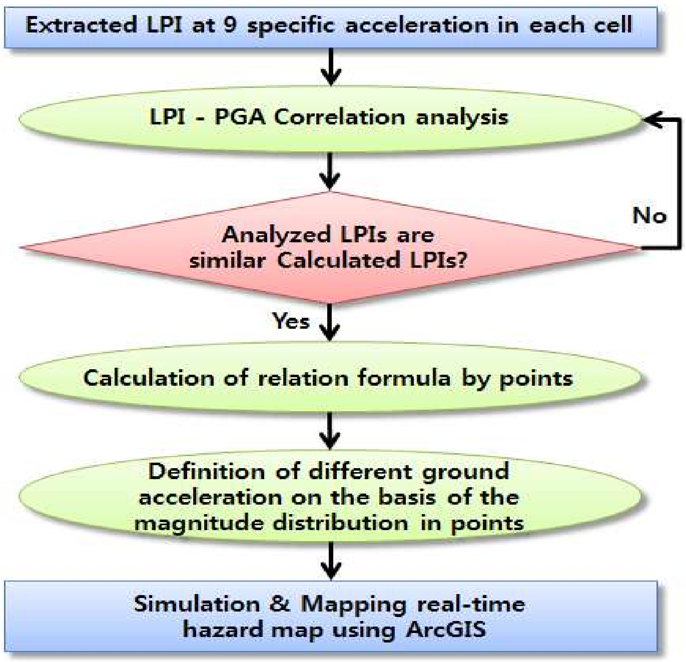
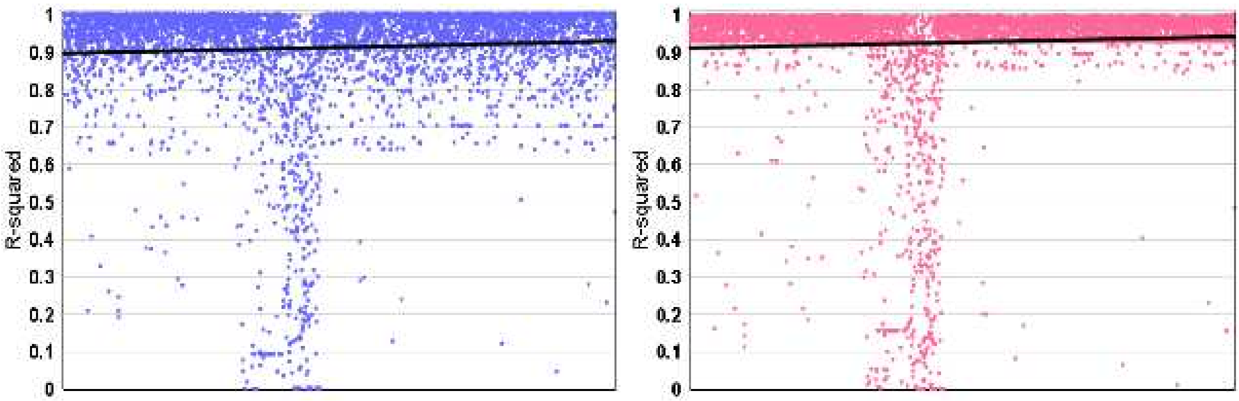


Fig. 5 – Procedure of drawing liquefaction hazard map in real time [5]

As shown Fig. 5, to draw a liquefaction hazard map in real time, it is necessary to define a proper relationship equations at every point. In this study, 2 regression functions, which those are hyperbolic function and logarithm fuctions were compared for selection of a proper relationship equation. The results are as show in Fig. 6 and Tab le 1.



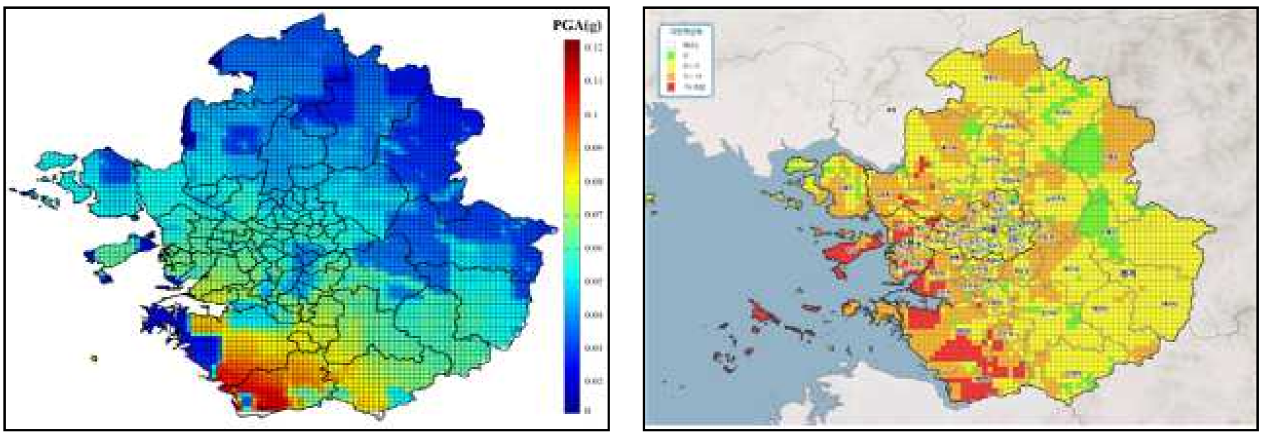
(a) Hyperbolic function (b) Logarithim function

Fig. 6 – Example of earthquake event simulation for drawing liquefaction hazard map in real time [4]

Table 1 – Comparison between hyperbolic & logarithm function [5]

Relationship function	R (avg)	R^2 (avg)
Hyperbolic	0.949	0.913
Logarithm	0.956	0.926

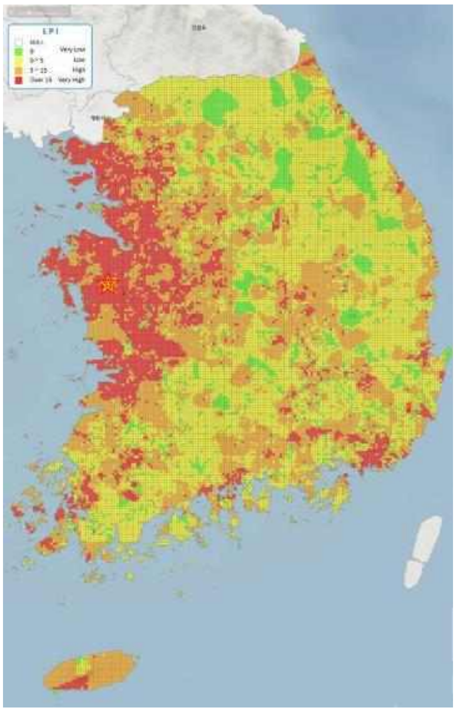
Table 1 show that log functional formula has more reliable results than hyperbolic functional formula. Using the logarithm function, we simulated earthquake events in 4 areas which were Hongsung, Mt.Odae, Paju and Yangsan. For example, the change of earthquake accelerations in the whole country was shown Fig. 7 (a) and the changeo of liquefaction hazard index, LPIs was shown in Fig. 7 (b).



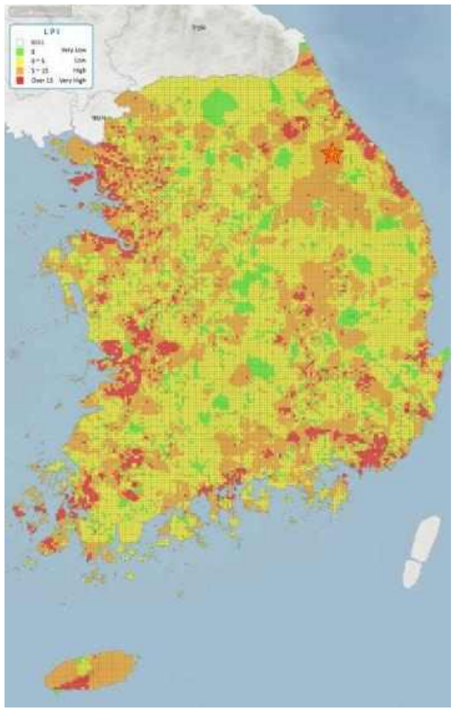
(a) PGA variation (b) LPI variation

Fig. 7 – Example of earthquake event simulation for drawing liquefaction hazard map in real time [4]

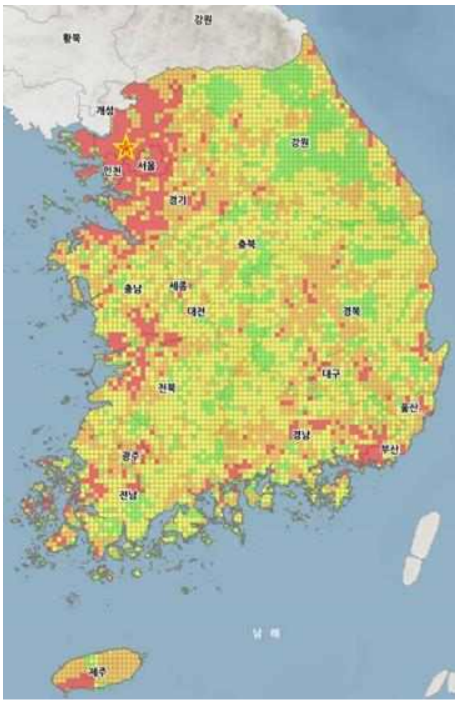
Finally, we drew four liquefaction hazard mpas at mignitude 6.5 as below.



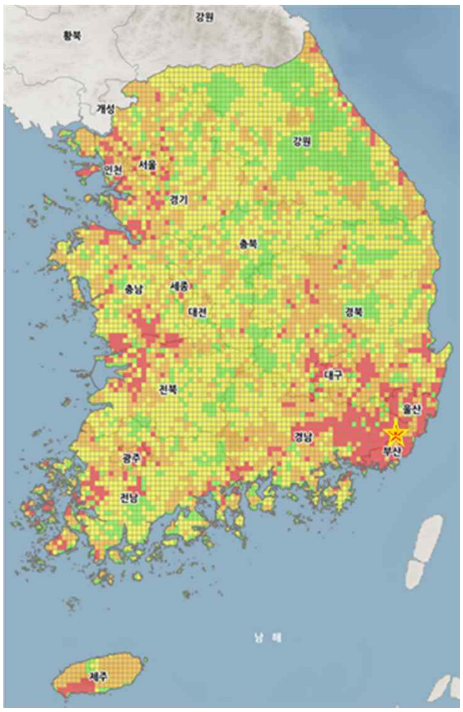
(a) Hongsung



(b) Mt.Odae



(c) Paju



(d) Yangsan

Fig. 8 – Liquefaction hazard maps in real time [5]

4. Conclusions

In this study, two kinds of mapping methods for macro liquefaction hazard maps were proposed and applied with over 110,000 borehole data. One is to draw liquefaction hazard map under a unique maximum earthquake acceleration. And the other is to draw liquefaction hazard map in real time.

In the first case, we calculated liquefaction potential indexes under various acceleration. Over million pieces of data on SPT-N value were adapted. At that time, peak ground acceleration was applied at 0.04g intervals from 0.06g to 0.38g. Hazard was marked by using 2km x 2km grid map. Besides, in an area where geotechnical information data were insufficient, liquefaction was evaluated by using conventional Kriging interpolation method. In special, a liquefaction hazard evaluation program to calculate LPI(Liquefaction Potential Index) was developed in this study. Using this program, LPI was calculated automatically at each point, and then 9 liquefaction hazard map for all parts of the country were created.

In the other case, to map real-time liquefaction hazard, the relationship between acceleration and LPI at a position was defined. As a result, the logarithmic equation proved to be suitable for being applied to all parts of the country. Based on the verification, real-time liquefaction hazard simulation and mapping were carried out for 4 areas, i.e., Hongseong, Mt. Odae, Paju, and Yangsan at earthquake magnitude 6.5. As a result, real time liquefaction hazard maps for artificial 4 events could be obtained.

Finally, it can be thought that this study will be useful for the work of creating a liquefaction hazard map again in updating geotechnical information data and revising seismic design codes through follow-up studies, not being limited to one-time nationwide hazard mapping.

Acknowledgements

This research was a part of the project titled 'Development of performance-based seismic design technologies for advancement in design codes for port structures', funded by the Ministry of Oceans and Fisheries, Korea.

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