Measures against liquefaction of residential land

1. Outline of Studies and Activities

Background	MLIT committees, etc.	Research	Reflection of results
		Development of Planning and Management Technologies for Ultra-Long-Life Houses (FY2008-2010 Integrated Technology Development Project) ・Experiment on liquefaction suppression effect by microbubble water	
March 11, 2011 Great East Japan Earthquake		Research on Disaster Prevention of Liquefaction of Residential Lots due to Liquefaction of Residential Lots (FY2011-2012 (Third Amendment), Reconstruction Funds)	
	Study group on reconstruction measures in liquefaction-stricken urban areas (Urban Development and Improvement Division, City Bureau of MLIT)	■Creation and publication of "Data Sheet on Damage Caused by Liquefaction to Residential Ground and Buildings" ・Analysis of liquefaction damage using 3D finite element method (FEM) ・Full-scale vibration test on drain pipe construction method	"Study and Survey for Reconstruction of Areas Affected by Liquefaction Caused by the Great East Japan Earthquake (Draft Guidelines)" (City Bureau of MLIT and NILIM, April 2012)
	Study group on the promotion of liquefaction countermeasures for residential land (Urban Safety Affairs Division, City Bureau of MLIT)	Research on Technologies for Disaster Reduction Planning in Coastal Cities (FY2012-2014) ■Development and publication of "Simplified Calculation Sheet for Effects and Impacts of Lowering Groundwater Levels" (Trial version) ・Centrifugal Force Loading Vibration Tests on the Lattice-Type Underground Wall Construction Method	"Study and Investigation of Groundwater Level Lowering Methods in Liquefaction-Affected Urban Areas (Draft Guidelines)" (City Bureau of MLIT and NILIM, January 2013)
		■Development and publication of "Simplified Evaluation Sheet for Effectiveness of Lattice-Type Underground Wall Construction Method" (Trial version) ・Measurement of the amount of settlement of damaged residential areas by aerial laser surveying ・Analysis of housing damage and settlement	"Study and Investigation of Lattice-Type Underground Wall Construction Method in Liquefaction-Affected Residential Areas (Draft Guidelines)" (City Bureau of MLIT and NILIM, April 2013)
	Exchange of opinions with affected municipalities	■Development and publication of "Calculation Sheet for Determining Liquefaction Damage Potential of Residential Lots" (Japanese and English versions) ・Development of software to support liquefaction mapping of residential land using engineering methods	"Technical Guidelines for Determining the Liquefaction Damage Potential of Residential Lots" (City Bureau of MLIT, March 2014) "Guidelines for Promoting Measures to Prevent Liquefaction in Urban Areas" (City Bureau of MLIT, March 2014)
April 14, 2016 Kumamoto Earthquake	Development of liquefaction countermeasure technology for integrated public facilities and residential land (Liquefaction countermeasures in urban areas where houses have already been built)		
Sept. 6, 2018 Hokkaido Eastern Iburi Earthquake	Utilization of various calculation sheets in the recovery and reconstruction of the 2016 Kumamoto Earthquake and the 2018 Hokkaido Eastern Iburi Earthquake		
	Development of Liquefaction Hazard Map Creation Method for Risk Communication (FY2018-FY2020 Comprehensive Technology Development Project)		"A Guide to Liquefaction Hazard Mapping for Risk Communication" (City Bureau of MLIT, February 2021)

The Great East Japan Earthquake of March 2011 caused liquefaction damage to as many as 27,000 buildings on reclaimed land along the Tokyo Bay coast. Restoring and reconstructing the extensive liquefaction-damaged areas required a liquefaction countermeasure method that integrates public facilities such as roads and residential areas into a single block. As technical support tools for the restoration and reconstruction, NILIM developed various calculation sheets for local governments in cooperation with the Urban Affairs Bureau of the Ministry of Land, Infrastructure, Transport and Tourism (MILT). These calculation sheets were used in the initial study phase of reliquefaction countermeasures in stricken areas, and were useful in speeding up the selection of liquefaction countermeasure construction methods. They have also been used in the liquefaction-stricken areas of the 2016 Kumamoto Earthquake and the 2018 Hokkaido Eastern Iburi Earthquake to examine methods for restoration and reconstruction, and have become indispensable in the promotion of liquefaction countermeasures for residential land nationwide.

The technical knowledge obtained in the process of developing these tools has been used in the “Study and Investigation of Groundwater Level Lowering Methods in Liquefied Urban Areas (Draft Guidelines)”[1) (January 2013, MILT, NILIM) and the “Study and Investigation of Lattice Underground Wall Methods in Liquefied Urban Areas (Draft Guidelines)”[2) (April 2013, MLIT, NILIM). The guidelines were further compiled by the Urban Bureau of MLIT in December 2015 as the “Guidelines for Promoting Measures against Liquefaction in Urban Areas.”[3)

As described above, the widespread liquefaction damage caused by the Great East Japan Earthquake led to a review of liquefaction countermeasures for residential areas, the development of countermeasure methods that integrate public facilities and residential areas, and the restoration and reconstruction of affected areas. In the process, the importance of consensus building between public organizations and residents was reaffirmed. The Ministry of Land, Infrastructure, Transport and Tourism, in its comprehensive technology development project “Development of Liquefaction Hazard Mapping Methods for Risk Communication” (City Bureau, GSI, NILIM, FY2018-2020), studied how to create hazard maps that take into account risk communication between residents and the government. The “Guidelines for Liquefaction Hazard Mapping for Risk Communication” was published in February 2021.

2. Main Research Results

In the Great East Japan Earthquake, residential areas were extensively damaged by liquefaction. Although liquefaction countermeasures have been taken for “cleared land” with no buildings on it, there were few cases of countermeasures for “built-up areas” where houses had already been built. Therefore, local governments have been exploring the options for countermeasures in liquefaction-damaged residential areas. NILIM, together with the City Bureau of MLIT, conducted a study on measures to prevent liquefaction of roads and other public facilities and residential areas in an integrated manner as technical assistance to local governments in the affected areas for the reconstruction of residential areas damaged by liquefaction. The study, entitled “Research on Disaster Prevention of Liquefaction of Residential Lots due to Liquefaction of Residential Lots (FY2011-2012 (Third Amendment), Reconstruction Funds). In the course of this study, two construction methods were identified as being promising for use in detached residential areas: groundwater level lowering and lattice-type underground wall construction. In addition, NILIM developed various tools such as the following calculation sheets in the “Research on Technologies for Disaster Reduction Planning in Coastal Cities (FY2012-2014).”

◆Development of “Simplified Calculation Sheet for Effects and Impacts of Lowering Groundwater Level”

The groundwater level lowering method reduces the damage from liquefaction by lowering the groundwater level and creating a non-liquefiable layer several meters below the ground surface by embedding pipes that allow groundwater to infiltrate and flow through the roadway portion of a residential area. (Figure 1)

This method is superior in that construction can be carried out within the area of roads and other public facilities, even while houses are still being built. On the other hand, in areas where there is loose clay in the deeper layers, consolidation settlement may occur as a side effect. Therefore, we developed the "Simplified Calculation Sheet for the Effects and Impacts of Lowering the Groundwater Level" as a technical support tool. By entering the ground investigation data and assumed earthquake scale in each area, the calculation sheet can easily obtain the liquefaction suppression effect corresponding to the amount by which the groundwater level is lowered from the current level and the amount of consolidation settlement of the lower clay layer, based on the standards of academic societies and other organizations (Figure 2).

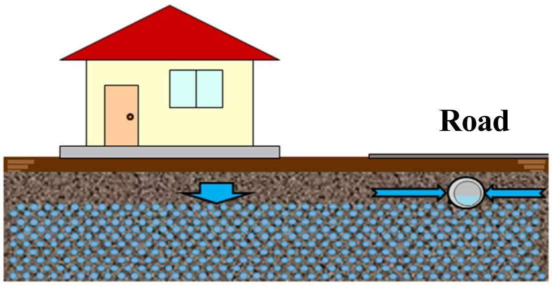

Figure-1 Groundwater level lowering method

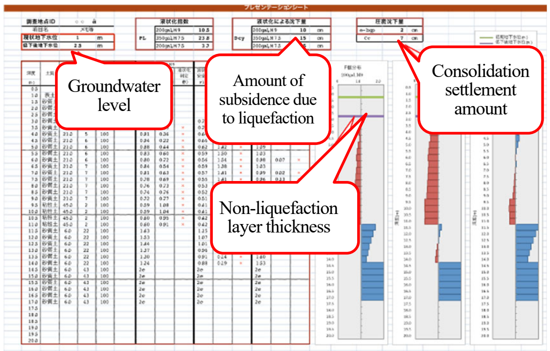

Figure-2 Example of output from groundwater level lowering method calculation sheet

◆Development of "Simplified Evaluation Sheet for Effectiveness of Lattice-Type Underground Wall Construction Method"

As shown in Figure 3, the lattice-type underground wall method suppresses shear deformation of the ground and prevents liquefaction by forming walls of soil and cement mixed underground in a lattice pattern and surrounding liquefiable sandy soil with the underground walls. Although this method requires a relatively large amount of work, it does not cause consolidation settlement and can be applied to ground with a low permeability, making it a promising method to consider in areas unsuitable for groundwater level lowering. However, in urban areas where houses exist, it is difficult to build an underground wall directly under the house, and there are restrictions on where the underground wall can be formed due to site boundaries and buried pipelines, so the distance between the grid of underground walls must be wide to correspond to the division of the house site. The question is whether a sufficient liquefaction suppression effect can be expected when this construction method is applied.

Therefore, analytical calculations for various combinations of ground and underground wall grids were performed in advance

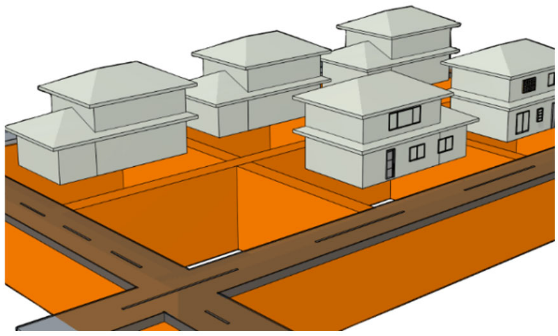

Figure-3 Lattice-type underground wall construction method

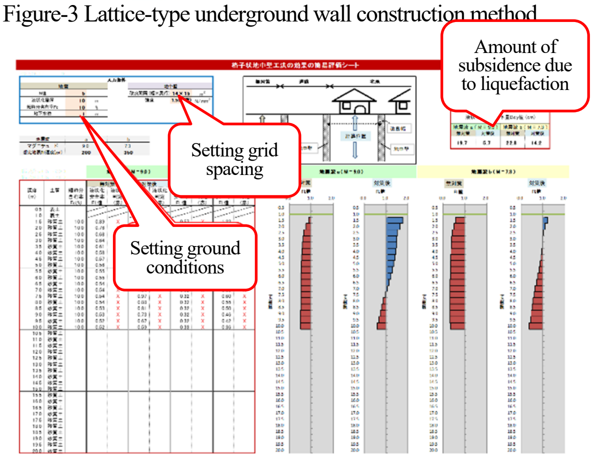

Figure-4 Example of output of calculation sheet for lattice-type underground wall construction method using a high-speed computer, and the results were compiled into an Excel sheet and made available to the public. Specifically, the results are displayed in an easy-to-understand graph by using a pull-down menu to select the calculation conditions, such as ground conditions, scale and strength of the underground wall grid, and level of earthquake ground motion (Figure 4).

◆Development of "Calculation Sheet for Determining Liquefaction Damage Potential of Residential Lots"

Based on the liquefaction damage caused by the Great East Japan Earthquake, the "Study Group on Promotion of Measures against Liquefaction of Residential Lots" established by MLIT compared the actual liquefaction damage caused by the Great East Japan Earthquake and the indicators of judgment results using various existing judgment methods, and compiled the "Technical Guidelines for Determining the Liquefaction Damage Potential of Residential Lots (April 2013)."

NILIM developed the "Calculation Sheet for Determining Liquefaction Damage Potential of Residential Lots," which facilitates secondary determination of the liquefaction damage potential at individual locations by entering data obtained from borehole investigations and soil tests into an Excel sheet in accordance with the technical guidelines (Figure 5).

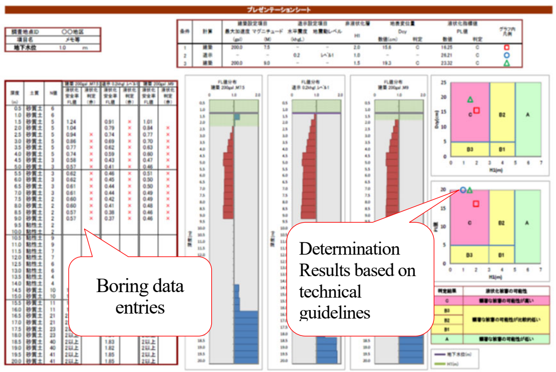

Figure-5 Example of output of calculation sheet for determining liquefaction damage potential of residential land (Boring data, etc., can be input to easily obtain judgment results based on national technical guidelines).

◆Development of software to support the creation of liquefaction maps for residential land

In order to promote the provision of liquefaction-related information by local governments, we have developed and released software that enables the creation of liquefaction maps in accordance with national technical guidelines using the "Calculation Sheet for Determining Liquefaction Damage Potential of Residential Lots."

This software uses existing borehole survey data from local governments to display on a map the liquefaction potential of residential land as determined by engineering methods, enabling the creation of highly accurate liquefaction maps that reflect the ground conditions (Figure 6). On the other hand, since the creation of liquefaction maps based on such an engineering method requires the accumulation of borehole data, it is expected that the accumulation of borehole data and soil test data will increase in the future through the promotion of kunijiban and other geo-related infrastructure DXs.

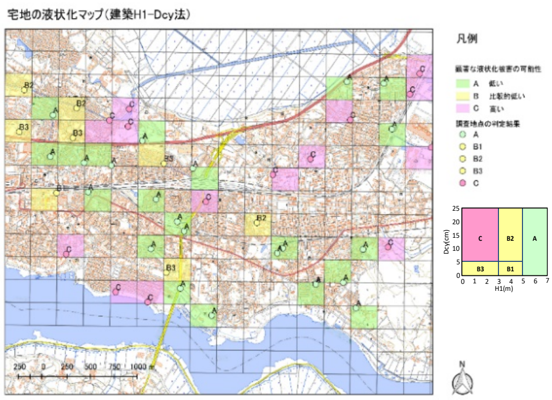

Figure-6 Example of output from software supporting the creation of liquefaction maps for residential areas (The "Calculation Sheet for Determining the Liquefaction Damage Potential of Residential Lots" can be used to create liquefaction maps that show the extent of damage at locations with boring survey data on a map.)

3. List of Related Reports and Technical Documents

1) "Study and Investigation of Groundwater Level Lowering Methods in Liquefaction Affected Urban Areas (Draft Guidelines)," January 2013, City Bureau of MLIT, NILIM

2) "Study and Investigation of Lattice Underground Wall Construction Method in Liquefaction-Affected Urban Areas (Draft Guidelines)," April 2013, City Bureau of MLIT, NILIM

3) "Guidelines for Promoting Liquefaction Countermeasures in Urban Areas," December 2015, City Bureau of MLIT

4) “Technical Guidelines for Determining the Liquefaction Damage Potential of Residential Lots,” April 2013, City Bureau of MLIT
5) NILIM Technical Bulletin No. 2, Release of “Simplified Calculation Sheet for Effects and Impacts of Groundwater Level Lowering” (Trial version) for local liquefaction countermeasures, August 2012, Urban Planning Department of NILIM
6) NILIM Technical Bulletin No. 4, Release of “Simplified Evaluation Sheet for the Effectiveness of Lattice-Type Underground Wall Construction Method” (Trial version) for liquefaction countermeasures for residential areas to be undertaken in the community, February 2013, Urban Planning Department of NILIM

4. Future Outlook

In order to further promote urban area liquefaction countermeasures, MLIT has launched the Five-Year Acceleration Measures for Disaster Prevention and Mitigation and National Land Toughness (R3-R7) initiative to improve the earthquake resistance of large embanked landfills, etc. in advance of a future anticipated major earthquake. This is expected to accelerate the development and utilization of liquefaction hazard maps by local governments.