Seismic damage of residential land and land evaluation using an embankment map

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ABSTRACT

Around major cities, the housing development called the bedroom town was developed, and the residential land development that downplayed safety was carried out with green destruction by a chaotic creation plan. In the residential areas, developed in the suburbs of Sendai around 1955-1965, a lot of houses suffered from geotechnical damage during the Great East Japan Earthquake. In this study, we made an embankment preparation map by comparing a digital map made from an old planning map and a current digital elevation map. Furthermore, we developed a map database of construction sites for preventative measure and a map database of applications for the dismantling of damaged property for locations under consideration for public development that were damaged by the Great East Japan Earthquake. We reviewed and compared prices of the inheritance tax street value by an embankment preparation map and a database of applications for the dismantling damaged property. It is reasonable to make different evaluations between residential lands that need ground improvement and residential lands that don't need ground improvement because they have been evaluated in the same way whether damage or not. We considered residential land evaluation formulae (street value evaluation formulæ) that evaluates value of residential land according to ground vulnerability measurements. In conjunction with proposing the consideration of ground structural characteristic correction to residential land price evaluation, we calculated a ground structural characteristic correction.

Key words: great east japan earthquake, district hit by an earthquake, embankment map, appraised value

1 INTRODUCTION

Around the major cities in Japan, residential projects that are so-called bedroom communities have been developed, where the residential areas have been developed with the neglect of safety and the destruction of green areas in conjunction with the unregulated land development plan. In the 1960s, Japan was affected by a wave of rapid urbanization. Sendai City also underwent large terrain modifications with the reduction of green spaces. In order to prevent a disaster caused by landslides or outflow of soil associated with rapid housing land development, the Act on the Regulation of Housing Land Development was enacted in November 1961 and took effect in September 1962. Then, the housing land development that was rapidly increasing around the major cities was made subject to a permit system for safety construction purposes. In Sendai City on March 11, 1965, the housing land development construction regulated area, including parts of Aoba, Taihaku, Miyagino, and Izumi Wards, was defined as the primary district. In this study, we present the Yagiyama district in Taihaku Ward, which is located in the hilly area of southwest Sendai City, as an example of a residential area in the vicinity of Sendai City, which suffered severe land damage in the Great East Japan Earthquake, and we review the ground formation and land evaluation of the housing development being affected by the earthquake and propose a method for calculating the price differential that should be applied between the affected land and the non-affected land from the earthquake.

2 PREPARATION OF MAP OF FILLED AND DEVELOPED LAND

The authors have prepared a Map of Filled and Developed Land from the three-dimensional elevation map (Triangulated Irregular Network) prepared by the authors based on the 1957 digital data map by creating grid data at the same points as the 2007 digital map information (5 m mesh elevation) published by the Geospatial Information Authority of Japan and subtracting the 1957 5 m mesh digital elevation data from the digital map information (5 m mesh elevation). The old topographic map and the digital map information (elevation) include measurement errors, respectively, and
as a result, areas of cut and fill are found even in a forest district and preserved green space with a topography not modified according to the current aerial photographs. Therefore, the Map of Filled and Developed Land excludes the preserved green space, etc., where it is considered that no topography modifications have been made, from the calculation of comparable areas. The areas ±1m are shown in white as a margin of measurement error.

3 RESIDENTIAL AREA DAMAGE

Generally, the possible damage patterns of housing ground are classified as follows: (i) landslide features, (ii) valley-filling-type fill, (iii) land-widening-type fill, (iv) collapse of a retaining wall or deformation, (v) edges of cut and fill slopes, (vi) insufficient soil compaction, and (vii) deformation of the foundation ground.

The Yagiyama district in Taihaku Ward, Sendai City, is a residential area developed before March 1965 when the housing land development construction regulated area was set up in Sendai City or before the implementation of a permit system for development activities under the City Planning Act of 1970, and the residential area that suffered severe damage in the Great East Japan Earthquake is considered to have failed to meet the housing development standards. Multiple ground disasters were reported in the Great East Japan Earthquake, where significant ground displacement was observed in the residential area developed from late 1955 to early 1965, particularly in the terrain with valley-filling-type fill or land-widening-type fill, and extensive damage was caused to the buildings located thereon. The current civil engineering and construction technology can reduce these disaster risks. However, in order to improve the ground, a large amount of ground improvement costs must be borne by buyer. A person who purchased the land must perform boring investigation and Swedish Weight Sounding test to understand the ground conditions of the land before starting housing construction. Furthermore, if the ground cannot bear the housing construction load, ground improvement work will have to be performed to ensure the ground stability of the site. The building site must correspond to various elements, such as soil, N-value, and borehole groundwater level. In this study, we consider and study the cut or filled condition of the land, etc., where the roadside land value is determined. Figure 1 shows the 2013 Land Tax Assessment Map prepared from digital data with the attributes in units of yen and represented on individual thematic maps.

5 LAND EVALUATION

5.1 Land Tax Assessment Evaluation

According to Figure 1: Publicly Announced Land Prices/Land Tax Assessment Map, the roadside land value is assessed generally in the same manner in similar areas depending on the time of the housing development (address). The National Tax Agency announced after the Great East Japan Earthquake that an adjustment rate determined on a region-by-region basis within the specified area can be multiplied by the roadside land value or the tax assessment rate for calculation for FY 2011. The Land Price Survey Committee of the Japanese Association of Real Estate defines the earthquake depreciation rate as the rate to reflect the significance of the impact that the earthquake depreciation factor has on the price formation of the target reference price. The Research Center for Property Assessment System published the Report on Earthquake Depreciation Rate and Individual Correction Factor used in the Evaluation of Land Damaged by the Great East Japan Earthquake in October 2011, stating that, considering that the earthquake depreciation rate is a depreciation rate for the property tax assessment associated with the Great East Japan Earthquake, the depreciation rate corresponding to maximum depreciation in the applicable area should be conservatively assessed (a value in the order of 5% to 10% should be applied). Since this rate is applied to the property tax assessment, it is recommended to assess the depreciation rate to the maximum depreciation, considering that the higher the assessed value, the higher the inheritance tax becomes. However, a buyer of housing land has no concerns for lower assessment, while a seller wants unaffected housing land in the same area to
be assessed at a higher rate.

5.2 Publicly Announced Land Prices
The Land Prices Public Announcement Act provides that the purpose of this act is “to contribute to the provision of an indicator related to general land sales prices and the calculation of the amount of proper compensation for land acquisition for public interest projects by selecting benchmark lands in cities and the surrounding areas, etc., and publicly announcing their market values, and thereby to contribute to the formation of proper land prices.” In the case of general land transactions, publicly announced land prices must be used as an indicator. Therefore, it is appropriate to consider publicly announced land prices as sales prices.

5.3 Relationship between Roadside Land Values and Publicly Announced Land Prices
If roadside land values are higher than actual land sales prices, the inheritance tax increases. Therefore, as a matter of fact, roadside land values are set lower than actual sales prices. Table 1 shows the comparison between roadside land values and publicly announced land prices. According to Table 1, it is found that roadside land values are evaluated approximately at 80% of publicly announced land prices.

Table 1. Contrast

<table>
<thead>
<tr>
<th>Sample Plot</th>
<th>Publicly Announced Land Prices</th>
<th>Roadside Land Values</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTaihaku-15</td>
<td>70,000</td>
<td>56,000</td>
<td>80.00%</td>
</tr>
<tr>
<td>PTaihaku-15</td>
<td>53,500</td>
<td>43,000</td>
<td>80.37%</td>
</tr>
<tr>
<td>PTaihaku-34</td>
<td>38,000</td>
<td>30,000</td>
<td>78.95%</td>
</tr>
<tr>
<td>PTaihaku-34</td>
<td>64,000</td>
<td>51,000</td>
<td>79.69%</td>
</tr>
</tbody>
</table>

6 TOPOGRAPHIC CHANGES AND LAND EVALUATION OF DEVELOPED RESIDENTIAL AREA

6.1 Map of Filled and Developed Land and Land Evaluation
Figure 2 shows the enlarged Matsugaoka district and Aoyama 1-chome district map from Figure 1: Land Tax Assessment Map superimposed by the Map of Filled and Developed Land and locations for reconstruction public works under consideration. There is difference in roadside land values between the districts: Matsugaoka is 51,000 yen/m² and adjoining Aoyama 1-chome is 31,000 yen/m². The Matsugaoka development is a housing development on flat land, while Aoyama 1-chome is a housing development on sloped land. Additionally, the Matsugaoka development is provided with bus routes on the main road, offering great traffic convenience. Both housing developments suffered ground cracking and extensive damage in some areas to residential houses during the Great East Japan Earthquake. However, as a result of studying this 2013 Land Tax Assessment Map superimposed by the map of locations for public works on the affected land under consideration, we found that the same land tax assessment is applied to both the affected land and non-affected land from the earthquake.

6.2 Study on Ground Improvement
In order to see how buildings suffered ground damage, we studied the damaged building sites at Aoyama 1-chome, where there are buildings that were completed in and after 1991 and have a time allowance before reconstruction. In the Great East Japan Earthquake, a large-scale fill development or land-widening-type fill was extensively damaged, while, if ground improvement had been performed to support building foundations, there were lots of ground improvements protecting the buildings from damage and collapse. We studied building sites, as shown in Figure 3 made from the Map of Filled and Developed Land, where buildings were damaged or collapsed.

As shown in the cross-sectional view (Figure 4) of the affected land along east-west direction, which is the frontage direction of the subject site, the existing ground is located at the edges of cut and fill slopes of the developed ground, where the maximum height of fill was 3.2 m at the steep slope of 27.0% to the east. The building suffered damage of a total collapse due to differential settlement of the filled ground on the east side. Ground improvement of at least 3 m on average to support the building foundation on the site may protect the building from damage. Methods of ground improvement generally include, for example, subsurface improvement, soil cement column improvement, steel pipe pile with wing tips, and Geo-cloth, and the application may differ depending on the groundwater level and soil conditions. Swedish Weight Sounding tests and boring investigation must be performed to determine the correct methods to be applied. However, in order to estimate ground
improvement costs, the use of the Map of Filled and Developed Land is effective as the old ground conditions can be easily determined.

6.3 Land Tax Assessment Method

A publicly announced land price is the value (unit: 1 m\(^2\)) of the land itself. On the other hand, the roadside land value is generally set as a block of land by the road on which the land fronts, and all the land fronting the road is of the same value (unit: 1 m\(^2\)) to which corrections are applied for the price of individual land lots depending on its shape, etc. Generally, the land evaluation using the land tax assessment method\(^4\) is performed as follows:

\[
M = \{(A_1 \times a_1) + (A_2 \times a_2 \times B)\} \beta_1 \times \beta_2
\]  

(1)

\(M\): Land price per m\(^2\), 
\(A_1\): Roadside land value, 
\(a_1\): Depth correction factor, 
\(B\): Corner lot. Additional amount for frontage on two roads.

\(\beta_1\): Lot shape correction (Irregular shaped lot correction factor, small frontage correction factor, large depth correction factor) 
\(\beta_2\): Topographic shape correction (Cliff correction factor)

The land is assessed on the value per m\(^2\) to obtain the land value multiplied by the land area. The authors consider that if a residential house is built on developed land potentially affected by an earthquake and requiring ground improvement, the ground improvement costs should be deducted from the land value. Therefore, we propose to consider a ground structure characteristic correction (\(\beta_3\)).

\[
M_1 = \{(A_1 \times a_1) + (A_2 \times a_2 \times B)\} \beta_1 \times \beta_2 \times \beta_3
\]  

(2)

6.4 Ground Improvement Costs

In this study, soil cement column improvement is considered ideal, since it is applicable to ground improvement of up to 9 m and widely available. Column improvement costs vary depending on the depth or area of improvement, and the cost was calculated based on the cost estimates from several contractors (Table 2).

<table>
<thead>
<tr>
<th>Terms</th>
<th>A two-storied wooden house</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor area</td>
<td>197.55 m(^2)</td>
</tr>
<tr>
<td>Building area</td>
<td>122.24 m(^2)</td>
</tr>
<tr>
<td>Soil cement column improvement method</td>
<td>(\varphi600) mm 320 kg/m(^3)</td>
</tr>
<tr>
<td>Average digging depth</td>
<td>3.0 m</td>
</tr>
<tr>
<td>Columns constructed</td>
<td>64</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Unit</th>
<th>U/P</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWS test cost</td>
<td>5</td>
<td>piece</td>
<td>12,000</td>
<td>60,000</td>
</tr>
<tr>
<td>Construction cost</td>
<td>54.26</td>
<td>m(^3)</td>
<td>6,000</td>
<td>325,560</td>
</tr>
<tr>
<td>Material cost</td>
<td>4.91</td>
<td>t</td>
<td>18,000</td>
<td>88,380</td>
</tr>
<tr>
<td>Top levelling cost</td>
<td>64</td>
<td>piece</td>
<td>1,000</td>
<td>64,000</td>
</tr>
<tr>
<td>Machine cost</td>
<td>1</td>
<td>set</td>
<td>70,000</td>
<td></td>
</tr>
<tr>
<td>Haulage cost</td>
<td>1</td>
<td>set</td>
<td>80,000</td>
<td></td>
</tr>
<tr>
<td>Administration cost</td>
<td>8</td>
<td>%</td>
<td>55,035</td>
<td></td>
</tr>
<tr>
<td>Total direct expense</td>
<td></td>
<td></td>
<td>742,975</td>
<td></td>
</tr>
<tr>
<td>Overhead expense</td>
<td>20</td>
<td>%</td>
<td>148,595</td>
<td></td>
</tr>
<tr>
<td>Total test cost</td>
<td></td>
<td></td>
<td>891,570</td>
<td></td>
</tr>
<tr>
<td>Unit cost (per m(^2))</td>
<td>1</td>
<td>m(^2)</td>
<td>7,294</td>
<td></td>
</tr>
</tbody>
</table>

7 STUDY ON GROUND STRUCTURE CHARACTERISTIC CORRECTION

7.1 Land Use District

Within the areas under the City Planning Acts, the building scale is limited according to the land use district in which the building is constructed. In the case of a building on a residential lot, in relation to the lot, the most influencing building foundation area is related to the building coverage ratio of the land use district. Although in some cases of a two-story residential building, the second floor area exceeds the first floor area, such rare
buildings are not considered in this study. The Aoyama 1-chome district subject to this study is in a category 1 low-rise exclusive residential district, and its maximum building coverage ratio is 50%.

7.2 Ground Structure Characteristic Correction

The ground improvement depth of the lot is determined from the cross-section of the land as specified in Section 6.2, and the improvement unit cost is obtained according to the ground improvement depth from Section 6.4 and divided by the roadside land value. The ground structure characteristic correction is obtained as follows:

\[
P(\beta) = 1 - \left( \frac{P}{A} \right) \times F
\]

where:
- \( P \) is the ground improvement unit price/m²
- \( A \) is the roadside land value/m²
- \( F \) is the building coverage ratio

\( P(\beta) \) is the corrected ground improvement unit price/m².

If the subject affected land of Figure 3 is given as an example and the ground improvement of 3.5 m on average is performed:

\[
\text{Lot area: } 268.33 \text{ m}^2
\]
\[
\text{Depth correction factor: } \alpha = 1.0
\]
\[
\text{Lot shape correction: } \beta_1 = 1.0
\]
\[
\text{Topographic shape correction: } \beta_2 = 1.0
\]
\[
\text{Ground structure characteristic correction: } \beta_3 = 1 - (0.12) = 0.88
\]

Thus, the roadside land value is obtained as follows:

\[
31,000 \times 1.0 \times 1.0 \times 1.0 \times 0.88 = 27,280
\]

Generally, sales prices use publicly announced land prices as the indicator. As the roadside land value is approximately 80% of the publicly announced land price, the roadside land value is divided by 0.8 to obtain a general sales price as follows:

\[
27,280 \text{ yen/m}^2 \times 0.8 \times 268.33 \text{ m}^2 = 9,150,053 \text{ yen}
\]

8 CONCLUSION

Real property is an important element in life for those who plan to acquire houses, as much as to say “House of Dreams.” If any defects are found in the property, the value of the property is lowered and the person who acquired the property suffers a significant loss. For this reason, the person who acquires the property needs a sufficient investigation and the broker must conduct a sufficient investigation. However, basic knowledge and basic data are prerequisites for starting an investigation. Previously, some of the data on the land may have been hidden because they affect the value of the property. However, the hidden data may contain important information. Such data should be disclosed as information for determining the value. In the Great East Japan Earthquake, a large-scale fill development suffered from cracking and collapse of the ground. In such a large-scale fill development, land transactions have been conducted without prior information. How would consumers feel when the property they bought expecting the house of their dreams suffered from cracking and collapse in a great earthquake? The collapse of the house of dreams could have been prevented by obtaining information before purchasing the property and taking necessary precautions. The property that needs to take precautions should have lower value than that of the property not requiring precautions. If the value of the property is lowered, the level of lowering is our concern. In this case, the land requiring ground improvement does not yet function as a building site but serves as a building site only after ground improvement work. The property (land) is an important asset that can be inherited by the future generation and that can be converted to money. Sufficient consideration is required to acquire such valuable property without failure. The Real Estate Appraisal Standards of the Ministry of Land, Infrastructure, Transport and Tourism provide that the real estate appraisal depends on “the appropriateness of collection and organization of necessary related data and the degree of the expertness in the analysis and interpretation of such data.” The ground structural characteristic correction is influence by the groundwater level and soil conditions of the land, but in this study, we propose to consider the ground structure characteristic correction in the land evaluation with the use of the Map of Filled and Developed Land.

REFERENCES

2) Japan Association of Real Estate Appraisers: Land prices committee, “Land prices Implementation Guidelines for Prefectures 【Business out of the member】”, 2013.06.P25