Development of technology for seismic retrofitting of retaining walls in old housing

(Research period: FY 2020–2023)

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Keywords: Retaining walls in housing lot, aging, anti-seismic reinforcement

1. Introduction

Most of the land in Japan is mountainous, and cities have been formed mainly on the limited area of the plains. However, with the increase in population and the resulting progress in urbanization, residential areas have been built on the slopes of hills (Photo 1). In 1961, the Act on Regulation of Residential Land Development was enacted to prevent disasters caused by cliff collapses and landslides when building housing on the lots on slopes. As a result, it became possible to designate areas for regulating housing lots and land development work (as of April 2019, 1,024,140 hectares had been designated nationwide), and technical standards were established for retaining walls on housing lots.

However, in recent years, there have been many cases of aging residential retaining walls being damaged by earthquakes, and it has become important to implement seismic countermeasures in response. This paper introduces the outline of the research on seismic retrofitting of retaining walls in old housing, which started in 2020 and is scheduled to last for four years.

Photo 1: Example of a hilly urban area (Nagasaki City)

2. Situations surrounding retaining walls on housing lots

There are various types of retaining walls in housing lots, and according to the *Manual for the Determination of Aging of Retaining Walls in Housing Lots* published by the City Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, a risk assessment should be made for the following types of retaining walls: masonry, stacked concrete blocks, gravity concrete, reinforced concrete, empty masonry, added layer, double-stage, and with overhanging slabs (Photo 2). It should be noted that the manual is only intended to determine the degree of danger associated with aging and not to evaluate earthquake resistance itself.

The Great Hanshin Earthquake of 1995 led to the establishment of a risk assessment system for damaged housing to mitigate and reduce secondary disasters. The system takes into account damage to retaining walls on the housing lots. During the 2011 off the Pacific Coast of Tohoku Earthquake, 5,728 residential lots were classified as dangerous or requiring caution in Sendai City. In addition, more than 10,000 retaining walls collapsed during the 2016 Kumamoto earthquake, mainly due to existing unqualified retaining walls, which made it an issue not only to address the aging of retaining walls in residential areas but also to improve earthquake resistance.

(a) Brick masonry (b) Concrete block masonry

(c) Empty brick masonry (d) Reinforced concrete retaining wall

Photo 2: Example of retaining walls in housing lot

3. Outline of the study

With the need to improve the seismic resistance of retaining walls on housing lots, the study was designed to examine seismic reinforcement methods, block piled retaining walls and brick piled retaining walls, and to deal with aging retaining walls that were difficult to reconstruct.

(1) Organizing damage patterns and seismic

reinforcement methods

Based on past damage that occurred during disasters, such as the Kumamoto earthquake, the type of damage to retaining walls in residential areas is classified by extracting the factors that affect seismic performance (figure), and the seismic reinforcement methods for retaining walls in housing lots are organized according to the classified damage types.

(2) Identifying situations of aging

Cases that require identification of the actual situation are selected, and evaluation tests of seismic performance are conducted.

(3) Verifying the effect of anti-seismic reinforcement

Based on the experimental results, an experimental model is designed and created for aging retaining walls in housing lots and for verifying the effectiveness of anti-seismic reinforcement, and the effectiveness of the anti-seismic reinforcement is verified through model vibration tests. In addition, a model for evaluating the reinforcement effect of retaining walls in housing lots will be developed through simulation analyses.

(4) Examining performance evaluation method

Based on the results of model vibration tests and simulation analyses, a sensitivity analysis is conducted, simple evaluation methods are discussed, and indicators of anti-seismic retrofit effectiveness and design examples to achieve target performance are presented.

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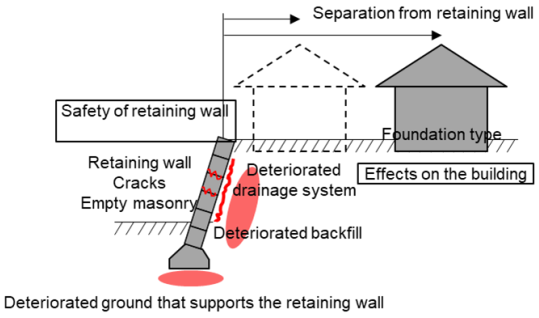

Figure: An example of items to be considered upon implementing the anti-seismic performance evaluation of retaining walls

4. Conducting full-scale experiments on retaining walls in existing housing lots

Load tests were conducted to measure the seismic performance of a retaining wall in a housing lot that was constructed nearly 50 years ago. The load was applied by cutting the retaining wall of the housing lot at a width of two meters and applying pressure with a jack from behind (Photos 3 and 4).

The results of the experiment are currently being analyzed, but it is assumed that the performance of the retaining wall was high from the beginning. Also, since there was almost no deterioration after a long period of time after installation, it was confirmed that the wall maintained very high seismic performance.

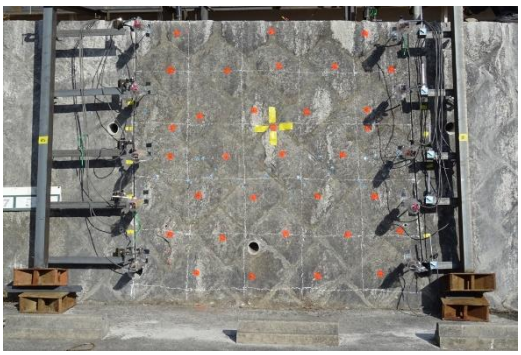

Photo 3: Retaining wall (brick masonry) with which the load test was conducted

Photo 4: Loading system at the back of the retaining wall

5. Conclusion

Based on the research plan, experiments and simulation analysis will be conducted to verify the effect of anti-seismic reinforcement of old retaining walls on housing lots, and design examples for seismic reinforcement will be examined.

☞For more information:

1) Outline of “Development of Technologies that Contribute to the Regeneration and Strengthening of Cities through the Rationalization of Structural Regulations Related to Buildings and the Ground”
http://www.nilim.go.jp/lab/hcg/kisojiban_hp/kisojiban.htm