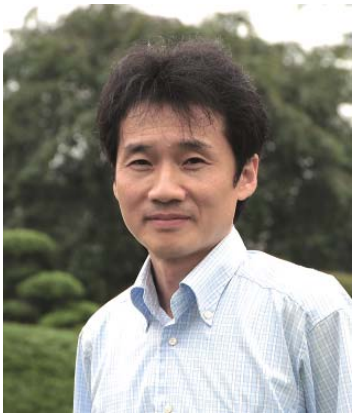
Development of Quakeproof Reinforcement Methods for Masonry Walls



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Railway lines in Japan are sometimes flanked by earth-retaining structures consisting of piled-up stones, known as masonry walls (see Fig. 1). Although railway operators are aware that these walls can collapse and damage trains in the event of an earthquake, the behavior of such structures when subjected to seismic motion has not yet been clarified. Against this background, the Railway Technical Research Institute (RTRI) investigated the deformation mechanism of masonry walls in earthquake conditions. Based on the results of this research, a technique called the pin-up method was developed to effectively reinforce masonry walls against earthquakes.

A model collapse test on a masonry wall revealed that its backfill cobblestones slid outward due to the relative movement between the ashlars on the front and the ground behind, thereby generating residual displacement in the wall. In view of these deformation-causing factors, the earthquake resistance of masonry walls is expected to improve if the movement of backfill cobblestones can be suppressed. It is therefore thought that measures to fix these cobblestones using grouting materials will provide an effective means of helping masonry walls to resist earthquakes. However, these cobblestones play a role in draining water that penetrates the ground, thereby preventing it from applying pressure to the backside of ashlars. If grouting material is injected into the backfill cobblestone layer at random, this drainage function may be lost. The RTRI therefore designed the pin-up method (types I and II) to enable the suppression of backfill cobblestone movement while maintaining its drainage function (see Fig. 2).

Type I of the pin-up method combines four adjacent ashlars and the backfill cobblestones in the wall behind them to create stiffening blocks, thereby achieving the goal of improving the earthquake resistance of the masonry wall while maintaining the drainage function of the backfill cobblestones and suppressing their movement. Type II, on the other hand, also anchors the combined stiffening blocks to the ground using deformed bars, and is applied when the level of earthquake resistance required is higher than that offered by type I. Pin-up method types I and II are so named because they can be likened to fixing masonry walls to the ground with pushpins.

Figure 3 shows the results of shaking table tests to verify the effect of earthquake reinforcement work applied to model masonry walls using pin-up method types I and II. When the models were subjected to sinusoidal wave excitation at a maximum acceleration of 7 m/s^2, deformation was suppressed to one-third or less that of a non-reinforced wall with the model reinforced using pin-up method type I. On the other hand, the model reinforced using type II showed virtually no deformation at all.

As these test results demonstrated that masonry walls reinforced using the pin-up method have a high level of earthquake resistance, the RTRI discussed concrete methods of reinforcement in consideration of actual conditions, clarified the quality of applicable grouting materials and decided on suitable methods of injection. Based on the results of model tests, the Institute also determined methods to evaluate the degree of deformation in masonry walls in earthquake conditions, evaluate their stability and design reinforcement work using the pin-up method. By summarizing these study results, the RTRI was able to create a manual for design and reinforcement work related to masonry walls.

In January 2009, the pin-up method was applied in actual masonry wall reinforcement work for the first time (see Fig. 4). The RTRI will strive to promote the adoption of this method over wide areas in order to contribute to the improvement of disaster prevention for railway wayside slopes.

Fig. 1 A view of masonry walls along railway lines

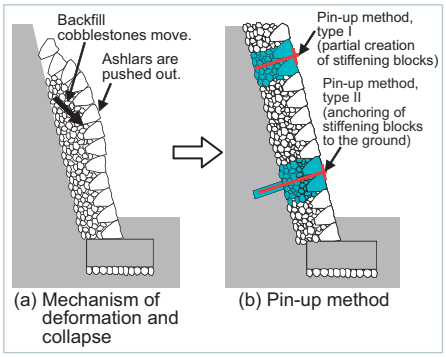

Fig. 2 Schematic view of the Pin-Up method

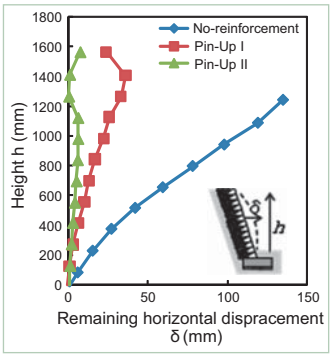

Fig. 3 Distribution curves of lateral residual displacement

Fig. 4 Appearance of reinforced masonry wall