Seismic performance of multi-anchor wall with double-wall facing

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ABSTRACT

Damage to the embankments of abutment backfills often affects emergency routes by introducing sharp drops in the road level between the bridge and backfill. Therefore, it is important to clarify the seismic performance of abutment backfills with reinforced double-wall facing to maintain the road level. The length of the necessary tie-bars is determined by the internal stability of the reinforced area. It follows that anchor plates may be installed in intersecting or binding configurations, which are not ordinary conditions, depending on the width of the road. In this study, a series of centrifugal shaking table tests was performed to investigate the seismic behavior of a multi-anchor wall with double-wall facing. The test results showed various deformations with different reinforcement positions; perpendicularity was best maintained when using a binding tie-bar configuration. Smaller deformation was observed for a wall using intersecting anchor plates compared to that using an ordinary configuration. This implies that crossing the reinforcement areas can improve, rather than adversely affect, the stability of the full structure.

Keywords: reinforced soil retaining wall, seismic behavior, double facing, model test

1 INTRODUCTION

Generally, reinforced soil retaining walls show stable performance even on soft grounds during earthquakes, because they are higher in flexibility compared to massive and rigid gravity-type retaining walls (Hashimoto et al. 2001). In accordance with the report by Miyata (2014), however, damage to reinforced soil walls was investigated after the Great East Japan earthquake in 2011. Damage to the embankments of abutment backfills was found to affect emergency routes by creating sharp drops in the road levels between the bridge and backfill regions. Tsuji et al. (2012) discussed the efficiency of a geotextile confined method for asphalt pavement in preventing the formation of bumps. The National Institute for Land and Infrastructure Management and Public Works Research Institute determined that the reduction of such damage should be utilized for emergency routes, and specified the necessity of taking countermeasures against the settlement of abutment backfills in the Specifications for Highway Bridges (2012).

On embankments with double-walled abutment backfills, anchor plates can be installed as reinforcements in intersecting or binding configurations, depending on the width of the road; these differ from the ordinary construction of anchor plates. The seismic performances of such structures must be clarified in order to ensure the appropriate design, construction, maintenance, and integrity of emergency routes after earthquakes.

In this study, a series of centrifugal shaking table tests was performed to investigate the behaviour of multi-anchor walls during earthquakes. Three conditions of ordinary, intersecting, and binding were used for the installed anchor plates to estimate the interaction between the reinforced areas.

2 CENTRIFUGAL SHAKING TABLE TESTS

Centrifugal shaking table tests were conducted under a field of 50g centrifugal acceleration on a 1/50 scale model of the soil structures. The deformations of the model structures were recorded by a high-speed camera located on the roof of the centrifuge apparatus. The camera captured images that were synchronized with the rotation of the model container.

2.1 Test conditions

Table 1 shows the test conditions for this study. The
height of the retaining walls was constant; the tie-bar lengths differed to reproduce the three conditions of the installed anchor plates. The model retaining walls were constructed exclusively of Toyoura sand, with a relative density of over 95%. Dried Toyoura sand was pluviated to form each layer of 20 mm in thickness; tie-bars and anchor plates were laid afterward. As the centrifugal acceleration reached 50g, a seismic wave with amplitude 2.0 m/s² and frequency 1.0 Hz, following the sine wave shown in Fig. 1, was provided.

Table 1. Test conditions.

| Test code | Length of tie-bar model (mm) | Installed anchor plate condition | Relative density of backfill (%) |
|-----------|-----------------------------|----------------------------------|--------------------------------|
| L375      | 75                          | Ordinary                         | 97.9                           |
| C425      | 85                          | Intersecting                     | 96.8                           |
| J775      | 155                         | Binding                           | 95.6                           |

2.2 Test setup

The schematics of the models in this study are shown in Fig. 2 to 4, with the three conditions for the installed anchor plates. In each test case, thin pressure sensors were embedded in the facing panels with identical surfaces to measure the earth pressure during the tests, as shown in Fig. 5(a). To observe the resistance to pullout, thin pressure sensors were positioned as shown in Fig. 5(b). The facing panels with the pressure sensors were placed in the 2nd and 4th layers from the bottom; the sensor-equipped anchor plates were connected by tie-bars.

Fig. 1. Response acceleration of shaking table

Fig. 2. Test setup of L375 (ordinary condition).

Fig. 3. Test setup of L425 (intersecting condition).

Fig. 4. Test setup of L775 (binding condition).

Fig. 5. Reinforcement member and facing panel, anchor plate
3 TEST RESULTS AND DISCUSSIONS

Photographs of the model ground before and after the seismic wave are shown in Fig. 6 to 8, depicting the ordinary, intersecting, and binding conditions, respectively. To visualize deformations of the model ground caused by seismic waves, outlines were drawn on the models. Settlement of the top surface and tilt in the facing panel were only observed in case L375, with ordinary-condition anchor plates. The degree of inclination was calculated as follows: the lateral displacement relative to the height of the soil wall was 2.25% in this test case. According to the Design and Construction Manual of Multi-anchored Reinforced Soil Wall (2015), this degree of inclination is classified as below construction management standards. This implies that reinforced soil walls have high seismic performance, agreeing with other reports such as Tatsuoka et al. (1996), Koseki et al. (2006), and Miyata (2014).

The deformation mechanisms of the ordinary condition test case are discussed below. The broken line in Fig. 6 indicates the active failure line, whose angle of 64.9° was calculated from the internal friction angle $\phi = 44.0^\circ$. Cave-in occurred near the center of the top of the soil wall after the seismic wave, behind the active failure line. This implies that the internal stability of the reinforced area was maintained during the earthquake, and that the tilt in the facing panel was caused by integral sliding of the entire reinforced region. These results imply that the combination of the two reinforced areas of the double-wall facing can prevent surface sinkage in the soil wall.

As shown in Fig. 7, the flat surface of the soil wall was retained, despite the slight inclination observed in the facing panel. Furthermore, even negligible deformation was not observed in the test case of the binding-reinforcement tie-bar (J775). These results support the hypothesis of improved stability in double-wall facing mentioned above.

The time progressions of earth pressure and pullout pressure during the seismic waves are shown in Fig. 9 and 10 for the ordinary and intersecting anchor plates, respectively. The pullout resistances of the anchor plates, recorded by PR2, are smaller than the earth pressures recorded by EP2 in each test case, as shown in Fig. 9 and 10. This indicates that the pullout resistances were maintained in both cases during the seismic wave. Therefore, the inclination of the facing panel for case L375 may have been caused by the integral sliding of the entire reinforced area. Notably, the pullout pressure in case C425 was less than half of the earth pressure. This value is also less than the calculated allowable pullout resistance of 78.42 kN. Furthermore, the pullout resistance in case C425 is 25% of that of L375, despite the mean value of earth pressure for C425 being half that for L375. These results suggest that the pullout safety is maintained at a high level despite the crossing of reinforced regions at the double-walled facing. Each side of the reinforced region worked as a whole against the seismic wave, leading to the small pullout pressures observed in C425. This condition of reinforcement by the retaining wall is performed as if the two reinforced regions are continuously connected by tie-bars.

Fig. 11 shows the time histories of earth pressure and tensile force worked on the tie-bars during the seismic wave. A difference between the earth pressure and tensile force is observed, as shown in this graph. It seems that friction near the tie-bar and aluminum plate contributes to reductions in strain in the aluminum plate.
4 CONCLUSIONS

This study has determined the seismic performances of multi-anchor walls with double-wall facing as applied to abutments. The following conclusions were found by comparative examinations of the test results.

1) Smaller inclinations in the facing panel were observed for ordinary and intersecting conditions, to degrees less than that specified by construction management standards. This implies that reinforced soil walls have good seismic performance.
2) The positioning of anchor plates in intersecting or binding configurations improve the seismic stability of a multi-anchor wall.

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