The effects of the 2016 Kumamoto earthquake on multi-anchored reinforcement wall

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ABSTRACT: Since the first application of multi-anchored reinforcement walls (MARWs) in 1985, numerous MARWs have been applied in Japan for more than 30 years. Although MARWs have sustained strong earthquakes during this period, such as the Kobe (1995), Chuetsu (2004), and Tohoku (2011) earthquakes, few MARWs were deformed by the Chuetsu Earthquake. Other MARWs were not disrupted. In 2016, several MARWs were damaged by a sequence of strong earthquakes that occurred in Kumamoto, Japan. The investigation of MARWs, which are at locations near the respective epicenters of the earthquakes, was conducted after the earthquake occurrence. The main method of investigation was visual observation. This paper presents a summary and results of the investigation. Nearly 90% of all MARWs showed no damage. Other MARWs exhibited minor damage.

Keywords: reinforced soil walls, anchor, earthquake, visual observation, road

1 INTRODUCTION

The Kumamoto earthquake (2016) event was a series of strong tremors occurring in the southwestern Japan, the maximum magnitude of which was 7.6. In this region, many soil structures such as embankments and retaining walls were deformed or disrupted. Mechanical reinforced structures (MRSs), which are representatives of the soil structure, also sustained earthquakes and might be damaged as well as other soil structures. We conducted a field survey of multi-anchored reinforcement soil walls (MARWs), which is a type of MRS in the affected area, and checked the degrees of deformation, which might be the source of soil leakage.

2 STRUCTUER

MARWs, which consist of concrete panels, steel plates, and steel bars, are useful to build vertical wall structures. Figure 1 shows details of the main MARW system components. The reinforced concrete panels are 1.5 m wide, 1 m high, and 115 mm thick. Pinned connections at the back of the facing panels are used to attach the anchor rods on 0.75 m centers along the running length of the wall face. The anchor rods are smooth circular bars of 19–25-mm diameter. Each rod is attached to a plate using a threaded end, washer, and nut. Standard steel anchor plates are 300 mm × 300 mm.

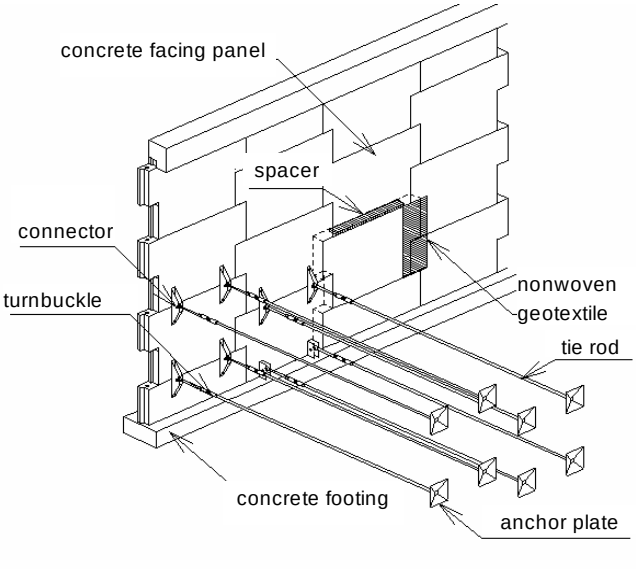

Figure 1. Details of MARW system

3 INVESTIGATION

3.1 *Selection of MARWs*

For this investigation, we selected 63 MARWs that satisfied the following conditions: (1) They sustained earthquakes with seismic intensity of 5 or higher. (2) We knew their locations. Earlier investigations revealed that no MARWs were damaged severely when the seismic intensity was lower than 5. Therefore, we did not select MARWs that sustained earthquakes with the seismic intensity lower than 5. Figure 2 depicts the locations of MARWs that were investigated and the number of MARWs for each scale of seismic intensity.

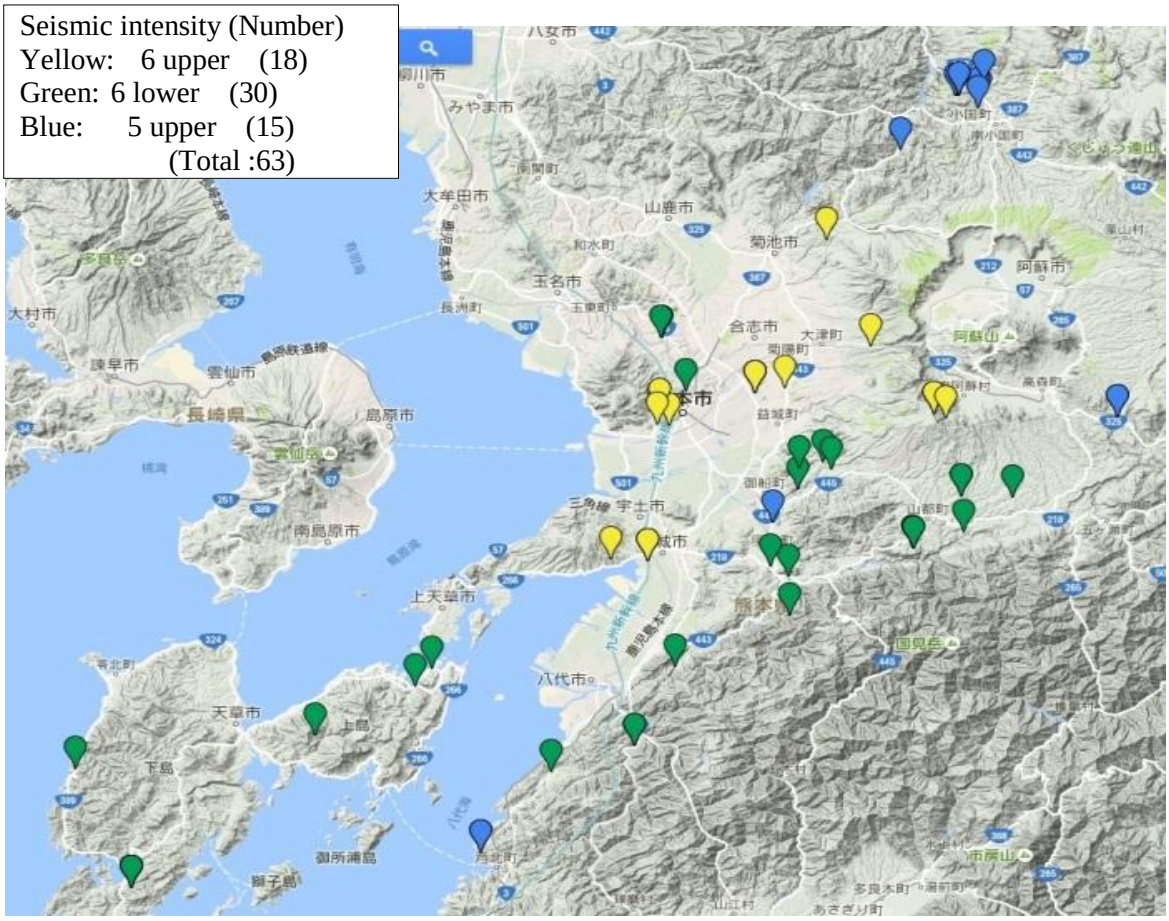

Figure 2. The locations and number of MARWs

3.2 *Implementation*

We observed the appearance of each MARW, assessed the presence or absence of abnormalities on the MARW and its surroundings, and recorded the results on the check sheet cited in "The Collaborative Research Report on the Development of MRS Maintenance Method." Table 1 shows a check sheet. It is difficult to ascertain whether the deformation derives from the earthquake or from other influences unless we have data of the MARW before the earthquake occurred. Therefore, to avoid neglecting abnormalities of MARWs, we assessed abnormalities including deformations and damage that did not seem to result from the earthquake.

Table 1. Check sheet

ATTRIBUTION					
ROUTE		**MANEGER**			
SER NO		**FILE NUMBER**			
ADDRESS		**GPS**	N		E
TYPE	☐ STRIP ☐ GEOGRID ☐ ANCHOR ☐ OTHER ( )	**MONTH OF CONST**	M		Y
REINFORCEMENT	**FACING** ☐ RC ☐ STEEL ☐ OTHER ( )	**INCLINATION**	☐ VERTICA ☐ SLOPE (DEG)		
HIGHT	m **LENGTH** m **DIMENTION** m^2	**SOIL TYPE**			
EMBANKMENT	m ~ m INCLINATION (DEG)	**FOUNDATION**			
DIST from ROAD SHOLDER	m	**HIGHT OF ROAD SHOLDER**	m		
FACE OF EMBANKMENT	☐ PLANT ☐ FLAME ☐ ANCHOR ☐ SHOTCRETE ☐ OTHER ( )				
LOCATION & STRUCTURE	☐ FILLED VALLEY ☐ SLOPING TERRAIN ☐ COLD DISTINCT ☐ BY THE SEA ☐ BESIDE A BRIDGE ☐ BESIDE A CALVERT ☐ BESIDE WATER ☐ MULTISTAGE ☐ BACK TO BACK ☐OTHER ( )				

	ITEMS	CHECK BOX	REMARKS
FACE	Bend or Curve	☐ F ☐ NF ☐ UNCF	
	Incline	☐ F ☐ NF ☐ UNCF	
	Water leakage	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
PANELS	Falling	☐ F ☐ NF ☐ UNCF	
	Deformation	☐ F ☐ NF ☐ UNCF	
	Edge defect or Crack	☐ F ☐ NF ☐ UNCF	
	Peeling off	☐ F ☐ NF ☐ UNCF	
	Elongation btw panels	☐ F ☐ NF ☐ UNCF	
	Discoloration	☐ F ☐ NF ☐ UNCF	
	Vegetation abnormal	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
SOIL	Leakage	☐ F ☐ NF ☐ UNCF	
	Subsidence	☐ F ☐ NF ☐ UNCF	
	Leakege of fine soils	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
CAPING CONCRETE	Incline	☐ F ☐ NF ☐ UNCF	
	Crack	☐ F ☐ NF ☐ UNCF	
	Elongation betw parts	☐ F ☐ NF ☐ UNCF	
	Discoloration	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
ENBANKMENT	Small collapes	☐ F ☐ NF ☐ UNCF	
	Erosion	☐ F ☐ NF ☐ UNCF	
	Subsidence	☐ F ☐ NF ☐ UNCF	
	Crack	☐ F ☐ NF ☐ UNCF	
	Slaking	☐ F ☐ NF ☐ UNCF	
	High water content	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	

	ITEMS	CHECK BOX	REMARKS
DRANAGE	Clogging	☐ F ☐ NF ☐ UNCF	
	Inpaired or Crack	☐ F ☐ NF ☐ UNCF	
	Scouring bases	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
FOUNDATION	Scouring bases	☐ F ☐ NF ☐ UNCF	
	Subsidence	☐ F ☐ NF ☐ UNCF	
	Sliding	☐ F ☐ NF ☐ UNCF	
	Tilting	☐ F ☐ NF ☐ UNCF	
	Crack	☐ F ☐ NF ☐ UNCF	
	Elongation btw parts	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
GROUND	Scouring	☐ F ☐ NF ☐ UNCF	
	Subsidence	☐ F ☐ NF ☐ UNCF	
	Sliding	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
FOOTING for GUARDFENCE	Inclination or Tilting	☐ F ☐ NF ☐ UNCF	
	Crack	☐ F ☐ NF ☐ UNCF	
	Deviation	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
ROAD	Crack	☐ F ☐ NF ☐ UNCF	
	Subsidence or cave-in	☐ F ☐ NF ☐ UNCF	
	Difference in level	☐ F ☐ NF ☐ UNCF	
	Cavitation	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	
BOUNDARY OF ADJACENT STRC	Elongation btw parts	☐ F ☐ NF ☐ UNCF	
	Inpaired	☐ F ☐ NF ☐ UNCF	
	Deformation	☐ F ☐ NF ☐ UNCF	
	Others	☐ F ☐ NF ☐ UNCF	
	Repair trace	☐ F ☐ NF ☐ UNCF	

F: FOUND, NF: NOT FOUND, UNCF: UNCONFIRMED

3.3 *Classification*

We checked the presence and the extent of damage that might cause soil leakage from the MARW. Table 2 shows damage of five types that might cause soil leakage from MSE. An MSE is generally deformed gradually along with other soil structures unless soil leakage from an MSE occurs. Therefore, in the MSE maintenance procedure, it is reasonable to assess such damage as soon as possible and to repair the damaged components if necessary. According to this idea, we classified the data.

Table 2. Damage of 5 types that might cause soil leakage

Damege type	Detail
Type A	Fracture of reinforcement (could lead a panel to fall)
Type B	Opening in panels
Type C	Elongation between two panels
Type D	Scouring under foundations
Type E	Elongation between panels and adjacent structures

4 RESULTS

Table 3 shows items applied to damage of five types that might cause soil leakage from MARWs in the check sheet and the number of MARWs for each type of damage sustained. We confirmed that this damage had few effects on the road function except for cases in which weight regulation of passing vehicles was applied. Details of each type of damage are the following.

Table 3. Damage of 5 types in check sheet and the number of MARWs for each type of damage sustained

Damege type	Detail	Corresponded item in the check sheet	Number
Type A	Fracture of reinforcement (could lead a panel to fall)	"Falling" in "Panels"	0
Type B	Opening in panels	(None)	0
Type C	Elongation between two panels	"Elongation between panels" in "Panels"	5
Type D	Scouring under foundations	"Scouring bases" in "Foundation"	1
Type E	Elongation between panels and adjacent structures	"Elongation between parts" in "Boundary of adjacent structures"	1
		Total	7

4.1 *Type C: Elongation between two panels*

Figures 2–4 show the opening or gap separating two panels. All this damage was detected on MARWs that have a bend section. The greatest distance between two panels was approximately 7 cm. Typically, the initial distance is 1.5 cm. This damage does not cause soil leakage from the MARW immediately because there is non-woven fabric (30 cm width) between and behind the two panels.

Figure 2. Gap separating two panels

Figure 3. Opening two panels (1)

4.2 *Type D: Scouring under foundations.*

Figure 5 shows scouring of the soil under the foundation of the panels. In this case, the cavity was found at the bottom of the foundation on the slope. This damage probably occurred because of flowing water when it rained, and not from the earthquake.

4.3 *Type E: Elongation between panels and adjacent structure.*

Figure 6 shows an opening between the panel and the adjacent structure. The width of this opening was 3 cm. It is unlikely that the soil leakage occurs constantly as long as the width of this opening does not increase.

Figure 4. Opening two panels (2)

Figure 5 Scouring under foundation

Figure 6. Elongation between panels and adjacent structure

5 CONCLUTION

We conducted an investigation of 63 MARWs that had been affected by the Kumamoto earthquake (2016). Among these MARWs, we found 7 MARWs having damage which might lead to soil leakage including the case in which the earthquake did not seem to cause. However, it is unlikely that this damage can influence the performance of MARWs immediately.

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