

## **Pullout Resistance of Reinforcement with Expanded End Subjected to Cyclic Load**

*Yasuyuki Nabeshima*

Akashi National College of Technology  
Akashi, Japan

*Takeharu Konami & Taketo Hayashi*

Okasan Livic Co.,Ltd  
Tokyo, Japan

*Hideyuki Ito*

Dai Nippon Construction  
Tokyo, Japan

### **ABSTRACT**

A new reinforced earth method, in which the reinforcements with expanded ends were used, was developed and applied to stabilize many natural slopes. This reinforcement has frictional resistance on the bar and bearing resistance at the expanded end, so it mobilized higher pullout resistance compared to other reinforcements.

A series of cyclic pullout tests was performed in this study to investigate pullout resistance of reinforcements with expanded ends under cyclic pullout conditions. Pullout resistance and behaviors of reinforcements with/without expanded ends were compared. Consequently, the pullout resistance of the reinforcement with expanded end was much higher than that without expanded end. The ultimate pullout load after cyclic loading was almost equal to that without cyclic loading.

**KEY WORDS:** cyclic pullout, model field test, reinforced earth method, reinforcement with expanded end, pullout resistance.

### **INTRODUCTION**

In the recent big earthquakes, such the 2004 Mid-Niigata Prefecture Earthquake and the 2007 Noto-Peninsula Earthquake, many road embankments, natural slopes and retaining structures suffered severe damages. Seismic countermeasures for road embankments, natural slopes and retaining walls had not been considered with eagerness. However, these earthquakes emphasized the necessity of seismic countermeasures for the soil structures. Because of the total number and total area of these structures are very large, the simple, workable and economical seismic countermeasures are eagerly needed.

Konami et al. (2004) and Ito et al. (2006) proposed a new type of reinforced earth method of natural slopes, in which the special reinforcements with expanded end are used. Because this reinforcement has bearing resistance at the expanded end, the proposed method has an advantage on the stabilization of the slopes. To apply this proposed

method into the seismic countermeasure of the slopes, it is necessary to know the seismic performance of the proposed reinforced earth method. In this paper, the pullout resistance of the reinforcement with expanded end is highlighted because it is a major factor of the seismic design of the proposed reinforced earth method. A series of cyclic pullout tests is performed to investigate pullout resistance of reinforcements with expanded ends under cyclic pullout conditions. Pullout resistance and behaviors of reinforcements with/without expanded ends were compared each others and discussed.

### **REINFORCEMENT WITH EXPANDED END**

#### **Outline**

Figure 1 shows an overview of the proposed reinforced earth method, in which the reinforcement with expanded end is used. The schematic diagram of the reinforcement with expanded end is shown in Figure 2. After drilling a hole in the slope, the proposed reinforcement is inserted into the hole and tensile load is applied to expand the end which is made of ten steel wires as shown in Figure 2. Grouting is injected into the hole and the facing is constructed by spraying mortar as the slope protection. Photograph 1 shows reinforcements before/after the expansion.

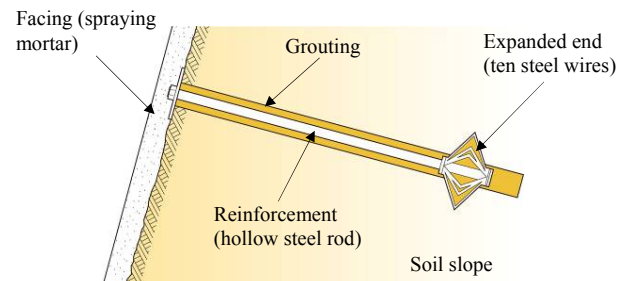


Figure 1. Overview of the proposed reinforced method.