Polymer Wall to Protect Underground Structures from Earthquakes: Development and Installation

Yoshitaka MURONO
Senior Researcher, Earthquake & Stractural Engineering, Structures Technology Division

1. Polymer anti-seismic piling

The newly developed 'polymer seismic isolation method' involves the construction of polymer walls on both sides of underground structure in order to reduce the seismic action transmitted from the surrounding ground onto the structure. The stiffness of the polymer material should be about 1/10 to 1/100 that of the surrounding ground. This method is not intended to prevent or control the seismic ground deformation itself, but to isolate structures from seismic forces transmitted from the surrounding ground. See Fig. 1.

The polymer seismic isolation method has the following advantages over conventional anti-seismic methods (such as the steel jacket method):

i.) The polymer reduces the seismic force transmitted from the ground, thereby reducing relative deformation of the structure. A steel jacket, for example, would reinforce only one part of the structure, whereas the polymer reduces the cross-sectional force on all structural parts, improving the seismic performance of the structure.

ii.) Use of a polymer with a stiffness of one-tenth of the sheer wave velocity of the surrounding ground will, depending on certain conditions, reduce the sheer force by up to half.

iii.) The polymer is installed from above ground, near a cut and cover tunnel, so the work can be done at any time, not just during the night when trains are not running. This shortens the retrofitting period, thereby reducing cost considerably.

iv.) There is no need to drill holes in the existing concrete structure.

2. Seismic reinforcement of an existing subway station

(1) Design calculations

A plan was drawn up to construct a four-story building directly above Nakagawa Station on the Blue Line operated by the Transportation Bureau of the City of Yokohama. The station had been constructed in a cut and cover tunnel. However, a seismic performance assessment of the existing tunnel discovered that the sheer force caused by a possible earthquake could exceed the bearing force capacity of the sidewalls and center pillars. The center pillars could be reinforced adequately by the steel jacket method, but there was no conventional effective method to reinforce the sidewalls. The decision was therefore made to install polymer anti-seismic piling.

Sheet piles had been left in place after the existing cut and cover tunnel was constructed, and the area available for anti-seismic measures was narrow. Taking into account these con-struction constraints, numerical analyses were carried out in order to determine the properties of the polymer isolation wall and its position. The analyses led to the decision to use a polymer material with a rigidity of approximately one-tenth of the sheer wave velocity of the surrounding ground. The analyses also determined that the polymer isolation piles (columns) should be arranged as indicated in Fig. 2. These decisions were reached after considering the existence of the sheet piles and other structural components left in place after the original construction, and after it was determined that the installation of polymer piling at a certain distance from the tunnel walls would still be effective.

The seismic performance of the retrofitted structure was evaluated under these conditions. The evaluation indicated that the relative deformation would be reduced by 30%, and that the sheer force on the sidewalls would remain within safety levels even in the event of a major earthquake. Incidentally, the center pillars were reinforced by the steel jacket method.

(2) Installation

Retrofitting was conducted in February, March and April 2006 in these three phases:

i.) A small ground stabilization machine equipped with an auger screw was used to bore holes in the ground and remove earth.

ii.) Polyethylene bladders were inserted against the walls of the drilled holes and a PVA polymer liquid was poured in to fill the bladders, to make the polymer anti-seismic piles.

iii.) The top 2 meters of the holes were filled not with the polymer material but with a sandy soil. Fig. 3 shows part of the retrofitting process.

3. Future potential

Relatively serious earthquakes have struck different parts of Japan over the last few years, prompting the general public to show greater interest in anti-seismic measures. We expect the above-mentioned polymer seismic isolation method to contribute effectively to the reinforcement of existing cut and cover tunnels.

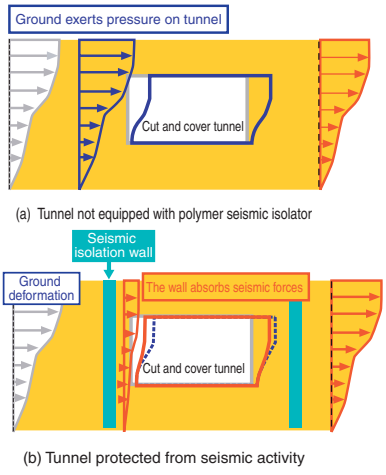

Fig. 1 Polymer seismic isolation method (conceptual diagram)

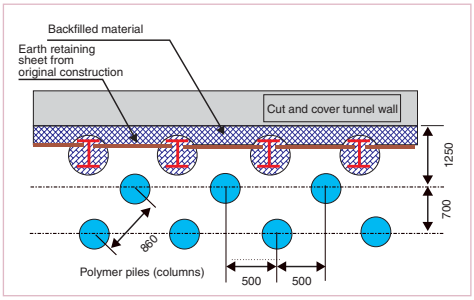

Fig. 2 Polymer seismic isolation method employed to retrofit Nakagawa Station (conceptual diagram)

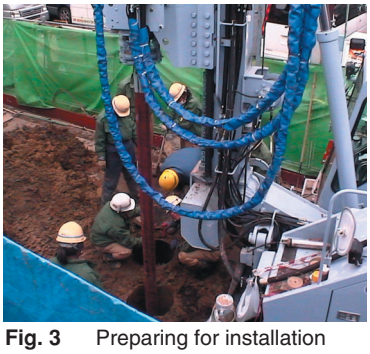

Fig. 3 Preparing for installation