

# A STUDY ON THE NEW WATER LEAK REPAIR METHOD FOR SUBWAY TUNNELS USING CRACK SELF-HEALING REPAIR MATERIALS

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## ABSTRACT

Tokyo Metro Co., Ltd. operates and maintains a subway system of about 195 km consisting of nine lines. Tunnels account for about 85% of the total length, and most of them are located under the center of Tokyo. Water leaks have begun to be found in some of them where they cross under or run near rivers, channels, canals or reclaimed lands.

Although water stop measures have been taken on the affected areas using considerable amounts of budget every year, many of the repaired areas exhibit the same problem again. It is urgently needed to develop new materials and techniques to stop water for proper long-term maintenance of these structures.

The authors conducted test construction in an existing subway tunnel to stop water leaking from cracks, using self-healing materials. The self-healing materials, which are under development at the University of Tokyo, consist of ordinary portland cement as the main ingredient and three types of admixtures: CSA-based expansive agent; geo-material; and chemical additive of the carbonate group.

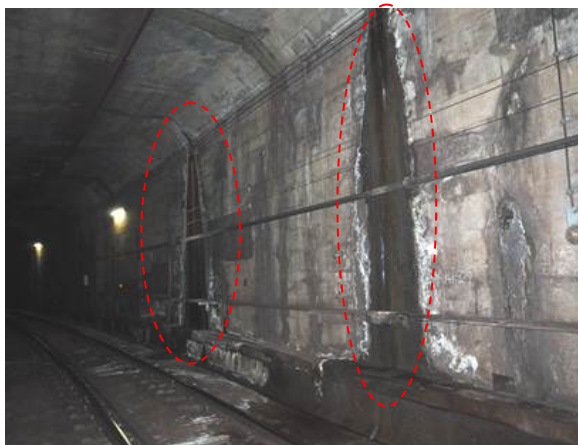
Two different techniques were used in the test construction, depending on the amount of leak water. For locations with a small amount of leakage, holes with diameters of about 15 mm were drilled into a depth of about 30 mm at intervals of 30 to 50 mm along the crack and filled with self-healing cement paste, and the surface was finished with self-healing cement mortar. Locations with a large leakage (about 14 liters per minute) were treated by a combined technique using inorganic waterstop agents for cracks which was placed before the placement of self-healing cement paste.

The results showed a high potential applicability of the materials and techniques tested in the study for use in subway tunnels.

# 1. INTRODUCTION

The Tokyo Metro system constitutes a part of important transportation infrastructure in the capital area of Japan. The subway is used by more than 6,000,000 people per day and operated at intervals of less than two minutes minimum, meeting strong demand for reliable on-time operation from users. About 85% of its total length are reinforced concrete tunnels, with some of them being in service for more than 80 years. Should an incident that affects the subway operation occur due to deterioration of these structures, serious social impacts and tremendous economic loss will result. Proper maintenance of these civil engineering structures will be increasingly important as they will become aged.

One of the serious problems recently found in the tunnels is water leakage [Figure 1(a)]. Some previously repaired areas show the same problem again [Figure 1(b)]. The purpose of this study was to evaluate the effectiveness of self-healing materials [1,2,3] developed for repair of cracks at the Institute of Industrial Science of The University of Tokyo, by testing them on an existing subway tunnel.



(a) Water leaks



(b) Recurrence of water leak

Figure 1: Water leaks

## 2. TEST CONSTRUCTION METHOD

### 2.1 Materials Used

The self-healing materials used in this study contained CSA expansive agent, geo-material and carbonate group-based chemical additive. The CSA agent which gives expansion by forming ettringite ( $3\text{CaO}\cdot\text{Al}_2\text{O}_3\cdot 3\text{CaSO}_4\cdot 32\text{H}_2\text{O}$ ) through hydration is commonly used for shrinkage compensation or chemical prestressing. Geo-materials generally include sand, clay, rock and other natural sediments. In this study clay-based material was used. The carbonate group-based chemical additive was

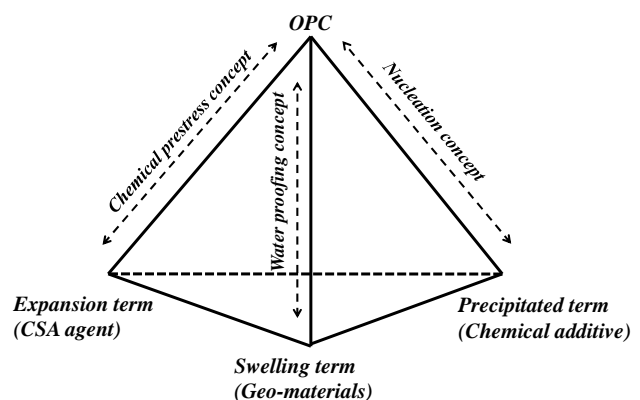


Figure 2: Design concept of crack self-healing materials [1]

The carbonate group-based chemical additive was

used to form crystalline hydrates in cracks. Figure 2 shows the material design concept for crack self-healing technology, explaining the role of each material in relation to ordinary portland cement which is the main ingredient.

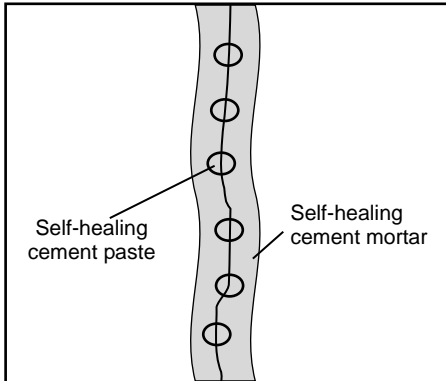
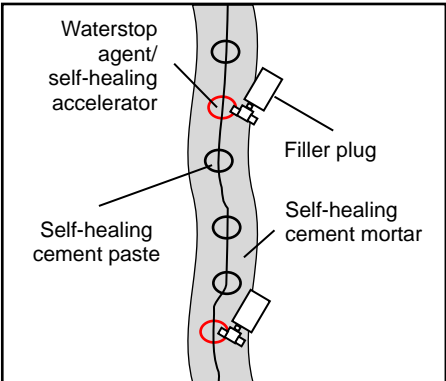
### 2.2 Test Construction Method

Two different repair techniques were used, depending on the amount of leak water as shown in Table 1.

Technique 1 is to drill holes of about 15 mm in diameter to a depth of about 30 mm at intervals of 30 to 50 mm, fill the holes with the self-healing materials, and finish the surface around the crack with the self-healing materials in a width of about 150 mm.

Technique 2 is a combination of Technique 1 and injection of inorganic waterstop agents developed for crack repair.

Table 1: Repair techniques

| Classification | Technique 1   | Technique 2   |
|----------------|---|---|
| Leakage amount | Small   | Large   |
| Method         |  <p>Drill holes, fill the holes and finish the surface with self-healing materials.</p> |  <p>Combination of Technique 1 and injection of inorganic waterstop agent.</p> |

### 3. TEST CONSTRUCTION RESULTS

The previously repaired area suffered leakage of water again, most likely due to deterioration of the repair materials with age and concrete shrinkage by temperature change.

Figure 3 shows the results of one-year monitoring from immediately after the test construction. Although seepage of water was observed at the upper part immediately after the test construction, the surface was found gradually drying at one week and three weeks. The surface was dry and sound at one year, with no recurrence of leakage. These suggest the effectiveness of the proposed water leak repair method using self-healing repair materials under the subway tunnel conditions.

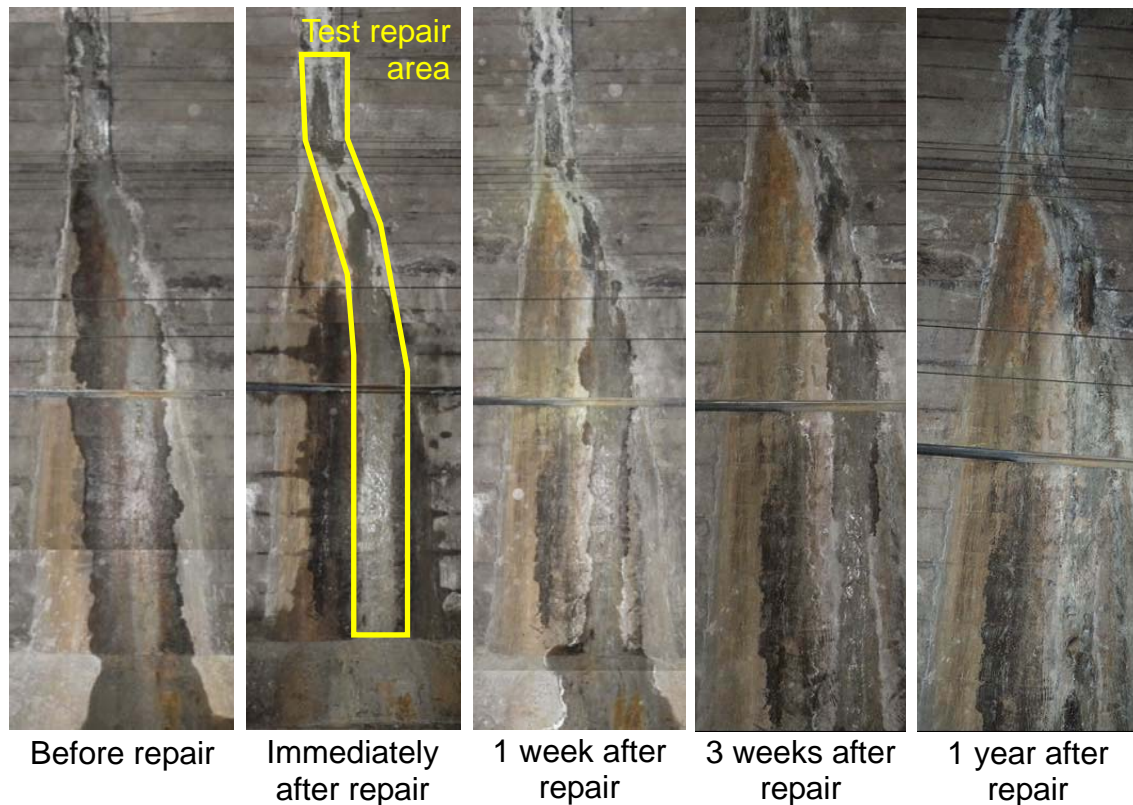


Figure 3: Test construction results (Technique 2)

#### 4. CONCLUSIONS

- (1) The proposed water leak repair method using self-healing repair materials was found to be effective under the subway tunnel conditions.
- (2) Combined use with waterstop agent is necessary where the amount of leak water is large. Simple water leak repair (Technique 1) using self-healing repair materials provides sufficient results where the leak amount is small.
- (3) It is preferable in water leak repair to add self-healing components to sealers and waterstop materials. Such new self-healing materials are currently under research and development.

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