Mechanisms Causing the Deterioration of Concrete Tunnel Lining

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Railway tunnels in Japan were first lined with concrete around 1910, so some of those tunnel linings will soon be 100 years old. Many are still in use, and the tunnels and their linings must of course to be maintained for many years to come. Old concrete used to be considered subject to age-related deterioration, but some concrete liners still remain in good condition after nearly 100 years, so deterioration is not due only to age.

We therefore conducted research to identify mechanisms that cause the deterioration of concrete linings. After taking samples of concrete from many old tunnels (see Fig. 1), we determined that there are a number of such mechanisms.

(1) The most common type of deterioration occurs when acid acts on the concrete. Acidic substances in the soot and smoke emitted from steam locomotives decades ago adhered to the tunnel wall, then corroded the concrete surface. The adherence of soot and dust, the decomposition of the cement paste, the concentration of chemical constituents, and the flaking of weakened concrete are all typical factors promoting discoloration to black, white, brown and other colors (see Fig. 2). In a very few tunnels, we also discovered places where similar deterioration had occurred due to the action of acidic groundwater.

(2) In some tunnels, sulfate ions in groundwater had penetrated into the concrete, forming blisters that cracked or corroded the concrete. Sulfur has a tendency to con-cen-trate along interfaces between carbonated and non-carbonated areas (see Fig. 3), and in such places we dis-covered a ten-dency for cracks to form and surface flaking to occur.

(3) Some linings were made with a concrete mixed with diatomaceous earth or a similar cement substitute, in order to cut costs at a time when cement was expensive. Concrete including such substances was found to have deteriorated and weakened near the surface. In cases where the cement had been mixed with large quantities of diatomaceous earth, it was evident that carbonation had reduced the compressive strength of the concrete (see Fig. 4), and it can be assumed that this action also caused deterioration.

Thus, a number of different mechanisms are responsible for concrete lining deterioration. Accurately understanding these mechanisms will make it possible to determine whether patching is necessary and identify the most suitable patching method. This, in turn, will help ensure safe rail transport. We are continuing our research to ensure that concrete that is almost 100 years old will continue to effectively serve its purpose.

Fig. 1 Obtaining concrete samples

Fig. 2 Concrete surface deterioration due to acidification

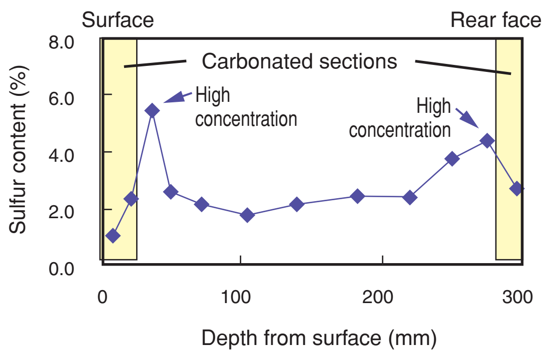

Fig. 3 Distribution of sulfur within typical concrete sample

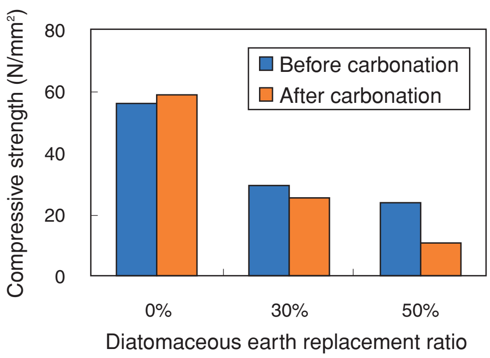

Fig. 4 Compressive strength variations, before and after carbonation in concrete containing diatomaceous earth