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## Development of Construction Technology to Improve Durability of Tunnel Entrance Concrete Lining

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The title of this doctoral thesis is “DEVELOPMENT OF CONSTRUCTION TECHNOLOGY TO IMPROVE DURABILITY OF TUNNEL ENTRANCE CONCRETE LINING”. The aim of this thesis is to improve the quality of the tunnel entrance concrete lining by “The Localized Pipe Cooling System” and “The Aqua Curtain Wet Curing System”.

It is highly probable that the concrete lining at a tunnel entrance will experience thermal cracks and drying shrinkage due to its exposure to external air and the dispersion of snow melting agents. Therefore, in order to avoid thermal cracks, “The Localized Pipe Cooling System” was developed. Also, to prevent drying shrinkage cracks and salt-damage, “The Aqua Curtain Wet Curing System” was developed at an actual construction site.

The construction of invert concrete, a section of the lining concrete, experiences cracks caused by temperature contraction caused by the cement heat of hydration and the fluctuations of the outer temperature. The creation of these cracks is caused by durable aggravation. Therefore, in order to minimize the creation of these cracks, we proposed “The Localized Pipe Cooling System”. This method consists of placing cooling pipes only in the parts of the lining concrete experiencing high tensile stress. In this particular case of this study, the cooling pipes were placed in the lower-center part of the lining concrete. To confirm the mechanism of this method, three-dimensional FEM thermal stress analysis was performed.

In addition, the localized pipe cooling method was applied to a real tunnel under construction. The application of this method was able to prevent the propagation of penetration cracks. Lastly, as a follow-up analysis, we measured the inner temperature and restriction distortion measured in blocks 1 to 4 of the concrete lining. We confirmed that the crack-propagation probability dropped by 31% from 68% to 37%.

There has been no such engineering method until now to enable water treatment in tunnel entrance concrete lining after the removal of formworks. The Aqua Curtain wet curing system has been developed to supply a sufficient amount of water to the vertical surfaces of concrete. The Aqua Curtain prevents rusting of reinforcing bars by making the surface of concrete denser. In this way, the Aqua Curtain also contributes to the realization of more resistant and long-life concrete structures. In other words, implementation of this system leads to improvement of the endurance and economy of concrete structures by reducing the consumption of resources.

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