The Cause and Solution of the Track Irregularity of Railroad Tunnel in Use

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1. Introduction

Recently, the related issue of underground space has become a widely debated topic due to several reasons, such as environmental issues, effective use of land space, economic efficiency, etc. Of late, Tunnels have been gradually extending in length and size as tunnel technology develops and as the social demand for them increases, which makes for lots of problems during the construction of longer tunnels. Among them, the problems at the time of construction are usually more definite than it's actually in use after completion. But efforts to find the cause of these problems has been mainly dominated by factors related to structural deterioration by the time elapsed because the cause and effect are obscure. In this paper, the factors which are required to improve in design and construction of large tunnels will be founded by the study of the defects that occurred. It will contribute to the development of large scale tunnel technology by suggesting the proper countermeasures.

2. Design and Feature of Large Railroad Tunnel

The cross section of a tunnel uses the ground surrounding the tunnel as part of its structural support is designed considering architectural limits, inclinations, facility space and space for maintenance as manual. Tunnels designed for high speed vehicles have been constructed with large cross sections not only to take into consideration air resistance, changes in air pressure and the effects on a railroad coach moving within that space but also to minimize the discomfort passengers may experience like ringing in the ears, vibrations and air pressure during their passing through the tunnel. <Fig 2.1> represent the view of a cross-section of a tunnel and the front view of an express railroad.

As the larger cross section of tunnel is constructed, the lower tunnel's stability become under the same ground because the tunnel brings the ground surrounding it into its structural support. The stability of large tunnels, which is likely to be dictated by the conditions and qualities of the ground needs to have large support structures, and is required to be thoroughly examined during both design and construction phases. Generally, the characteristics of large tunnel construction are as follows.

- Increment of disturbed zone in the tunnel
- Increment of appearing possibility of multiple layers during excavation
- Requirement of large supports's installation with stiffness
- Increment of management's difficulty in quality during construction due to a lowering of approach
- Decrease of safety due to increase of Cycle Time each tasks
- Increment of collapse Possibility during excavation
3. Track Irregularity and Defect in Large Railroad Tunnel

The large railroad tunnel (cross section area: 107m², length: 10km) was constructed with a concrete ballast for convenient and economical maintenance. There is a slight difference between sections shown in <Fig 3.1>, though the bottom of I~IV sections were found to have similar types of track irregularities and cracks that have occurred in the 7 years since the tunnel was completed.

Precise measurement has been taken to measure the amount of track irregularity since it had been first found by transportation safety inspectors (No.36). Track irregularity occurred in four sections of the entire tunnel and of those four, two sections in particular were found to exceed the management limit (high-low) for track irregularities.

The results of the inspection showed longitudinal/ transversal cracks were found to be concentrated along the bottom in the four sections mentioned previously. Cracks were found in the bottom where maximum track irregularity occurred, which rarely transferred onto adjacent lining. It shows the type of cracks on the bottom and along the lining where track irregularity has occurred.
3.1 Field Investigation

Various field tests were performed, with an analysis of the construction data to identify the causes of track irregularities. First, the slope of the tectonic line is characterized to be high; such a high angle was found to affect the inspected sections throughout the results from geological surveys and boring inside the tunnel. Second, the low quality of the concrete base on the ground was found by geophysical investigation methods such as GPR (Ground Penetration Radar), Impact Echo, Tomography, and the Coring specimens of bottom concrete. <Fig 3.3> shows the result of tomography and Coring in tunnel inside.

3.2 Construction Data Analysis

From the results of the data, the ground of the sections where the track irregularities have occurred was estimated to be good during construction, so that excavation length / 1 cycle was found to be longer than that of the design. <Fig 3.4> shows that excavation length / 1 cycle by design support pattern compares with that of the construction.

Generally, the stability of tunnel is very important during construction. When the displacement of tunnel converges to be stable, next excavation should be allowed to begin. Excavation for the lower part is rapider than that of the upper part during the excavation, which results in the instability of the tunnel and expanding the loose zone of adjacent ground (refer to <Fig 3.4>).
4. Countermeasure

The reinforcement was applied on the weak ground with the fundamental causes of tunnel defects such as the track irregularities and cracks. Regularly, monitoring was recommended for the stability of the tunnel.

4.1 Reinforcement

In the case of the track irregularities of the vulnerable ground, it’s essential to insert supporting stiffeners like Rockbolt or Micropile into the ground and to grout into the adjacent zone.

4.2 Maintenance

To begin with, it should be ensured of the safety for train operation in case of large scale tunnel where the track irregularities has occurred. Therefore, taking appropriate repair and reinforcement measures and monitoring on key management items in vulnerable sections continuously are needed to ensure the safety of the tunnel.

A step-by-step emergency response plan, which is based on the continuous monitoring and various measurement results, is necessary to be applied as short-/mid-term countermeasures. And the inspection for structure's specificity should be accomplished in a timely manner.

Monitoring on vulnerable sections, which is applied the proposed repair and reinforcement methods, should be performed on a regular basis as long-term countermeasures. Hereafter, new management like automated measuring system is needed to analyze behavior of vulnerable sections.

5. Conclusions

In general, as most of defects of tunnel in use are caused by complex factors, it is indistinct to reveal the priority order of the direct and indirect causes of defect.

The defect of tunnel in use cannot be dominated simply by structure deterioration as time passes. It appears likely to us that it has been caused by potential problem during the design and construction stages. Proceeding from what has been said above and what has been inspected about the relation between design and construction, it should be concluded as follows:

1) The causes of the track irregularities of tunnel is described by the result of inspection as follows:

- Track irregularities were caused by the lack of appropriate management for construction, by the low quality of bottom concrete on the weak ground and irregularity of concrete thickness during construction.
- The repeated loading and unloading of trains at high speeds seem to have caused the serious deformation of the structure from the bottom concrete to the ballast in tunnel in use.
• After cracks on the concrete ballast have occurred, which ultimately led to the track irregularities of the railroad whose expansion coefficient was larger than that of concrete.

2) It is difficult to maintain for excavation's face due to the size of cross-section in large tunnel under low quality of bottom concrete on the weak ground having very poor rock quality, which led to irregular behavior by the repeated load and unload and the difference of support condition for structure.

3) Recently, various complexed technologies has been applied to tunnel construction which has been large-sized so that it does induce the problem to the technology in each field and to the mutual technologies. To reach a fuller understanding of the problem, futher studies on tunnel defect are needed.

References