Seismic refraction survey on the tunnel pavement and evaluation of seismic velocity of tunnel ground surface

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There have been many reported cases in which deformation, such as tunnel ground heaving and squeezing of sidewalls, occurred in a tunnel days, months or even decades after construction. Therefore, a diagnostic method is required that is able to provide constant and reproducible monitoring from construction stage to maintenance stage. We are carrying out a study to develop a diagnostic method to estimate the soundness of tunnel ground from time-dependent behavior from in an actual two tunnels, the New tunnel and the Old tunnel, with time-dependent deformation. The Old tunnel was conducted after closure after opening of the New tunnel. From the results of a series of laboratory tests and field experiments, we found it is possible to estimate the soundness of tunnel ground using seismic velocity. So, we carried out field experiment of actual tunnel with time-dependent deformation and the result of case study evaluating the soundness of tunnel ground using seismic velocity. The geology of both tunnels in this study is hydrothermally altered pyroclastic rock. Heaving occurred in two sections replaced by timbering in a hydrothermally altered andesite zone in the New tunnel after completion in 2014. The Old tunnel was completed in 1977 using the timbering support method. The Old tunnel has 5 sections of time-dependent deformation. A seismic refraction survey was carried out in both tunnels in order to evaluate the soundness of tunnel ground. We used a hydraulic impactor as the seismic source and MEMS (Micro electro mechanical systems) sensors as seismic receivers. The hydraulic impactor was used to avoid damages to the pavement as a non-blasting seismic source. MEMS sensors enabled down-sizing of the survey equipment and to reduce the hours needed for receiver handling. P-wave generation was achieved using a vertical shot. Each shot is stacked 3 times at each shot point in order to improve S/N ratio. The survey line is 450 m length in the New tunnel, 1,500m in the Old tunnel. The interval of receivers is 6.0m, and the interval of shot points is 3.0m- 6.0m. If the decrease of P-wave velocity due to the time-dependent deformation or the loosening by stress release from the excavated surface, the seismic velocity in the deeper zone may be assumed to be indicate the original seismic velocity of ground because it is far from influence of the excavation. In other words, the surface part having lower seismic velocity originally had higher velocity but it decreased as tunnel excavation work progressed. Based on this assumption, the soundness of tunnel ground can be evaluated by a decrease in the ratio of surface seismic velocity to deep zone. The decrease rate of P-wave velocity of No.1 to No.5 block and non-deformed zone of the Old tunnel and the zone of initial deformation 1 and 2 of the New tunnel. The decrease rate of P-wave velocity of No.1 to No.5 block with time-dependent deformation is estimated 25% to 44%. While, the decrease rate of P-wave velocity of the other zone with no time-dependent deformation is 8% to 16%. Thus, it is confirmed that the decrease rate of P-wave velocity in the zone with time-dependent deformation is higher than that in the other zones. And it is suggested that the threshold of this tunnel ground may exist between 16% and 25%.

Keywords: tunnel, seismic velocity, time-dependent deformation

