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2016年熊本地震によるJR豊肥本線立野トンネルの被害と復旧

九州旅客鉄道(株)　神川　孝洋

2016年の熊本地震により，JR豊肥本線の立野トンネルでは坑内の覆工にひび割れが生じたほか，終点方坑口部では坑門の破断や覆工の剝落が生じた．これらの変状のうち，覆工のひび割れについては，地震動による揺れ方が異なる地層の境界が変状区間内に存在することから，その境界の前後で覆工の応答が異なったことが発生要因となった可能性がある．また，坑門の破断などについては，終点方坑口部は痩せた尾根状地形の先端に位置しており，また地山が比較的軟質であることから，地震により地盤が大きく変位したために発生したと考えられた．これらの変状に対して，覆工のひび割れが顕著な区間に対しては薄型パネルを用いた内面補強工を実施した．また，終点方坑口部では既設の坑門を残した状態で既設覆工の撤去および縫い返しを行い，RC造の閉合断面で覆工を再構築した．

Damage and Restoration of the Tateno Tunnel on the JR Hohi Main Line Caused by the 2016 Kumamoto Earthquake

By Takahiro Kamikawa, Kyushu Railway Company

The 2016 Kumamoto Earthquake caused cracks on the lining inside the Tateno Tunnel on the JR Hohi Main Line, fracture of the tunnel portal, and spalling of the lining at the end of the tunnel. Since the deformation section contains a stratum boundary of which both sides move differently due to the earthquake motion, the cracks on the lining may have been caused by the difference in the response of the lining in each stratum. Regarding the fracture of the tunnel portal, it is thought that the fracture occurred due to a large displacement of the ground caused by the earthquake because the portal at the end of the tunnel is located at the steep convex slope where the ground is relatively soft. In response to these deformations, the inner surface was reinforced using thin panels in the sections where cracks in the lining were prominent. At the end of the tunnel, the existing lining was removed and replaced, leaving the existing portal in place, and the lining was reconstructed with a closed RC cross-section.

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中央導坑先進工法による脆弱地山の掘削と覆工作業の効率化

―国道294号白河バイパス　南湖トンネル―

西松・壁巣特定建設工事共同企業体　八巻　大介

南湖トンネルは，国道294号白河バイパス整備事業のうち，日本最古の公園といわれる史跡名勝「南湖公園」に隣接する里山をNATMにより施工する474mの道路トンネルである．工事は福島県白河市市街地で行われたため，周辺住民への騒音・振動・交通への配慮を最大限実施した．トンネル掘削作業は，一軸圧縮強度0.1N/mm^{2}以下，地山強度比0.1～1.2である火砕流二次堆積物や砂質凝灰岩がトンネル延長の約7割を占める非常に脆弱な地質構造に対し，FEM解析によりトンネルの安定性を検討のうえ，中央導坑先進工法により施工を行った．また覆工作業においては，自動化セントルを導入し，一連の作業の大半を機械化することで作業員の削減を行った．

Excavation Works in Weak Ground Using the Center Drift Advancing Method and Improving Efficiency of Lining Works

―The National Route 294 Shirakawa Bypass, Nanko Tunnel―

By Daisuke Yamaki, Nishimatsu-Kabesu Specified Construction Joint Venture

The Nanko Tunnel is a 474 m road tunnel constructed using NATM in the mountain closed to the living area adjacent to the Nanko Park, the reputed oldest public park in Japan, a historic site, and a place of scenic beauty, as part of the National Highway 294 Shirakawa Bypass Construction Project. Since the construction works were carried out in the urban area of Shirakawa City, Fukushima Prefecture, consideration was maximally given to the noise, vibration, and traffic for the local residents. The geological structure along the line of the tunnel is extremely weak, with about 70 % of the tunnel length comprised of secondary pyroclastic flow deposits and sandy tuff with an unconfined compression strength of less than 0.1 N/mm^2 and competence factor of 0.1–1.2. After FEM analysis was conducted to determine the stability of the tunnel, the tunnel excavation work was carried out using the center drift advancing method. Also, introducing the automated tunnel lining form and mechanizing most of the operations allowed to reduce the number of workers.

解説

45 東京メトロにおけるトンネル全般検査にドローンを導入

東京地下鉄(株)　菅原　　健

東京地下鉄(株)は，東京圏を事業基盤として，9路線，営業キロ195kmで運営している．保有する土木構造物は，トンネル，高架橋，橋梁，土工などからなり，このうち約85%をトンネルが占める．トンネルの維持管理にあたっては，国土交通省「鉄道に関する技術上の基準を定める省令」にもとづき，2年ごとに軌道上からの目視および必要箇所の打音を行う通常全般検査や，20年を超えない周期で高所作業車上からの近接目視および必要箇所の打音を行う特別全般検査などによりトンネルの状態を確認している．本稿では，トンネルの通常全般検査の一部にドローンの運用を開始したことから，導入までの流れとその取り組みについて述べる．

Introducing Drones for Tunnel Overall Inspections conducted by Tokyo Metro

By Ken Sugawara, Tokyo Metro Co., Ltd.

Tokyo Metro Co., Ltd. operates 9 lines with a total operating distance of 195 km in the Tokyo metropolitan area. The civil engineering structures owned by the company include tunnels, viaducts, bridges, and earth structures, of which tunnels account for about 85 %. According to the “Technical Regulatory Standards on Japanese Railway” issued by the Ministry of Land, Infrastructure, Transport and Tourism, the condition of the tunnels must be inspected through the following methods: An usual overall inspection that includes visual inspection from the tracks and hammering test where necessary is conducted every two years. A special overall inspection that includes close visual inspection and hammering test from aerial platform truck where necessary is conducted in a period not exceeding 20 years. In this paper, the authors describe the process and efforts from the start of operation of drones to the introduction of drones as part of the usual overall inspection of tunnels.

研究

51 前方探査データを活用した切羽評価点の判定に関する研究

(株)鴻池組　阪口　　治

山岳トンネル工事において，掘削中に前方探査を実施して，地質やその性状を把握することが試みられている．削孔検層法を用いた前方探査では，穿孔時の油圧データを測定し，得られたデータを用いて穿孔エネルギーを算出する．しかし，個々の油圧データ，例えば回転圧などには，地山の特徴を示しているデータがあり，穿孔エネルギーのみで地山を評価することは，得られたデータを有効活用できていない可能性がある．本研究では，掘削時に取得した穿孔データと切羽評価との関連性を詳細に分析し，穿孔データから切羽の評価点を算出できるかを検証した．今回の検証では，穿孔エネルギーのほかに，穿孔速度，フィード圧，回転圧に着目して検証した結果，いくつかの項目で切羽評価の可能性を示した．また，穿孔データを用いて切羽評価を行うには，いくつかの課題があることを確認した．

A Study on the Determination of Face Assessment Scores Based on Drilling Data Ahead of Tunnel Face

By Osamu Sakaguchi, Konoike Construction Co., Ltd.

During the mountain tunneling attempts have been made to predict the geology and its conditions through measures while drilling. In measures while drilling using the drill logging, the hydraulic pressure data during drilling is measured and the drilling energy is calculated using the obtained data. However, individual hydraulic data, such as rotational pressure, show the characteristics of the ground, and assessing the ground based on drilling energy alone may not be an effective use of the obtained data. In this study, the authors performed a detailed analysis of the relationship between the drilling data acquired while drilling and face assessment and verified whether the face assessment scores could be calculated from the drilling data. In this verification, the authors focused on the penetration rate, feed pressure, and rotation pressure in addition to the drilling energy, and the results showed the possibility of face assessment in several items. It was also confirmed that there are several issues to be solved for face assessment using the drilling data.

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山岳トンネルにおけるAIを用いた地山等級推定の基礎的検討

鉄道・運輸機構　黒田　　晴

山岳トンネルでは，施工前に得られる地山の情報量や質に限界があるため，施工中の観察・計測結果にもとづいて当初設計の地山等級を見直すことが通例となっている．この施工中の設計変更の際には，各種観察・計測結果を総合して的確に判断する必要があるが，昨今の事業量に対する技術者の不足から，各現場に十分な能力のある技術者を配置することが困難となりつつあり，経験の浅い技術者が現場で地山等級を判断することが想定される．そこで，掘削が終盤に近づいている北海道新幹線後志トンネル（北上沢工区）のデータを教師データとし構築したAIの基礎的な検討結果を報告するものである．

A Fundamental Study of AI-Based Estimation of Ground Classification in Mountain Tunneling

By Sei Kuroda, Japan Railway, Construction, Transport and Technology Agency

In the case of mountain tunneling, the amount and quality of information available for the ground before construction is limited, and it is customary to revise the ground classification in the initial design based on the results of observations and measurements during construction. When making design changes during construction, it is necessary to make accurate decisions by combining the results of various observations and measurements. However, due to the recent shortage of engineers in inverse proportion to amount of projects, it is becoming difficult to assign engineers with sufficient skills to each site, and inexperienced engineers are expected to determine the ground classification on site. In this paper, the authors report the results of a fundamental study of AI developed using teaching data obtained from the Shiribeshi Tunnel (Kamikitazawa Lot) of the Hokkaido Shinkansen, which is approaching the final stage of excavation.