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スメクタイトを多量に含む膨張性地山におけるトンネルの施工

―北海道新幹線　立岩トンネル(立岩工区)―

鉄道・運輸機構　宮川　直也

立岩トンネルは北海道新幹線の新八雲(仮称)駅の終点方の約1.6～18.7kmに位置する全長17,035mの山岳トンネルである．起点方から立岩，山崎，ルコツ，豊津の４工区に分割し施工中であり，立岩工区は約５kmの工区である．当該工区の地質は，新第三紀中新世の海成層である訓縫層が広く分布している．また，当該工区の地山特性として工区の大半を占める玄武岩は熱水変質を受けているため，スメクタイトの含有量が多量である．また，一軸圧縮強度が0.6～230N/mm^{2}程度であり，土かぶりが200m程度であることから地山強度比は0.5～7.0程度であった．本稿では，立岩トンネル(立岩工区)における膨張性地山での掘削施工および対策工の施工実績について報告する．

Building a Tunnel in Squeezing Ground Containing Large Amounts of Smectite
—The Hokkaido shinkansen, the Tateiwa Tunnel (the Tateiwa Lot)—

By Naoya Miyakawa, Japan Railway, Construction, Transport and Technology Agency

The Tateiwa Tunnel is a 17,035 m long mountain tunnel located approximately 1.6 to 18.7 km from Shin-Yakumo station (tentative name) toward the end point on the Hokkaido Shinkansen. The tunnel project is divided into 4 lots starting from the starting point : Tateiwa, Yamazaki, Rukotsu, and Toyotsu. The Tateiwa lot is about 5 km long. The geology of the construction area is comprised of the widely distributed Kun-nui Formation, a marine sediment from the Neogene epoch of the Miocene age. In addition, the basalt that makes up the majority of the construction area has a high smectite content due to hydrothermal alteration. The uniaxial compressive strength ranged from 0.6 to 230 N/mm^2, and because the covering was approximately 200 m, the competence factor ranged from 0.5 to 7.0. In this paper, the authors report on the excavation works in squeezing ground and the work result of measures against it in the Tateiwa tunnel (the Tateiwa Lot).

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開業50年を経た蛇紋岩トンネルの維持管理

―JR函館本線　神居トンネル―

北海道旅客鉄道(株)　中西　祐介

JR函館本線の神居トンネルについては，建設時から地山の押し出しなどにより難航した鉄道トンネルであり，1969(昭和44)年の供用開始後も長期間にわたり緩やかな路盤隆起と内空縮小が継続している．1996(平成８)年にもっとも変状が顕著な箇所に対してロックボルトなどを施工し変状を抑制させたが，この箇所のほかに変状が続く２か所に対して，2019～2010(平成22～令和元)年にかけて側壁と路盤部へのロックボルト施工と部分的にインバート改築を実施した．本稿では，対策を実施した箇所の変状概要や対策内容，対策後も継続して実施している路盤隆起と内空縮小の計測結果について報告する．

Maintenance of a Tunnel in Serpentine Ground after 50 Years of Operation
—The JR Hakodate Main Line, the Kamui Tunnel—

By Yusuke Nakanishi, Hokkaido Railway Company

The Kamui Tunnel which located at JR Hakodate Main Line had a difficult construction because of extrusion from natural ground. The roadbed of this tunnel has heaved, and the inner section has decreased slightly in such situation since 1969, when the tunnel start of service. We took some countermeasures for the tunnel's most conspicuous deformation by rock bolts to control displacement in 1996. For the other two conspicuous deformations, we applied rock bolts to roadbed and side wall, and carried out partial rebuilt of some invert from 2010 to 2019. This time, I report the outline of these deformations, countermeasures, and measurement results for roadbed heaving and the inner section decreasing, and consider the effect of the countermeasures.

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未固結砂質地山における天端崩落とその対策

―千葉県道73号銚子海上線　清滝トンネル―

千葉県　鈴木　政和

主要地方道である千葉県道73号銚子海上線のうち，国道356号から東総広域農道までの区間は幅員が狭小で屈曲が多く，また，年々交通量が増加の傾向にあることから改良工事を計画し，Ⅲ期の本事業((仮称)清滝バイパス)が計画された．本工事は，当該区間にある延長432mのトンネル((仮称)清滝トンネル)を構築するものである．本トンネルは，坑口から200m付近までは比較的堅固な泥岩層を主体とするが，以降はトンネル天端より徐々に未固結な砂質土層に移り変わり，砂質土層の領域の広がりに応じて段階的に補助工法の仕様を変更しながら掘削を進めた．補助工法を併用しながら慎重に掘削を進めたが２回の崩落が発生した．本稿は，砂質土層における崩落の状況と，崩落状況に応じて適用した補助工法の経緯を述べる．

Crown Collapse of a Tunnel in Unconsolidated Sandy Ground and Measures against It
―The Chiba Prefectural Route 73 Choshi-Unakami Line, the Kiyotaki Tunnel―

By Masakazu Suzuki, Chiba Prefecture

The section from National Route No. 356 to Tohso Koiki Nodo on the Chiba Prefectural Route No. 73 (Choshi-Unakami line), a major local road, has a narrow width and many bends. The traffic volume on the road tends to increase year by year, so improvement work was planned, including this project (tentative name: Kiyotaki Bypass) as Phase III. The goal of the project is to construct a 432 m long tunnel (tentative name: Kiyotaki Tunnel) in this section. The ground to excavate is mainly composed of a relatively hard mudstone up to about 200 m from the tunnel portal, after which it gradually shifts to unconsolidated sandy soil from the top of the tunnel. As the sandy soil expanded, the specifications of the auxiliary methods were changed step by step. Although the excavation was carefully carried out using auxiliary methods, two collapses occurred. In this paper, the authors describe the circumstances of the collapses in the sandy soil and the background of the auxiliary methods applied according to the collapse conditions.

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都市部における多様な工法を用いたトンネル掘削と道路陥没事故後の対応

―福岡市地下鉄七隈線延伸事業（天神南～博多）―

福岡市　山本　智之

福岡市地下鉄七隈線は，2005(平成17)年２月に橋本～天神南間の12.7kmを先行して部分開業した．その後，残る都心部区間について，2011(平成23)年度から天神南～博多ルートの事業化に向けた取組みを進め，2013(平成25)年度に土木本体工事に着手し，軌道工事や駅建築・設備工事等を含め約９年の工事期間を経て，2023(令和５)年３月27日に開業を迎えた．この七隈線延伸事業では，地下鉄建設延長としては短いものの，福岡市都心部地下において，シールド工法，NATM，アンダーピニング工法など多様な手法を活用しており，本稿ではこの工事内容について報告するとともに，2016(平成28)年11月に発生し市民や関係者に多大なご迷惑をおかけした道路陥没事故とその後の再掘削に至る検討経緯についても合わせて報告する．

Tunnel Excavation in Urban Center Using Various Tunneling Technologies Methods and Response after Road Cave-in Accident
―The Fukuoka City Subway Nanakuma Line Extension Project (Tenjin Minami-Hakata)―

By Tomoyuki Yamamoto, Fukuoka City

The Fukuoka City Subway Nanakuma Line partially opened in February 2005, with a 12.7 km section between Hashimoto and Tenjin-Minami before the rest. After that, efforts to operationalize the remaining urban section of the line, the Tenjin-Minami to Hakata route, began in FY2011. The tunneling works began in FY2013, and after approximately nine years of construction, including installing tracks, stations, and facilities, the line is scheduled to open on March 27, 2023. Although the Nanakuma Line extension project is a short-distance subway extension, it utilizes various methods such as shield tunneling, NATM, and underpinning in the underground of central Fukuoka City. In this paper, the authors report on the details of the construction work and also describe the road cave-in accident that occurred in November 2016, which caused great inconvenience to citizens and related parties, and the process of investigation led to the subsequent re-excavation.

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突発的に出現した大礫への対応と立坑内注水によるシールド直接切削到達

—東京下水道　千川増強幹線—

東京都　畠平　敏行

東京都下水道局が整備する千川増強幹線は，東京都文京区千石・豊島区南大塚地区における浸水被害を軽減することを目的とし，豊島区立上池袋東公園内の発進立坑から，文京区立窪町東公園の到達立坑まで約2.5kmにわたり，泥水式シールド工法によって整備する内径3.75mの下水道施設である．本シールドは河川に浸食された谷底低地箇所を掘削することから，掘進中に突発的に出現した大礫への対応が課題となった．また，シールド到達は，シールドで立坑を直接切削して到達する工法を採用し，切削周辺からの地下水や土砂の流入による周辺家屋などへの影響を抑制するために到達立坑内へ注水した状態で到達することとした．本稿では，これらの対策と結果について報告する．

Response to the Sudden Appearance of Large Boulders and Shield TBM Directly Boring the Arrival Shaft by Injecting Water in the Shaft

—The Tokyo Sewerage, Senkawa Enhanced Sewer Main—

By Toshiyuki Hatahira, Tokyo Metropolitan Government

The Senkawa Enhanced Sewer Main is being constructed by the Bureau of Sewerage, Tokyo Metropolitan Government to reduce inundation damage in the Sengoku and Minami-Otsuka areas in Bunkyo city and Toshima city. It is a sewerage facility with an inner diameter of 3.75 m excavated using the slurry shield method over a distance of 2.5 km from the starting shaft in Kami-Ikebukuro Higashi Park, Toshima city, to the arriving shaft in Kubomachi Higashi Park, Bunkyo city, Tokyo. Because this shied TBM excavated at the valley bottom that had been eroded by a river, it was necessary to deal with cobbles that suddenly appeared during the excavation. A technique with which the shield TBM directly cut the wall of the shaft was selected as the shied TBM arrival method. Water was injected into the arrival shaft to prevent the inflow of groundwater and sediment from the cutting area into the shaft from affecting surrounding houses and other structures. In this paper, the authors report on these measures and results.