

野田久慈道路は、東日本大震災からの早期復興に向けたリーディングプロジェクトに位置づけられた復興道路である三陸沿岸道路のうち、岩手県野田村～久慈市を結ぶ延長約25kmの自動車専用道路である。このうち、久慈長内トンネル(L=1,445m)ではトンネル作業の自動化、機械化を進めており、その一つとして覆工作業におけるセントルのセット作業の自動化システムを開発し現場での適用を行った。本稿では、そのシステムの概要と、実施の際に在来工法との比較を行った結果について報告する。

## Development and On-site Application of an Automatic Setting Up System of Tunnel Lining Form

—The Noda-Kuji Road, the Kuji-Osanai Tunnel—

By Katsuhiko Abe, Ministry of Land, Infrastructure, Transport and Tourism

The Noda-Kuji Road is a 25 km long expressway connecting Noda village and Kuji city in Iwate Prefecture, as part of the Sanriku Coast Expressway. It is a Recovery Road designated as a leading project for early recovery from the Great East Japan Earthquake. In the Kuji-Osanai Tunnel (L=1,445 m) on the road, automatization and mechanization of tunneling work are undergoing, including the development and on-site application of an automated system for setting up tunnel lining form during lining work. In this paper, the authors present an overview of the system and the results of a comparison with conventional tunneling methods used during work.

上半3心円道路トンネルの覆工に、流動性に優れた材料分離がない現場流動覆工コンクリートを採用し、これをマニピュレータ方式配管切替え装置と吹上げ方式打込み装置で移動型枠内に打込み、型枠パイプレータでパターン締固めする覆工コンクリート自動施工システムを採用した。この自動施工システムは、各種センサで施工状況と締固め状態を数値で可視化でき、PCシステムで打込み装置と締固め装置を自動制御するものである。あわせて覆工コンクリートの出来形管理に、Laser Scannerを用いた山岳トンネルDigital出来形測量検測を試行した。本稿では、現場流動覆工コンクリート自動施工と山岳トンネルDigital出来形測量検測システムの適用性と有効性について報告する。

## Application of ICT for Automatic Concrete Lining and Digital Measuring System of Finished Cross-section

—The San-En Nanshin Expressway, the San-En Road No.2 Tunnel—

By Teruaki Agawa, Ministry of Land, Infrastructure, Transport and Tourism

An automatic concrete lining system was adopted for the lining of a tunnel with a cross-section of the top heading formed by 3-center arcs, which uses in-situ fluid lining concrete with excellent fluidity and no material segregation. In this automatic lining system, the concrete is poured into the traveling form with a manipulator-type piping switching device and an upward concrete-injection device and compacted with form vibrators by following a pattern. The automatic lining system allows numerical visualization of the working status and compaction conditions using data from various sensors, and automatically controls the pouring and compacting devices using a PC system. At the same time, we tried a digital measuring system of a finished cross-section of mountain tunnels using a laser scanner for the management of the finished shape of the lining concrete. In this paper, the authors report on the applicability and availability of the on-site automatic fluid concrete lining and the digital measuring system of the finished cross-section for mountain tunnels.

本トンネルでは、発進坑口部と中間部に類似の性状を有すると考えられる破碎帯が存在し、とくに中間部では小土かぶりの破碎帯直上にキャビン宿泊施設が存在した。したがって、事前にキャビン宿泊施設への沈下影響予測を精度よく行い、その後の施工に反映させることが重要な課題であった。本検討では類似の破碎帯が存在する発進坑口部における計測結果を用いた逆解析により、破碎帯掘削時における応力解放率および地山の変形係数を精度よく求め、中間小土かぶり部におけるトンネルの安定性、沈下影響および補助工法の妥当性の検討を行った。検討の結果、元設計どおり施工しても問題がないことが確認できたことから、沈下計測を行いながら慎重に施工を行った。その結果、地表面沈下量を許容値以下に抑えたうえで、中間小土かぶり部をトンネル掘削することができた。

### Shallow NATM Excavation in Fracture Zone Directly below Cabin Accommodation Facilities

#### —The National Route 161, the Komatsu Widening Project, the Kita-Komatsu Tunnel— By Atsushi Takagi, Ministry of Land, Infrastructure, Transport and Tourism

There are fracture zones with similar characteristics at the starting portal and in the middle part of the tunnel. Especially, in the middle part of the tunnel, cabin accommodations were located directly above the fracture zone with a small covering. Therefore, it was an important issue to accurately predict the impact of the settlement on the cabin accommodation facilities in advance and reflect the prediction results in the subsequent construction works. In this study, the stress release rate and the modulus of deformation of the ground during excavation of the fracture zone were accurately calculated with inverse analysis using the measurement results at the starting portal where a similar fracture zone existed, and the stability of the tunnel, the settlement impact, and the adequacy of the auxiliary method in the middle small covered area were examined. After the study, it was confirmed that carrying out the tunneling works according to the original design should pose no problem, so the works were carefully carried out while measuring the settlement. As a result, it was possible to bore the tunnel in the middle small covered area while keeping the surface settlement below the allowable value.

本工事は、浸水被害の軽減を目的として、江東区平野・三好地区に内径2,400mmの下水道管を泥土圧シールド工法により施工するものである。この地区は、海を埋め立て、商業・工業の町として発展しており、軟弱地盤、狭隘な道路、埋設物が輻輳しているといった特徴がある。このような施工環境の中、コスト縮減、工期短縮、環境負荷軽減を目指し、反力壁を用いない条件で、9か所の急曲線施工を実施した。本稿は、このような難易度の高い工事において実施した急曲線部の綿密な施工管理について報告するものである。

### Shield Tunneling through Nine Sharp Curves in Soft Ground without Ground Improvement

#### —The Tokyo Sewerage, the Main Branch Sewer near Hirano and Miyoshi, Koto City— By Koji Habara, Tokyo Metropolitan Government

The goal of this project is to reduce inundation damage by constructing sewer pipes with an inner diameter of 2,400 mm in the Hirano and Miyoshi areas of Koto city, using the muddy soil pressure balanced shield tunneling method. This area has been developed as a commercial and industrial town by reclaiming land from the sea and is characterized by soft ground, narrow roads, and congestion of buried objects. In such a construction environment, nine steep curves were constructed without building a reaction wall to reduce costs, duration, and environmental burden. In this paper, the authors report on the thorough construction management of the steep curves in such a challenging construction project.

山岳トンネルの掘削時に行った切羽前方探索データを用いて、切羽前方の地山評価を試みた。本稿では評価指標として地山等級を採用し、穿孔データと地山等級との関係を詳細に分析することにより、切羽前方探索データの活用方法を考察した。評価に用いたデータは、穿孔速度、フィード圧、打撃圧、回転圧、打撃数とそれらのデータから算出される穿孔エネルギーである。まず、穿孔データと地山等級との関係をヒストグラムやボックスプロットを用いて整理し、分析を行った。その結果、穿孔エネルギー、回転圧、打撃数の分布においては地山等級による違いが見られた。次に、穿孔データの有効性および組合せによって判別精度を向上することが可能かを検証するため、判別分析を行った。その結果、データ組合せ時の判別精度、採用データを平均化する場合の有効な距離、他の要素を追加した場合の判別に対する有効性などを確認した。

### Fundamental Study to Determine Ground Grade Based on Drilling Data Ahead of Tunnel Face

By Osamu Sakaguchi, Konoike Construction CO., LTD.

An attempt was made to evaluate the ground ahead of a tunnel face using the drilling data ahead of the tunnel face during the excavation of a mountain tunnel. In this paper, the authors adopted the ground grade as an evaluation index and considered how to utilize the drilling data ahead of the tunnel face by analyzing the relationship between the drilling data and the ground grade in detail. The data used for evaluation were drilling speed, feed pressure, impact pressure, rotation pressure, the number of impacts, and drilling energy calculated from these data. First, the relationship between the drilling data and ground grade was organized and analyzed using histograms and box plots. The results showed that the distribution of drilling energy, rotation pressure, and number of impacts varied with the ground grade. Next, discriminant analysis was conducted to verify the validity of the drilling data and determine whether the combination of the data could improve the discrimination accuracy. As a result, the authors confirmed the accuracy of discrimination for combined data, determined the effective distance when averaging the adopted data, and the effectiveness of the discrimination when other factors are added.