Iranian Journal of Engineering Geology
Spring 2025, Vol.18, No.1

Investigating the guidance method and improvement of TBM's equipment in adverse geotechnical conditions, Case study: Azad project

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Abstract

A tunnel boring machine (EPB Hard Rock type) was used to construct the Azad Water Transfer Tunnel. The adverse geotechnical conditions in a fault zone presented special risks to the machine operation. These risks were also experienced in the Bazideraz Tunnel (machine jamming and stopping, conditioning of excavated materials). In order for the TBM to advance, there was a need to make adjustments to the guidance method and make changes to the structure of the TBM's equipment. In this study, various research methods were used to investigate the operation and improvement of the Azad Tunnel Machine equipment, including: Reviewing previous technical experiences through research texts and literature (related to the Bazideraz Tunnel), examining geological observations during the machine's advance, analyzing machine deflection measurement data, conducting excavation material grading tests, analyzing operating parameters recorded in the machine's data logger system (Thrust, Penetration rate, Face pressure), and documenting remedial solutions. The results show that the implementation strategies for guidance the machine in the fault zone (using additional hydraulic cylinders, installing stage high-pressure pumps, Changing the excavation mode from closed mode to semi-open and open mode, etc.) have been correctly adopted based on technical thinking and engineering judgments. The results of this study can be useful in transferring technical experiences about the guidance method and improvement of TBM's equipment and prevent the stopping of TBM.

Keywords: *TBM, Fault Zone, Conditioning, Deviation Measurement, Operating Parameters, Additional Hydraulic Cylinder*

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Extended Abstract:

1. Introduction

A tunnel boring machine (EPB Hard Rock type) was used to construct the Azad Water Transfer Tunnel. The adverse geotechnical conditions in a fault zone presented special risks to the machine operation. These risks were also experienced in the Bazideraz Tunnel (machine jamming and stopping, conditioning of excavated materials). In order for the TBM to advance, there was a need to make adjustments to the guidance method and make changes to the structure of the TBM's equipment.

2. Materials and methods

In this study, various research methods were used to investigate the operation and improvement of the Azad Tunnel Machine equipment, including: Reviewing previous technical experiences through research texts and literature (related to the Bazideraz Tunnel), examining geological observations during the machine's advance, analyzing machine deflection measurement data, conducting excavation material grading tests, analyzing operating parameters recorded in the machine's data logger system (Thrust, Penetration rate, Face pressure), and documenting remedial solutions.

3. Results

The results show that the implementation strategies for guiding the excavation machine in the fault zone (using additional hydraulic cylinders, installing stage high-pressure pumps, Changing the excavation mode from closed mode to semi-open and open mode, etc.) have been correctly adopted based on technical thinking and engineering judgments.

4. Conclusion

The results of this study can be useful in transferring technical experiences about the guidance method and improvement of TBM and prevent the stopping of TBM.

References:

Acaroglu, O. Erdoğan, C. and Ekinci, E. 2016- Analysis of the EPB-TBM Excavation Parameters Used in a Tunnel Construction in Istanbul," Proceedings of the 2nd World Congress on Mechanical, Chemical, and Material Engineering (MCM'16), Budapest, Hungary – August 22 – 23, Paper No. MMME 113 DOI: 10.11159/mmme16.113.

Aghanabati, A. 1998- Major sedimentary and structural units of Iran (map)," Geosciences, 7, 29-30.

Alavi, M. 1991- Sedimentary and structural characteristics of the Paleo-Tethys remnants in northeastern Iran, Geological Society of America Bulletin, 103, 983-992.

Amberg, F. 2001- Gotthard base tunnel, TBM heading equipment, Progress in Tunneling After 2000, AITESITA, World Tunnel Congress, Milano, June 10-13.

Ball, R.P.A. Young, D.Y. Isaacson, J. Champa, J. and Gause, C. 2009- Research in soil conditioning for EPB tunneling through difficult soils, In: Almeraris, G., Mariucci, B. (Eds.), Rapid Excavation and Tunneling Conference (RETC), Las Vegas, USA, pp. 320–33.

Barla, G. 2000- Lessons Learnt from the excavation of a large diameter TBM tunnel in complex hydrogeological conditions, International Conference on Geotechnical & Geological Engineering Melbourne, Australia, 19-24 November 2000.

Barla, G., and Pelizza, S. 2000- TBM tunnelling in difficult ground conditions. In: Paper Presented at the ISRM International Symposium.

Bayati M, Hamidi JK. 2017- A case study on TBM tunnelling in fault zones and lessons learned from ground improvement. Tunn Undergr Space Technol. 63:162–70.

BTS. 2005- Closed-Face Tunneling Machines and Ground Stability, British Tunneling Society (Closed-Face Working Group) in association with the Institution of Civil Engineers: Thomas Telford Publishing, London (77 pp).

Cao, A.Gao, H. Fan, S.Guo L., You, Z.Lei Y., Sun, Y.and He, J . 2025- Study on vibration mechanism and dynamic characteristics for TBM main bearing defects, Journal of Mechanical Systems and Signal Processin., https://doi.org/10.1016/j.ymssp.2024.111807

Cui, G. and Ke, X. 2023- Rescue technology of the jamming accident for the double-shield TBM in complex geological conditions: A case study. Alexandria Engineering Journal. Volume 79, 15 September 2023, Pages 374-389.

Dalgıç, S. 2003- Tunneling in fault zones, Tuzla tunnel, Turkey. Tunnelling and Underground Space Technology. 18 (5), 453–465.

De Biase, A. Grandori, R. Bertola, P. and Scialpi, M. 2009- Gibe II tunnel project- Ethiopia-40 bars of mud acting on the TBM‘‘special designs and measures implemented to face one of the most difficult events in the history of tunnelling. In: Paper Presented at the Rapid Excavation and Tunnelling Conference (RETC), Las Vegas, USA.

Farrokh, E. and Rostami, J. 2008- Correlation of tunnel convergence with TBM operational parameters and chip size in the Ghomroud tunnel, Iran. Tunnelling and Underground Space Technology. 23(6):700-710.

Farrokh, E. and Rostami, J. 2009- Effect of adverse geological condition on TBM operation in Ghomroud tunnel conveyance project. Tunnelling and Underground Space Technology. 24(4):436-446.

Finnsson, S. 2001- Two tunnel boring machines for Lesotho: A design and case study, Progress in Tunneling After 2000, AITES-ITA, World Tunnel Congress. Tunnelling and Underground Space Technology, Volume 15, Issue 1, January-March 2000: 49-54.

Grandori, R. Gager, M. Antonini, F. and Vigle, A. 1995- Evinos-Mornos tunnel – Greece, In: Proceedings of the Rapid Excavation & Tunnelling Conference, Chapter 47: 747–767.

Guetter, W. and Weber, W. 2001- Two tunnels in totally different geological formations, In: Proceedings of the Rapid Excavation & Tunnelling Conference, Chapter 21: 241–260.

Herrenknecht, M. Thewes, M. and Budach, C. 2011- The development of earth pressure shields: From the beginning to the present," Geomechanics and Tunnelling, vol. 4, no. 1, pp. 11–35. https://doi.org/10.1002/geot.201100003

Hoek, E., Marinos, P. and Benissi, M. 1998- Applicability of the Geological strength index (GSI) classification for very weak and sheared rock masses. The case of the Athens Schist Formation, Bulletin of Engineering Geology and Environmen, Vol. 57 (2):151-160.

Home, L. 2016- Hard rock TBM tunneling in challenging ground: Developments and lessons learned from the field. Tunn. Undergr. Space Technol. 57, 27–32.

Huang, S. Wang, S. Xu, C. Shi, Y. and Ye, F. 2019- Effect of Grain Gradation on the Permeability Characteristics of Coarse-grained Soil Conditioned with Foam for EPB Shield Tunneling, KSCE Journal of Civil Engineering, Geotechnical Engineering, Springer, Volume 23, pages 4662–4674.

Joudaki, V, Koohiyan-Afzal, F, Aalianvari, A, Ajalloeian, R. and Sohrabi-Bidar, A. 2017- Study of the Surface Dissolution Forms and Development of Groundwater in the lot4 of Ghomroud Tunnel Site. Journal of GEOSCIENCES; 26(103): 29 – 40, (In Persian).

Joudaki, V, Ajalloeian, R. and Yazdkhasti, N. 2018- Comparison results of Two-dimensional Resistivity Inversion with Geological Conditions in the Excavation of lots 3 and 4 of Ghomroud Tunnel. Journal of Engineering Geology. 11(1): 49-64, (In Persian).

Joudaki, V. Ajalloeian, R , Mobarghaei, N, Sohrabi-Bidar, A, and Aalianvari, A. 2020- The Status of the Principles of Land Ethics in Monitoring the Eco-Hydrological Effects of Civil Projects. Journal of Engineering Geology. 12(4):123-143,(In Persian).

Joudaki, V. Hassanpour, J. and Ajalloeian, R. 2019- Relationship of Geosciences and Mechanical Engineering in Increasing the Productivity of Tunnel Boring Machines. Journal of Engineering Geology.11(4): 1-24,(In Persian).

Joudaki, V., Sohrabi-Bidar, A., Ajalloeian, R., Amini, N. and Dickmann, T. 2018- Evaluation of Tunnel Seismic Prediction (TSP) Test Results based on Geological Observations and Analysis of the Parameters of the EPB Hard Rock Machine. Journal of Engineering Geology, 11(2): 15-31, (In Persian).

Joudaki, V., Ghazifard A. and Haghshenas, E. 2021- Urban Geology effects of Sarpol-e-Zahab on the sensitivities of the implementation of two civil structures. Journal of Disaster Prevention and Management Knowledge (DPMK).11(3): 238 – 254, (In Persian).

Joudaki, V. Hassanpour, J. Ajalloeian, R ,and Masih Tehrani. M. 2020- The need to localize the knowledge of improving tunnel boring machines in the diverse geological conditions of Iran. Journal of mechanical engineering, , 29(130): 11-24, (In Persian).

Joudaki, V. Derikvandi, M. Mirzaei, M. Farzinpour, M.R. and Hoseyni, S. 2024- The Study of Geotechnical Hazards and Implementation Challenges of Dalukosh Tunnel (Project of Main Road of Aliguodarz-Masjed Soliman). Journal of Civil and Project, 6(10), 11–32.

Kim, T. Lee, I. Chung, H. Park, J. and Ryu, Y. 2021- Application Ranges of EPB Shield TBM in Weathered Granite Soil: A Laboratory Scale Study, Appled Sciences, No. 11, 2995, pp. 1-15, https://doi.org/10.3390/app11072995

Liu, LP. Wang, XG. Li, CB. and Tan, ZH. 2023- Jamming of the double-shield tunnel boring machine in a deep tunnel in Nyingchi, Tibet Autonomous Region, China. Tunn Undergr Space Technol. 2023;131: 104819.

Lovat, R.P. 2000- Cleuson Dixence Penstock Tunnel, AITES – ITA World Tunnel Congress, Durban, South African, Vol. 24: 611–614.

Marinos, P.G. 1998- TBM excavation in weak rock heterogeneous rock masses for the Athens Metro, Journal of Bulletin of Engineering Geology and Environment, Springer Berlin / Heidelberg, Vol.57: 151-160.

Nie, Y. Zhang, Q. Du, Y. and Du, L. 2025-TBM jamming risk prediction method based on fuzzy theory and Bi-LSTM. Tunnelling and Underground Space Technology. Volume 157, 106329.

Peila, D. 2014- Soil Conditioning for EPB Shield Tunnelling, KSCE Journal of Civil Engineering, No. 18(3), pp. 831-836.

Peila, D. Picchio, A. and Chieregato, A. 2013- Earth pressure balance tunnelling in rock masses: Laboratory feasibility study of the conditioning process, Tunnelling and Underground Space Technology, Elsevier, Volume 35, p. 55–66, https://doi.org/10.1016/j.tust.2012.11.006

Pourhashemi, M. Azali, S.T. Amiri, A. and Khorasani, E. 2018- Rock Conditioning in EPB-Tunneling, Case Study: Southern Extension of Tehran Metro Line 6, Dubai, UAE, s.n.

Shang, Y., Xue, J., Wang, S., Yang, Z. and Yang, J. 2004- A case history of tunnel boring machine jamming in an interlayer shear zone at the yellow river diversion project in China, Engineering Geology, Vol. 71 (3-4): 199-211.

Shaterpour-Mamaghani, A. Tumac, D. and Avunduk, E. 2016- Double shield TBM performance analysis in difficult ground conditions: a case study in the Gerede water tunnel, Turkey. Bull. Eng. Geol. Environ. 75 (1), 251.

Shen, C. Tsai, H. Hsieh, Y. and Chu, B. 1999- The methodology through adverse geology ahead of Pinglin large TBM. In: Paper Presented at the Proceeding of the Rapid Excavation and Tunnelling Conference.

Stocklin, J. 1968- Structural history and tectonics of Iran : a review. American Association Petroleum Geologists, Bulletin; 52(7): 1229 – 1258.

Stocklin, J. 1977- Structural correlation of the Alpine range between Iran central Asia. Memoire Hors-Serve No.8 dela Societe Geologique de France, 8: 333-353.

Sun, Z. Liu, J. Cheng, Y. Wu, Y. and Sun, W. 2023- Load characterization of the main bearing of a large tunnel boring machine based on dynamic characteristic parameters, Journal of Advances in Mechanical Engineering, Vol. 15(3) 1–13, https://doi.org/10.1177/16878132231164233

Tarigh Azali, S. Ghafoori, M. Lashkaripour, G.R. and Hassanpour, J. 2013- Engineering geological investigations of mechanized tunneling in soft ground: A case study, East–West lot of line 7, Tehran Metro, Iran. Engineering Geology, 166(8), Pages 170-185.

Tarigh Azali, S. and Moammeri, H. 2012- EPB-TBM tunneling in abrasive ground, Esfahan Metro Line 1. In:Phienwej, N., Boonyatee, T. (Eds.), ITA-AITES World Tunnel Congress (WTC), Bangkok, Thailand.

Thewes, M. 2007- TBM Tunneling Challenges- Redefining The State of The Art, Underground Space: The 4th Dimension of Metropolises: Proceedings of the 33rd ITA-AITES World Tunnel Congress. London: Taylor & Francis. ISBN: 9780415408073. http://www.ita-aites.cz/files/tunel/2007/wtc2007/mc-3.pdf.

Todaro, C. Carigi, A. Peila, L. Martinelli, D. and Peila, D. 2022- Soil conditioning tests of clay for EPB tunnelling, Underground Space, Volume 7, Issue 4, Pages 483-497, https://doi.org/10.1016/j.undsp.2021.11.002

Tseng, D. Tsai, B. and Chang, L. 2001- A case study on ground treatment for a rock tunnel with high groundwater ingression in Taiwan, International Journal of Tunnelling and Underground Space Technology, Vol. 16: 175-183.

Wang, C. Zhao, W. Chen, C. Wang, Y. and Wang, X. 2024- A parameter design model for EPB shield soil conditioning in gravel stratum based on machine learning, Construction and Building Materials, Volume 411, 12, https://doi.org/10.1016/j.conbuildmat.2023.134637

Wenner, D. and Wannenmacher, H. 2009- Alborz service tunnel in Iran: TBM tunnelling in difficult ground conditions and its solutions. In: Paper Presented at the 1st Regional and 8th Iranian Tunneling Conference, Tehran, Iran.

Wittke, W. 2007- Conditioning of the intact rock, In: W. 6. V. G. G. E. Geotechnik in Forschung und Praxis, ed. Stability Analysis and Design for Mechanized Tunneling. Aachen: Translated from the German edition: Statik und Konstruktion maschineller Tunnelvortriebe, pp. 250-264.

Xu Z.H. Wang, W.Y. Lin, P. Nie, L.C. Wu, J. and Li. Z.M. 2021- Hard-rock TBM jamming subject to adverse geological conditions: Influencing factor, hazard mode and a case study of Gaoligongshan Tunnel. Tunnelling and Underground Space Technology. Volume 108, 103683.

Xu, Z.H. Yu, T.F. Lin, P. Wang, W.Y. and Shao. R.Q. 2022- Integrated geochemical, mineralogical, and microstructural identification of faults in tunnels and its application to TBM jamming analysis. Tunnelling and Underground Space Technology. Volume 128.

Yang, Z. Wang, L. Zhou, J. Li, D. Zhang, K. and Guo, X. 2023- Mechanical characteristics of a tunnel boring machine cutterhead during rock breaking: Physical model tests and transient dynamic analysis, Journal of Advances in Mechanical Engineering, Volume 15, Issue 3. 1-11, https://doi.org/10.1177/16878132231159971

Ye, X. Wang, S. Yang, J. Sheng, D. and Xiao, C. 2016- Soil Conditioning for EPB Shield Tunneling in Argillaceous Siltstone with High Content of Clay Minerals: Case Study, International Journal of Geomechanics, American Society of Civil, pp. 1-8, https://doi.org/10.1061/(ASCE)GM.1943-5622.0000791

Zhang, Q. Ma,Y. Du, Y. Du ,L. Wang, M. Zhang, S. and Nie, Y. 2025- Investigation into the collapse height of TBM jamming machinery induced by fault fracture zones and the verification of applicability. Tunnelling and Underground Space Technology. Volume 155, Part 1, 106196.