Water Resources Publication Series on Hydroelectric & Pumped Storage Projects

PART-II/III

GEOLOGICAL SURPRISES & MITIGATION MEASURES ADOPTED

CASE STUDIES RELATED TO UNDERGROUND WORKS

Central Board of Irrigation and Power
New Delhi

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Part II / III

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DISCLAIMER

This book titled "*Geological Surprises & Mitigation Measures Adopted*" is a compilation of information and data available in the various texts under 'References' as well as from websites on 'Case Studies Related to Underground Works' encompassing hydroelectric projects & PSP. The book is prepared for general information purpose. It is no way intended for any other purpose. Though all efforts have been made to present the data correctly, there may be errors. It does not constitute legal, engineering or technical advice.

Contribution made by all the committee members of Research Scheme on Power (RSoP) of Central Power Research Institute (CPRI), undertaken by CBIP previously in 2016, is duly acknowledged.

Front Cover *:*

Geological surprise encountered during tunnelling in Nathpa Jhakri Hydroelectric Project and the mitigation measure undertaken.

Back Cover*:*

Illustrations of Rockburst/Spalling, Water ingress, Cavity formation/Flowing ground and Inflammable gas confrontation during tunnelling in the Himalayas.

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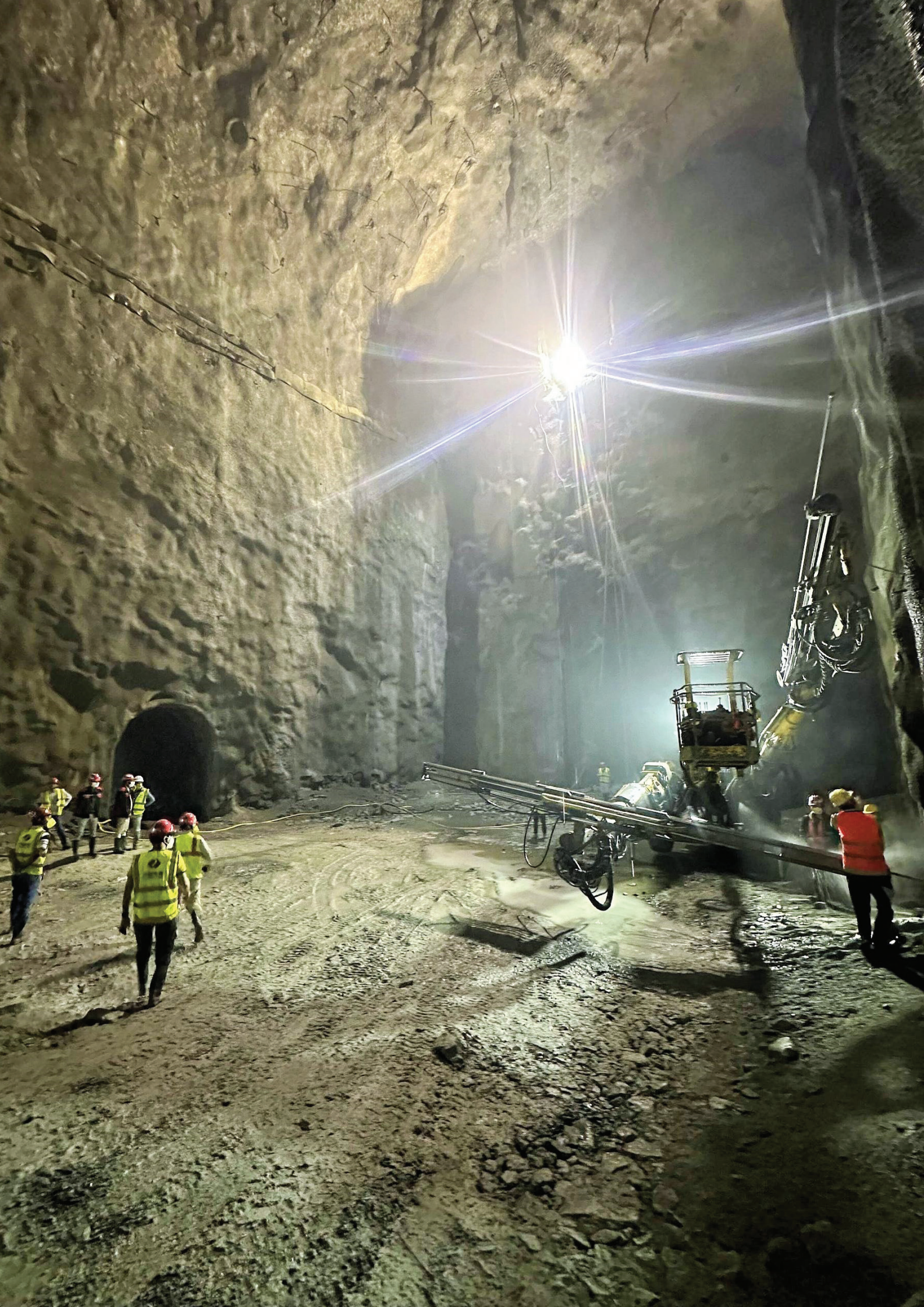

घनश्याम प्रसाद
अध्यक्ष तथा पदेन सचिव भारत सरकार
GHANSHYAM PRASAD
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केन्द्रीय विद्युत प्राधिकरण
विद्युत मंत्रालय
भारत सरकार
सेवा भवन, आर.के. पुरम
नई दिल्ली–110066
Central Electricity Authority
Ministry of Power
Sewa Bhawan, R. K. Puram
New Delhi-110066

FOREWORD

India is on a path to substantially augmenting its hydropower capacity, with an ambitious target around 67GW by 2031-32. This growth includes adding hydroelectric projects and expanding the pumped storage capacity to balance its renewable energy grid. Fortunately, the nation is gifted with considerable hydropower potential and more than 75% of the potential is located in the Himalayan region. Being snow fed and very steep in their gradient, the major rivers originating in the region have considerable potential in hydropower generation. To harvest the energy from these rivers, hydropower projects are envisaged in the region that involve long tunnels and appurtenant underground structures.

However, as per experience, the Himalayan geology poses special challenges, which are associated with engineering geological conditions of the rock mass. Due to active tectonic movement, the rock mass in the region is relatively weak and highly deformed. The region poses several adverse geological conditions and extraordinary geological occurrences that affect construction of the subsurface structures. The tunneling and underground works in such media with mixed lithology, varying tectonic behaviour and trapped water reservoir become a costly affair and hazardous operation due to encountering of problems of squeezing, swelling, running ground, sudden ingress of water combined with a poor state of rock, excessive temperature and gases in rocks. In fact, the certainty of uncertainties is the hallmark of Himalayan geology and 'geological surprises' are common along deep and long tunnels in the young and tectonically disturbed high mountainous terrains.

In cases of the projects sited in regions with complex geological condition, it is observed that, multi-phase structural deformation/tectonism pose challenging situations to unravel the complexity of the prevailing geological conditions, for safe execution and timely development of the projects. Harnessing the hydropower potential in such areas of adverse setups can only be materialised by applying pragmatic professional approaches.

In this context, this book presents 'Case Studies' of various adverse geological problems that have been encountered at different underground project components during construction of hydroelectric projects including pumped storage scheme, in the Himalayan & Peninsular regions and the corresponding measures undertaken for mitigating the issues.

The compiled documentation of knowledge and experiences, as well as the pragmatic information and useful suggestions, furnished in this book, would be greatly useful for hydropower project developers in competently dealing with similar detrimental challenges when faced, and in establishing safe & sustainable projects in complex set ups, within the scheduled timeframe.

I wish to compliment the members of the 'Publication Committee', for the dedicated efforts made by them in bringing out this comprehensive document. I trust that this valuable book brought out by CBIP, will be immensely beneficial for all those project developers, involved in establishment of hydropower schemes involving tunneling & underground works, as well as well as, in general, to all allied tunnelling professionals in the country.

(Ghanshyam Prasad)

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Plot No. 4, Diplomatic Enclave
Malcha Marg, Chanakyapuri,
New Delhi - 110021
Tel (O) : 91-11-2611 5984
91-11-2688 2866
E-mail : secretary@cbip.org
Website : www.cbip.org

A.K. DINKAR
Secretary

PREFACE

In India, with the rapid pace of development for harnessing water resources for power generation, the importance of underground diversion structures and underground powerhouses has increased enormously during the recent years. However, the construction of these structures pose challenges to engineering skill, when they are located in complex and varied geological settings, like the Himalayas, characterized by intricate and delicate geological conditions.

The Himalayan geology is unique and unpredictable, which is evident from the fact that in almost all the hydropower projects executed in region, major geological problems have occurred during execution of underground works, leading to considerable delays and related cost overruns. Project developers are often overawed by the sudden geological changes faced during construction and the adverse encounters are viewed as 'geological surprises'.

Efficient hydropower project construction, involving underground works, in adverse geological setup, demands a pragmatic professional approach in effectively tackling the issues. Accordingly, in this context, this comprehensive compendium has been prepared, presenting compiled documentation of 'geological surprises' encountered during execution of underground works in hydropower projects and the technical / innovative solutions adopted in mitigating the issues.

This book titled, ***"Geological Surprises & Mitigation Measures Adopted"***, forms the second part of the Water Resources publication series on: hydroelectric project & pumped storage scheme development. The Part-I book released earlier is titled, ***"Advance Tools & Techniques for Efficient Project Development"***. This Part-II book embodies numerous '*Case Studies*' exemplifying various measures adopted in effectively tackling major problems in tunneling and underground works, encompassing diverse geological issues that include: squeezing ground condition, rock bursting, high-temperature gradient, heavy ingress of water, existence of shear zones and toxic / inflammable gas emission, etc. encountered in hydropower projects, located in the Himalayan and Peninsular regions in India, as well as in neighboring countries in the Himalayas, sited in similar geological setup.

Earlier in 2016, CBIP had undertaken a research project under Research Scheme on Power (RSoP) program of Central Power Research Institute (CPRI), Bangalore, titled, *"Compilation of Data on Latest Technologies in Geological & Geotechnical Investigations and Problems Faced & Mitigation Measures adopted during Execution"*. However, since then, there has been further developments and accordingly, it was felt necessary to bring out this publication, presenting the updated information & documentation of various *'Case Studies'* of experiences in effectively tackling the adverse geological issues. Moreover, the book also discusses about the '*Challenges in Hydropower Project Development in the Himalayan & Peninsular Regions*' and brings out *'Pragmatic Considerations & Useful Suggestions'* in tackling adverse issues faced during execution of diverse underground works.

The compiled documentation of knowledge and experiences, as furnished in the book, would be greatly useful for hydroelectric and pumped storage project developers: Pragmatic knowledge gained herefrom and judicious implementation of apt tools and techniques would be helpful towards enhancing confidence in strategically dealing with similar problems once arisen and thereby establishing safe & sustainable projects within schedule. Moreover, the information provided in this book shall be useful for those developers, as well, who are associated with construction of various road / rail tunnels and underground spaces.

Aditya K. Dinkar
Secretary
Central Board of Irrigation and Power

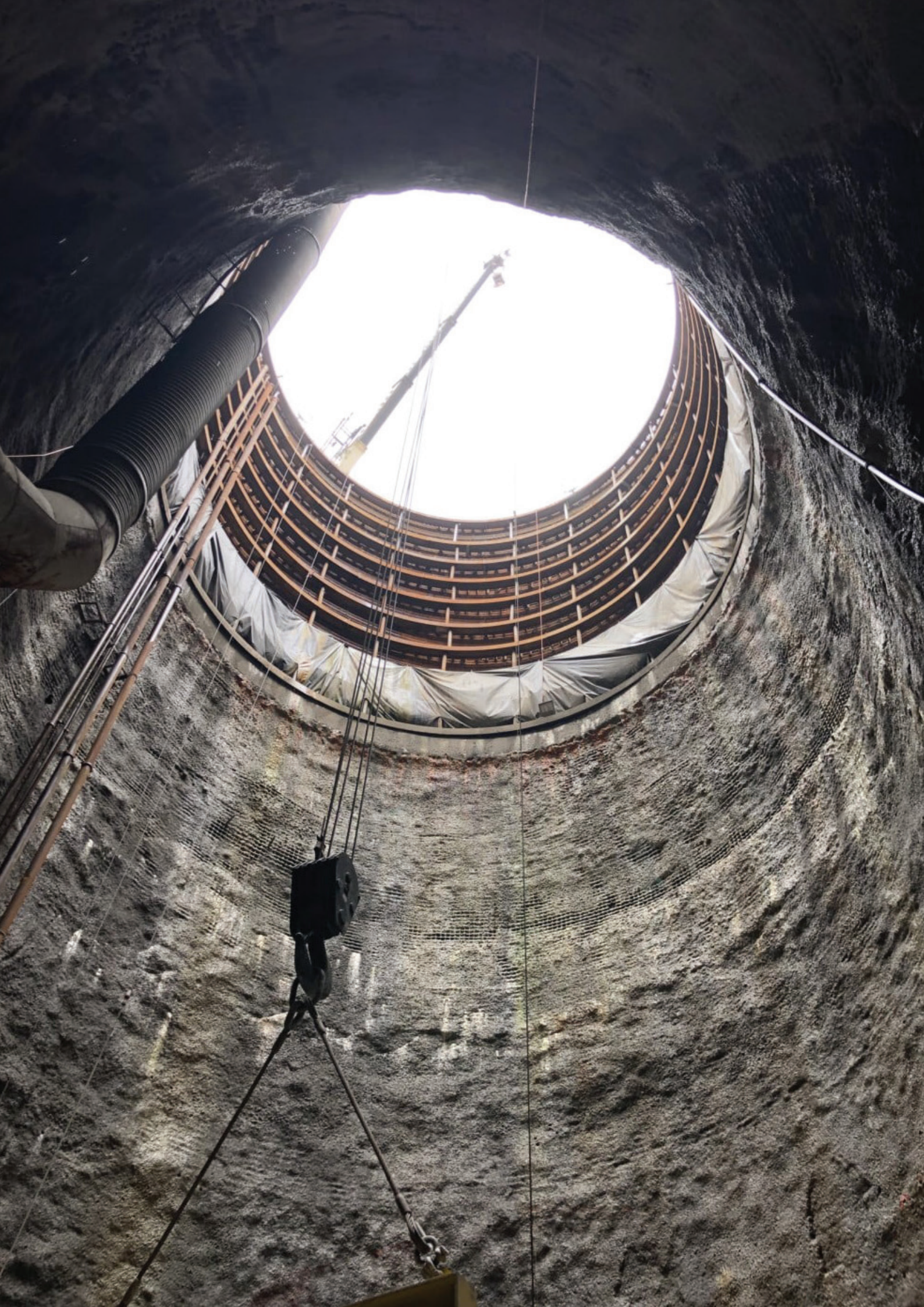

TABLE OF CONTENTS