JUNE2010 EDITION

Technical Manual *for* Design *and* Construction *of* Road Tunnels—CIVIL ELEMENTS



Officials



Technical Manual for Design and Construction of Road Tunnels—CIVIL ELEMENTS



American Association of State Highway and Transportation Officials



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ISBN: 978-1-56051-45

This is a preview. Click here to purchase the full publication.

Pub Code: DCRT-1

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FOREWORD TO FHWA MANUAL

The Federal Highways Administration *Technical Manual for Design and Construction of Road Tunnels*—*Civil Elements* has been published to provide guidelines and recommendations for planning, design, construction, and structural rehabilitation and repair of the civil elements of road tunnels, including cut-and-cover tunnels, mined and bored tunnels, immersed tunnels, and jacked box tunnels. The latest edition of the *AASHTO LRFD Bridge Design Specifications* and the *AASHTO LRFD Bridge Construction Specifications* are used to the greatest extent applicable in the design examples. This Manual focuses primarily on the civil elements of design and construction of road tunnels. It is the intent of FHWA to collaborate with AASHTO to further develop manuals for the design and construction of other key tunnel elements, such as ventilation; lighting; fire life safety; and mechanical, electrical, and control systems.

FHWA intends to work with road tunnel owners in developing a manual on the maintenance, operation, and inspection of road tunnels. This Manual is expected to expand on the two currently available FHWA publications: 1) *Highway and Rail Transit Tunnel Inspection Manual* and 2) *Highway and Rail Transit Tunnel Maintenance and Rehabilitation Manual*.

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M. Myint Lwin, Director Office of Bridge Technology

ACKNOWLEDGMENTS

AASHTO's *Technical Manual for Design and Construction of Road Tunnels—Civil Elements* was originally published by FHWA in May 2009 (FHWA-NHI-09-010) and revised in December 2009 (FHWA-NHI-10-034). This AASHTO June 2010 edition incorporates graphic and editorial improvement, as well as minor technical revisions. The development of this manual was led by Principal Investigators including C. Jeremy Hung, P.E.; J. Monsees, Ph.D., P.E., N. Munfakh, P.E., and J. Wisniewski, P.E. of Parsons Brinckerhoff, Inc., funded by the National Highway Institute, and supported by Parsons Brinckerhoff, Inc., as well as numerous authors and reviewers acknowledged hereafter including the following primary authors from Parsons Brinckerhoff, Inc. (PB), and Gall Zeidler Consultants, LLC:

- Chapter 1-Planning: Nasri Munfah and Christian Ingerslev
- Chapter 2-Geometrical Configuration: Christian Ingerslev and Jeremy Hung
- Chapter 3-Geotechnical Investigation: Jeremy Hung and Raymond Castelli
- Chapter 4—Geotechnical Report: Raymond Castelli and Jeremy Hung
- Chapter 5-Cut-and-Cover Tunnels: John Wisniewski and Nasri Munfah
- Chapter 6-Rock Tunneling: James Monsees and Sunghoon Choi
- Chapter 7—Soft Ground Tunneling: James Monsees
- Chapter 8—Difficult Ground Tunneling: James Monsees and Terrence McCusker (Consultant)
- Chapter 9-Sequential Excavation Method: Vojtech Gall and Kurt Zeidler
- Chapter 10—Tunneling Lining: John Wisniewski
- Chapter 11-Immersed Tunnels: Christian Ingerslev and Nasri Munfah
- Chapter 12-Jacked Box Tunneling: Philip Rice and Jeremy Hung
- Chapter 13—Seismic Considerations: Jaw-Nan (Joe) Wang
- Chapter 14-Construction Engineering: Thomas Peyton
- Chapter 15-Geotechnical and Structural Instrumentation: Charles Daugherty and Doug Anderson
- Chapter 16—Tunnel Rehabilitation: Henry Russell

The Principal Investigators would like to especially acknowledge the support of the FHWA Task Manager, Firas Ibrahim, and the reviews and recommendations provided by the FHWA technical reviewers including Jesus Rohena, Jerry DiMaggio, Steven Ernst, and Peter Osborn. Furthermore, the reviews and contributions of the following members of the AASHTO T-20 Tunnel Committee are also acknowledged:

- Kevin Thompson, Chair, California Department of Transportation
- Bruce Johnson, Vice Chair, Oregon Department of Transportation
- Donald Dwyer, New York State Department of Transportation
- Louis Ruzzi, Pennsylvania Department of Transportation
- Prasad Nallapaneni, Virginia Department of Transportation
- Michael Salamon, Colorado Department of Transportation
- Bijan Khaleghi, Washington Department of Transportation
- Alexander Bardow, Massachusetts Highway Department
- Dharam Pal, The Port Authority of New York and New Jersey
- Moe Amini, California Department of Transportation
- Harry Capers, Arora and Associates, P.C.

The Principal Investigators and authors would like to express our special thanks to Dr. George Munfakh of PB for his continuing support, advice, and encouragement.

We further acknowledge the support of Gene McCormick of PB and the contributions and reviews from Sunghoon Choi, Joe O'Carroll, Doug Anderson, Kyle Ott, Frank Pepe, and Bill Hansmire of PB; Dr. Andrzej Nowak of University of Nebraska; and Tony Ricci and Nabil Hourani of the Massachusetts Highway Department.

Chapter 8 is an update of Chapter 8, "Tunneling in Difficult Ground," of the *Tunnel Engineering Handbook*, Second Edition, by Terrence G. McCusker (Bickel, et al., 1996). The Principal Investigators appreciate PB's providing the original manuscript for the chapter.

In addition, we appreciate the information provided by Herrenknecht AG, the Robbins Company, and several other manufacturers and contractors from the tunneling industry.

Lastly, the Principal Investigators and authors would like to extend our gratitude to the support provided by a number of professionals from PB and Gall Zeidler Consultants, LLC including Taehyun Moon, Kevin Doherty, Mitchell Fong, Rudy Holley, Benny Louie, Tim O'Brien, and Dominic Reda for their assistance; Jose Morales and Jeff Waclawski for graphic support; and finally Amy Pavlakovich, Lauren Chu, Alejandra Morales, Mary Halliburton, and Maria Roberts for their assistance and overall word processing and compiling.

PREFACE

The increased use of underground space for transportation systems and the increasing complexity and constraints of constructing and maintaining above ground transportation infrastructure have prompted the need to develop this technical manual. This FHWA Manual is intended to be a single-source technical manual providing guidelines for planning, design, construction, and rehabilitation of road tunnels, and encompasses various types of tunnels including mined and bored tunnels (Chapters 6–10), cut-and-cover tunnels (Chapter 5), immersed tunnels (Chapter 11), and jacked box tunnels (Chapter 12).

The scope of the Manual is primarily limited to the civil elements of design and construction of road tunnels. FHWA intended to develop a separate manual to address in details the design and construction issues of the system elements of road tunnels including fire life safety, ventilation, lighting, drainage, finishes, etc. This Manual therefore only provides limited guidance on the system elements when appropriate.

Accordingly, the Manual is organized as presented below:

Chapter 1 is an introductory chapter and provides a general overview of the planning process of a road tunnel project including alternative route study, tunnel type study, operation and financial planning, and risk analysis and management.

Chapter 2 provides the geometrical requirements and recommendations of new road tunnels including horizontal and vertical alignments and tunnel cross section requirements.

Chapter 3 covers the geotechnical investigative techniques and parameters required for planning, design, and construction of road tunnels. In addition to subsurface investigations, this chapter also addresses in brief information study; survey; site reconnaissance, geologic mapping, instrumentation, and other investigations made during and after construction.

Chapter 4 discusses the common types of geotechnical reports required for planning, design, and construction of road tunnels including Geotechnical Data Report (GDR), which presents all the factual geotechnical data; Geotechnical Design Memorandum (GDM), which presents interpretations of the geotechnical data and other information used to develop the designs; and Geotechnical Baseline Report (GBR), which defines the baseline conditions on which contractors will base their bids.

Chapter 5 presents the construction methodology and excavation support systems for cut-and-cover road tunnels, describes the structural design in accordance with the *AASHTO LRFD Bridge Design Specifications*, and discusses various other design issues. A design example is included in Appendix C.

Chapters 6 through 10 present design recommendations and requirements for mined and bored road tunnels.

Chapters 6 and 7 present mined/bored tunneling issues in rock and soft ground, respectively. They present various excavation methods and temporary support elements and focus on the selection of temporary support of excavation and input for permanent lining design. Appendix D presents common types of rock and soft ground tunnel boring machines (TBM).

Chapter 8 addresses the investigation, design, construction, and instrumentation concerns and issues for mining and boring in difficult ground conditions including mixed face tunneling; high groundwater pressure and inflow; unstable ground such as running sands, sensitive clays, faults, shear zones, etc.; squeezing ground; swelling ground; and gassy ground.

Chapter 9 introduces the history, principles, and recent development of mined tunneling using Sequential Excavation Method (SEM), also commonly known as the New Austrian Tunneling Method (NATM). This chapter focuses on the analysis, design, and construction issues for SEM tunneling.

Chapter 10 discusses permanent lining structural design and detailing for mined and bored tunnels based on LRFD methodology, and presents overall processes for design and construction of permanent tunnel lining. It encompasses various structural systems used for permanent linings including cast-in-place concrete lining, precast concrete segmental lining, steel line plate lining, and shotcrete lining. A design example is presented in Appendix G.

Chapter 11 discusses immersed tunnel design and construction. It identifies various immersed tunnel types and their construction techniques. It also addresses the structural design approach and provides insights on the construction