



JUNE 2010  
E D I T I O N



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



American Association of State Highway and Transportation Officials



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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*.



M. Myint Lwin, Director  
Office of Bridge Technology

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- Chapter 10—Tunneling Lining: John Wisniewski
- Chapter 11—Immersed Tunnels: Christian Ingerslev and Nasri Munfakh
- Chapter 12—Jacked Box Tunneling: Philip Rice and Jeremy Hung
- Chapter 13—Seismic Considerations: Jaw-Nan (Joe) Wang
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# 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

methodologies including fabrication, transportation, placement, joining, and backfilling. It addresses the tunnel elements' water tightness and the trench stability and foundation preparation requirements.

**Chapter 12** presents jacked box tunneling, a unique tunneling method for constructing shallow rectangular road tunnels beneath critical facilities such as operating railways, major highways, and airport runways without disruption of the services provided by these surface facilities or having to relocate them temporarily to accommodate open excavations for cut-and-cover construction.

**Chapter 13** provides the general procedure for seismic design and analysis of tunnel structures, which are based primarily on the ground deformation approach (as opposed to the inertial force approach); i.e., the structures should be designed to accommodate the deformations imposed by the ground.

**Chapter 14** discusses tunnel construction engineering issues, i.e., the engineering that must go into a road tunnel project to make it constructible. This chapter examines various issues that need be engineered during the design process including project cost drivers, construction staging and sequencing, health and safety issues, muck transportation and disposal, and risk management and dispute resolution.

**Chapter 15** presents the typical geotechnical and structural instrumentation for monitoring: 1) ground movement away from the tunnel, 2) building movement for structures within the zone of influence, 3) tunnel movement of the tunnel being constructed or adjacent tubes, 4) dynamic ground motion from drill and blast operation, and 5) groundwater movement due to changes in the water percolation pattern.

**Chapter 16**, the last chapter, focuses on the identification, characterization, and rehabilitation of structural defects in a tunnel system.

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# CHAPTER 1

## Planning

### 1.1—INTRODUCTION

Road tunnels, as defined by the American Association of State Highway and Transportation Officials (AASHTO) Technical Committee for Tunnels (T-20), are enclosed roadways with vehicle access that is restricted to portals regardless of type of structure or method of construction. The Committee further defines road tunnels not to include enclosed roadways created by highway bridges, railroad bridges, or other bridges. This definition applies to all types of tunnel structures and tunneling methods, such as cut and cover tunnels (Chapter 5); tunnels mined and bored in rock (Chapter 6), soft ground (Chapter 7), and difficult ground (Chapter 8); immersed tunnels (Chapter 11); and jacked box tunnels (Chapter 12).

Road tunnels are feasible alternatives to cross a water body or traverse through physical barriers such as mountains, existing roadways, railroads, or facilities, or to satisfy environmental or ecological requirements. In addition, road tunnels are viable means to minimize potential environmental impact, such as traffic congestion, pedestrian movement, air quality, noise pollution, or visual intrusion; to protect areas of special cultural or historical value, such as conservation of districts, buildings, or private properties; or for other sustainability reasons, such as to avoid the impact on natural habitat or reduce disturbance to surface land. Figure 1.1-1 shows the portal for the Glenwood Canyon Reverse Curve Tunnel—twin 4,000-ft long tunnels carrying a critical section of I-70 unobtrusively through Colorado’s scenic Glenwood Canyon.



**Figure 1.1-1**—Glenwood Canyon Reverse Curve Tunnel