3.5 Design Process

The basic process used in the design of a road tunnel is:

1. Define the functional requirements, including design life and durability requirements;
2. Carry out the necessary investigations and analyses of the geologic, geotechnical and geo hydrological data
3. Conduct environmental, cultural, and institutional studies to assess how they impact the design and construction of the tunnel;
4. Perform tunnel type studies to determine the most appropriate method of tunneling.
5. Establish design criteria and perform the design of the various tunnel elements. Appropriate initial and final ground support and lining systems are critical for the tunnel design, considering both ground conditions and the proposed method of construction. Perform the design in Preliminary and Final design phases. Interim reviews should be made if indicated by ongoing design issues.
6. Establish tunnel alignment, profile and cross-section
7. Determine potential modes of failure, including construction events, unsatisfactory long-term performance, and failure to meet environmental requirements. Obtain any necessary data and analyze these modes of failure;
8. Perform risk analysis and identify mitigation measures and implement those measures in the design
9. Prepare project documents including construction plans, specifications, schedules, estimates, and geotechnical baseline report (GBR).

Design Standards

Road tunnels discussed in this Manual cover all roadways including freeways, arterials, collectors, and local roads and streets in urban and rural locations following the

functional classifications from FHWA publication “Highway Functional Classification: Concepts, Criteria, and Procedures”.

AASHTO’s “Green Book” - A Policy on Geometric Design of Highways and Streets, which is adopted by Federal agencies, States, and most local highway agencies, provides the general design considerations used for road tunnels from the standpoint of service level, and suggests the requirements for road tunnels which should not differ materially from those used for grade separation structures.

The Green Book (AASHTO, 2004) also provides general information and recommendations about cross section elements and other requirements specifically for road tunnels.

In addition to the Green Book (AASHTO, 2004), standards to be used for the design of geometrical configurations of road tunnels should generally comply with the following documents supplemented by recommendations given in this Manual. Additional criteria may include:

- AASHTO A Policy on Design Standards - Interstate System
- Standards issued by the state or states in which the tunnel is situated
- Local authority standards, where these are applicable
- National and local standards of the country where the international crossing tunnel is located

HORIZONTAL AND VERTICAL ALIGNMENTS

Planning and design of road tunnel alignments must consider the geological, geotechnical and groundwater conditions at the site as well as environmental constraints as discussed in Planning. Maximum grade, horizontal and vertical curves, and other requirement/constraints for road tunnel horizontal and vertical alignments are discussed in this Section

Maximum Grades

Road tunnel grades should be evaluated on the basis of driver comfort while striving to reach a point of economic balance between construction costs and operating and maintenance expenses.

Maximum effective grades in main roadway tunnels preferably should not exceed 4%; although grades up to 6% have been used where necessary.

Long or steep uphill grades may result in a need for climbing lanes for heavy vehicles. However, for economic and ventilation reasons, climbing lanes should be avoided within tunnels; the addition of a climbing lane part-way through a tunnel may also complicate construction considerably, particularly in a bored tunnel.

Horizontal and Vertical Curves

Horizontal and vertical curves shall satisfy Green Book's geometrical requirements. The horizontal alignment for a road tunnel should be as short as practical and maintain as much of the tunnel length on tangent as possible, which will limit the numbers of curves, minimize the length and improve operating efficiency.

However, slight curves may be required to accommodate ventilation/access shafts location, portal locations, construction staging areas, and other ancillary facilities as discussed in Planning. A slight horizontal curve at the exit of the tunnel may be required to allow drivers to adjust gradually to the brightness outside the tunnel.

When horizontal curves are needed, the minimum acceptable horizontal radii should consider traffic speed, sight distances, and the super-elevation provided. In general, for planning purpose, the curve radii should be as large as possible and no less than 850 to 1000-ft radius. A tighter curve may be considered at the detailed design stage based on the selected tunneling method.

Super elevation rate, which is the rise in the roadway surface elevation from the inside to the outside edge of the road, should preferably lie in the range 1% to 6%.

When chorded construction is used for walls where alignments are curved, chord lengths should not exceed 25 feet (7.6 m) for radii below 2,500 feet (762 m), and 50 feet (15 m) elsewhere.

Sight and Braking Distance Requirements

Sight and braking distance requirements cannot be relaxed in tunnels. On horizontal and vertical curves, it may be necessary to widen the tunnel locally to meet these requirements by providing a "sight shelf".

When designing a tunnel with extreme curvature, sight distance should be carefully examined, otherwise it may result in limited stopping sight distance.

Other Considerations

Road tunnels with more than one traffic tube should be designed so that in the event that one tube is shut down, traffic can be carried in the other.

For reasons of safety, it is not recommended that tunnels be constructed for bi-directional traffic; however, they should be designed to be capable of handling bi-directional traffic during maintenance work, which should be carried out at times of low traffic volume such as at night or weekends.

When operating in a bi-directional mode, appropriate signage must be provided. In addition, suitable cross-over areas are required, usually provided outside the tunnel entrances, and the ventilation system and signage must be designed to handle bi-directional traffic.