Seismic Considerations for Road Tunnels

Course Number: GE-02-504

PDH: 4

Approved for: AK, AL, AR, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

State Board Approvals

Florida Provider # 0009553 License #868
Indiana Continuing Education Provider #CE21800088
Maryland Approved Provider of Continuing Professional Competency
New Jersey Professional Competency Approval #24GP00025600
North Carolina Approved Sponsor #S-0695
NYSED Sponsor #274

How Our Written Courses Work

This document is the course text. You may review this material at your leisure before or after you purchase the course.
After the course has been purchased, review the technical material and then complete the quiz at your convenience.
A Certificate of Completion is available once you pass the exam (70% or greater).
If a passing grade is not obtained, you may take the quiz as many times as necessary until a passing grade is obtained).
If you have any questions or technical difficulties, please call (508) 298-4787 or email us at admin@PDH Pro.com.

Module 13: Seismic Considerations

Learning Objectives

By the end of this section, you will be able to:

- **Identify** the primary seismic deformation modes for underground structures, including ovaling, racking, and longitudinal strains.
- **Calculate** peak ground velocity (PGV) and ground motion attenuation at various tunnel depths using standardized empirical formulas.
- **Evaluate** the relative stiffness of tunnel linings using compressibility and flexibility ratios to determine soil-structure interaction requirements.

Executive Summary: Unlike above-ground structures, tunnels are constrained by the surrounding ground, requiring a seismic design approach focused on accommodating ground deformations rather than resisting inertial forces. While tunnels generally perform well during earthquakes, significant risks arise from ground failure hazards like fault rupture, liquefaction, and landsliding, as well as transverse racking and ovaling caused by ground shaking.

Introduction

Tunnels generally perform better during earthquakes than above-ground structures because they are constrained by the surrounding ground and typically do not experience the strong vibratory amplification seen in bridges. Furthermore, seismic ground motion amplitude tends to decrease with depth.

Despite this, seismic design must not be overlooked. Severe damage is often associated with **ground failure**, such as:

- **Fault rupture** through a tunnel.
- **Landsliding**, particularly at tunnel portals.
- **Soil liquefaction**.

Design and analysis should be based on the **ground deformation approach**, where the structure is designed to accommodate deformations imposed by the surrounding medium.

Determination of Seismic Environment

Earthquake Fundamentals

General: Earthquakes result from abrupt movements on fractures called **faults**. This release of built-up strain energy is called **fault rupture**.

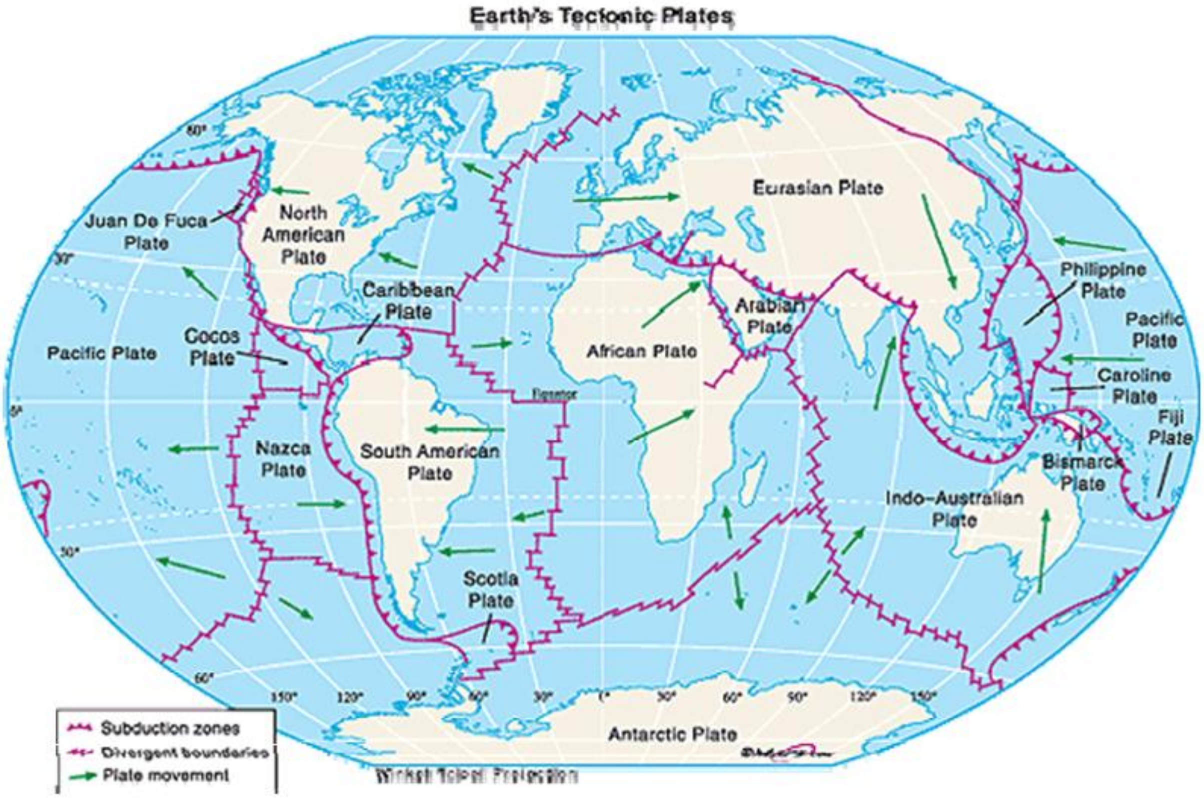

Figure 13-1. Major Tectonic Plates and Their Approximate Direction of Movement. (Source: www.maps.com)

Fault Movements

Faults are created when stresses exceed material strength.

- **Fault Creep**: Slow, relatively continuous movement that does not cause an earthquake.
- **Primary Fault Rupture**: Rupture propagating in a narrow zone traceable back to crystalline rock.
- **Blind Thrust Faults**: Thrust faults that do not break the ground surface.

Types of Faults

Faults are classified by their mode of relative displacement.

- **Strike Slip Faults**: Relative movement is essentially horizontal.
- **Dip Slip Faults**: Deformation is perpendicular to the fault plane, involving **Normal** (extensional) or **Reverse/Thrust** (compressional) motion.
- **Oblique Slip Faults**: Show both strike slip and dip slip displacement.

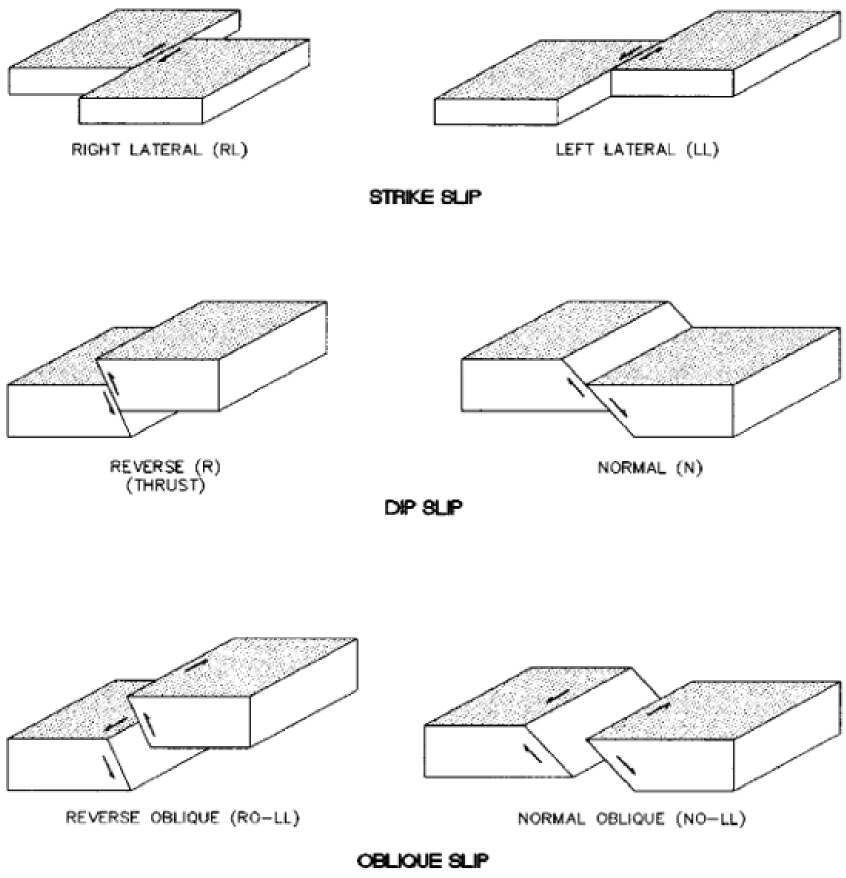

Figure 13-2. Types of Fault Movement

Earthquake Magnitude

A measure of energy released. The **moment magnitude (Mw)** scale is a unifying measure of the kinetic energy released.

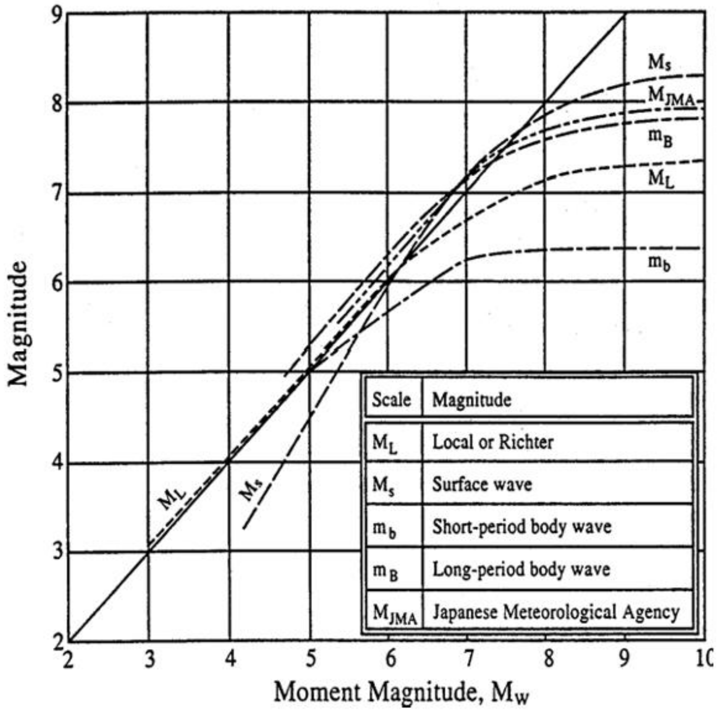

Figure 13-3. Comparison of Earthquake Magnitude Scales (Heaton, et al., 1986)

Source Geometry

The **hypocenter** (focus) is the point where slip initiates; the **epicenter** is the point directly above it on the surface.

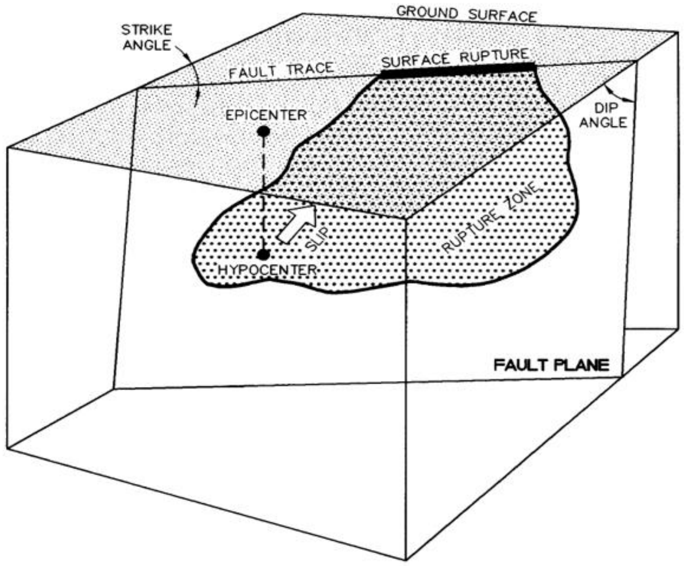

Figure 13-4. Definition of Basic Fault Geometry Including Hypocenter and Epicenter

Ground Motion Hazard Analysis

Seismic hazard analysis involves identifying sources, evaluating their potential, and characterizing the intensity of design motions at the site.

- **Deterministic Approach**: Identifies worst-case scenarios from capable sources.
- **Probabilistic Approach**: Incorporates rupture likelihood and magnitude distributions to compute the probability of exceedance.

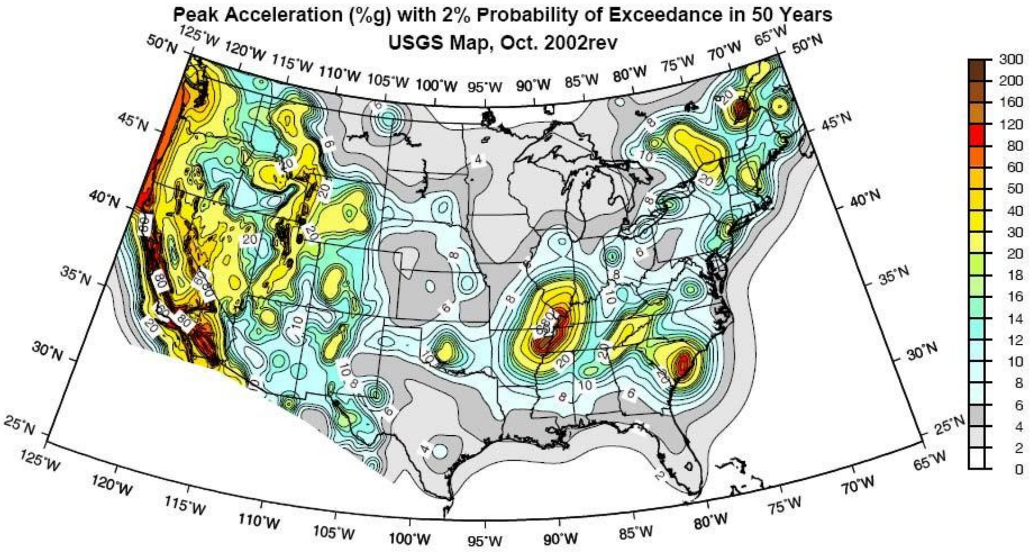

Figure 13-5. National Ground Motion Hazard Map by USGS (2002) - Peak Ground Acceleration with 2% Probability of Exceedance in 50 Years (2,500-yr Return Period) - for Site Class B, Soft Rock

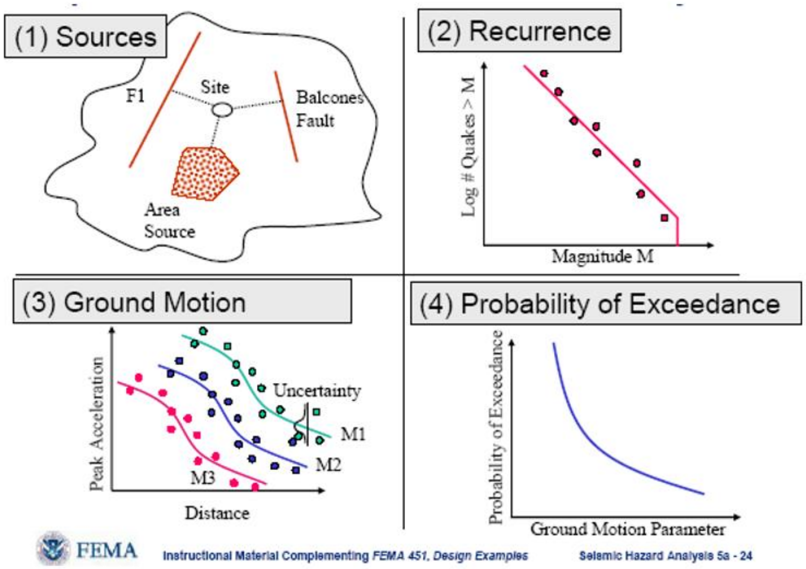

Figure 13-6. General Procedure for Probabilistic Seismic Hazard Analysis