California High-Speed Train Program

Two Level Seismic Performance Based Engineering Design

Pacific Earthquake Engineering Research Center
2011 PEER Annual Meeting
TSRP: Systems

October 01, 2011

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CA High-Speed Rail Authority

- CAHSR Authority – established 1996 by state legislation as state entity responsible for:
  - Planning, constructing, operating high-speed train system
  - Governed by 9-member appointed Board (5 by governor, 2 each by Senate and Assembly)

California High Speed Train Project (CHSTP) - Basic Features

- 800-mile system
- Max operating speed of 220 mph
- 100% electric power
- Proven, reliable technology operational throughout Europe & Asia
- Safely grade-separated from all cross traffic and pedestrians

Some CA High-Speed Train Facts

Phase 1: San Francisco - Anaheim

- Speed up to 220 mph – 500+ miles in under 3 hrs
- Up to 13 new high-speed stations
- Planned operational by 2020

Phase 2: Sacramento – Merced; LA – San Diego; Altamont Rail Project

- Additional 300 miles – up to 11 stations
- FY 2011/2012 funds zeroed in pending budget
- Cost estimate and operating date TBD

INITIAL CONSTRUCTION
Starting in the Central Valley

The foundation for true high-speed rail

- Only section where California's HST system will travel 220-mph maximum operating speed for long periods of time (enabling the two-hour, 40-minute requirement for trip time between LA and San Francisco)
- Initial track in the Central Valley will serve as testing and proving ground for new high-speed train technology in the United States
- Less expensive land and less complex engineering in the Valley
- Near-term job creation benefits (conservative estimate of 100,000 jobs – direct and indirect – over life of the first $6.3 billion in construction)

First Construction Segment

- Conditions to receive Federal Rail stimulus funds
  - Located in Central Valley
  - Must connect to operating passenger rail system
- North of Fresno to north side of Bakersfield - as far as approximately $6.3B will stretch and dependent on alignment. Connect to operating railways on both ends – approximately 120-140 miles
- Final alignment dependent on final environmental document
- This is first segment – build north & south from here

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Target Procurement Milestones

- Multiple Design-Build Construction Packages
- First construction package – Design-Build ~$1.5+B
- Request for contractor team qualifications: 3rd Qtr 2011
- Request for contractor proposals: 1st Qtr 2012
  - Selection based on “Best Value”
- Target first construction contract: 2nd Half 2012

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Seismic Design Requirements

Reference documents used to develop Seismic Design Criteria

• Caltrans Seismic Design Criteria	• Caltrans Bridge Design Manuals
• Taiwan HSR Design Specifications	• ASCE 7
• BART Design Criteria	• AREMA
• Japanese Design Standards	• Chinese HSR Design Code
• Sound Transit Design Criteria	• California Building Code

Application of Seismic Design Requirements

Primary Structures - Performance-based Design

- Structures that directly support high-speed train service
  - Bridges and aerial structures
  - Tunnels, underground and earth retaining structures
  - Passenger stations and building structures supporting track
  - Tracks and rail fasteners
  - Earth embankments
  - Train control facilities
  - Operation and communication facilities
  - Traction power facilities, power distribution network facilities, and other equipment facilities

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Application of Seismic Design Requirements

Secondary Structures - Force-based Design

- Structures not directly supporting high-speed trains
- Use California Building Code (CBC)
- Not necessary for immediate resumption of train service
  - Stations
  - Administrative buildings
  - Shop buildings
  - Storage facilities
  - Cash handling buildings
  - Parking structures
  - Training facilities

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Performance Criteria

No Collapse Performance Level (NCL)

Performance Objectives	Acceptable Damage
No Collapse Performance Level (NCL): The main objective is to limit structural damage to prevent collapse under all dead load and live load during and after a Maximum Considered Earthquake (MCE). The performance objectives are: 1. No collapse 2. Safe evacuation of passengers and personnel mitigated through containment measures 3. No flooding or mud inflow for underground structures	• Significant yielding of reinforcement steel or structural steel. Minor fracturing of secondary or redundant steel members with no collapse • Extensive cracking and spalling of concrete, but minimal loss of vertical load carrying capability • Large permanent offsets that may require extensive repairs or complete replacement before operation may resume

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Performance Criteria

Operability Performance Level (OPL)

Performance Objectives	Acceptable Damage
Operability Performance Level (OPL): The main objective is to protect the track structure such that disruption of service will be minimal following a Operating Basis Earthquake (OBE). The performance objectives are: 1. No derailment. Trains able to safely brake to a stop. 2. Rail deformations and stresses limited to protect against derailment.	• Rail deformations and stresses limited to protect against derailment
3. Elastic structural response with no concrete spalling or measurable deformations.	• No concrete spalling or steel reinforcement yielding
4. Minimal disruption of high-speed train service. 5. Resumption of normal service within a few hours. 6. Provide safe performance in aftershocks. 7. No rocking of bridge foundations. 8. No flooding or mud inflow for underground structures.	• No measurable permanent deformations

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Design Earthquakes

Maximum Considered Earthquake (MCE)

The greater of:

- 950 year return period (~10% probability of exceedance in 100 years)
- Caltrans ARS for deterministic maximums

Operating Basis Earthquake (OBE)

- 50 year return period (~86% probability of exceedance in 100 years)

Seismic Design Philosophy

For Maximum Considered Earthquake (MCE)

- Use performance based design

For Operating Basis Earthquake (OBE)

- Use force or performance based elastic design

For track-structure interaction

- Contains OBE load cases for design

Seismic Design Requirement - Ground Motions

Ground Motion Guidelines

- Guidance to develop design earthquake ground motions for 30% Design
- Procedures and methods reviewed by Technical Advisory Panel (TAP)

Single Entity Approach – Project Management Team to lead development of ground motions for statewide system

- Phase I (FY 2010-2011)
  - Merced-Fresno
  - Fresno-Bakersfield
  - San Jose-Merced
- Phase II (FY 2011-2012+) – remaining regional sections

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Seismic Design Requirements - Fault Crossings

Fault Rupture Analysis and Mitigation

- Fault crossings at grade, not on structures or in tunnels
- Provides guidelines for:
  - Identifying and screening hazardous faults
  - Determining fault rupture displacement
  - Mitigating measures to meet seismic performance requirements
- Fault Displacement Analysis:
  - TAP recommended that fault displacement analysis be conducted by single entity
  - Highly specialized expertise
- Variance Procedure

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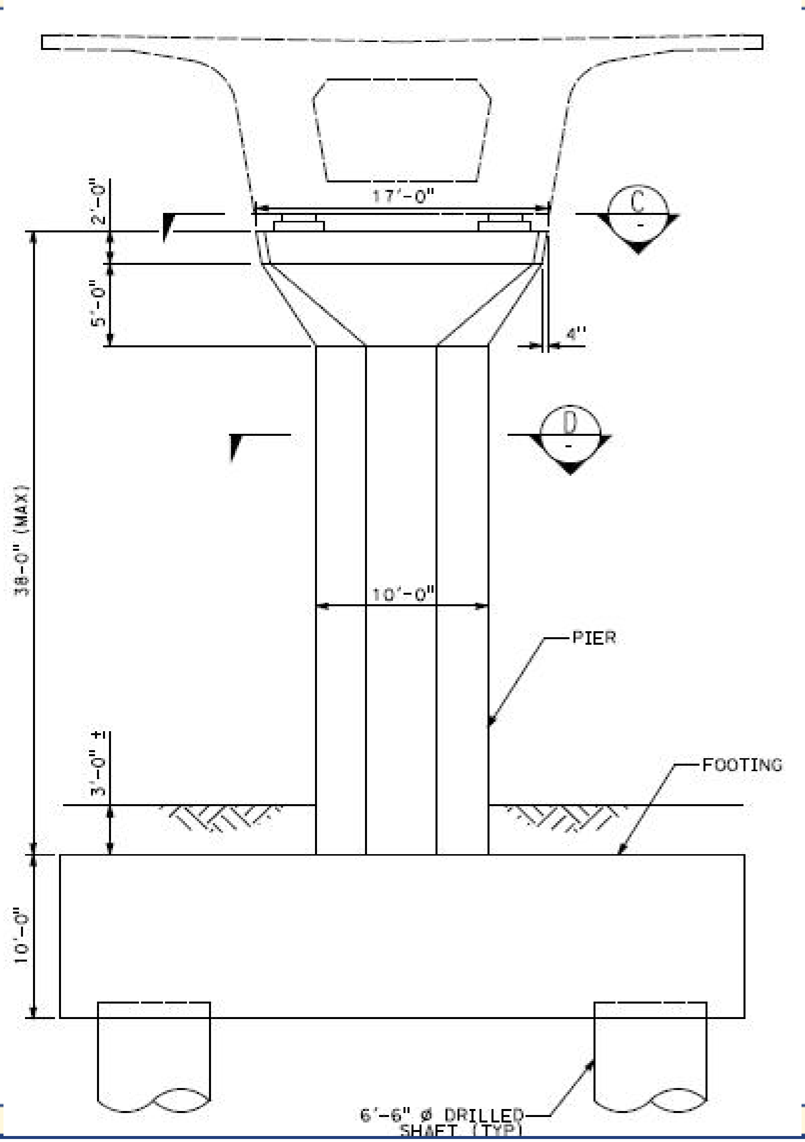
Track-Structure Interaction

- Provides guidelines for:
  - Limiting vibrations and deformations of structures which can be magnified under high-speed train loading
  - Ensuring track safety
    - Limits rail stress
    - Limits changes in track geometry
    - Ensures adequate wheel to rail contact
  - Ensuring passenger comfort
  - Performing analysis to verify criteria is met
- Includes seismic ground motions (OBE 50 year) to meet Operability Performance Level
  - No Derailment

Standard Viaduct Design

- Two track single girder
- Simple span
- Conventional bearings/shear keys
- Two heights
- Two span lengths
- Two seismic zones

Typical Section 120 ft span



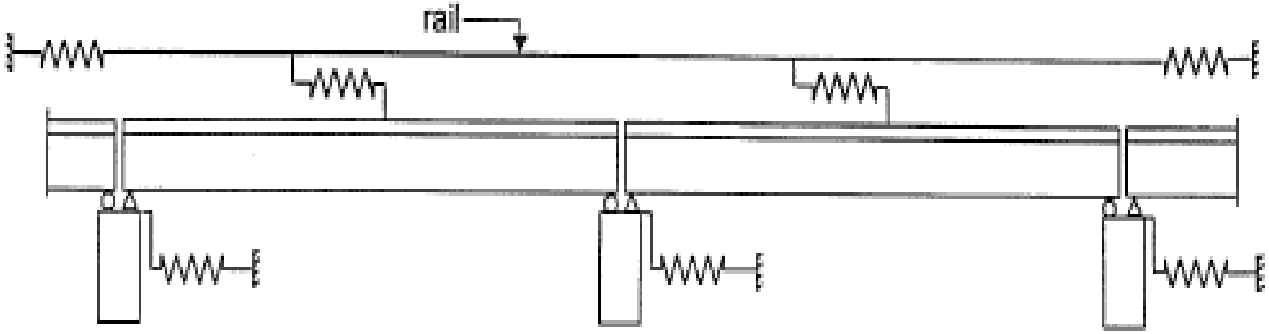
Standard Design

- Column design governed by OBE from Track Structure Analysis

- Foundation design governed by
  - Group 1 or OBE (3% difference, both Strength Loadings)
  - Resistance factors larger than MCE demands

- Actual foundation conditions unknown

Track Structure Interaction Model



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Earthquake Early Warning System

Features

- Used system-wide
- Additional sensors at hazardous fault zones
- Integrated with train control, communications and signal systems
- Capable of triggering appropriate response for at-risk trains to bring them to a safe stop as soon as p-waves are detected.
- Coordinated with maintenance and inspection protocols

Research Topics

- Dynamic Impact factor for speed
- Resonance zones for speed greater than 220
- Seismic isolation of long viaduct with CWR
- Track vibration mass damper systems
- Structure frequency limits for riding comfort

Discussion