Workshop on Seismic Design and Performance of High Speed Rail Systems

Jean-Pierre Bardet, University of Southern California
Tat S. Fu, University of New Hampshire
Pascal Rivoire, Ecole Normale Supérieure de Cachan, France
Fuyuan Gong, Tsinghua University, China

August 11, 2010
Outline

• Introduction
• Project status
  o International visits (100% completed)
  o Design codes (70%)
  o California HSR seismic demands (85%)
• Challenges and future work
  o Workshop organization
  o Collaborations
Outline

• Introduction
• Project status
  o International visits
  o Design codes
  o California HSR seismic demands
• Challenges and future work
  o Workshop organization
  o Collaborations
Motivations:
- US has no prior experience in building High Speed Rail (HSR) systems
- Several countries (Japan, France, China, ... ) have extensive knowledge in HSR
- CA HSR will be subjected to earthquakes

Objectives:
- Perform a state-of-the-art review of seismic designs for High Speed Rail (HSR) systems
- Survey the best practices by various countries and adapt them for CA
- Plan a workshop that brings together HSR experts and organizations from various countries
- Identify high priority research topics for PEER
Outline

• Introduction
• Project status
  o International visits
  o Design codes
  o California HSR seismic demands
• Challenges and future work
  o Workshop organization
  o Collaborations
<table>
<thead>
<tr>
<th>Country</th>
<th>Total network length (km)</th>
<th>Scheduled trains</th>
<th>Test run speed record</th>
<th>Average speed of fastest scheduled train</th>
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</thead>
<tbody>
<tr>
<td>China</td>
<td>3300 [5]</td>
<td>431 km/h (maglev) 350, 330, 300, 250, 200 km/h (conventional)</td>
<td>502 km/h (maglev) 394 km/h (conventional)</td>
<td>313 km/h [6]</td>
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<tr>
<td>Japan</td>
<td>2459</td>
<td>300, 275, 260 km/h (conventional)</td>
<td>581 km/h (maglev) 443 km/h (conventional)</td>
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<tr>
<td>France</td>
<td>1700</td>
<td>320, 300, 280, 210 km/h</td>
<td>574 km/h</td>
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<td>Germany</td>
<td>1290</td>
<td>300, 280, 250, 230 km/h (conventional)</td>
<td>550 km/h (maglev) 406 km/h (conventional)</td>
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<td>300, 250 km/h</td>
<td>404 km/h</td>
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<td>Italy</td>
<td>814.5</td>
<td>300, 260, 200 km/h</td>
<td>368 km/h</td>
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<td>Taiwan</td>
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<td>300, 240 km/h</td>
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<td>Turkey</td>
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<td>250 km/h</td>
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<td>&lt;140 km/h</td>
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<tr>
<td>South Korea</td>
<td>240.4</td>
<td>300, 240 km/h</td>
<td>355 km/h</td>
<td>200 km/h</td>
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<tr>
<td>Belgium</td>
<td>214</td>
<td>300, 250 km/h</td>
<td>347 km/h</td>
<td>237 km/h [4]</td>
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<td>United Kingdom</td>
<td>109 [13]</td>
<td>300 km/h, 225 km/h, 201 km/h</td>
<td>335 km/h</td>
<td>219 km/h [4]</td>
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<tr>
<td>Netherlands</td>
<td>100 [7]</td>
<td>300, 250, 140/160 km/h (8)</td>
<td>336.2 km/h [9]</td>
<td>&lt;140 km/h</td>
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<tr>
<td>Switzerland</td>
<td>79</td>
<td>250, 200 km/h</td>
<td>280 km/h [12]</td>
<td>&lt;140 km/h</td>
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<tr>
<td>Austria</td>
<td>0</td>
<td>230 km/h</td>
<td>275 km/h</td>
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<td>Finland</td>
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<td>255 km/h</td>
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<td>210 km/h</td>
<td>260 km/h</td>
<td>151 km/h</td>
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<tr>
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<td>275 km/h</td>
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<tr>
<td>Russia</td>
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<td>250 km/h</td>
<td>290 km/h</td>
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<tr>
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<td>303 km/h</td>
<td>173 km/h</td>
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<td>United States</td>
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<td>241 km/h, 201 km/h</td>
<td>296 km/h (jet) 264 km/h (conventional)</td>
<td>161 km/h</td>
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</table>

Source: <http://en.wikipedia.org/wiki/High-speed_rail_by_country>
International Institutions & Experts

**California:** California High-Speed Rail Authority; Kleinfelder; Parsons Brinkerhoff; SC Solutions; John Chirco; Roupen Donikian Alice Wiggins-Tolbert; Mike Hawkins; Bruce Armistead; Dan Levitt; Tony Daniel;s Bruce Hilton; Vince Jacob; Victor Zayas; Endi Zhai

**China:** China Railway Eryuan Engineering Group; Railway Institutes; Southwest Jiaotong University; Jianlin Ma; Renda Zhao; Sirong Yi; Anhong Li;

**France:** SYSTRA; TGV; SNCF; Freyssinet; Patrice Schmitt; Serge Montens; Huy Lam; Gregoire Jeanson; Antoine Domange

**Japan:** Railway Technical Research Institute; Japan Railway Construction, Transport and Technology Agency; Tokyo Institute of Technology; University of Tokyo; Waseda University; Masa Hamada; Junichi Koseki; Kazuhiko Kawashima; Akihiko Nishimura; Yoshitaka Murono; Xiu Luo; Kimitoshi Ashiya; Masamichi Sogabe

**Korea:** Korea Railroad Research Institute; Chungsuk Engineering; S. C. Yang; K. S. Hong

**Taiwan:** Taiwan High Speed Rail Corporation; Koa Corporation; Moh and Associates Inc; James Yang; Jimmy Lin; Yung-Her Huang; Jedar Hsieh
JAPAN

- Shinkansen (新幹線)
- 2459 miles
- EQ regions
- Good track record

Contact:
- Railway Technical Research Institute (RTRI) – Dr. Yoshitaka Murono; Dr. Xiu Luo; Dr. Kimitoshi Ashiya, …
- JR Soken Engineering – Dr. Akihiko Nishimura
- Universities – Prof. Masa Hamada; Prof. Junichi Koşeki
RTRI Materials
France

- TGV (Train à Grande Vitesse)
- 1700 miles
- 1st train in 1981
- Fastest in the world
- Connects to EU

Contact:
- TGV; Systra; SNCF
- Patrice Schmitt; Serge Montens; Huy Lam; Gregoire Jeanson; Antoine Domange
TGV / SYSTRA / SNCF Visit

1/25/2010
Union internationale des chemins de fer (UIC) & Eurocode Materials

European Standard
Norme Européenne
Europäische Norm

December 2009

EN 1998-1

English version

This document is a draft European Standard. It is distributed for review and comments. It is subject to change without formal approval to be used as a European standard.

SEISMIC DESIGN OF BUILDINGS TO EUROCODE 8

EDITED BY
AHMED V. ELGHAZOULI
China
• Under construction
• 16,000 miles (by 2020)
• $50B (2009 alone)

Contact:
• China Railway Eryuan Engineering Group (CREEGC) – Anhong Li
• Southwest Jiaotong University (SWJU) – Prof. Jianlin Ma; Prof. Renda Zhao; Prof. Sirong Yi, ...
Chinese Design Codes

Other design standards that would be useful

1. High Speed Railway
2. Road Tunnel
3. Concrete Structures
4. Water Supply and Sewerage
5. Steel Structure of Railway Bridge
6. Reinforced and Pre-stressed Concrete Structure
7. Tunnel of Railway
Etc.
Outline

• Introduction
  o PEER-USC HSR research objectives
• Current and completed tasks
  o International visits
  o Design codes
  o CA seismic demands
  o Bridge crossings
• Next tasks
  o Plan a workshop
  o Submit journal papers
4 Seismic Design Codes

Caltrans code:
• Only for highway
• Adapted to the area

Chinese code for railway engineering.

Eurocode 8: seismic design for bridges.
• New section for isolating devices.

Japanese code:
• Reliability proved on Japanese earthquakes
Translations

Chinese (71 pages)
• Translated by Fuyuan Gong (Tsinghua University)

Japanese (240 pages)
• Will be translated by Uena (Kyoto University) starting September 1, 2010
# Analysis and Comparison of Codes

## 4 major topics: Hazards / Performance criteria / Analysis / Structural design

<table>
<thead>
<tr>
<th>Topics Covered</th>
<th>Caltrans (bridge)</th>
<th>China (HSR)</th>
<th>Euro (general structures)</th>
<th>Japan (HSR)</th>
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<tr>
<td>Specific to Railways</td>
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<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Demand</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Ground Motion Representation</td>
<td>X</td>
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<td>Ground Classification</td>
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<td>X</td>
</tr>
<tr>
<td>Response Spectrum</td>
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<tr>
<td>Displacement Limit</td>
<td></td>
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<tr>
<td>Structures</td>
<td></td>
<td></td>
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<tr>
<td>Foundations</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Bridges</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Tunnels</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Embankments</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Retaining Walls / Abutments</td>
<td></td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Components (columns, beams, etc)</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base Isolation</td>
<td></td>
<td></td>
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<tr>
<td>Analysis</td>
<td></td>
<td></td>
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<tr>
<td>Equivalent Static</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Modal</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Inelastic</td>
<td></td>
<td>X</td>
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<tr>
<td>Ductility Design</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Others</td>
<td></td>
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<td></td>
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<tr>
<td>Liquefaction</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
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</table>
Seismic Hazards
# Design Earthquakes

<table>
<thead>
<tr>
<th>Caltrans (bridge)</th>
<th>China (HSR)</th>
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<tr>
<td><strong>Ordinary bridges</strong></td>
<td>low-level EQ</td>
</tr>
<tr>
<td>deterministic assessment corresponding to the MCE</td>
<td>return period of 50 years</td>
</tr>
<tr>
<td><strong>Important bridges</strong></td>
<td>design EQ</td>
</tr>
<tr>
<td>deterministic or probabilistic assessment</td>
<td>475 years</td>
</tr>
<tr>
<td><strong>$T &lt; 0.5\text{sec}$</strong></td>
<td>high-level EQ</td>
</tr>
<tr>
<td>Spectral acceleration magnification = 0</td>
<td>2475 years</td>
</tr>
<tr>
<td><strong>$0.5 &lt; T &lt; 1.5\text{sec}$</strong></td>
<td></td>
</tr>
<tr>
<td>linear interpolation</td>
<td></td>
</tr>
<tr>
<td>$T &gt; 1.5\text{sec}$</td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td></td>
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</table>

The shape and magnitude of the ARS curves are dependent upon the peak rock acceleration, depth of bedrock, fault distance, earthquake moment magnitude, damping ratio, and geotechnical site conditions.

<table>
<thead>
<tr>
<th>Euro (general structures)</th>
<th>Japan (HSR)</th>
</tr>
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<tbody>
<tr>
<td><strong>Type 1</strong></td>
<td>Level 1</td>
</tr>
<tr>
<td>others</td>
<td>based on ARS determined for firm ground classified in the conventional allowable stress design method; return period of 50 years; max value = 250gal (damping ratio 5%)</td>
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<tr>
<td><strong>Type 2</strong></td>
<td>Level 2</td>
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<tr>
<td>have a surface-wave magnitude, $Ms &lt; 5.5$</td>
<td>ARS targeting near-land interpolate EQs (Mag. 8, 30-40km to epicenter)</td>
</tr>
<tr>
<td></td>
<td>Level 2 (Spectrum I)</td>
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<tr>
<td></td>
<td>ARS targeting determined according to statistical analysis based on past EQs produced by inland active faults</td>
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<tr>
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<td>Level 2 (Spectrum II)</td>
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<tr>
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<td>ARS targeting determined according to rupture mechanism of faults</td>
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<td>Level 2 (Spectrum III)</td>
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</tbody>
</table>
Design Code Flowcharts

China

Japan

China’s Code for seismic design of railway engineering (71 pages)

Earthquakes
- Low level (return period = 50 years)
- Design level (475 years)
- High level (2475 years)

Earthquake regions
- Seismic intensity
  - 6
  - 7
  - 8
  - 9

Sites
- I: Vs > 500
- II: 250 < Vs ≤ 500
- III: 150 < Vs ≤ 250
- IV: Vs ≤ 150

Structures
- Category B, C and new bridges
- Category B bridges
- Bridges abutments
- Foundations, retaining walls, tunnels, bridge supports
- Category B and new bridges
- Simple beams in bridges

Analysis methods
- Time-history / dynamic
- Response spectrum
- Equivalent Static
- Nonlinear time-history / dynamic
- Simplified ductility analysis

Performance criteria
- 1 (no/min. damage)
- 2 (some damage)
- 3 (no collapse)

Japan’s Design Standards for Railway Structures and Commentary (Seismic Design) (29 page Digest)

Ground motions
- Level 1
- Level 2 (Spectrum I)
- Level 2 (Spectrum II)

Sites
- G0, G1, G2, ..., G7 (hard rock to soft soil)

Structures
- General (can be represented by 1-DOF system)
- Complex
- Important
- Others

Analysis methods
- Nonlinear spectrum method
- Time-history dynamic

Performance criteria
- 1 (functions retained)
- 2 (repair needed)
- 3 (no collapse)

Structural members: Damage level 1, 2, 3 & 4
- Foundations: Stability level 1, 2, & 3
Outline

- Introduction
- Project status
  - International visits
  - Design codes
  - California HSR seismic demands
- Challenges and future work
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  - Collaborations
Distances to Faults along CA HSR

Data: SIO, NOAA, U.S. Navy, NGA, GEBCO
<table>
<thead>
<tr>
<th>Segment Type</th>
<th>Length (km)</th>
<th>Length (miles)</th>
<th>Fault Crossing</th>
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<tbody>
<tr>
<td>Aerial</td>
<td>201.7</td>
<td>125.2</td>
<td>7</td>
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<tr>
<td>At Grade</td>
<td>703.7</td>
<td>437.0</td>
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<tr>
<td>Cut &amp; Fill</td>
<td>195.9</td>
<td>121.6</td>
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<td>Embankment</td>
<td>2.1</td>
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<td>Retaining Wall</td>
<td>28.8</td>
<td>17.9</td>
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<td>Trench</td>
<td>11.6</td>
<td>7.2</td>
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<tr>
<td>Tunnel</td>
<td>67.6</td>
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<tr>
<td>Under Consideration</td>
<td>168.3</td>
<td>104.5</td>
<td>12</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1379.7</strong></td>
<td><strong>856.8</strong></td>
<td><strong>33</strong></td>
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</table>
To begin an analysis, identify your site using the site selection tool [Mark Site]. You can select a new site, or modify your previously selected site location by clicking this button again. You can also enter or modify your site location at any time by entering coordinates in the fields at the bottom of the map.
Caltrans Bridges & CA HSR

- 11,000+ existing Caltrans bridges
- 336 bridges within 250m of HSR
- 962 bridges within 500m of HSR
- Many more new bridges needed for crossings between HRS and roads
Outline

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# California High Speed Rail International Workshop

**Location:** UC Berkeley / San Francisco, CA  
**Time:** November 2010 (2 days)  
**Participants:**  
- PEER university researchers and students  
- California High Speed Rail Authority  
- Consultants working on CA HSR  
- Experts from France, Japan, China, etc.  
(informal invites to experts are already given)  
**Objective:** Discuss important issues for CA HSR; identify research areas and collaborative opportunities among participants  
**Agenda:**  
- Keynotes by various countries  
- Sessions by areas/themes (Earthquakes, derailments, thermal deformation, braking, ...)

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Challenges

• Workshop was postponed due to concerns on commercial propagandas and international competitions

• Much effort and time was spent on gathering, translating, and analyzing design codes from various countries
Future Work and Collaborations

- Workshop for PEER researchers and HSR consultants about seismic issues on HSR systems
- HSR systems: Armen Kiureghian, ___
- Spatial variation of ground motions: Jack Baker, _________
- Bearings and dampers: __________
- Surface faulting crossing: __________
- Southern California Earthquake Center
- A bright future for HSR research....
Workshop on Seismic Design and Performance of High Speed Rail Systems

University of Southern California (USC)
JP Bardet (bardet@usc.eud)
Tat S. Fu (tsf@usc.eud)
Pascal Rivoire (rivoire.pascal@gmail.com)
Fuyuan Gong (gongfy07@126.com)