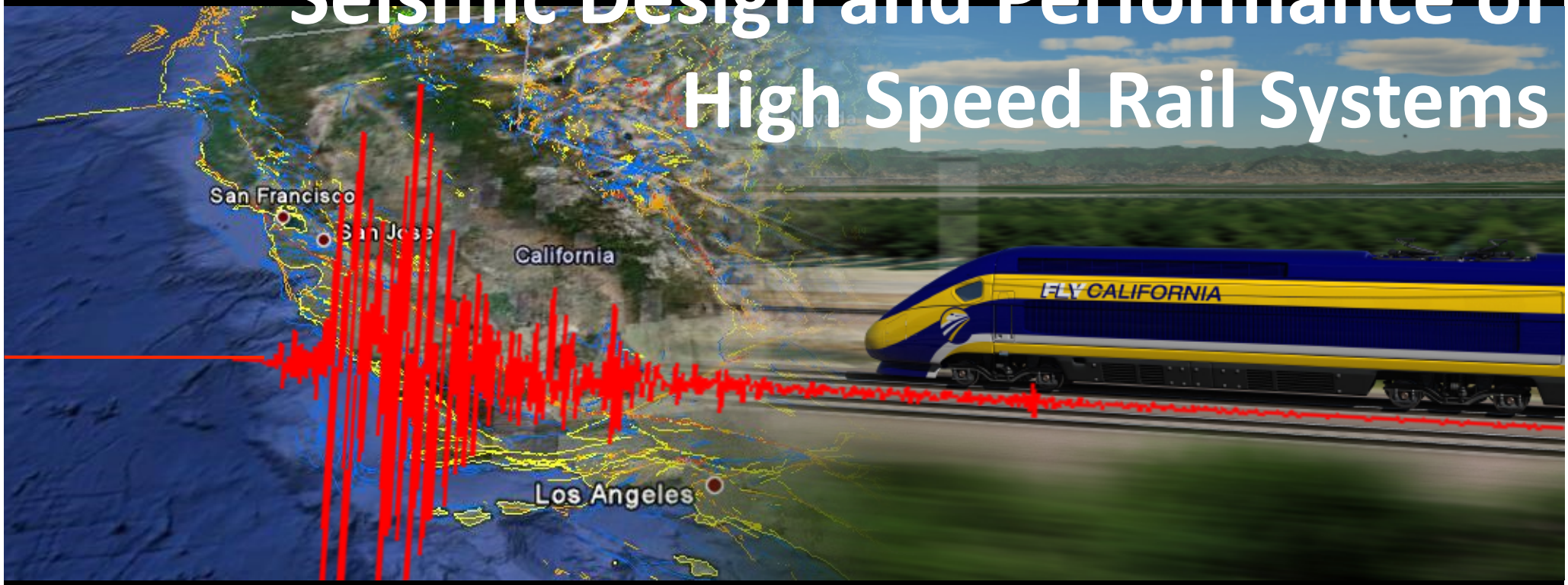
PEER

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

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
  - International visits (100% completed)
  - Design codes (70%)
  - California HSR seismic demands (85%)
- Challenges and future work
  - Workshop organization
  - Collaborations

Outline

- Introduction
- Project status
  - International visits
  - Design codes
  - California HSR seismic demands
- Challenges and future work
  - Workshop organization
  - Collaborations

CALIFORNIA
High-Speed Rail Authority

CA.GOV

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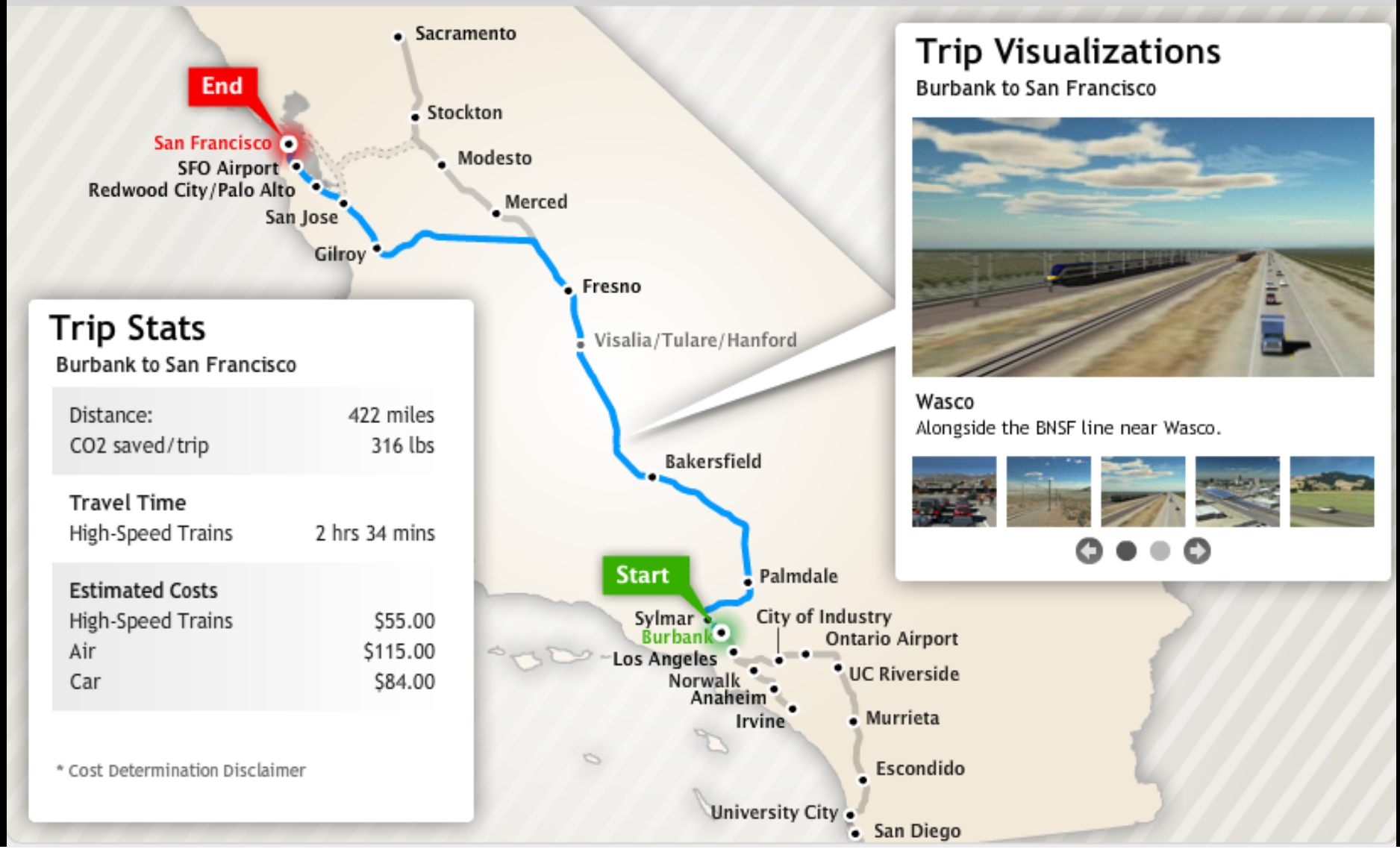
Interactive Rail Map

Burbank To San Francisco



Trip Stats

Burbank to San Francisco

Distance:	422 miles
CO2 saved/trip	316 lbs
Travel Time	
High-Speed Trains	2 hrs 34 mins
Estimated Costs	
High-Speed Trains	$55.00
Air	$115.00
Car	$84.00

* Cost Determination Disclaimer

Trip Visualizations

Burbank to San Francisco

Wasco

Alongside the BNSF line near Wasco.

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
  - International visits
  - Design codes
  - California HSR seismic demands
- Challenges and future work
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Around the World

Country	Total network length (km)	Scheduled trains	Test run speed record	Average speed of fastest scheduled train[3]
China	3300 [5]	431 km/h (maglev) 350, 330, 300, 250, 200 km/h (conventional)	502 km/h (maglev) 394 km/h (conventional)	313 km/h[6]
Japan	2459	300, 275, 260 km/h (conventional)	581 km/h (maglev) 443 km/h (conventional)	256 km/h
France	1700	320, 300, 280, 210 km/h	574 km/h	272 km/h
Germany	1290	300, 280, 250, 230 km/h (conventional)	550 km/h (maglev) 406 km/h (conventional)	226 km/h
Spain	1272.3	300, 250 km/h	404 km/h	236 km/h
Italy	814.5	300, 260, 200 km/h	368 km/h	178 km/h
Taiwan	335.5	300, 240 km/h	315 km/h	245 km/h
Turkey	245	250 km/h	303 km/h	<140 km/h
South Korea	240.4	300, 240 km/h	355 km/h	200 km/h
Belgium	214	300, 250 km/h	347 km/h	237 km/h[4]
United Kingdom	109[13]	300 km/h, 225 km/h, 201 km/h	335 km/h	219 km/h[4]
Netherlands	100[7]	300, 250, 140/160 km/h[8]	336.2 km/h[9]	<140 km/h
Switzerland	79	250[11], 200 km/h	280 km/h[12]	<140 km/h
Austria		230 km/h	275 km/h	153 km/h
Finland	0	220 km/h	255 km/h	152 km/h
Norway	0	210 km/h	260 km/h	151 km/h
Portugal	0	220 km/h	275 km/h	<140 km/h
Russia	0	250 km/h	290 km/h	172 km/h[10]
Sweden	0	200 km/h	303 km/h	173 km/h
United States	0	241 km/h, 201 km/h	296 km/h (jet) 264 km/h (conventional)	161 km/h

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

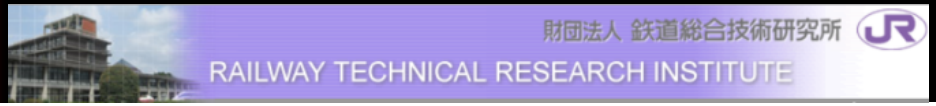
China: China Railway Eryuan Engineering Group; Railway Institutes; Southwest Jiaotong University; Jianlin Ma; Renda Zhao; Sirong Yi; Anhong Li;

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

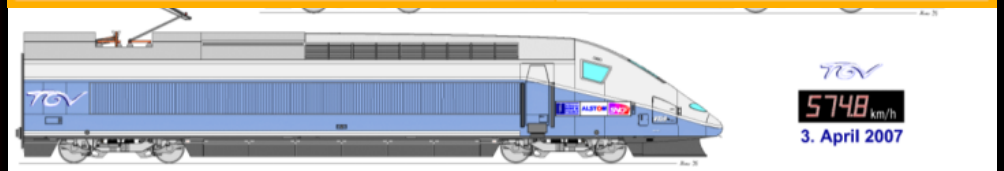
Contact:

- **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

Railway Technical Research Institute (RTRI)

3/2/2010

RTRI Materials



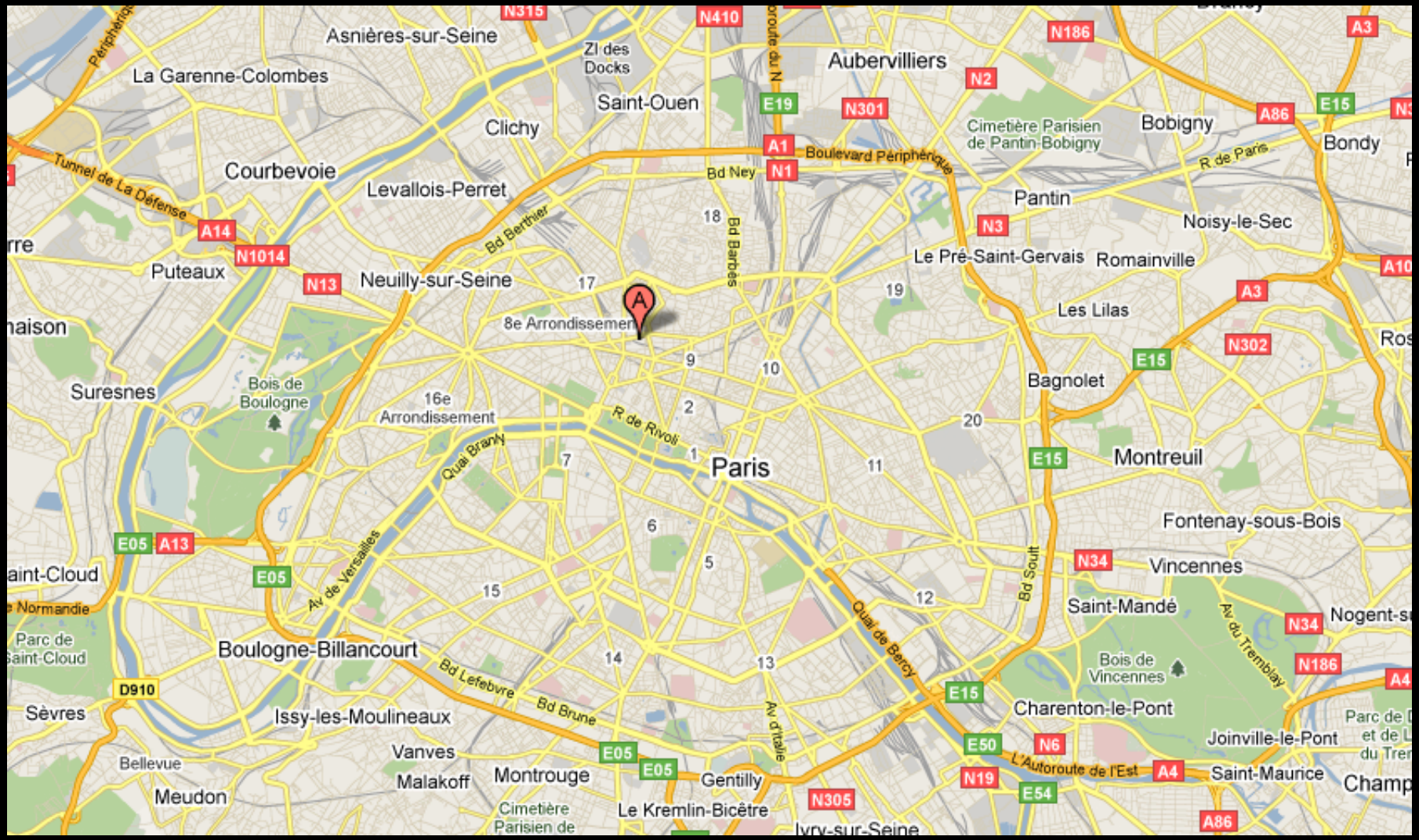
France

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

Contact:

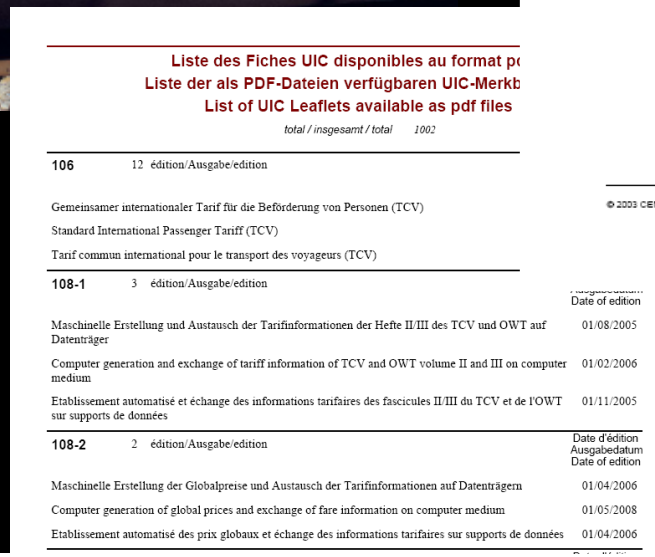
- TGV; Systra; SNCF
- Patrice Schmitt; Serge Montens; Huy Lam; Gregoire Jeanson; Antoine Domange

TGV / SYSTRA / SNCF Visit



1/25/2010

Union internationale des chemins De Fer (UIC) & Eurocode Materials



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Liste der als PDF-Dateien verfügbaren UIC-Merkb
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total / insgesamt / total 1002

106	12 édition/Ausgabe/edition	
	Gemeinsamer internationaler Tarif für die Beförderung von Personen (TCV)	
	Standard International Passenger Tariff (TCV)	
	Tarif commun international pour le transport des voyageurs (TCV)	
108-1	3 édition/Ausgabe/edition	Date of edition
	Maschinelle Erstellung und Austausch der Tarifinformationen der Hefte II/III des TCV und OWT auf Datenträger	01/08/2005
	Computer generation and exchange of tariff information of TCV and OWT volume II and III on computer medium	01/02/2006
	Etablissement automatisé et échange des informations tarifaires des fascicules II/III du TCV et de l'OWT sur supports de données	01/11/2005
108-2	2 édition/Ausgabe/edition	Date d'édition Ausgabedatum Date of edition
	Maschinelle Erstellung der Globalpreise und Austausch der Tarifinformationen auf Datenträgern	01/04/2006
	Computer generation of global prices and exchange of fare information on computer medium	01/05/2008
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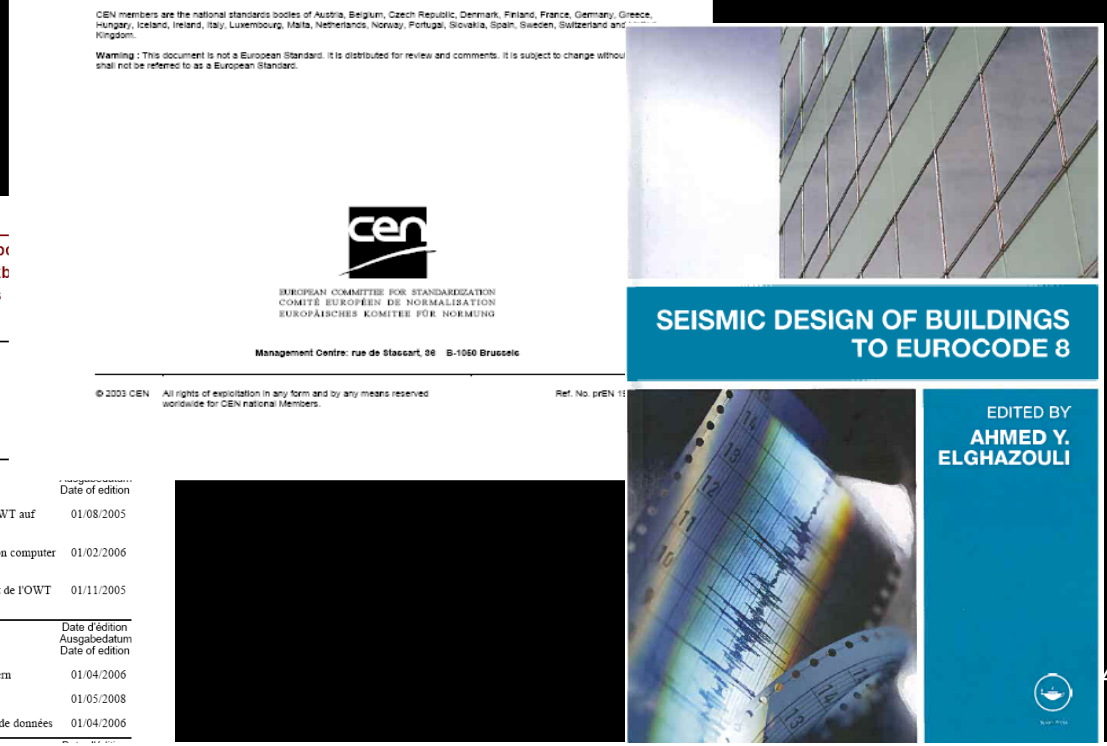

FINAL DRAFT
prEN 1998-1

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

December 2003

ICS 91.120.20

Will supersede ENV 1998-1-1:1994; ENV 1998-1-2:1994 and ENV 1998-1-3:1995

English version

Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings

Eurocode 8: Calcul des structures pour leur résistance aux séismes - Partie 1: Règles générales, actions sismiques et règles pour les bâtiments

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COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

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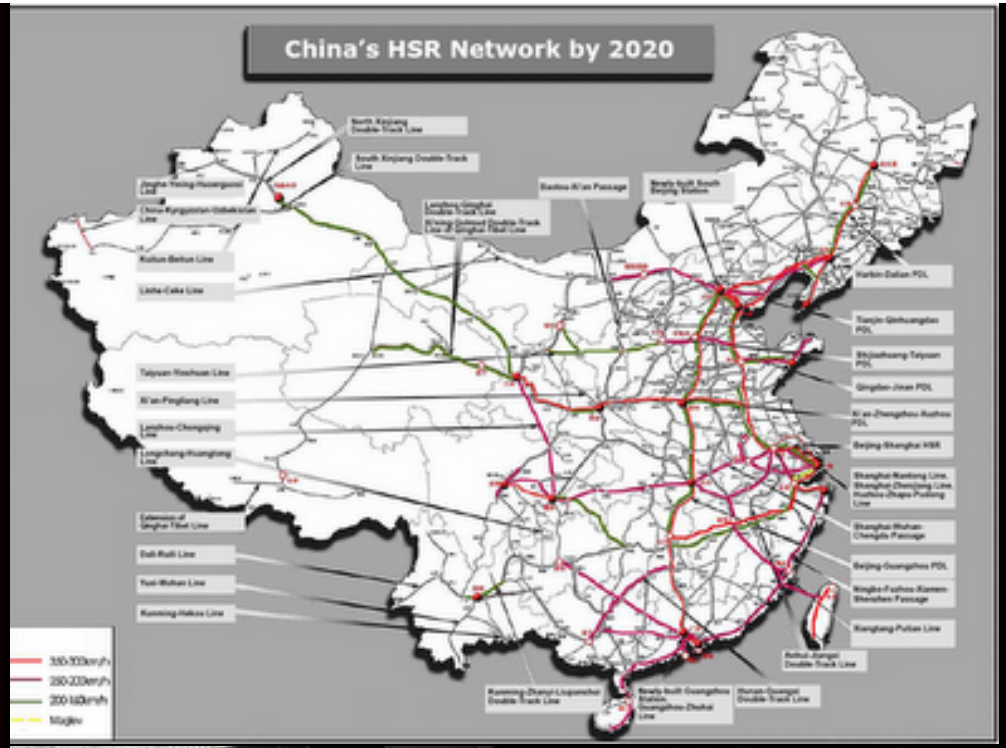
Ref. No. prEN 19



China

- Under construction
- 16,000 miles (by 2020)
- $50B (2009 alone)

Contact:

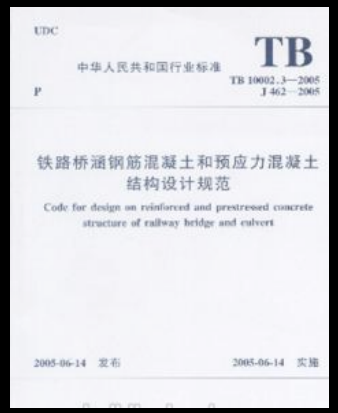
- **China Railway Eryuan Engineering Group (CREEGC)** – Anhong Li
- **Southwest Jiaotong University (SWJU)** – Prof. Jianlin Ma; Prof. Renda Zhao; Prof. Sirong Yi, …

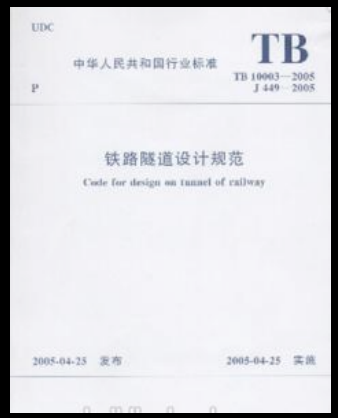
中国中铁二院工程集团有限责任公司
CHINA RAILWAY ERYUAN ENGINEERING GROUP CO. LTD

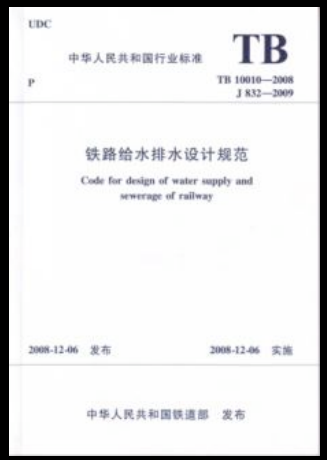
西南交通大學
Southwest Jiaotong University

Chinese Design Codes

Other design standards that would be useful





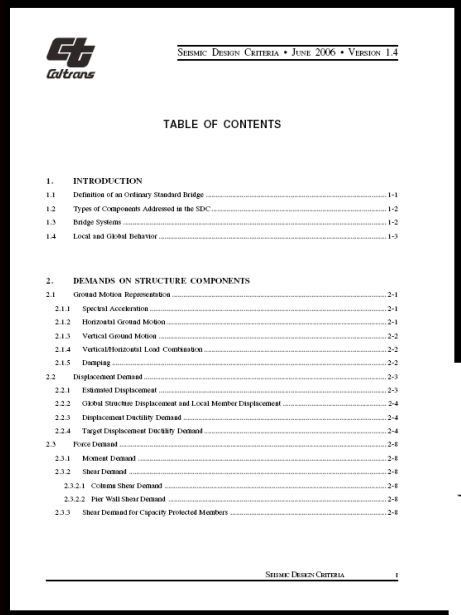


1 High Speed Railway
2 Road Tunnel
3 Concrete Structures
4 Water Supply and Sewerage
5 Steel Structure of Railway Bridge
6 Reinforced and Pre-stressed Concrete Structure
7 Tunnel of Railway
Etc.

Outline

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

4 Seismic Design Codes


Caltrans

SEISMIC DESIGN CRITERIA • JUNE 2006 • VERSION 1.4

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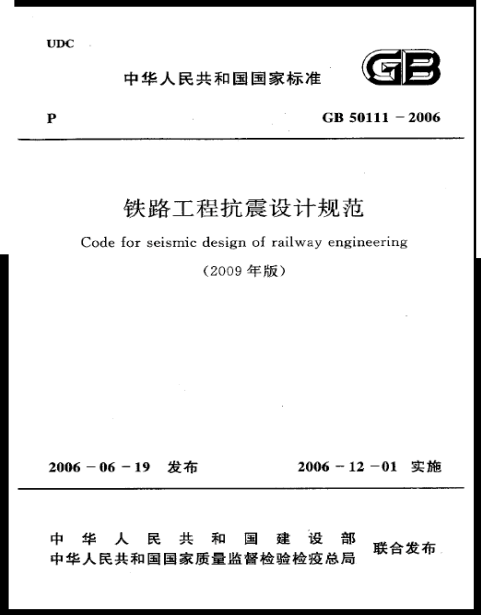
SEISMIC DESIGN CRITERIA 1


UDC

中华人民共和国国家标准

GB

P

GB 50111 – 2006

铁路工程抗震设计规范

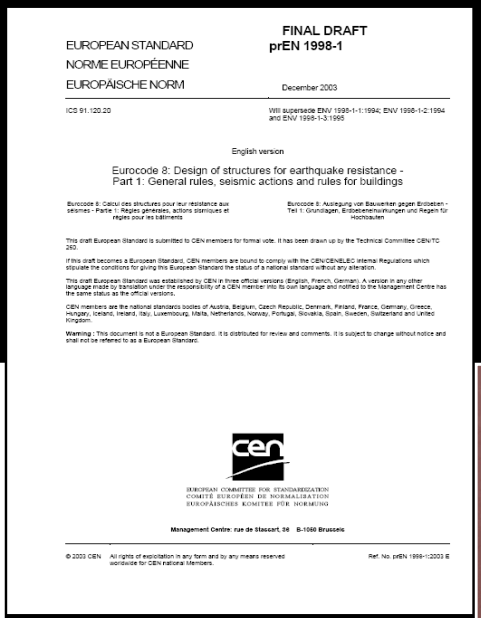
Code for seismic design of railway engineering

（2009 年版）

2006 – 06 – 19 发布

2006 – 12 – 01 实施

中 华 人 民 共 和 国 建 设 部
中华人民共和国国家质量监督检验检疫总局 联合发布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Ref. No. prEN 1998-1:2003 E


平成11年10月

国土交通省鉄道局 監修
鉄道総合技術研究所 編

鉄道構造物等設計標準・同解説
耐震設計

2007.03

Design Standards for Railway Structures and Commentary
(Seismic Design)

Editorial Supervisor, Railway Bureau of the Ministry of Land, Infrastructure and Transport Government of Japan

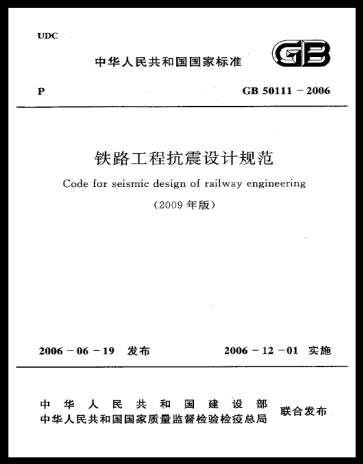
Caltrans code:
- Only for highway
- Adapted to the area

Chinese code for railway engineering.

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

Japanese code:
- Reliability proved on Japanese earthquakes

Translations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中华人民共和国国家标准 GB

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2006 – 06 – 19 发布 2006 – 12 – 01 实施

中华人民共和国建设部
中华人民共和国国家质量监督检验检疫总局 联合发布

Chinese (71 pages)

- Translated by Fuyuan Gong (Tsinghua University)


平成11年10月

国土交通省鉄道局 監修
鉄道総合技術研究所 編

鉄道構造物等設計標準・同解説

耐震設計

丸善株式会社

Japanese(240 pages)

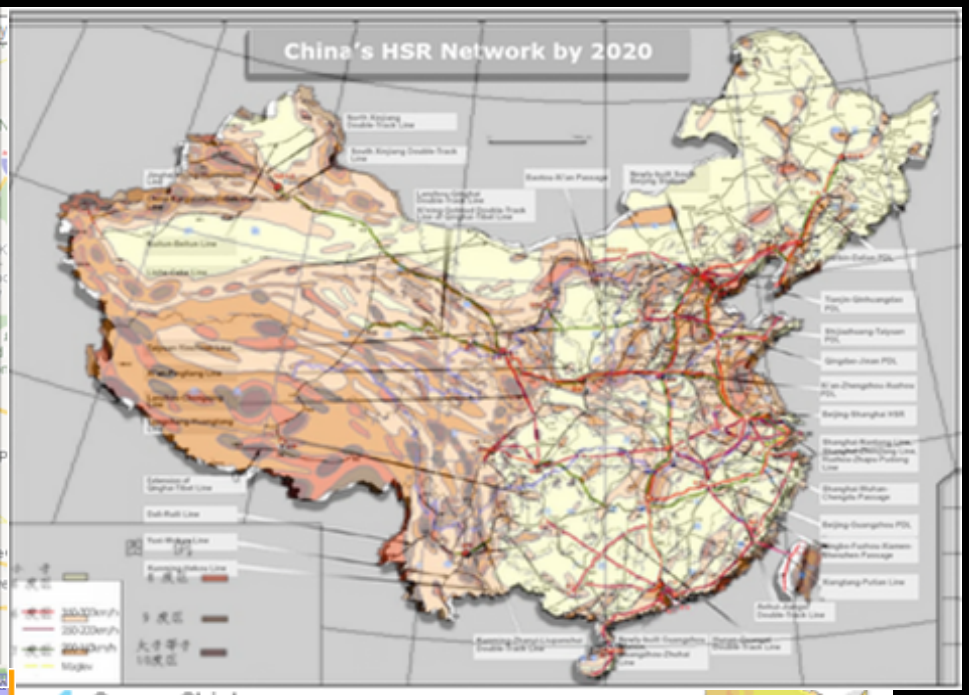
- Will be translated by Uena (Kyoto University) starting September 1, 2010

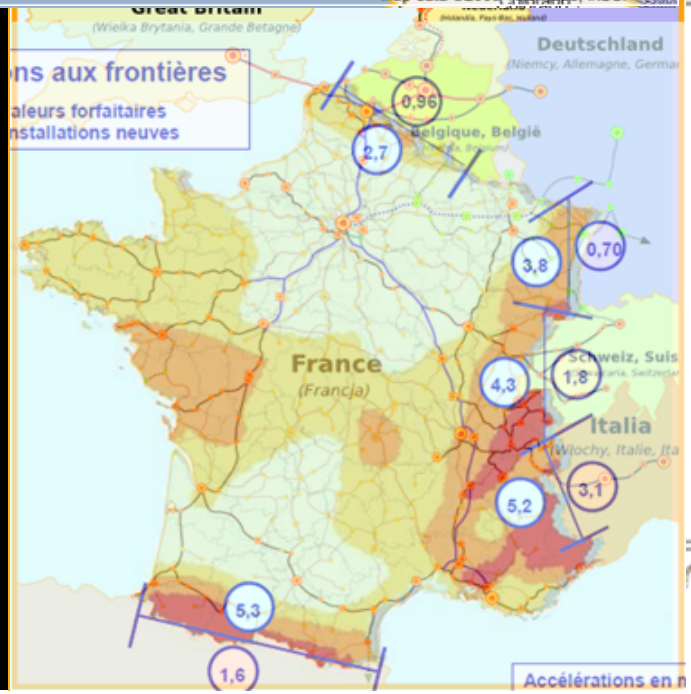
Analysis and Comparison of Codes

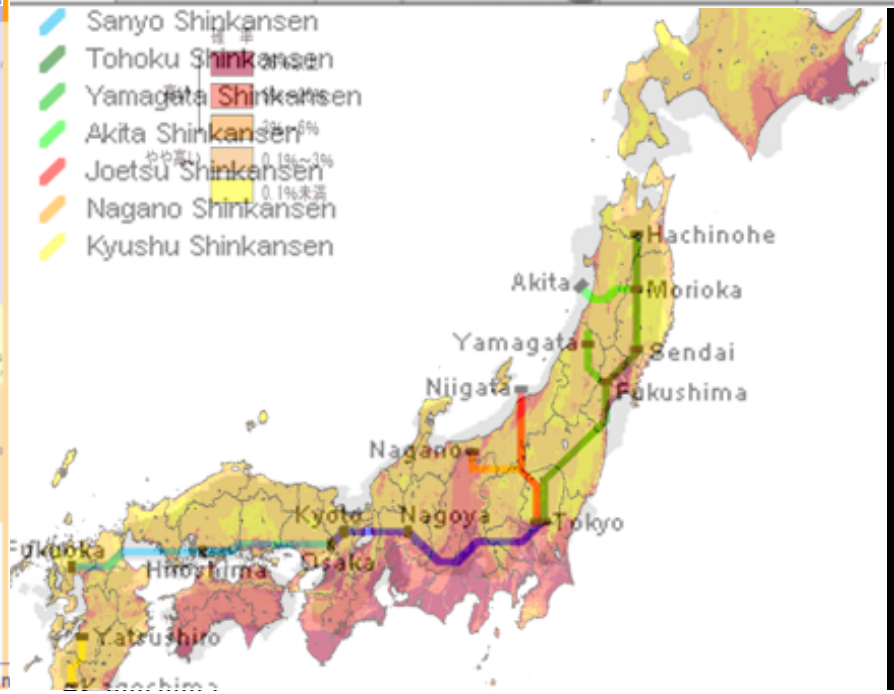
Topics Covered	Caltrans (bridge)	China (HSR)	Euro (general structures)	Japan (HSR)
Specific to Railways		X		X
Demand				
Ground Motion Representation	X	X	X	X
Ground Classification	X	X	X	X
Response Spectrum	X	X	X	X
Displacement Limit	X		X	X
Structures				
Foundations	X	X	X	X
Bridges	X	X	X	X
Tunnels		X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

<u>4 major topics:</u> Hazards / Performance criteria / Analysis / Structural design

Seismic Hazards







Design Earthquakes

Caltrans (bridge)

Ordinary bridges	deterministic assessment corresponding to the MCE
Important bridges	deterministic or probabilistic assessment

T<0.5sec	Spectral acceleration magnification = 0
0.5<T<1.5sec	linear interpolation
T>1.5sec	20%

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.

China (HSR)

low-level EQ	return period of 50 years
design EQ	475 years
high-level EQ	2475 years

seismic level = 6	Ag (m/s^2) = 0.05g
7	0.10g-0.15g
8	0.20g-0.30g
9	0.40g

Euro (general structures)

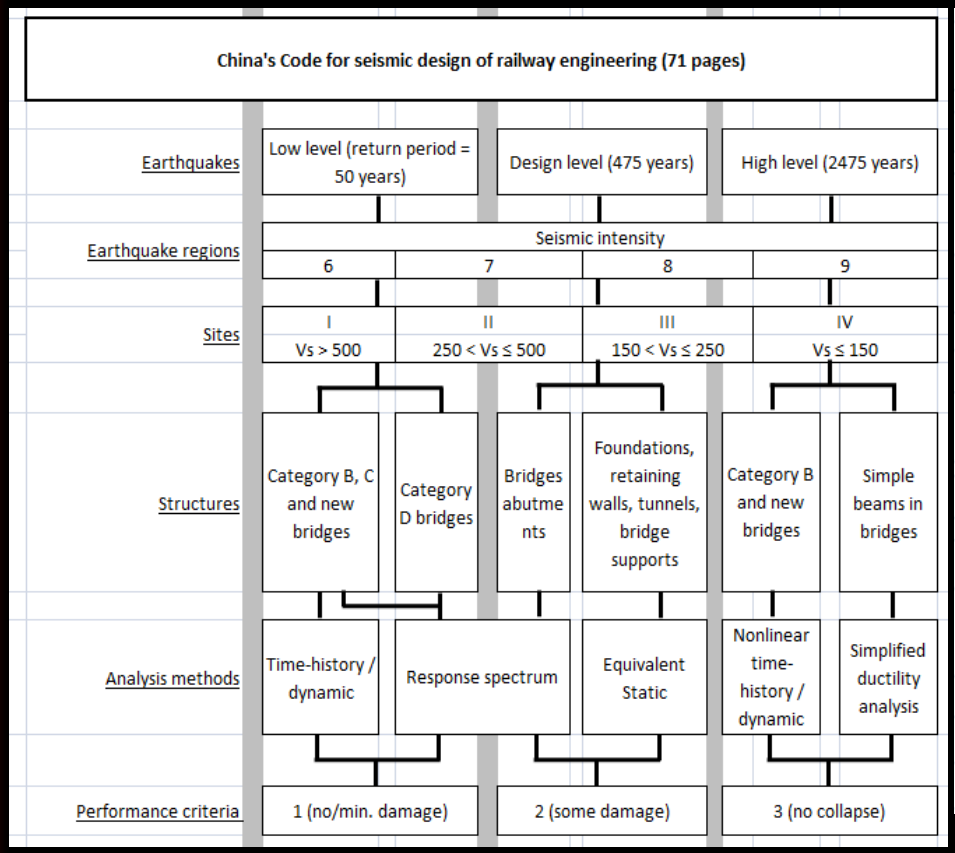
Type 1	others
Type 2	have a surface-wave magnitude, Ms <5.5

Japan (HSR)

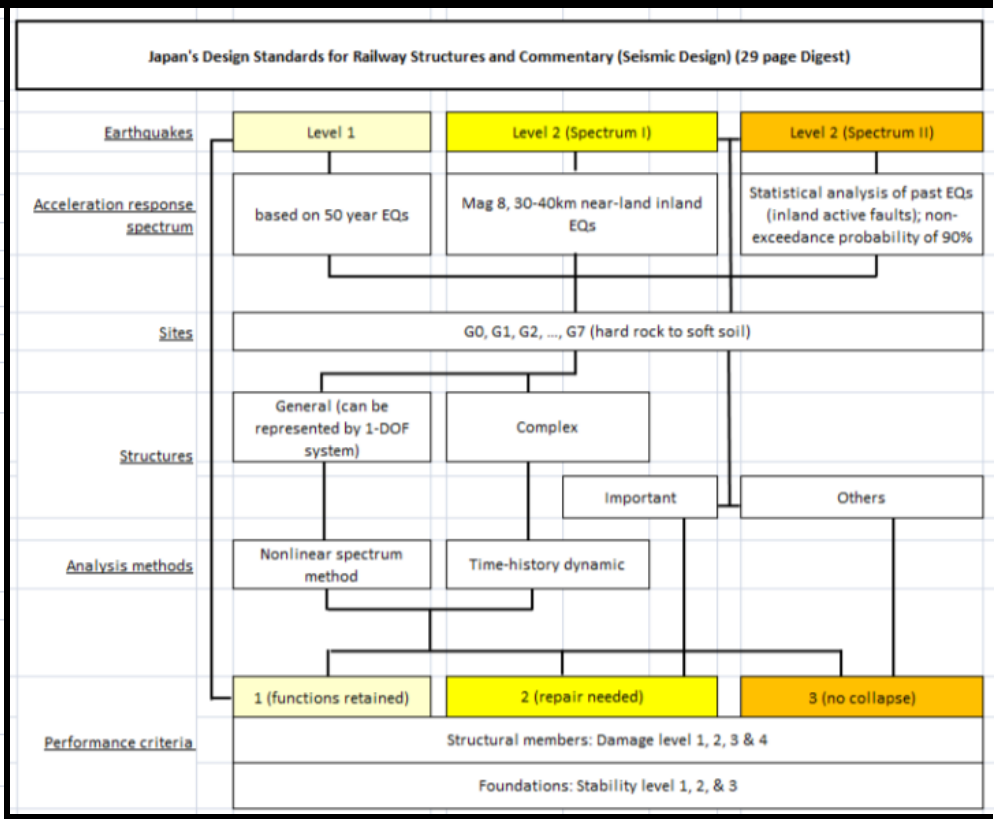
Level 1	based on ARS determined for firm ground classified in the conventional allowable stress design method; return period of 50 years; max value = 250gal (damping ratio 5%)
Level 2 (Spectrum I)	ARS targeting near-land interpolate EQs (Mag. 8, 30-40km to epicenter)
Level 2 (Spectrum II)	ARS targeting determined according to statistical analysis based on past EQs produced by inland active faults
Level 2 (Spectrum III)	ARS targeting determined according to rupture mechanism of faults

Design Code Flowcharts

China



Japan



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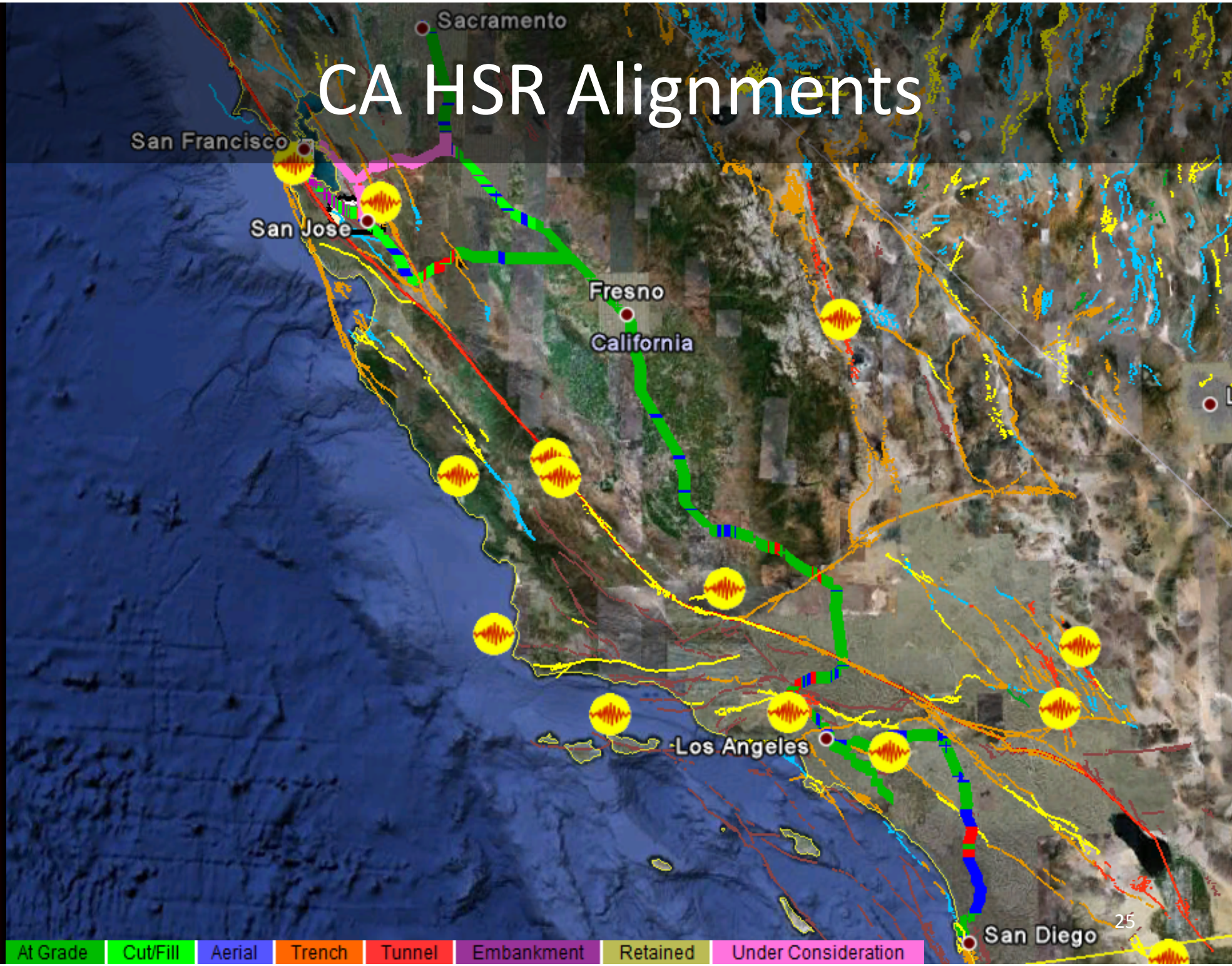
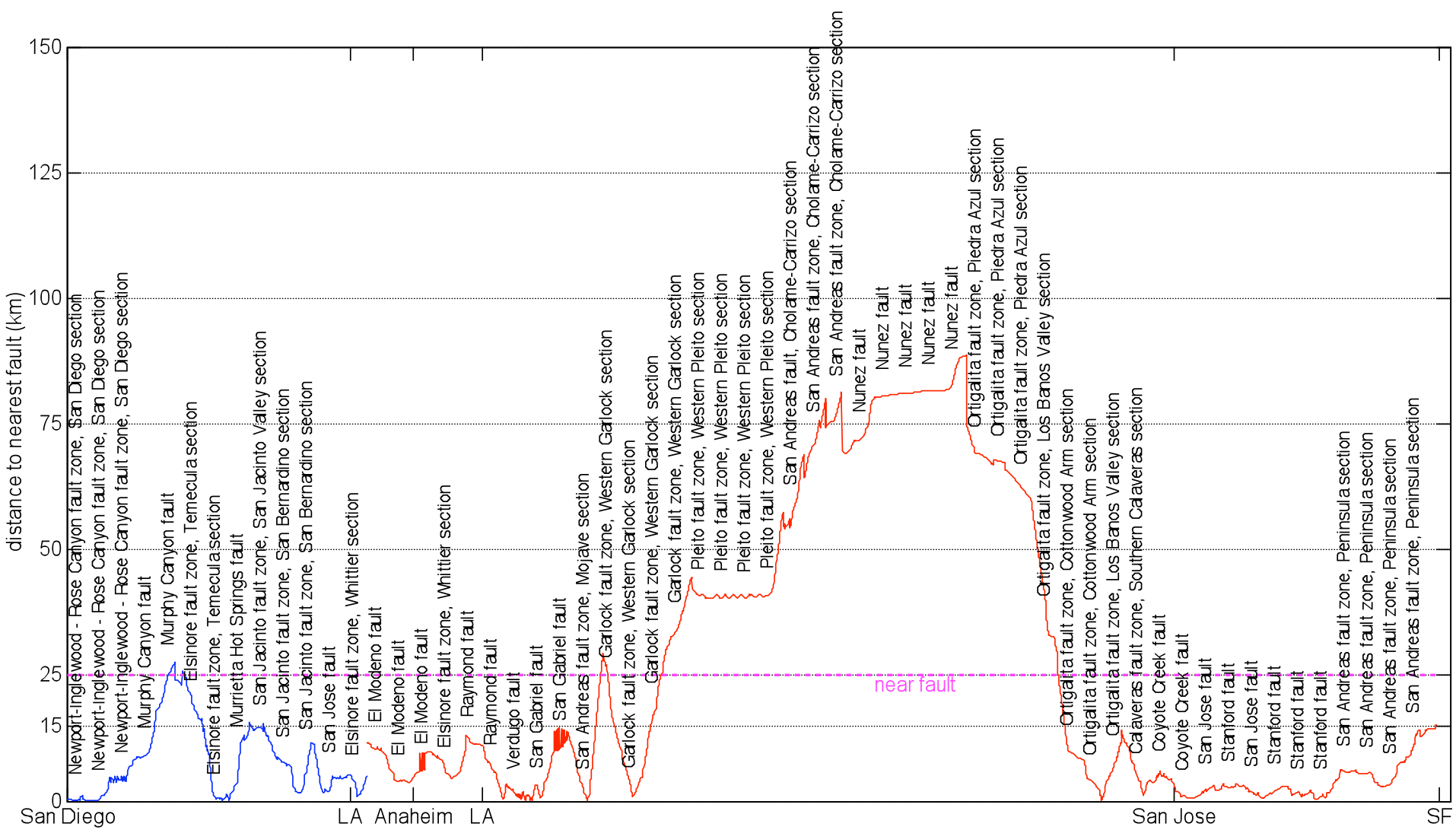
CA HSR Alignments



Distances to Faults along CA HSR



Aerial

At Grade

Cut & Fill

Embankment

Retaining Wall

Trench

Tunnel

Segment Type	Length (km)	Length (miles)	Fault Crossing
Aerial	201.7	125.2	7
At Grade	703.7	437.0	9
Cut & Fill	195.9	121.6	2
Embankment	2.1	1.3	0
Retaining Wall	28.8	17.9	0
Trench	11.6	7.2	1
Tunnel	67.6	42.0	2
Under Consideration	168.3	104.5	12
total	1379.7	856.8	**33**

Response Spectra - Caltrans ARS Online

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RESOURCES

- Caltrans
- Research & Innovation
- Earthquake Engineering
- Geotechnical Services

Developed By

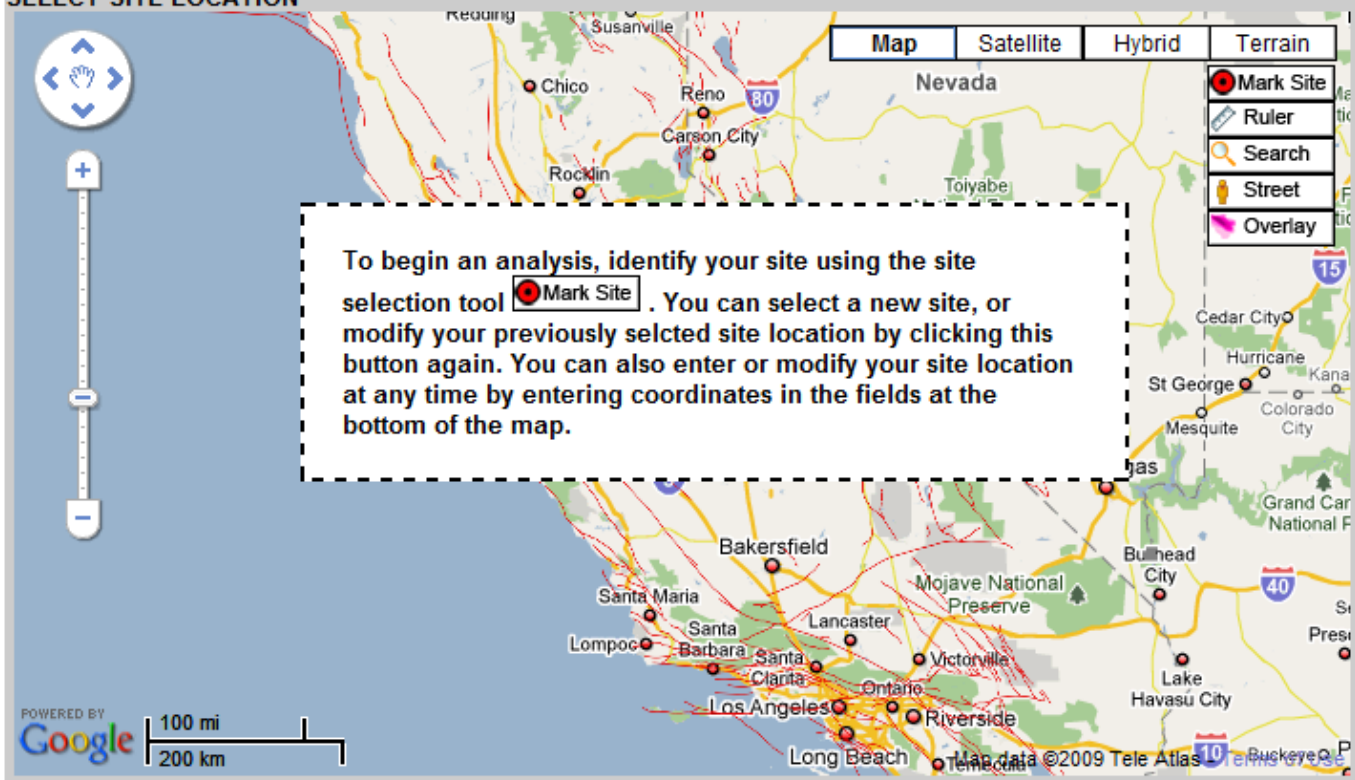
GeoResearch Group — Caltrans — Research & Innovation

In Partnership With

Caltrans ARS Online

This web-based tool calculates both deterministic and probabilistic acceleration response spectra for any location in Californ

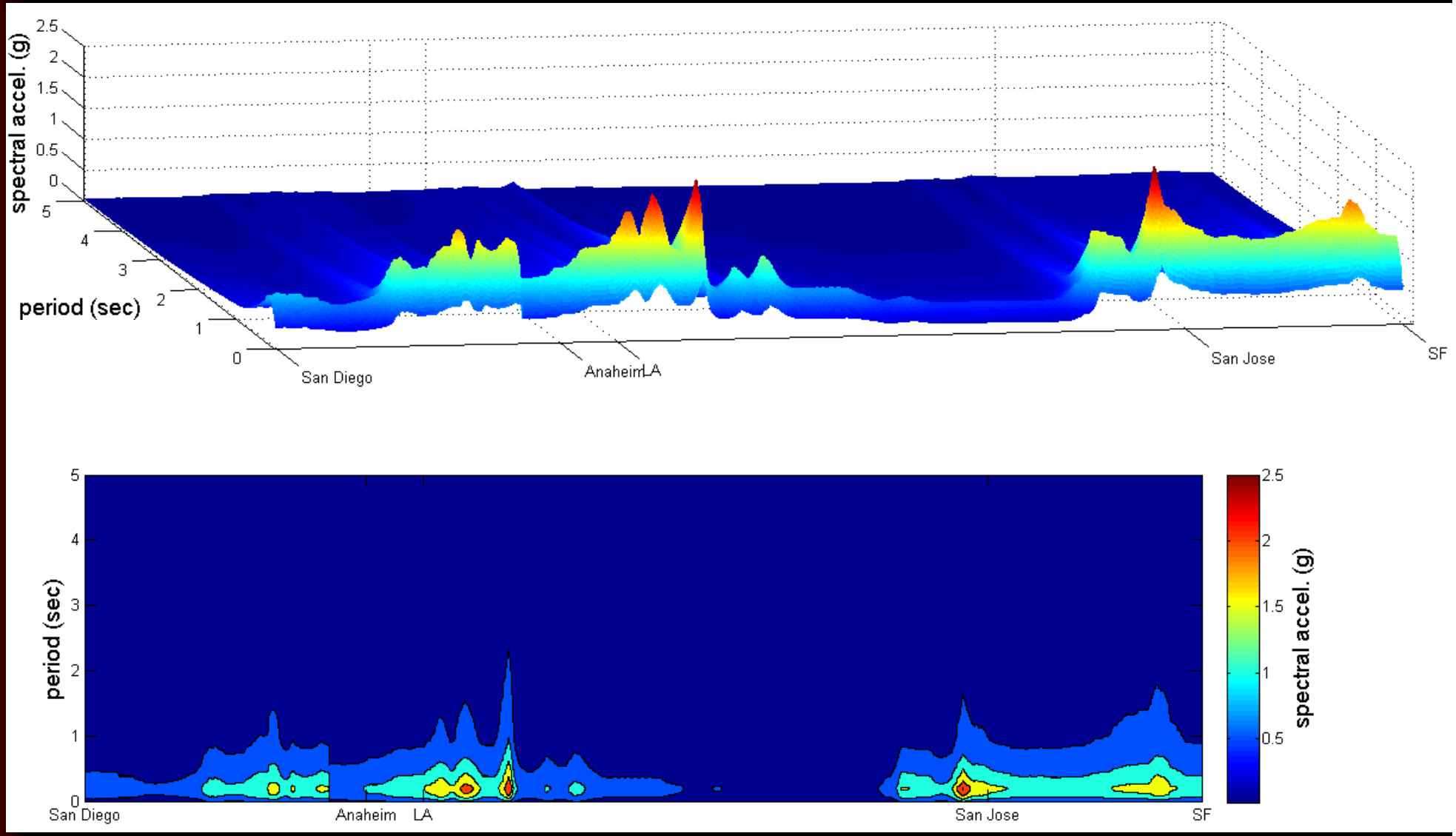
SELECT SITE LOCATION



To begin an analysis, identify your site using the site selection tool Mark Site . You can select a new site, or modify your previously selcted 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.

Latitude: Longitude: V_{S30}: m/s Calculate

Spectral Accel. along CA HSR



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

- Introduction
- Project status
  - International visits
  - Design codes
  - California HSR seismic demands
- Challenges and future work
  - Workshop organization
  - Collaborations

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, …)

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….

PEER

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Workshop on Seismic Design and Performance of High Speed Rail Systems

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