High Speed Rail and Earthquakes

PEER Annual Meeting

Transportation Systems Research Program

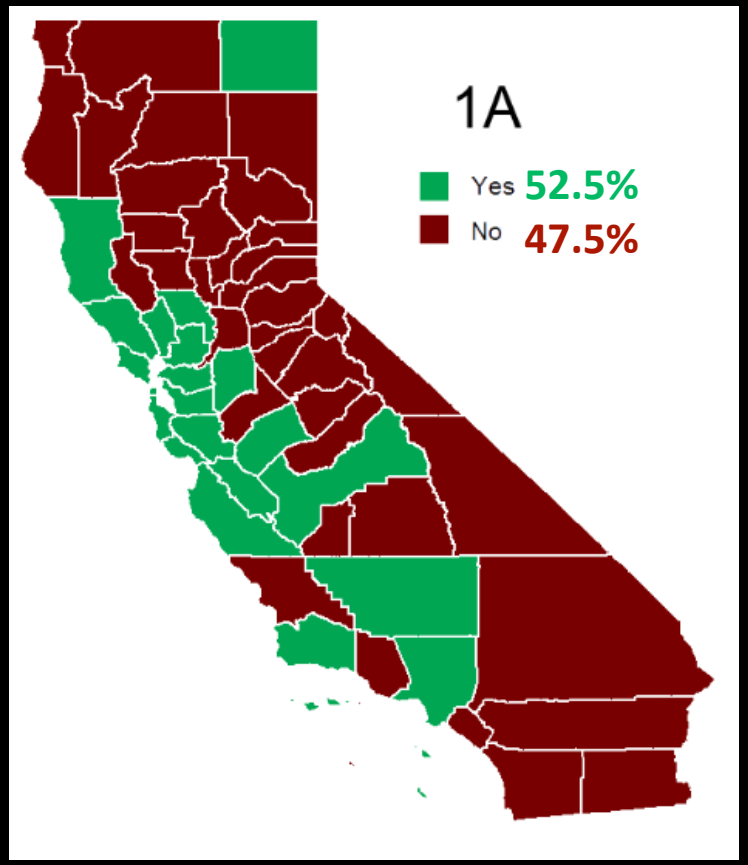
Jean-Pierre Bardet & Tat S. Fu @ USC

Oct 16, 2009

California High Speed Rail (HSR)

Proposition 1A (2008)

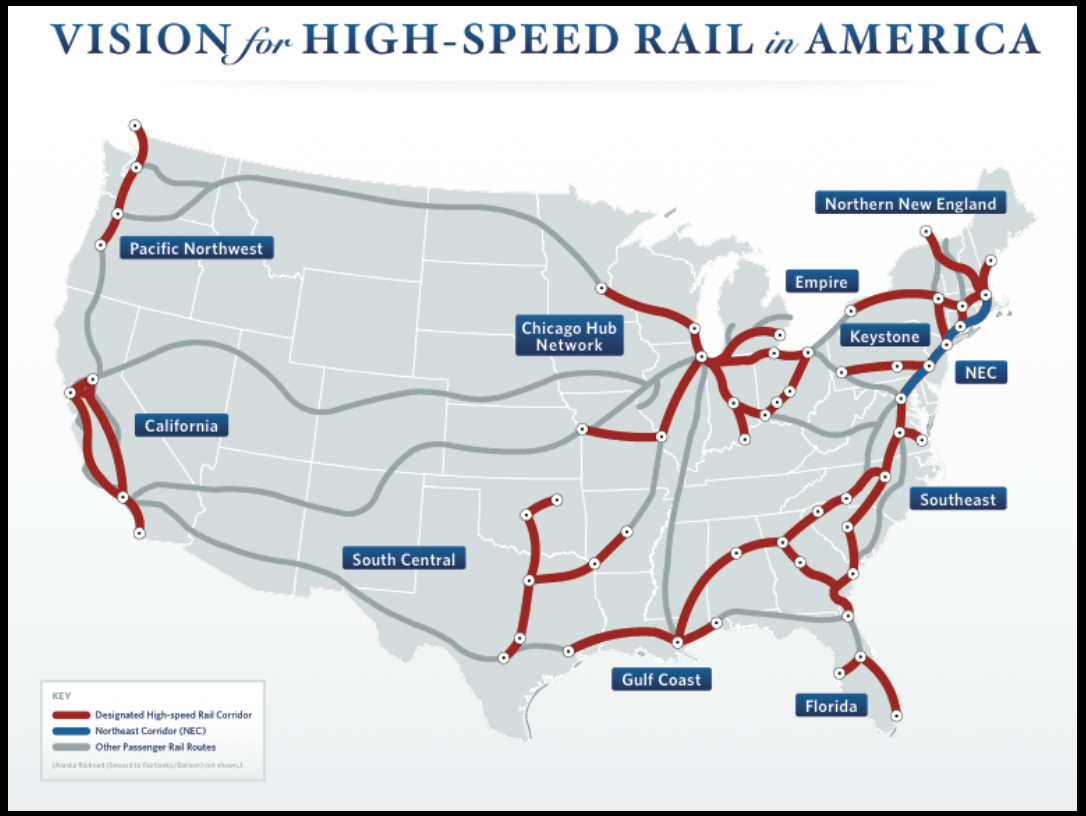
Safe, Reliable High-Speed Passenger Train



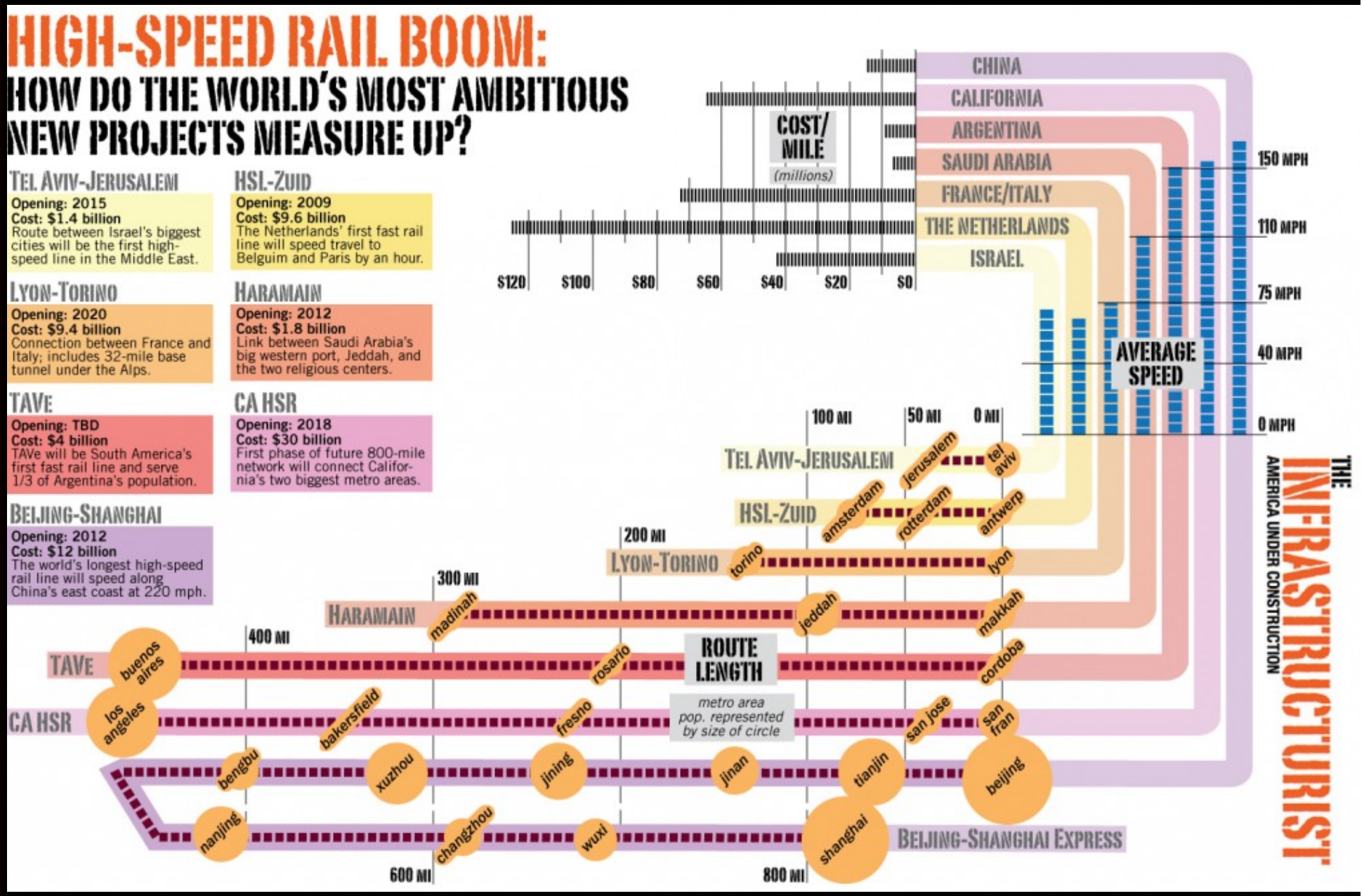
http://en.wikipedia.org/wiki/California_Proposition_1A_%282008%29

Reinvestment and Recovery Act

"faster, cheaper & easier than building more freeways or adding to an overburdened aviation system"



http://www.sustainablecityblog.com/2009/04/obama-unveils-high-speed-rail-vision/



http://www.infrastructurist.com/2009/04/06/chart-comparing-new-hs-projects-around-the-world/

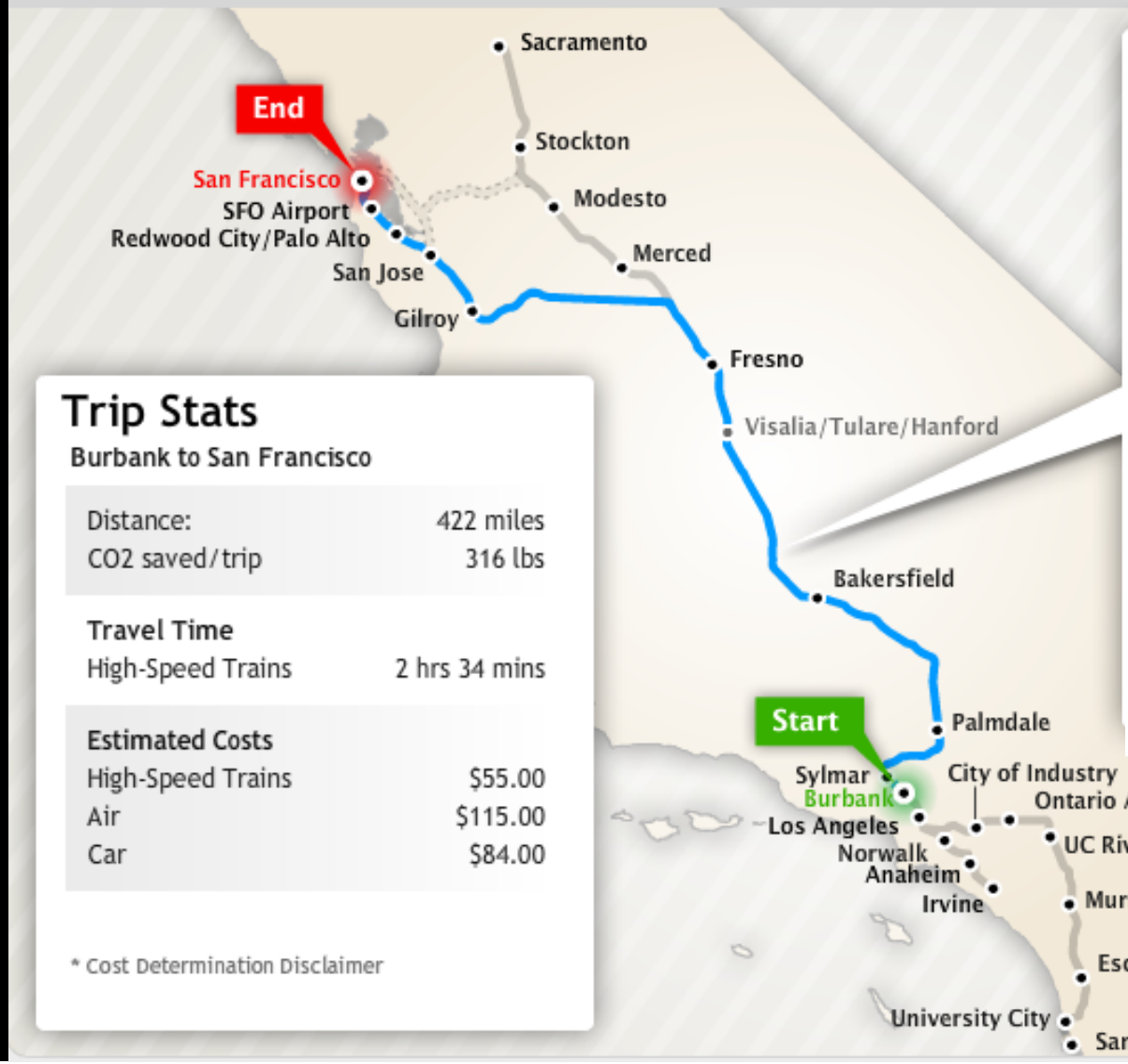
Sonny Astani Dept of Civil & Environ. Engineering
USC

CALIFORNIA High-Speed Rail Authority

Home | FAQs | Routes | Gallery | News & Facts | Library | Board | Contact

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

Earlier Today:

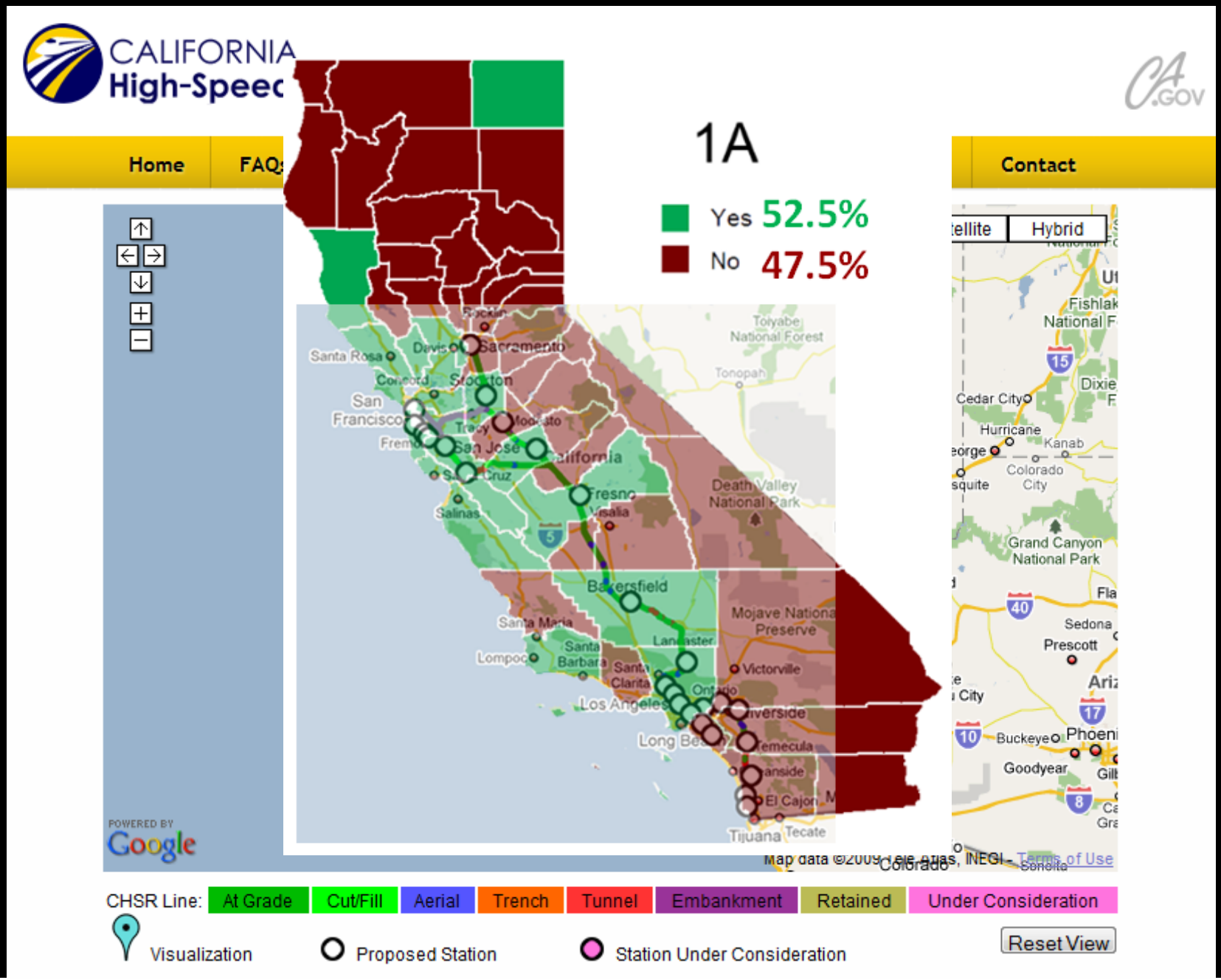
Burbank to SF with United Air:

Check in:	45 min
DELAY (fog):	1 h 20 min
Flight:	1 h 19 min
SFO – Downtown:	30 min
Total:	**3 h 54 min**
Fare:	**$230**

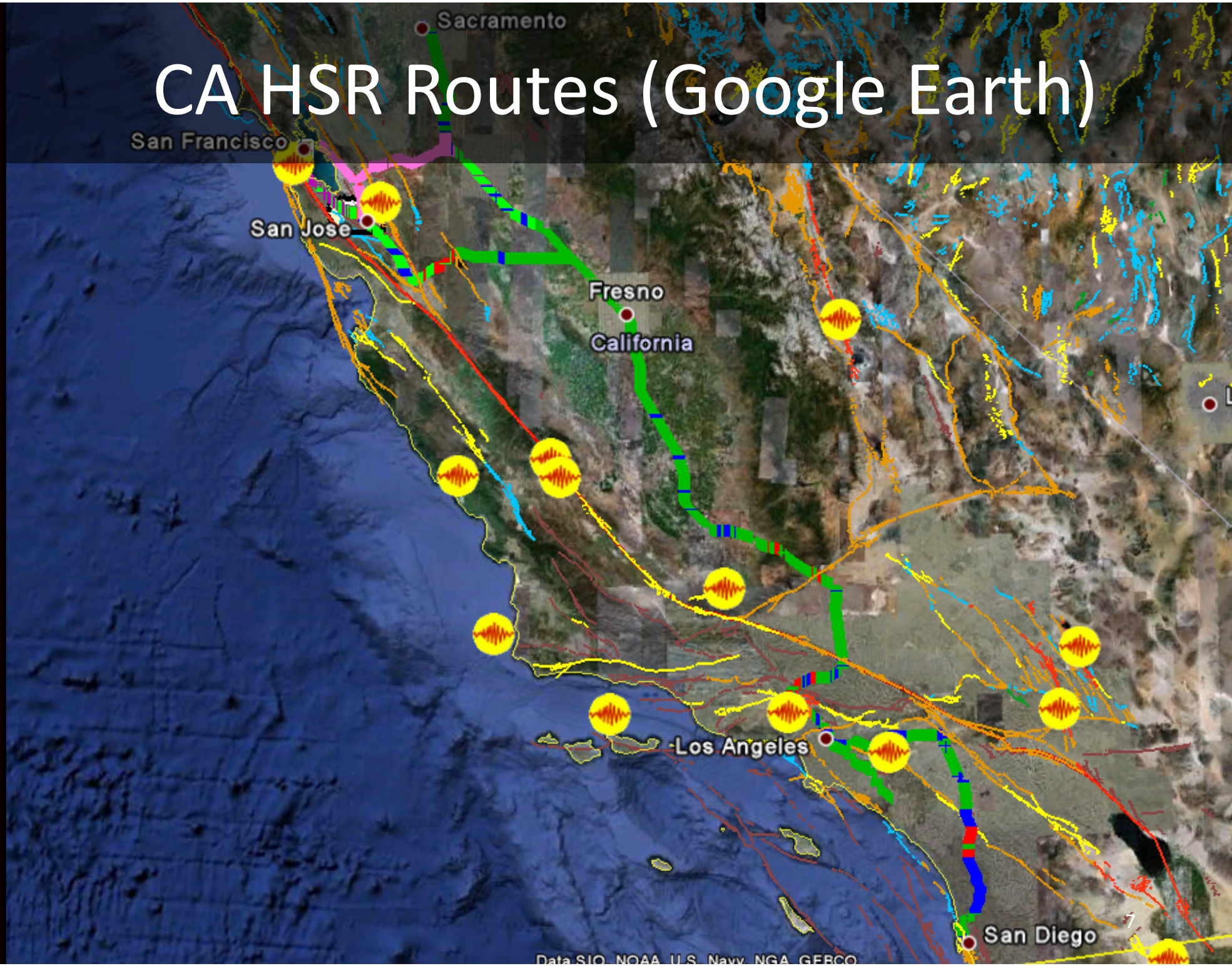
Outline

- **Introduction**
  - CA High Speed Rail (HSR)
  - HSR systems around the world
- **Earthquakes and HSR**
- **Earthquake hazards for CA HSR**
  - Earthquake faults
  - Liquefaction
- **Solution example**

CA HSR Routes (Google Map)



CA HSR Routes (Google Earth)



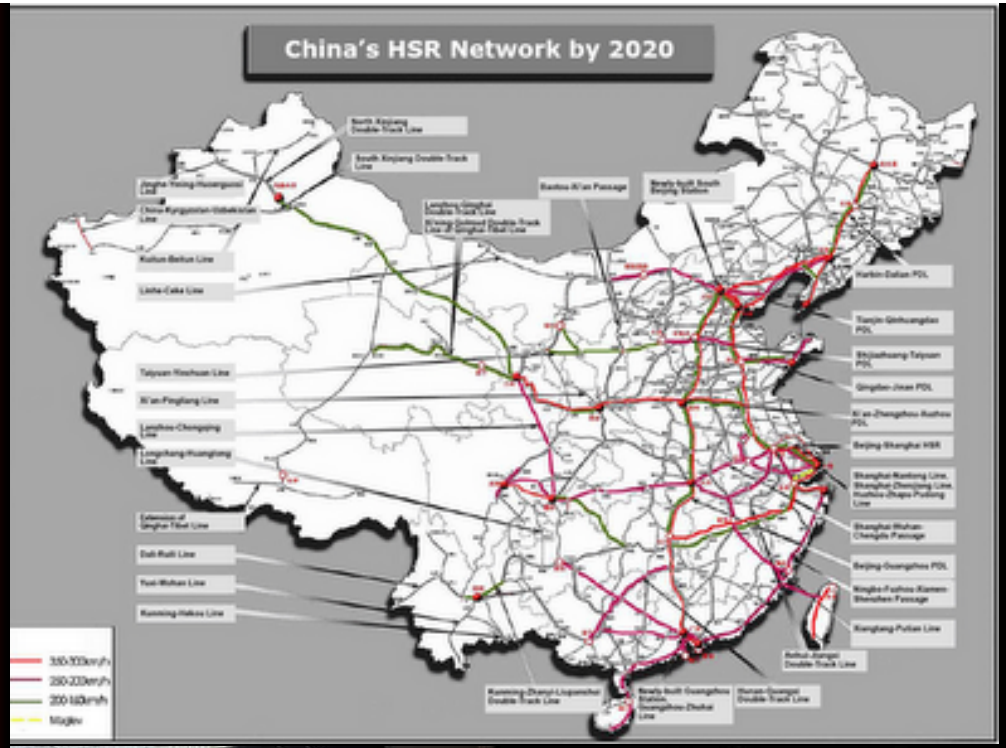
around the World

JAPAN

- Shinkansen (新幹線)
- 1528 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 Koseki



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

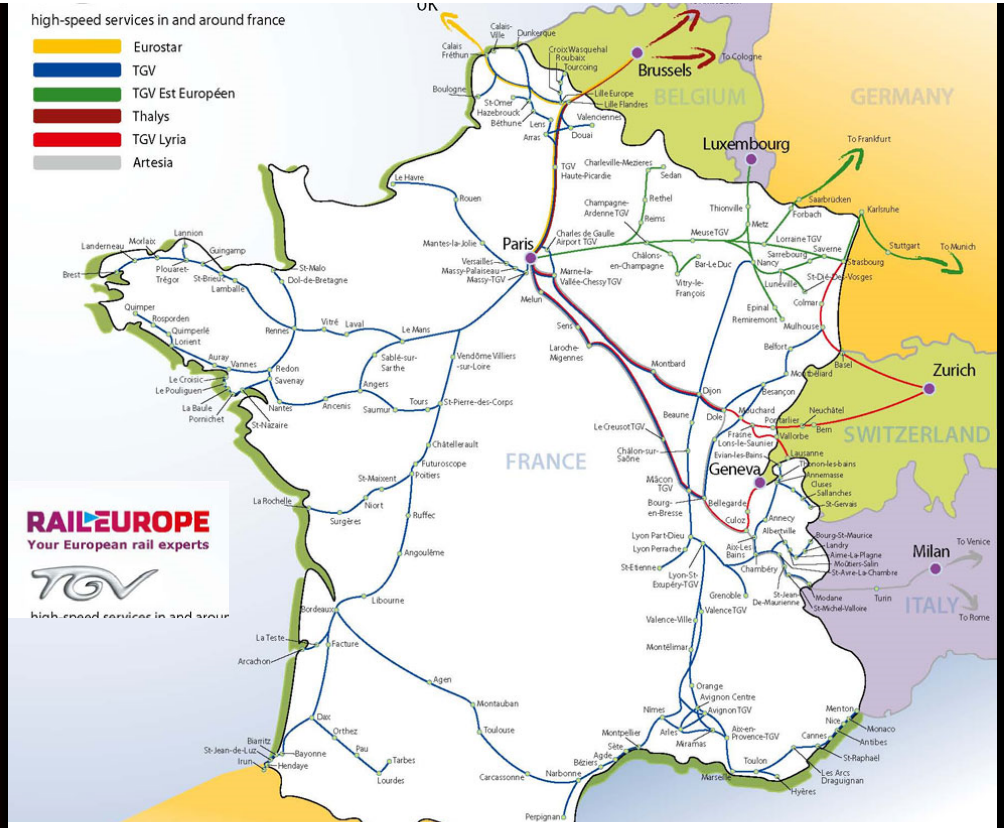
西南交通大學
Southwest Jiaotong University

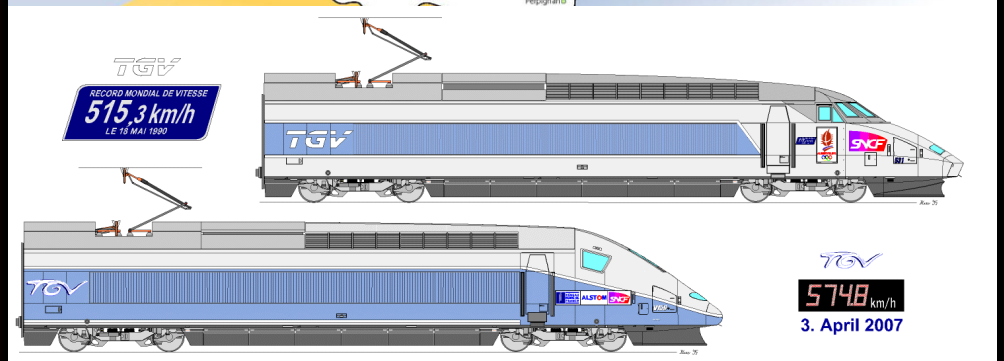
China

- 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, …





France

- TGV (Train à Grande Vitesse)
- Fastest in the world
- Systra

Outline

- **Introduction**
  - CA High Speed Rail (HSR)
  - HSR systems around the world
- **Earthquakes and HSR**
- **Earthquake hazards for CA HSR**
  - Earthquake faults
  - Liquefaction
- **Solution example**

Earthquakes and HSR

M6.6 EQ
Niigata-ken Chuetsu Japan
October 23, 2004

M8.0 EQ
Wenchuan, Sichuan, China
May 12, 2008


920


Japan

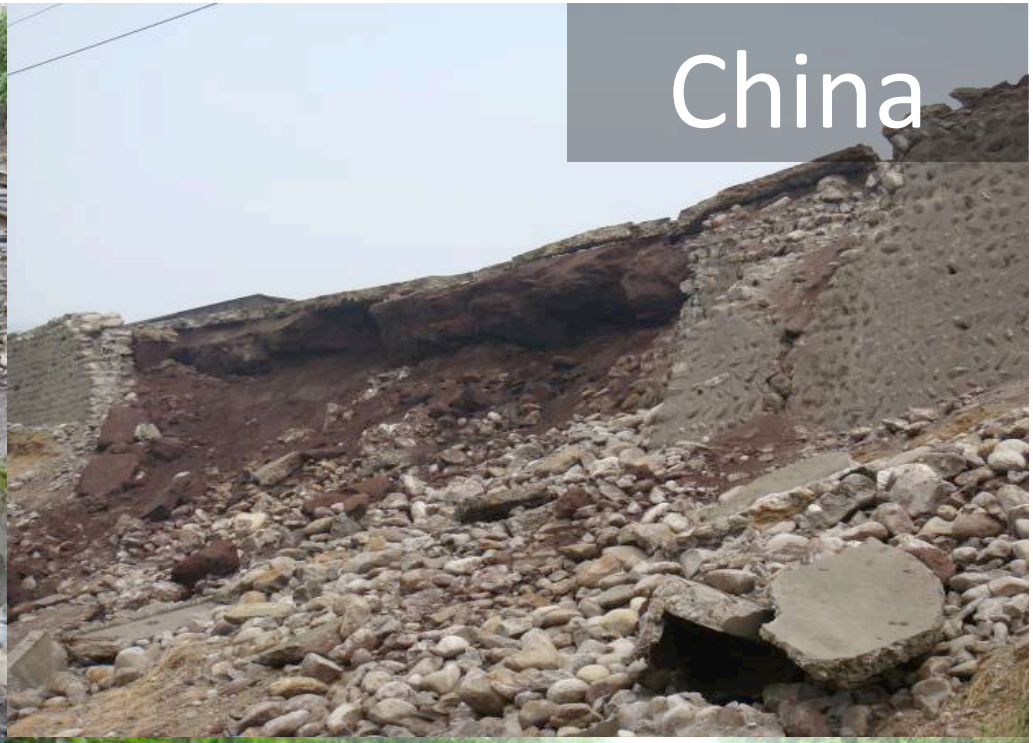
Japan

Japan


2008/05/21 08:34


China

China

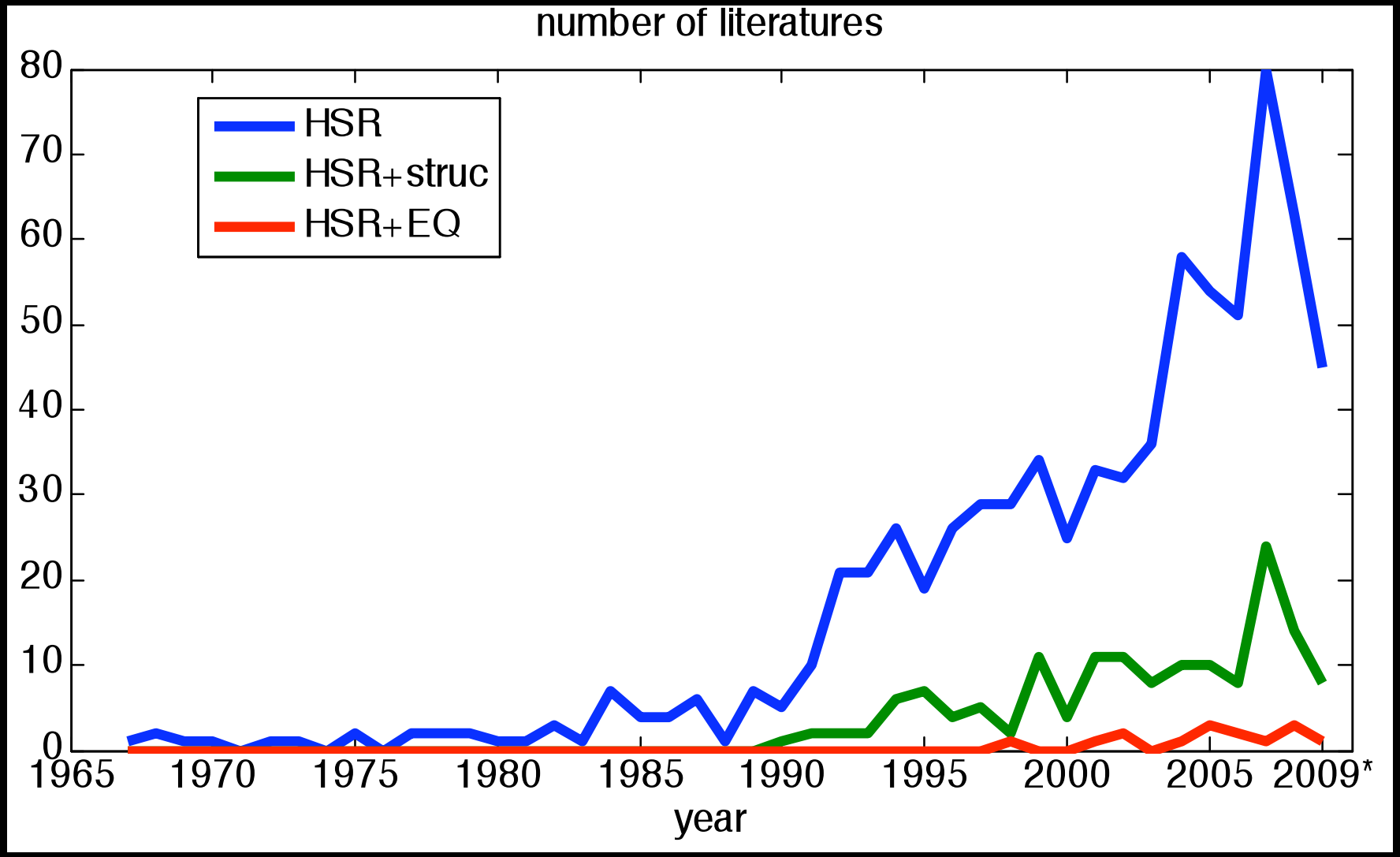


China

Fault Crossing

The Chichi, Taiwan, Earthquake of September 21, 1999

Literature Review

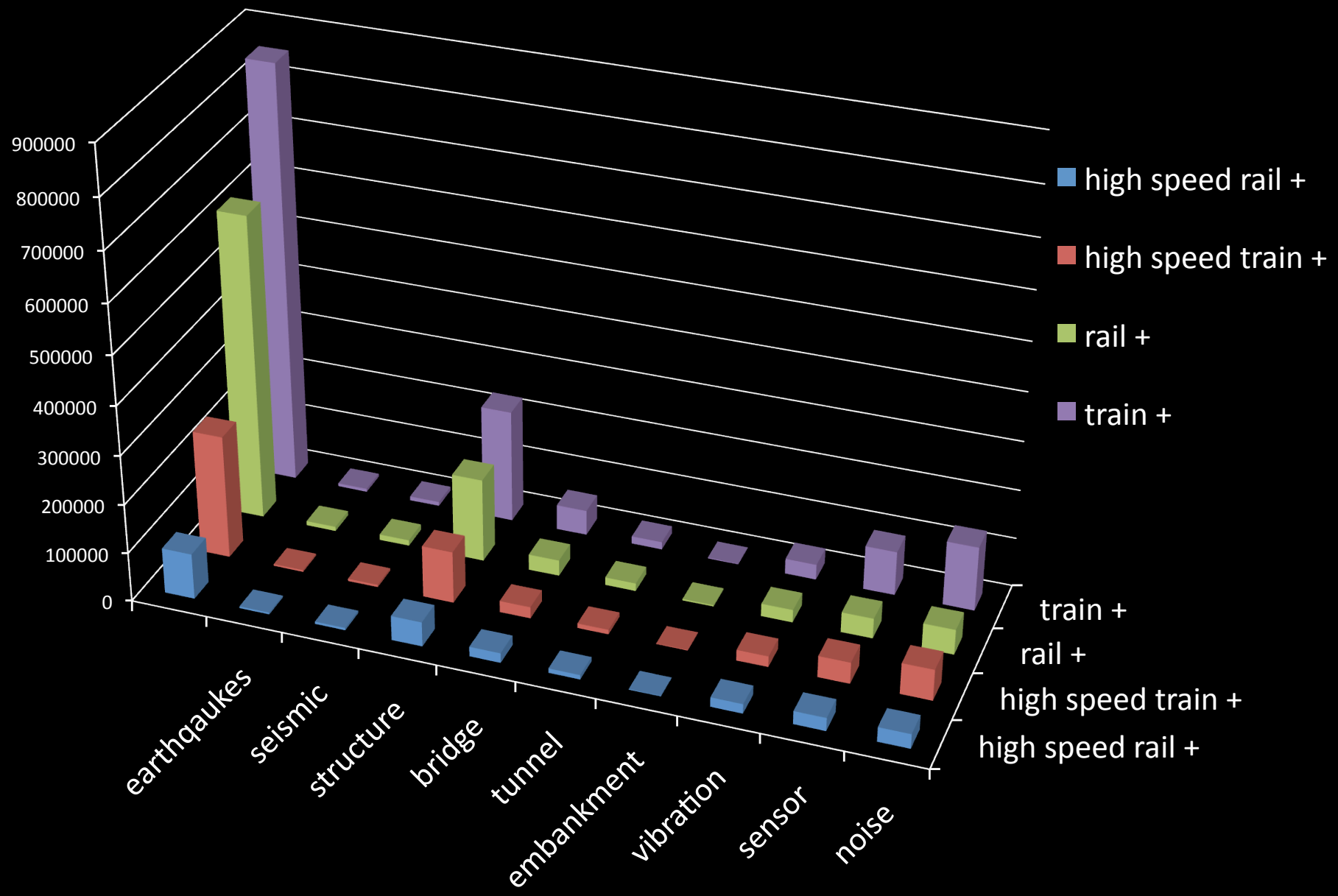


Keyword search on "Web of Science"

Literature Review

	# of Results			
keywords	high speed rail +	high speed train +	rail +	train +
(nothing)	93400	252000	623000	854000
earthquake	3720	3740	9040	6360
seismic	4960	4960	11600	8420
structure	50300	106000	170000	230000
bridge	20000	23500	32400	51300
tunnel	9350	9640	16100	15600
embankment	1320	1320	3090	1700
vibration	19600	22200	26100	31400
sensor	26900	43700	41400	90300
noise	29900	63700	51800	132000

Keyword search on "Google Scholar (Engineering, Computer Science, and Mathematics)"


900000
800000
700000
600000
500000
400000
300000
200000
100000
0
earthqaukes
seismic
structure
bridge
tunnel
embankment
vibration
sensor
noise
high speed rail +
high speed train +
rail +
train +
train +
rail +
high speed train +
high speed rail +

Railway Technical Research Institute (RTRI)

2007.03

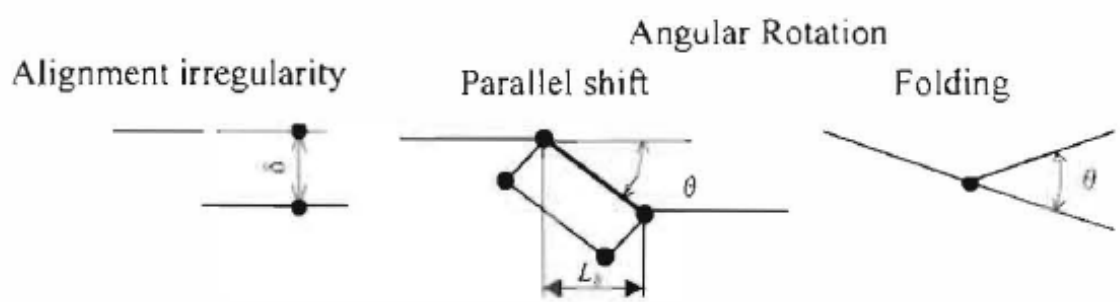
Design Standards for Railway Structures and Commentary (Seismic Design)

2007.03

Design Standards for Railway Structures and Commentary
(Seismic Design)

Table 12 Limit Values of Differential Displacement of Track Surfaces in a Seismic Condition

Direction	Maximum Speed (km/h)	Angular rotation θ (·1/1000)			Alignment Irregularity (mm)
		Parallel shift		Folding	
		L_b=10m	L_b=30m		
Lateral	130	7.0		8.0	14
	160	6.0		6.0	12
	210	5.5	3.5	4.0	10
	260	5.0	3.0	3.5	8
	300	4.5	2.5	3.0	7
	360	4.0	2.0	2.0	6



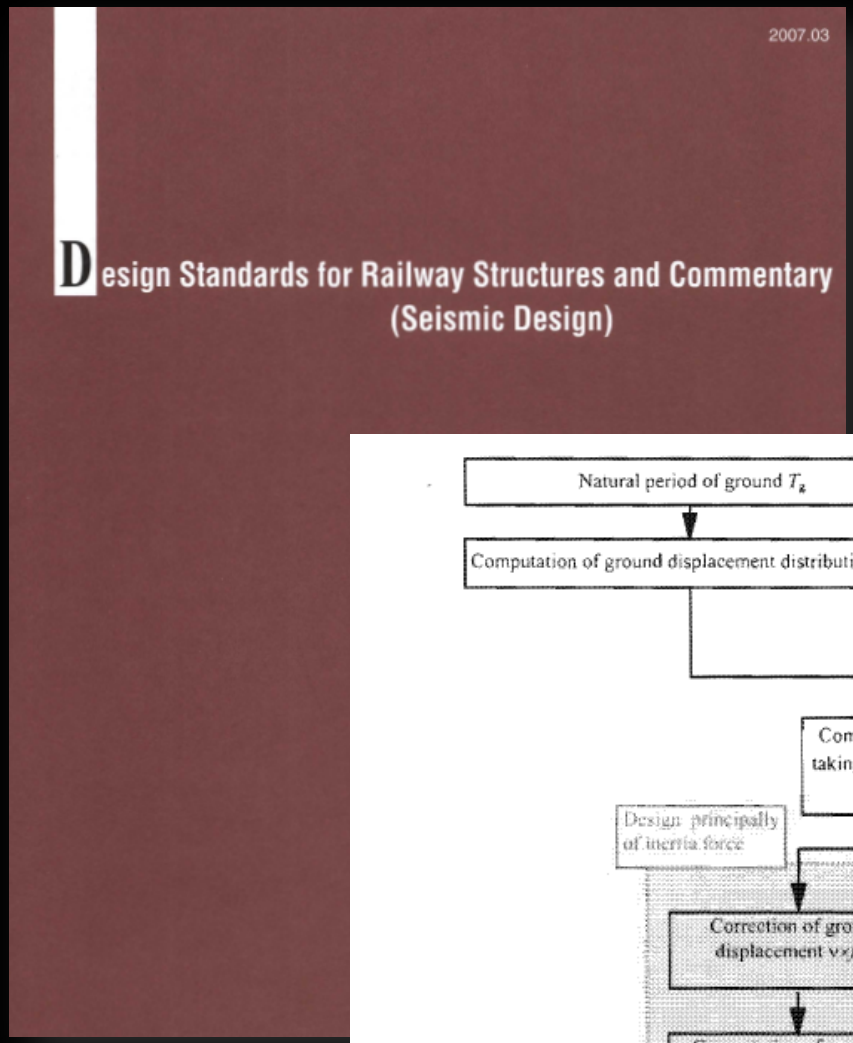
Retaining Wall

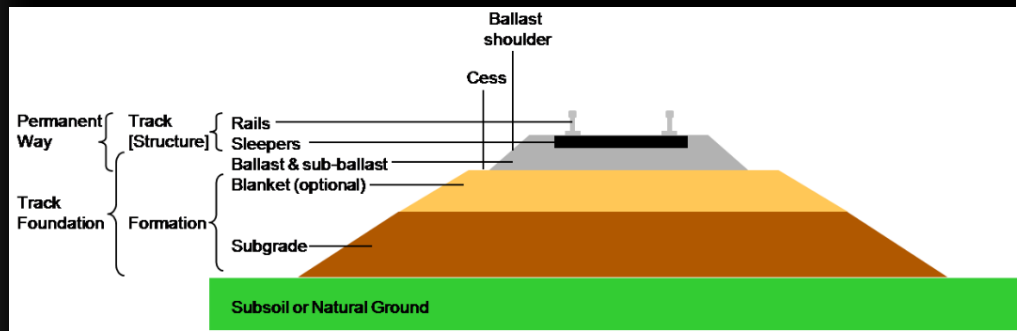
2007.03

Design Standards for Railway Structures and Commentary (Seismic Design)

Figure 23 Flow of Structural Analysis for Retaining Wall subjected to Level-2 Earthquake Motion

Foundation





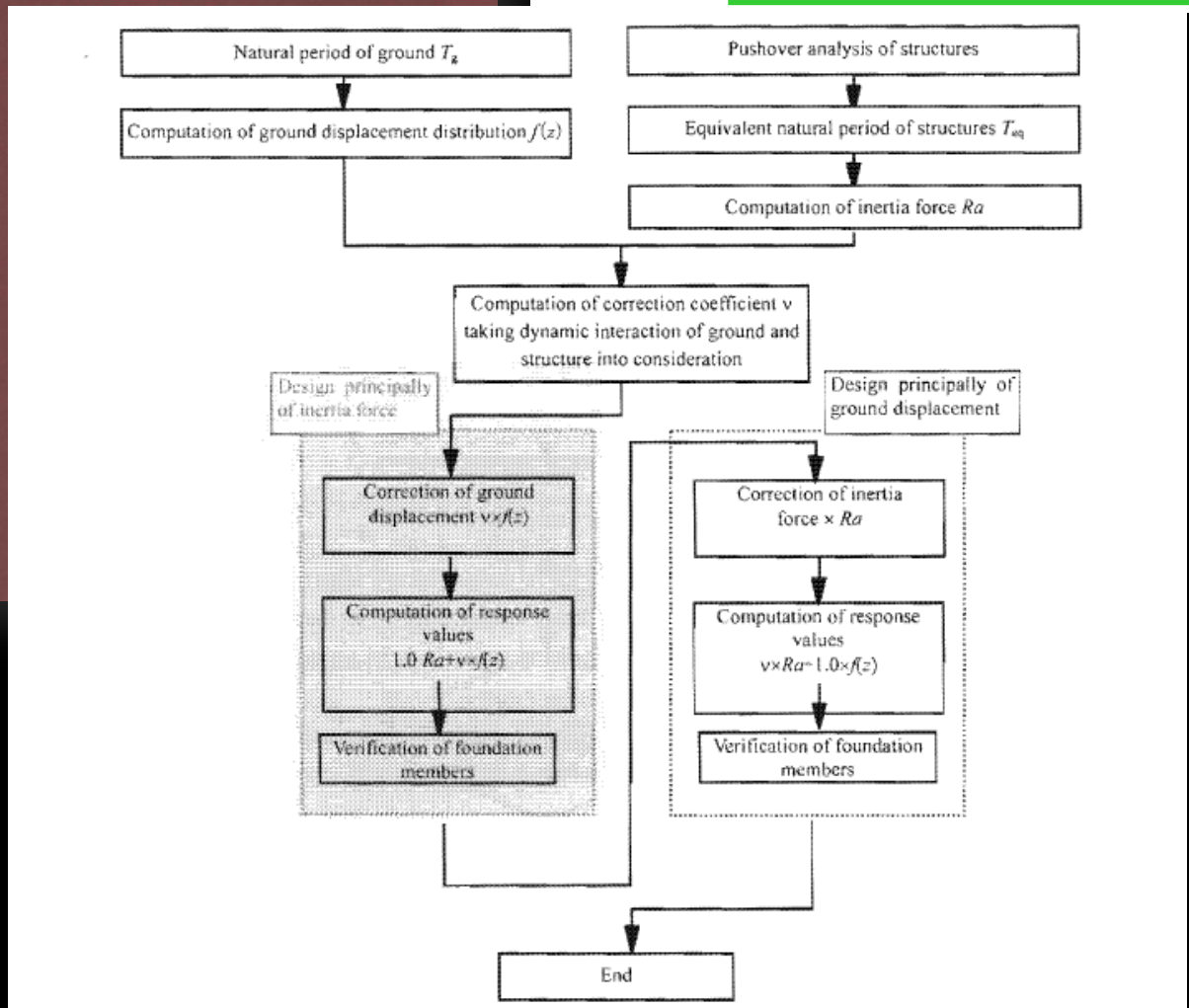


Figure 19 Flow Chart for Computing the Response Value of Foundation Structures by Seismic Deformation Method

Embankment

2007.03

Design Standards for Railway Structures and Commentary (Seismic Design)

Figure 20 Flow Chart for Seismic Design of Embankments

Bridge

2007.03

Design Standards for Railway Structures and Commentary
(Seismic Design)

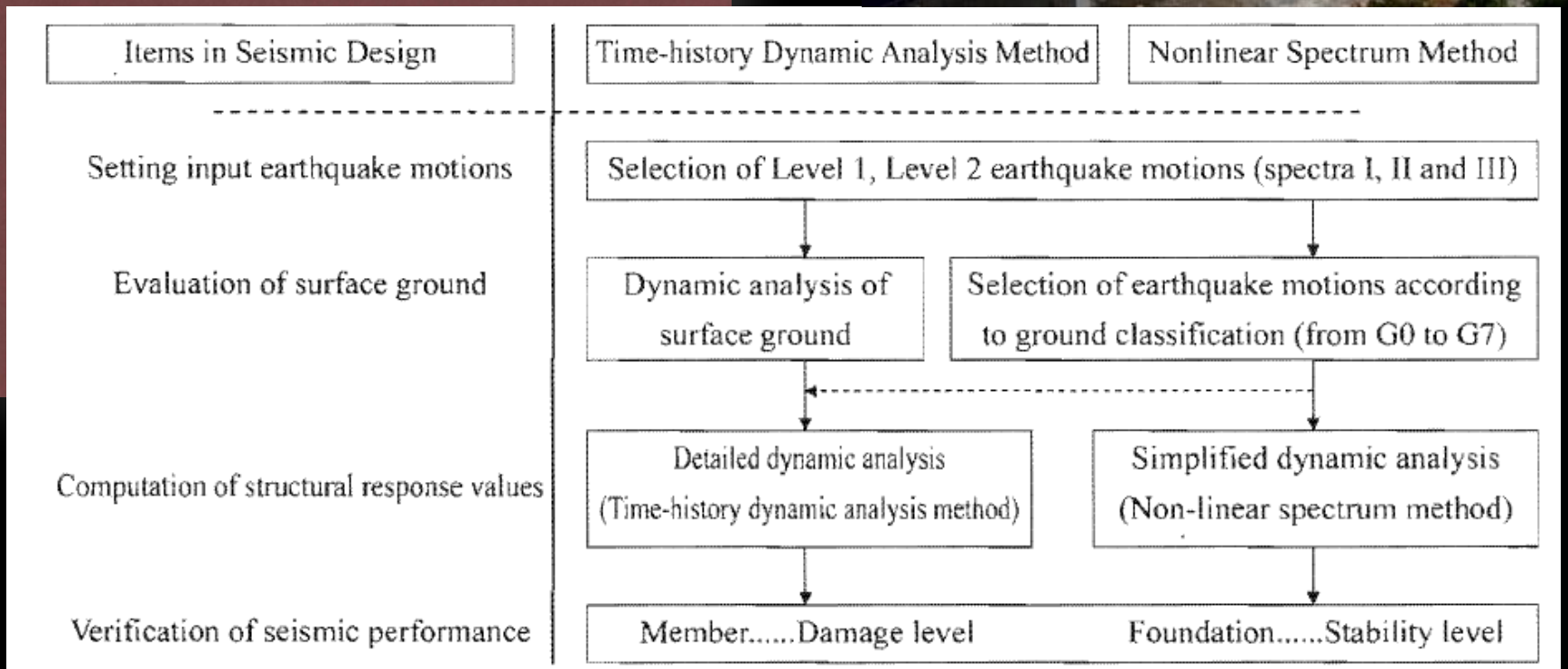


Figure 2 Seismic Design Procedure for Bridges and Viaducts

Liquefaction

2007.03

Design Standards for Railway Structures and Commentary
(Seismic Design)

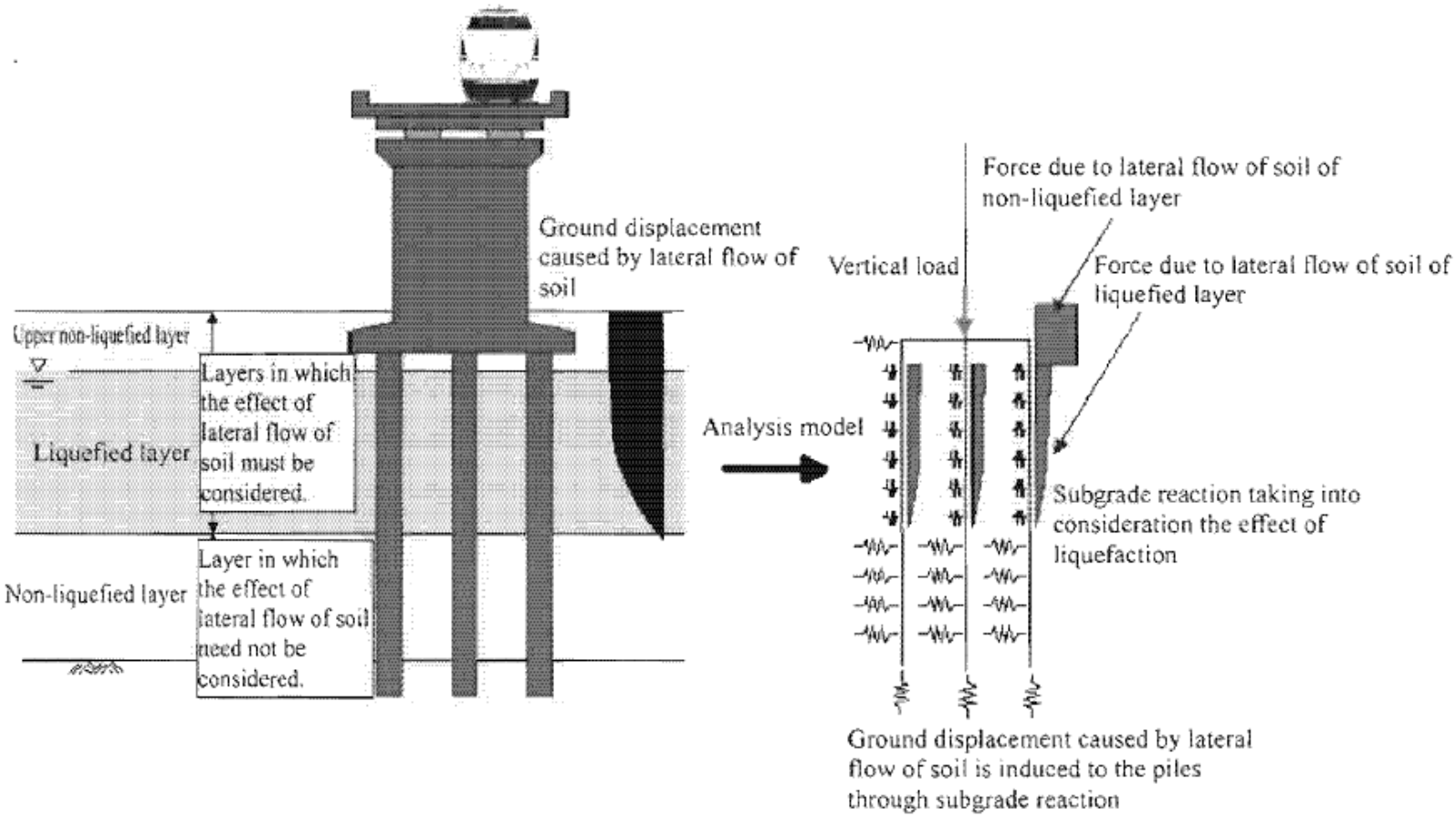
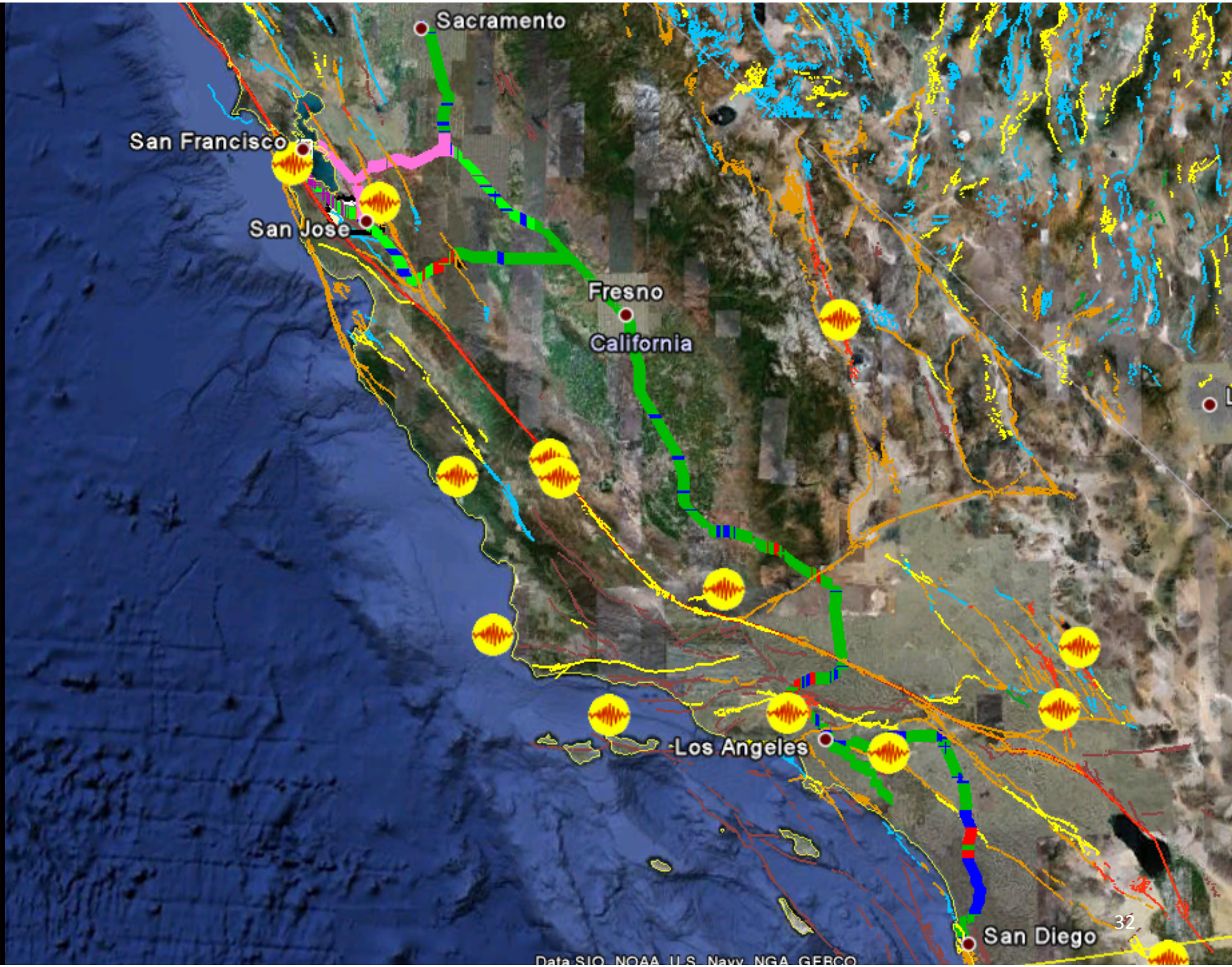


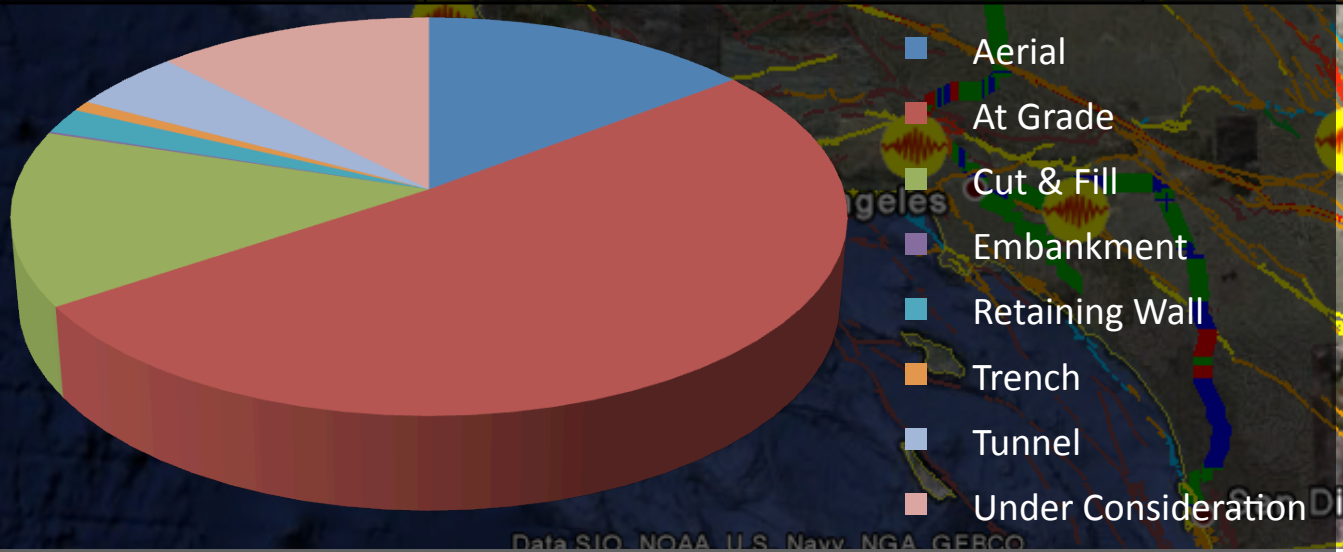
Figure 11 Consideration of Ground Displacement Caused by Lateral Flow of Soil

Outline

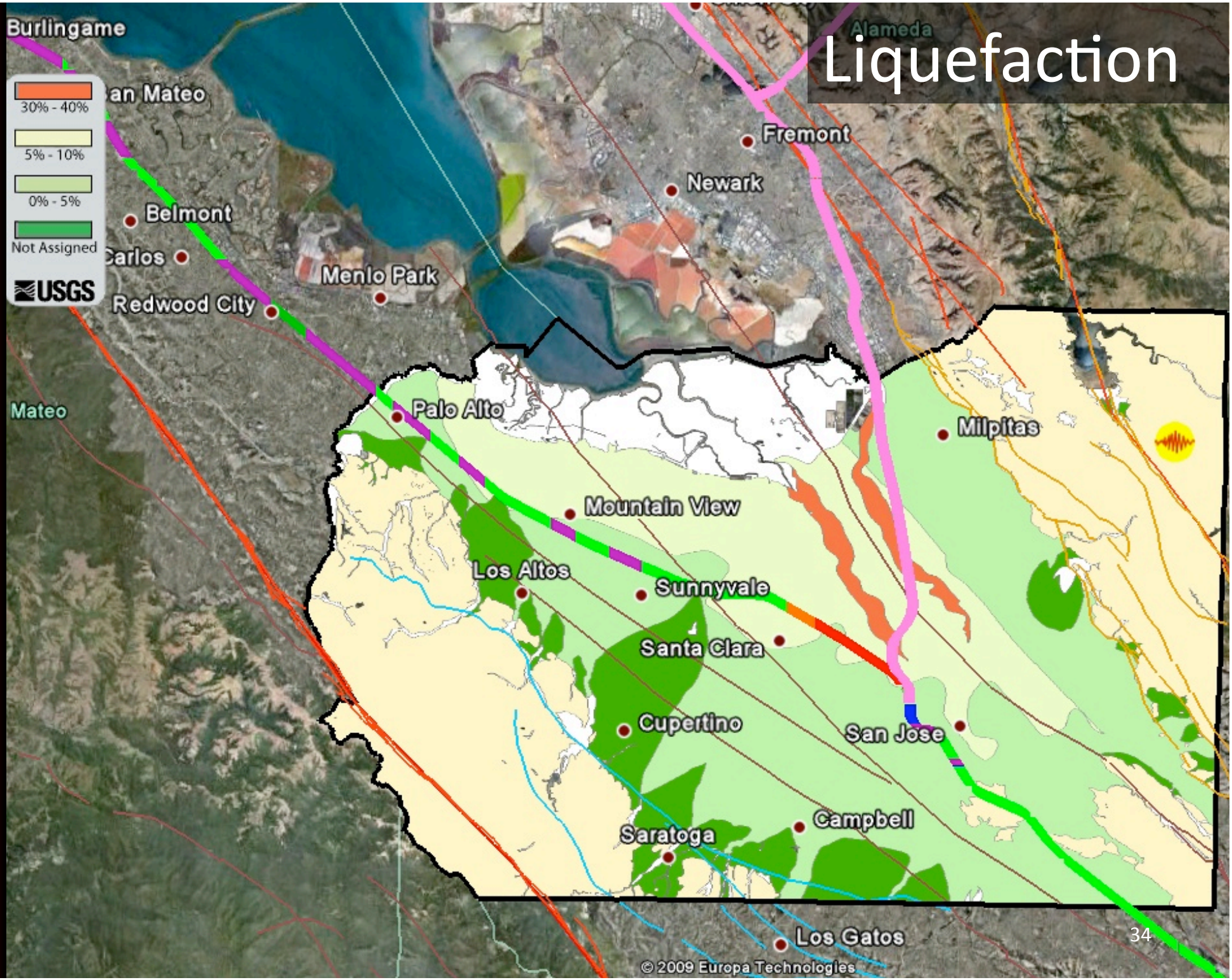
- **Introduction**
  - CA High Speed Rail (HSR)
  - HSR systems around the world
- **Earthquakes and HSR**
- **Earthquake hazards for CA HSR**
  - Earthquake faults
  - Liquefaction
  - Major earthquakes in CA
- **Solution example**


Sacramento
San Francisco
San Jose
Fresno
California
Los Angeles
San Diego
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

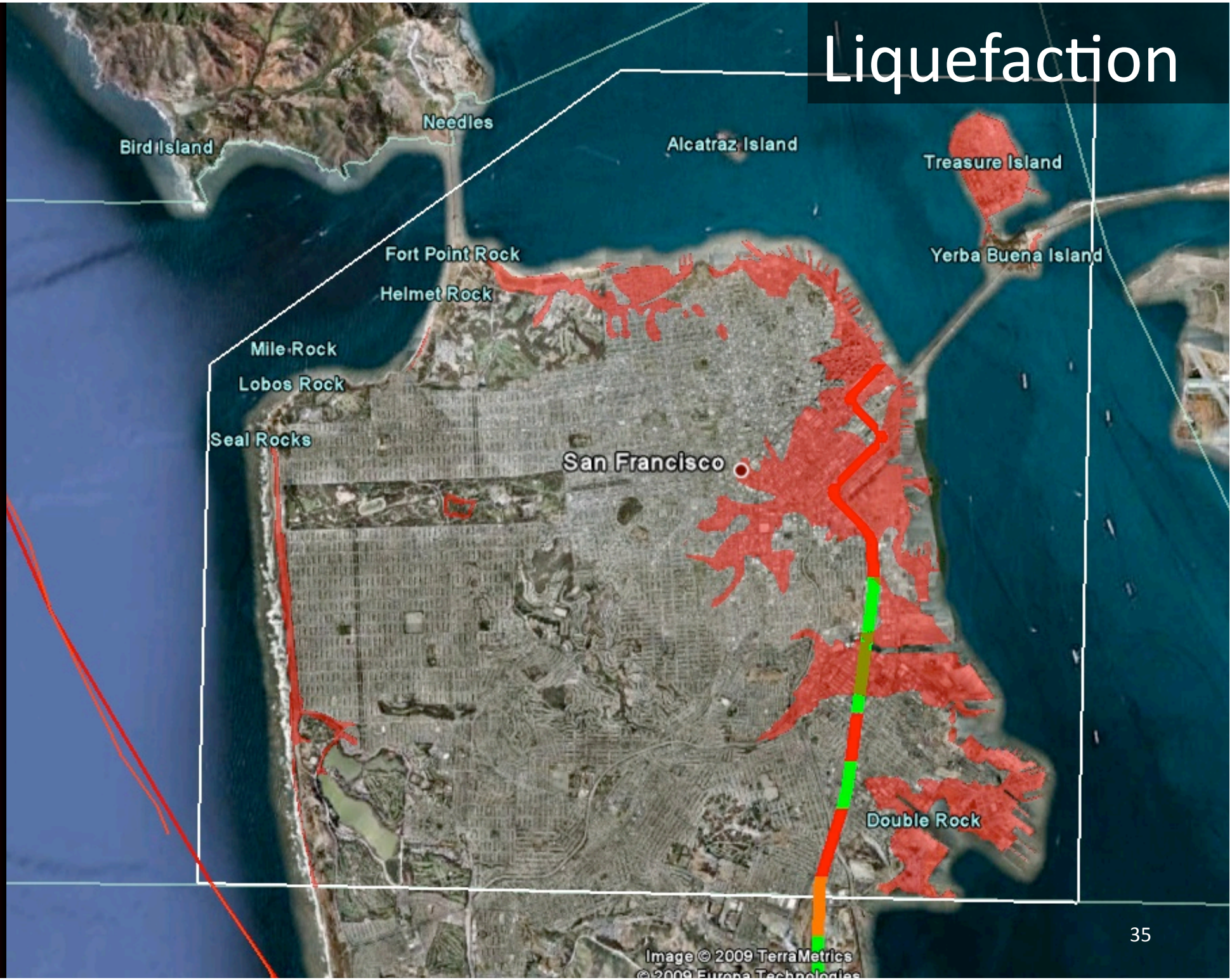
segment type	length(km)	length(miles)	fault crossing
Aerial	201.7	125.2	1
At Grade	703.7	437.0	5
Cut & Fill	195.9	121.6	2
Embankment	2.1	1.3	0
Retaining Wall	28.8	17.9	0
Trench	11.6	7.2	1
Tunnel	67.6	42.0	3
Under Consideration	168.3	104.5	6
total	1379.7	856.8	18



Liquefaction



Liquefaction



Outline

- **Introduction**
  - CA High Speed Rail (HSR)
  - HSR systems around the world
- **Earthquakes and HSR**
- **Earthquake hazards for CA HSR**
  - Earthquake faults
  - Liquefaction
- **Solution example**

Caltrans ARS Online

CA.GOV CALIFORNIA DEPARTMENT OF TRANSPORTATION

Home | Travel | Business | Engineering | News | Maps | Jobs | About Caltrans | Contact Us

ARS ONLINE

- Home
- About
- Help
- Errata Report
- Technical References

RESOURCES

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

Developed By

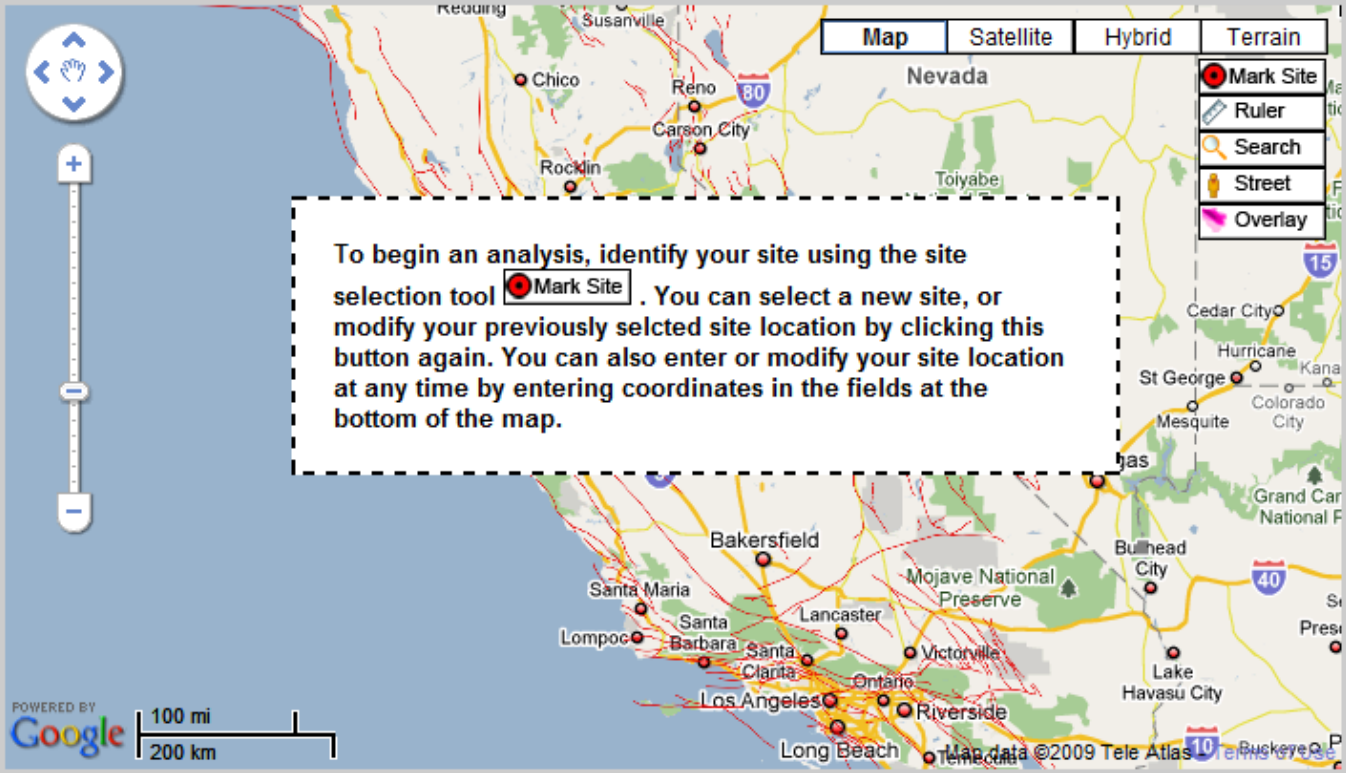
GeoResearch Group — Caltrans — Research & Innovation

In Partnership With

Caltrans ARS Online

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

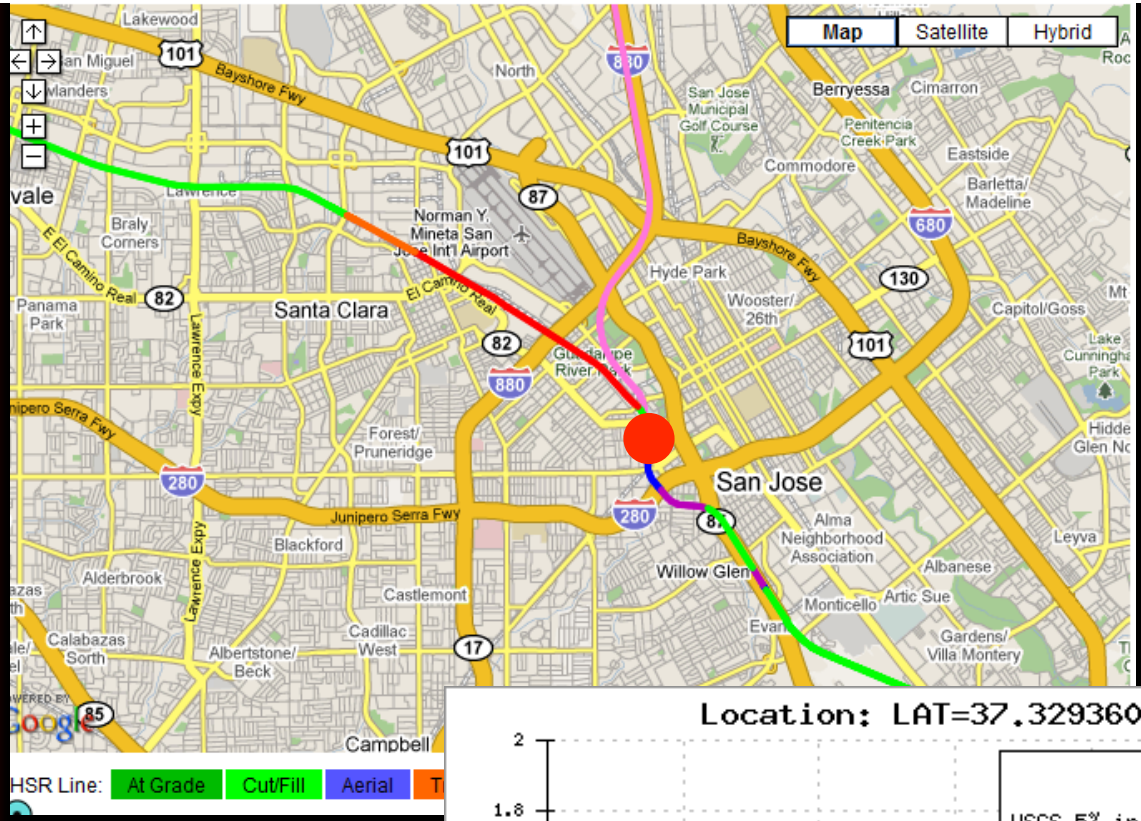
SELECT SITE LOCATION

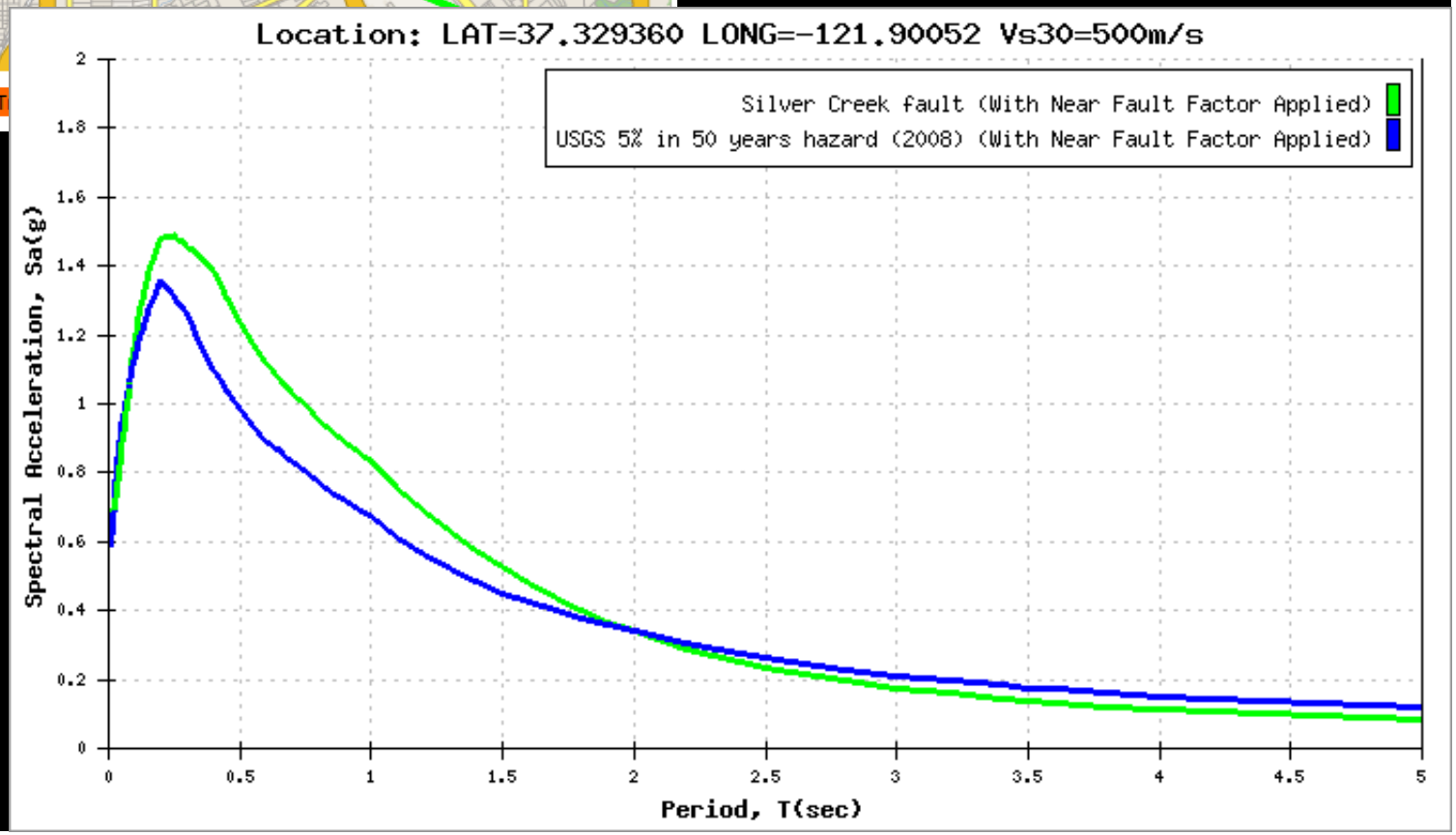


To begin an analysis, identify your site using the site selection tool Mark Site . You can select a new site, or modify your previously selcted site location by clicking this button again. You can also enter or modify your site location at any time by entering coordinates in the fields at the bottom of the map.

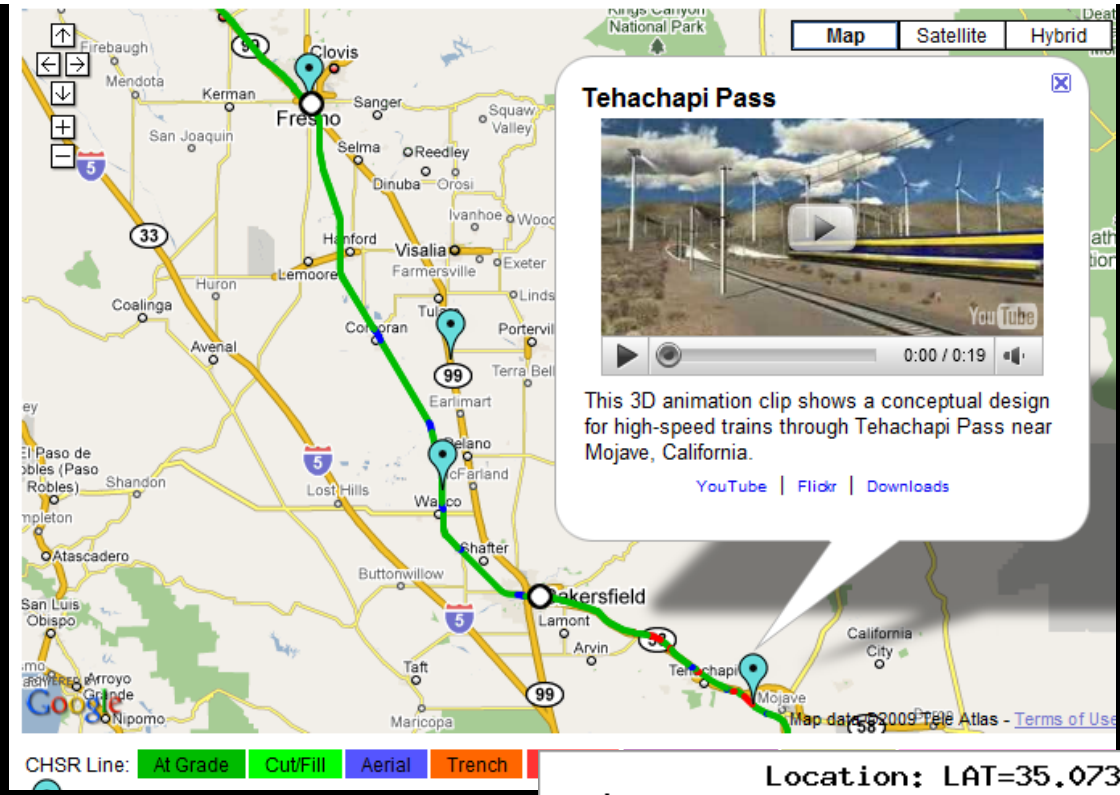
Latitude: Longitude: V_{S30}: m/s Calculate

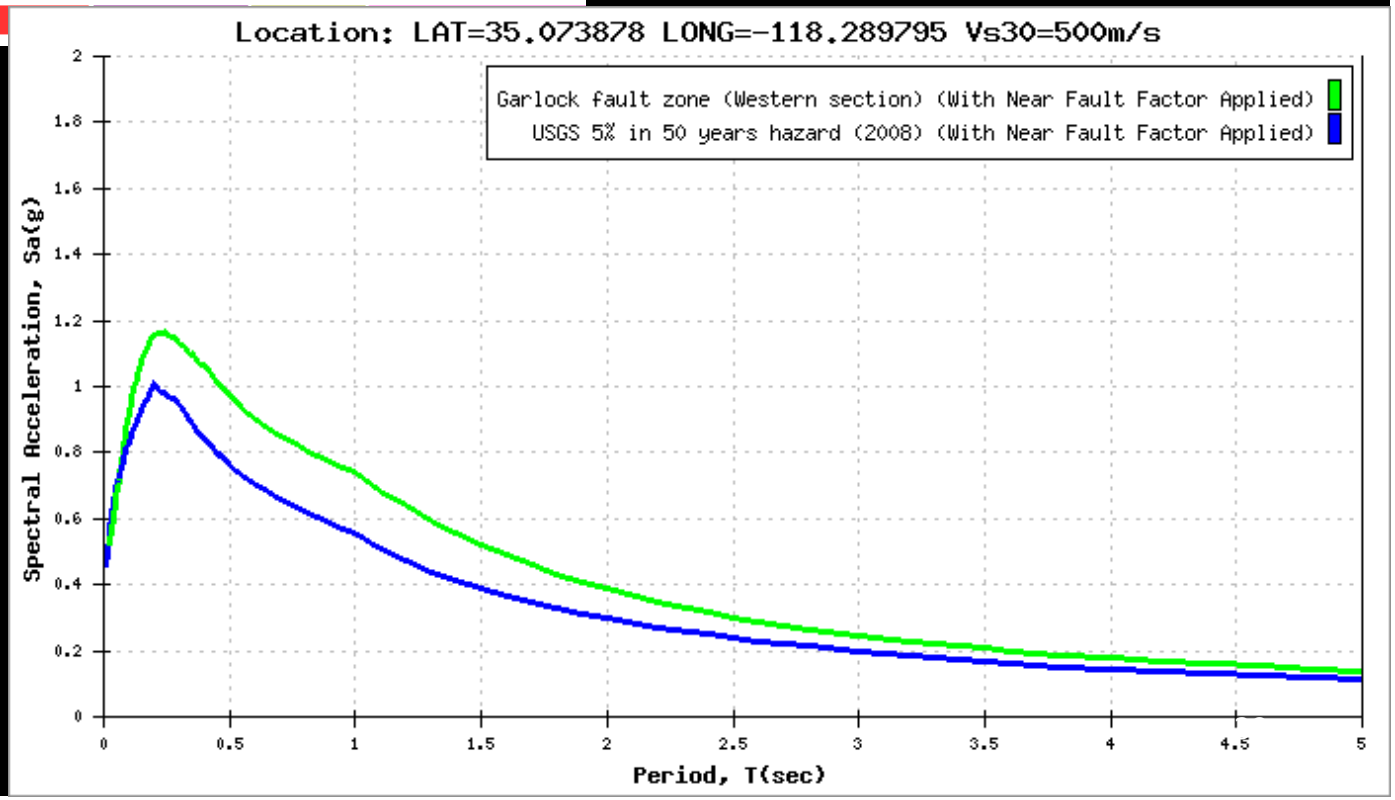
Response Spectra



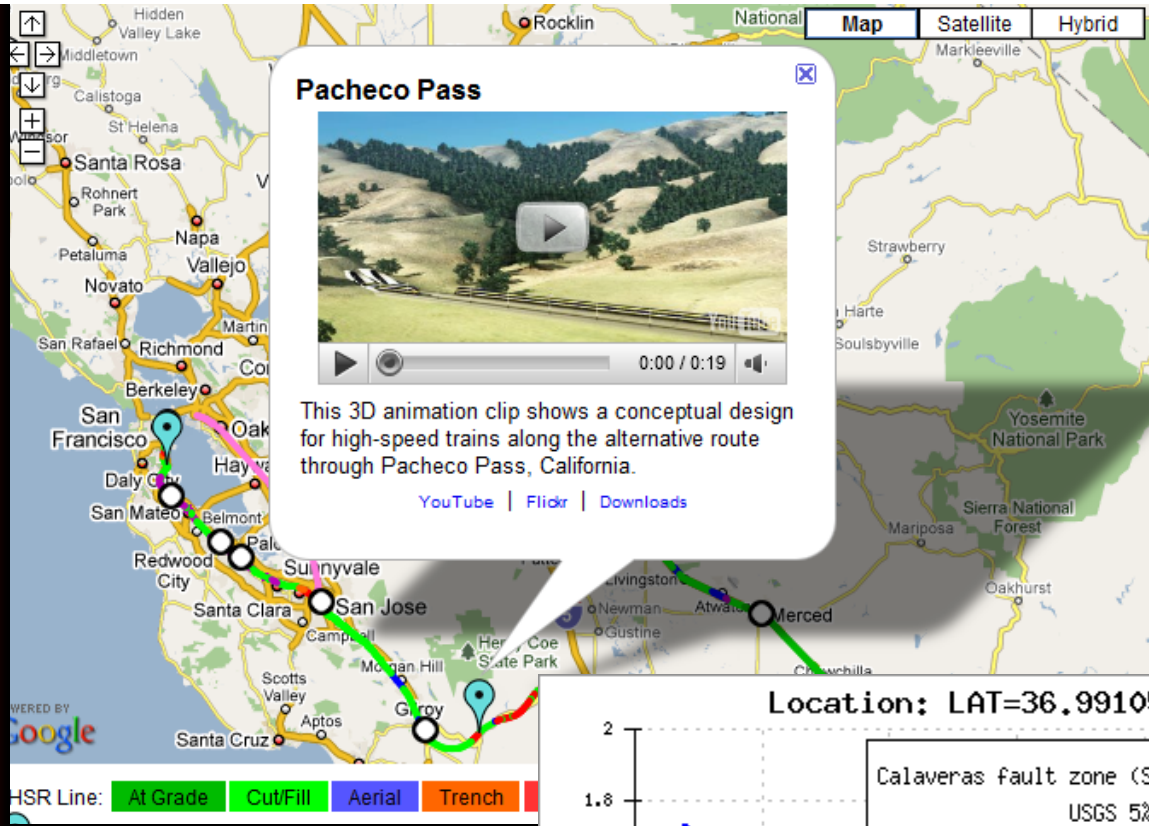


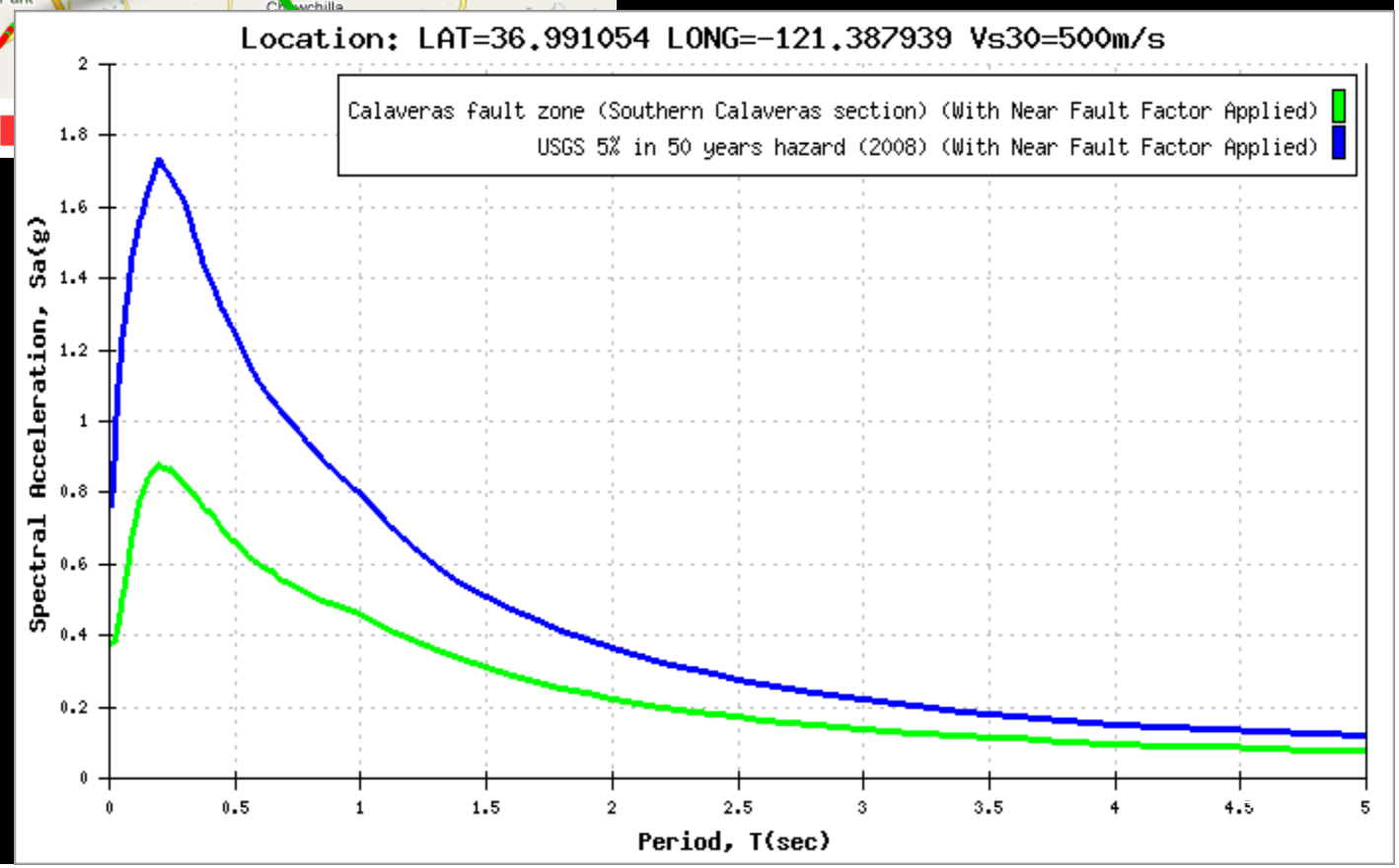
Response Spectra

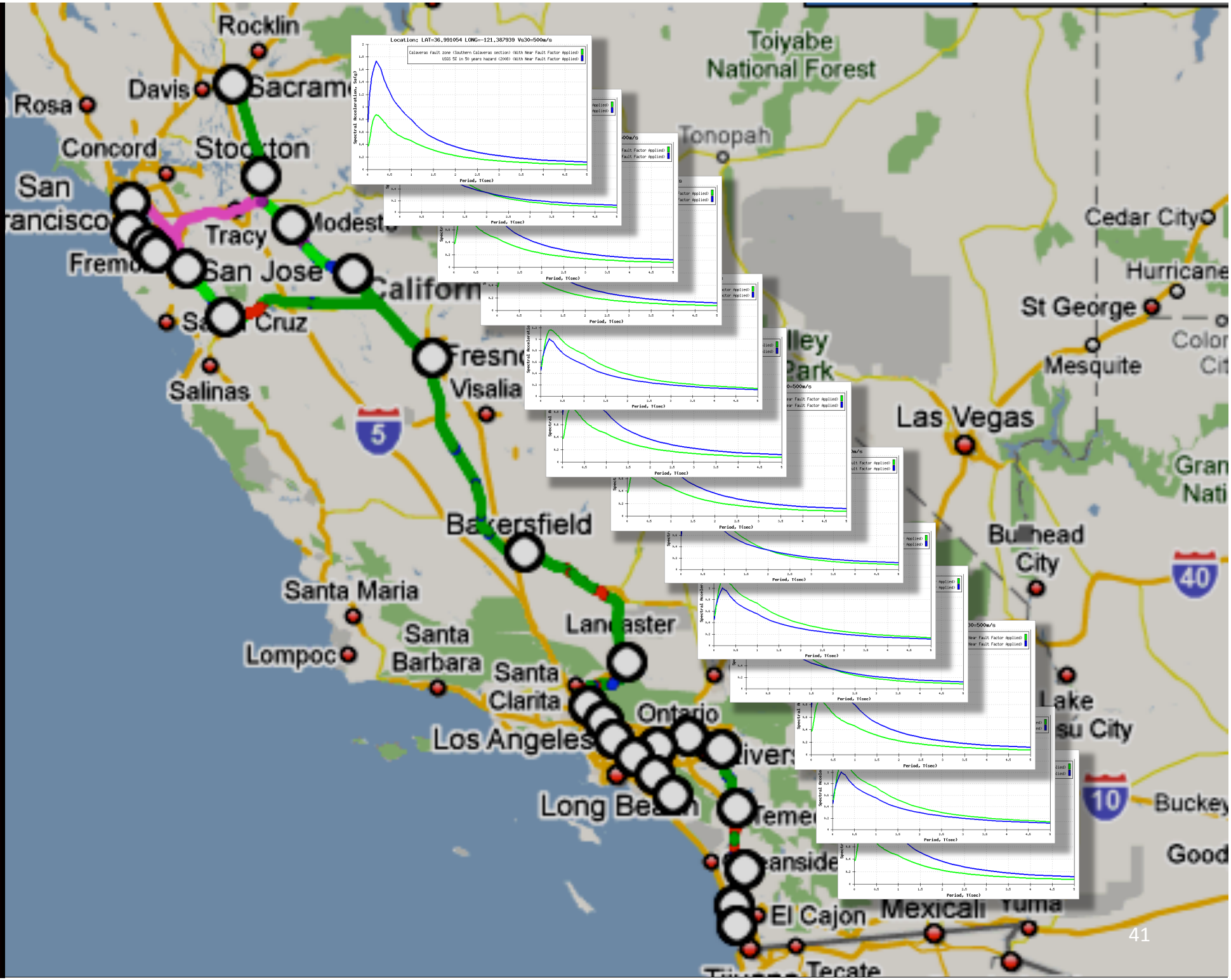




Response Spectra






Rocklin
Davis
Rosa
Concord
Stockton
San
Tracy
Modesto
San Jose
Salinas
Santa Cruz
Fresno
Visalia
Bakersfield
Santa Maria
Lompoc
Santa Barbara
Santa Clarita
Los Angeles
Ontario
Long Beach
Lancaster
Toiyabe National Forest
Tonopah
Cedar City
Hurricane
St George
Mesquite
Las Vegas
Bullhead City
Lake Havasu City
Buckeye
Good
El Cajon
Mexicali
Tecate
Yuma
5
40
10
Location: LAT=36.991054 LONG=-121.387939 Vs30=500m/s
Calaveras Fault zone (Southern Calaveras section) (With Near Fault Factor Applied)
USGS 5% in 50 years hazard (2008) (With Near Fault Factor Applied)
Spectral Acceleration, Sa(g)
Period, T(sec)

Summary

- Japan, China, France, and a few other countries have had HSR systems for some time
- U.S. launched an ambitious HSR program, but it is its first HSRs
- Earthquakes have damaged HSR abroad
- CA HSR will have to be designed to resist earthquakes
- The Pacific Earthquake Engineering Research Center (PEER) has developed a large body of knowledge in seismic transportation research applicable to HSR

USC
Civil Engineering

Jean-Pierre Bardet: ***bardet@usc.edu***
Tat S. Fu: ***tsf@usc.edu***

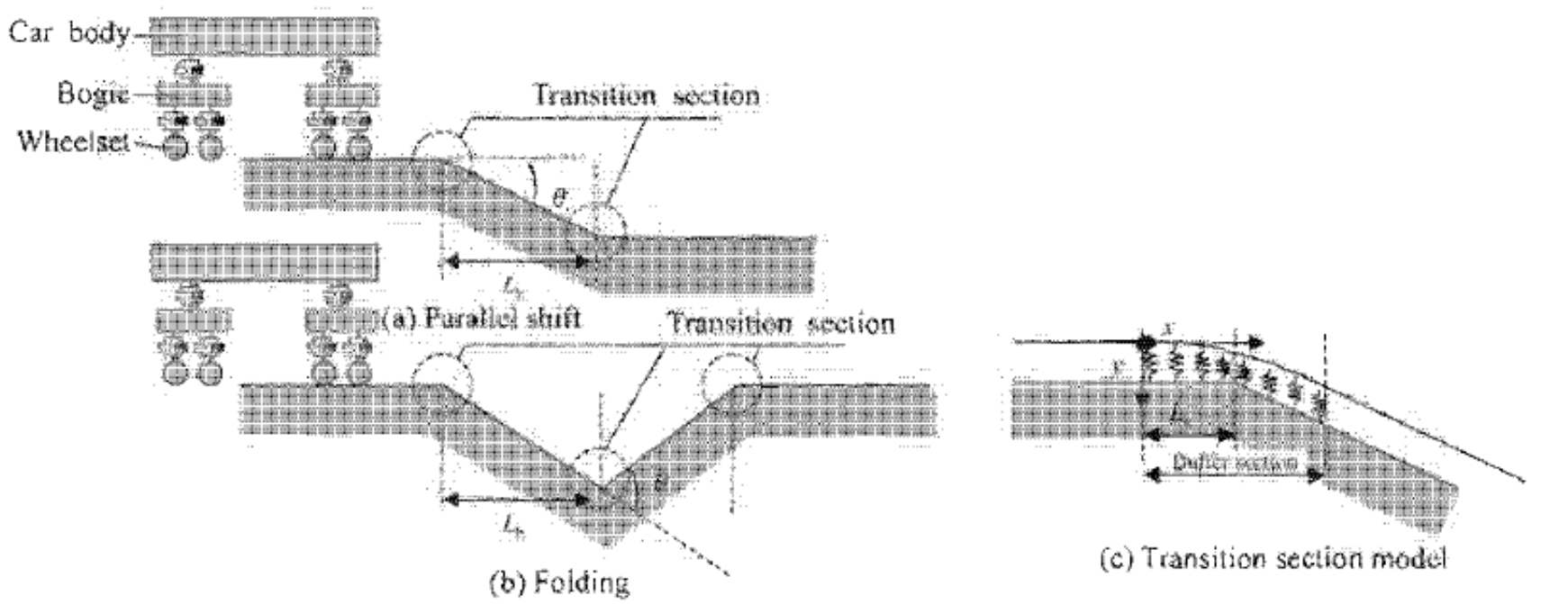


Figure 8 Model for Setting Limit Values for Angular Rotation on Track Surfaces