

1. Introduction

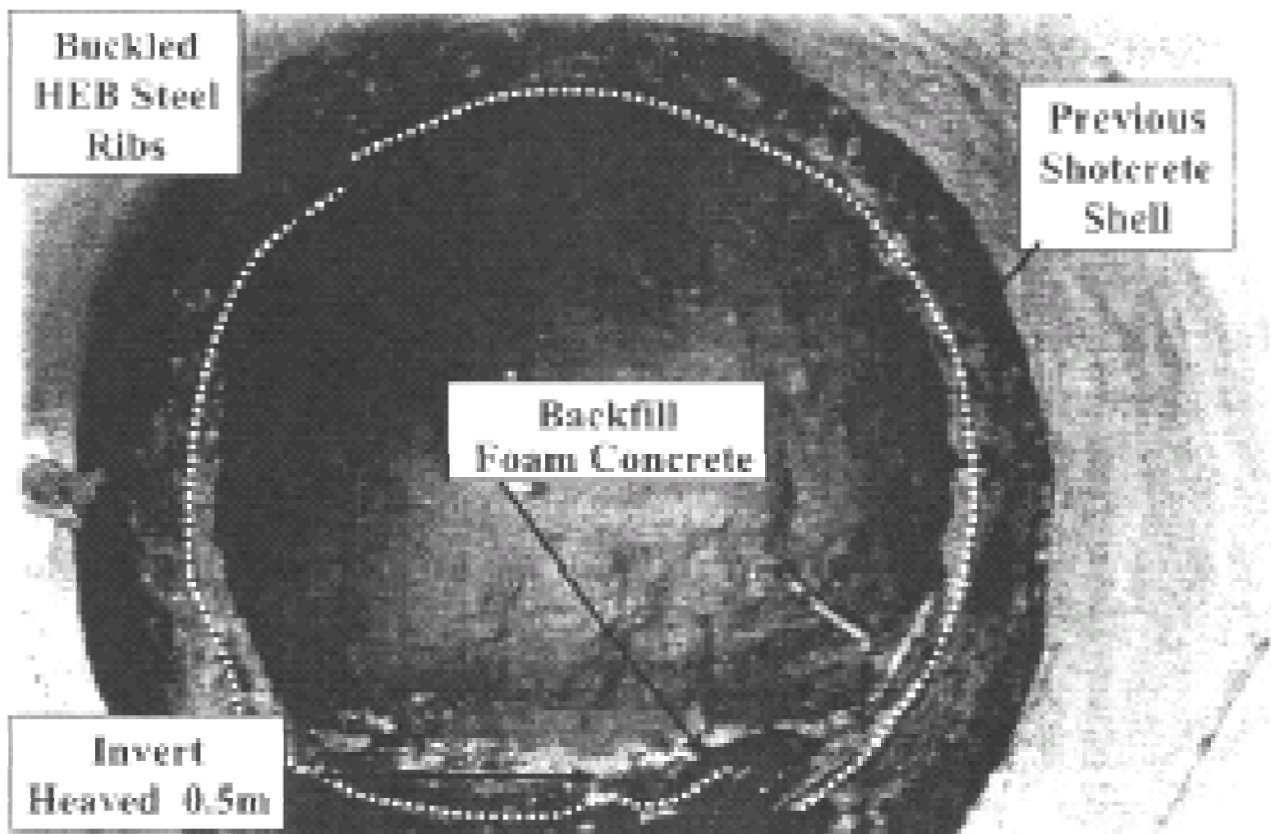
Earthquake-induced damages to **above-** and **under-ground** structures are directly related to the seismic ground response and failure during shaking. With few exceptions (e.g. damages due to tsunamis), this reality is verified in every old and recent earthquake.

For example

Recent strong earthquakes in Greece and abroad



Izmit - Turkey, M=7.2, 17-08-1999



Collapse of Bolu Tunnel

GEORGE BOUCKOVALAS, National Technical University of Athens, 2016

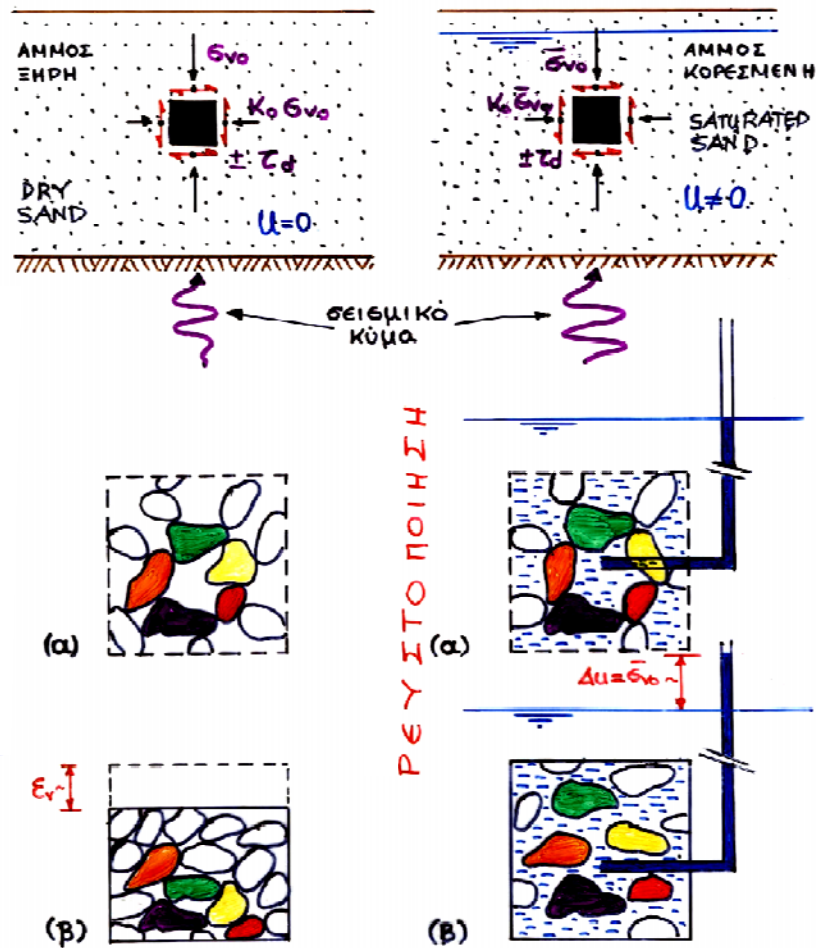


Izmit - Turkey, $M=7.2$, 17-08-1999

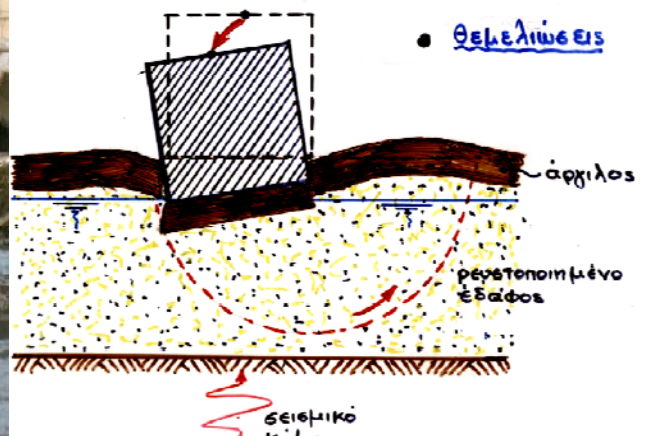


MECHANISM OF SOIL LIQUEFACTION

ΔΥΝΑΜΙΚΗ ΣΥΝΙΣΤΗΣΗ



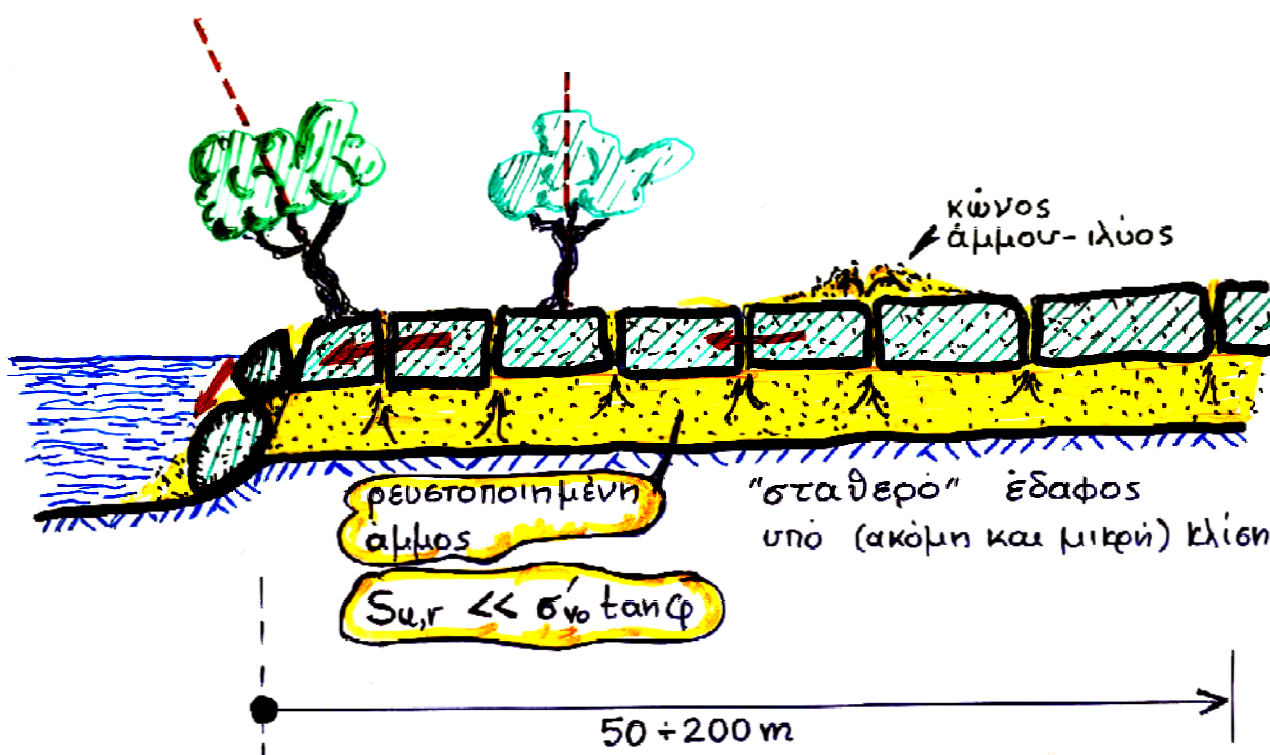
Adapazari, Turkey (1999)



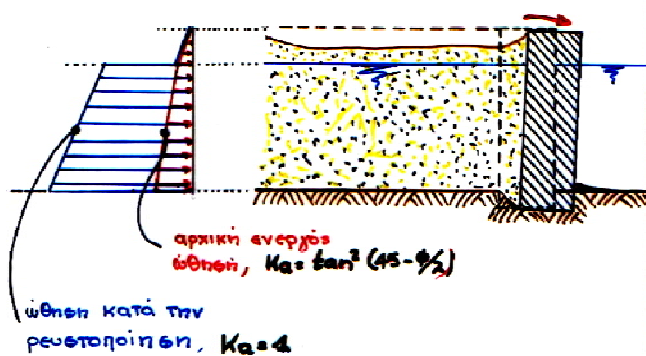
Izmit - Turkey, $M=7.2$, 17-08-1999



• LATERAL SPREADING



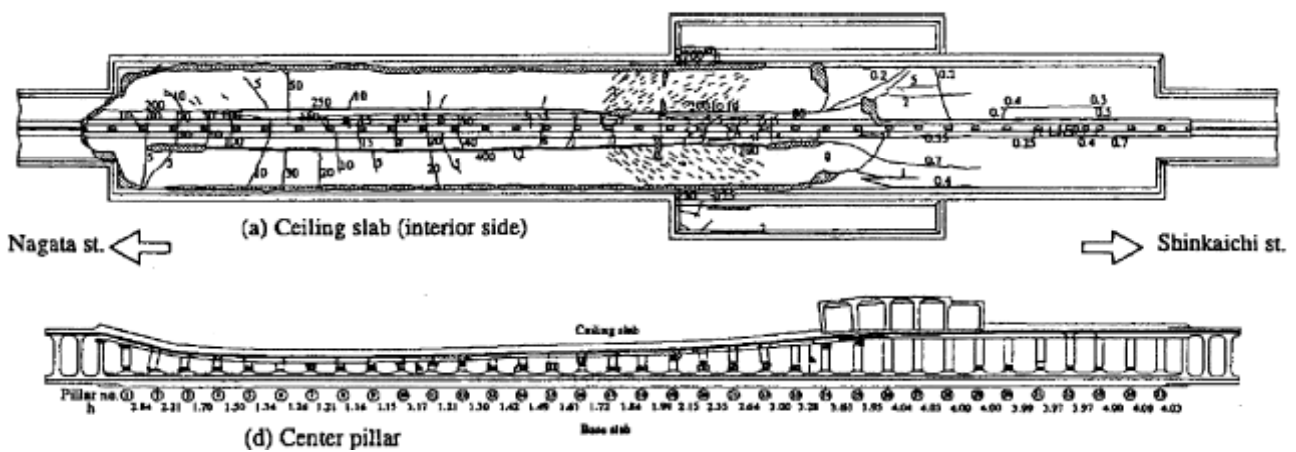
Kobe (1995)



Kobe (1995)

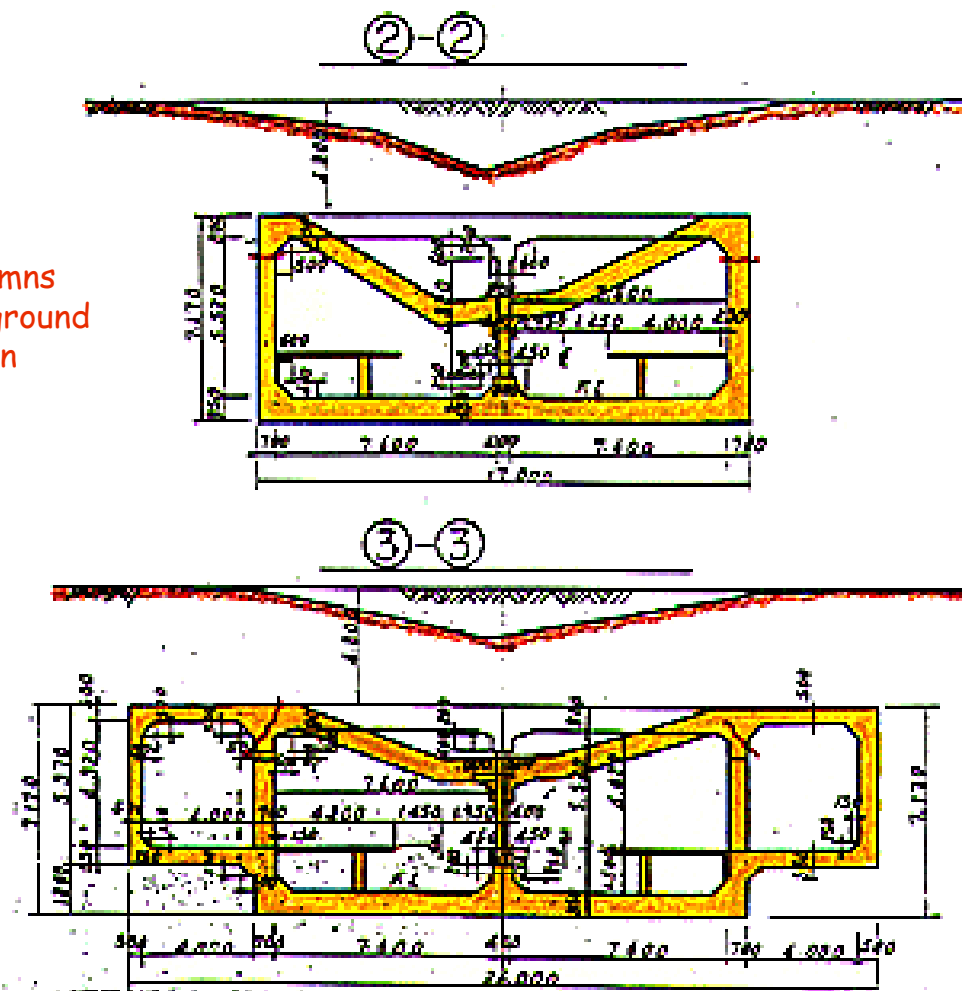


Kobe 1995
Collapse of columns
in DAIKAI underground
metro station



Kobe 1995
Collapse of columns
in DAIKAI underground
metro station

Kobe 1995
Collapse of columns
in DAIKAI underground
metro station



Chi-Chi earthquake, Taiwan, $M=7.6$, 21-09-1999





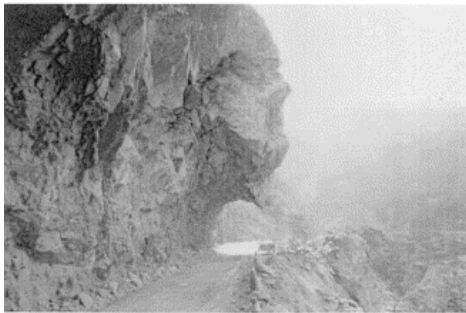
SLOPE FAILURE



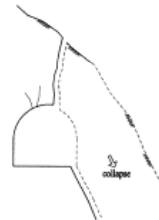
(a)



(b)



(c)



(d)

(a) photo of Chi-Shue Tunnel before Chi-Chi Earthquake; (b) photo of Chi-Shue Tunnel after Chi-Chi Earthquake; (c) slope failure induced tunnel collapse at Sta. 45k+573 of Highway No. 8; (d) sketch of damage pattern.

(from Wang et al. 2001)



Longitudinal cracks from "ovalization" of Yuluh tunnel section, Chi-Chi 1999 earthquake (Schiff and Tang eds, 2000)

Athens-Greece, $M=5.9$, 12-09-1999



• 100 buildings collapsed

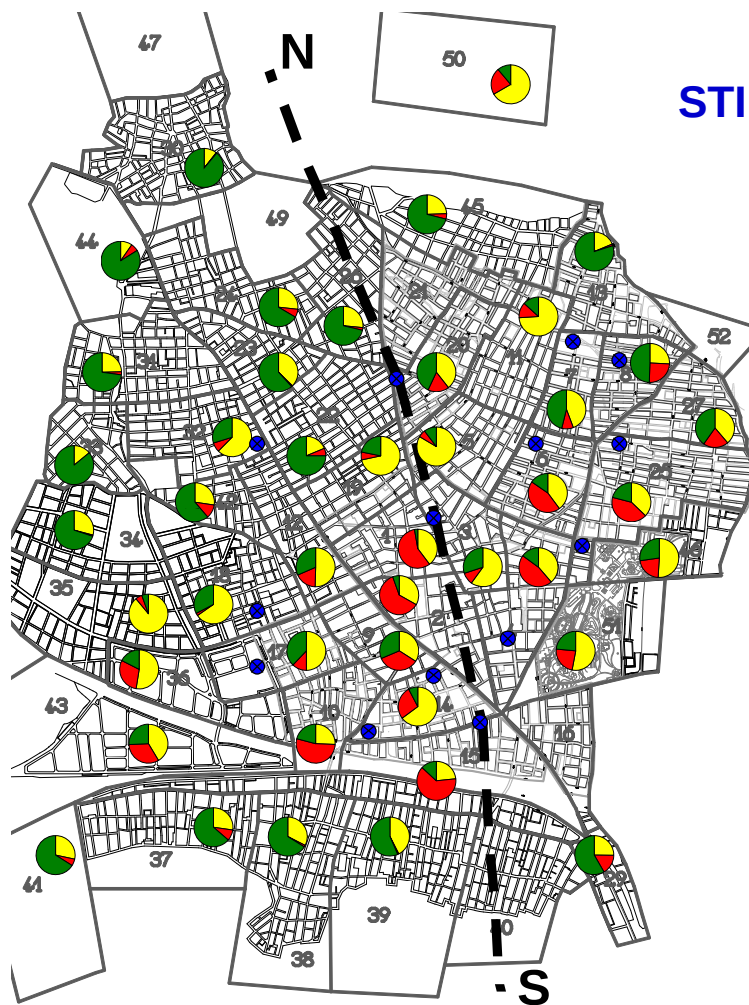
• 143 casualties

• 2,000 injured

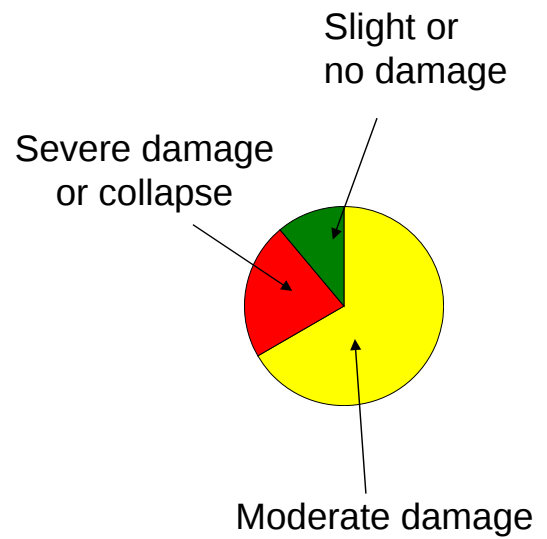
• 100,000 homeless



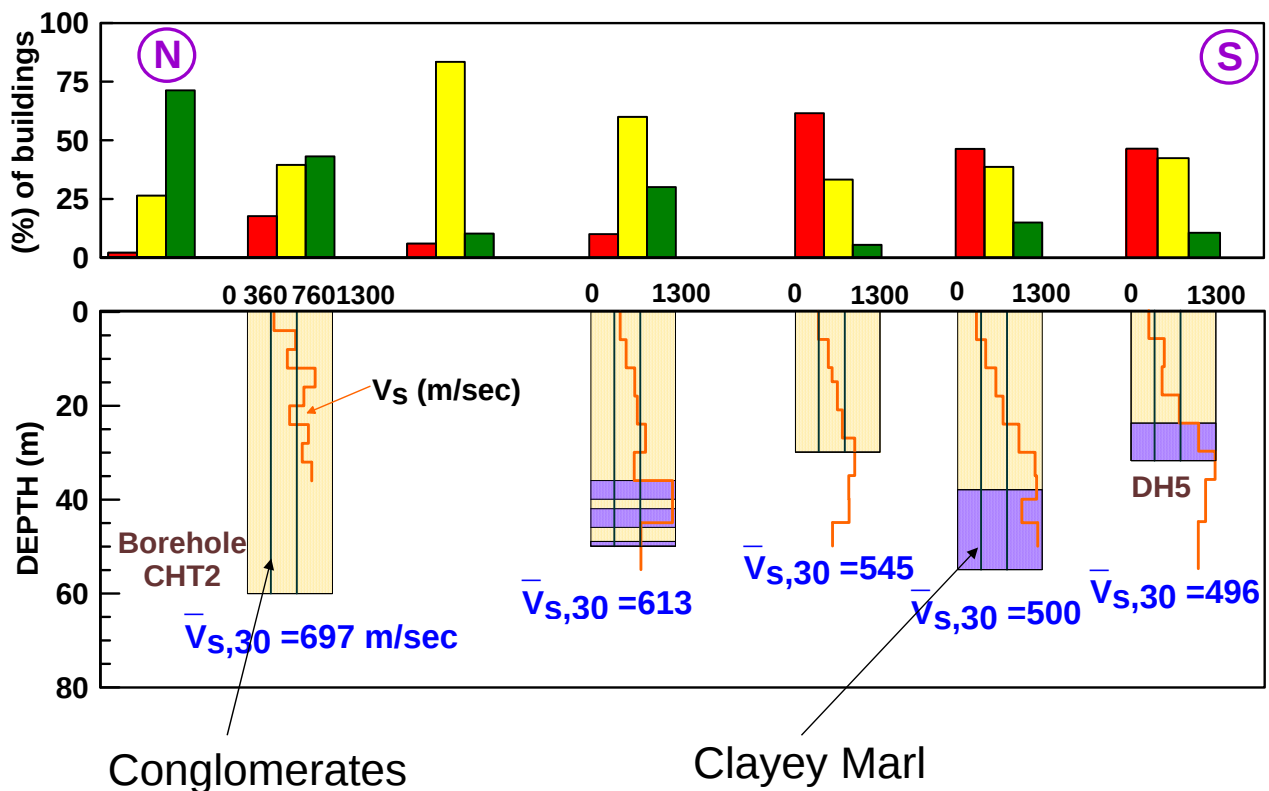
~40 m



STIFF SOIL AMPLIFICATION at Ano Liosia municipality



Cross-section N-S



Alaska
 $M=7.9$
3-11-2002



- 48" pipe dynamically pushed to limit of VSM
- Shattered pipe housing indicates high velocity impact with vertical support member

Earthquake of

Bam - Iran

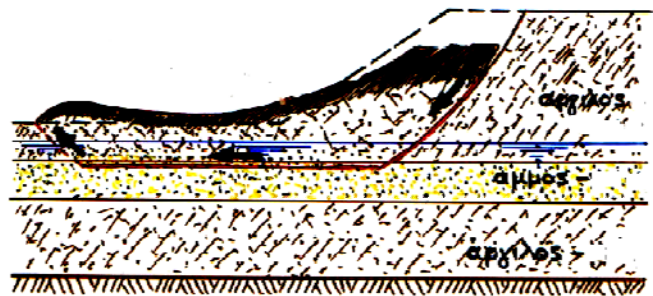
$M=6.6$

26-12-2003

..... 30,000 casualties



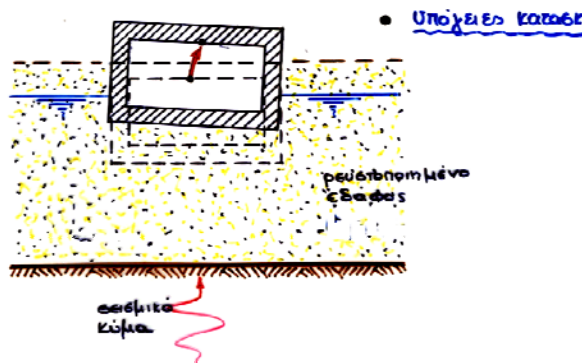
Chile Earthquake, Mw = 8.8 February 27, 2010



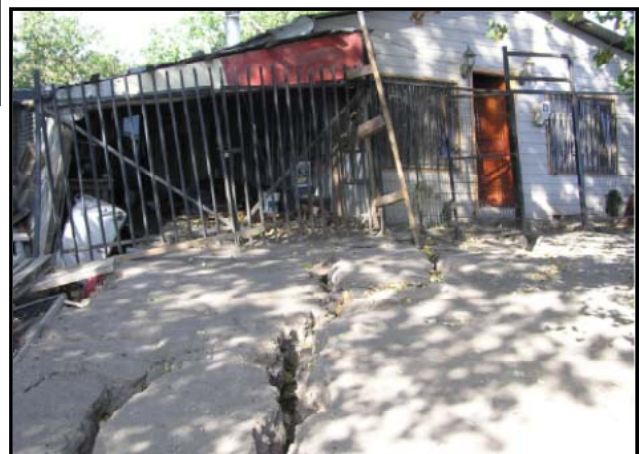
Chile Earthquake, Mw = 8.8 February 27, 2010



Chile Earthquake, Mw = 8.8 February 27, 2010



Chile Earthquake, Mw = 8.8 February 27, 2010



Darfield-Christchurch earthquake (magnitude 7.1), Sept 4, 2010

By: P. Marinos, Th. Rodogianni, G. Tsiambaos,
N. Sabatakakis & B. Christaras

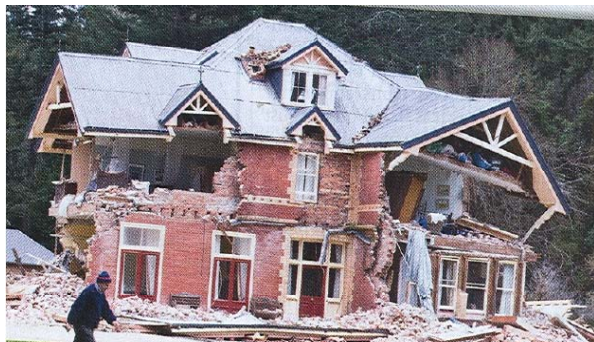


Strike slip fault



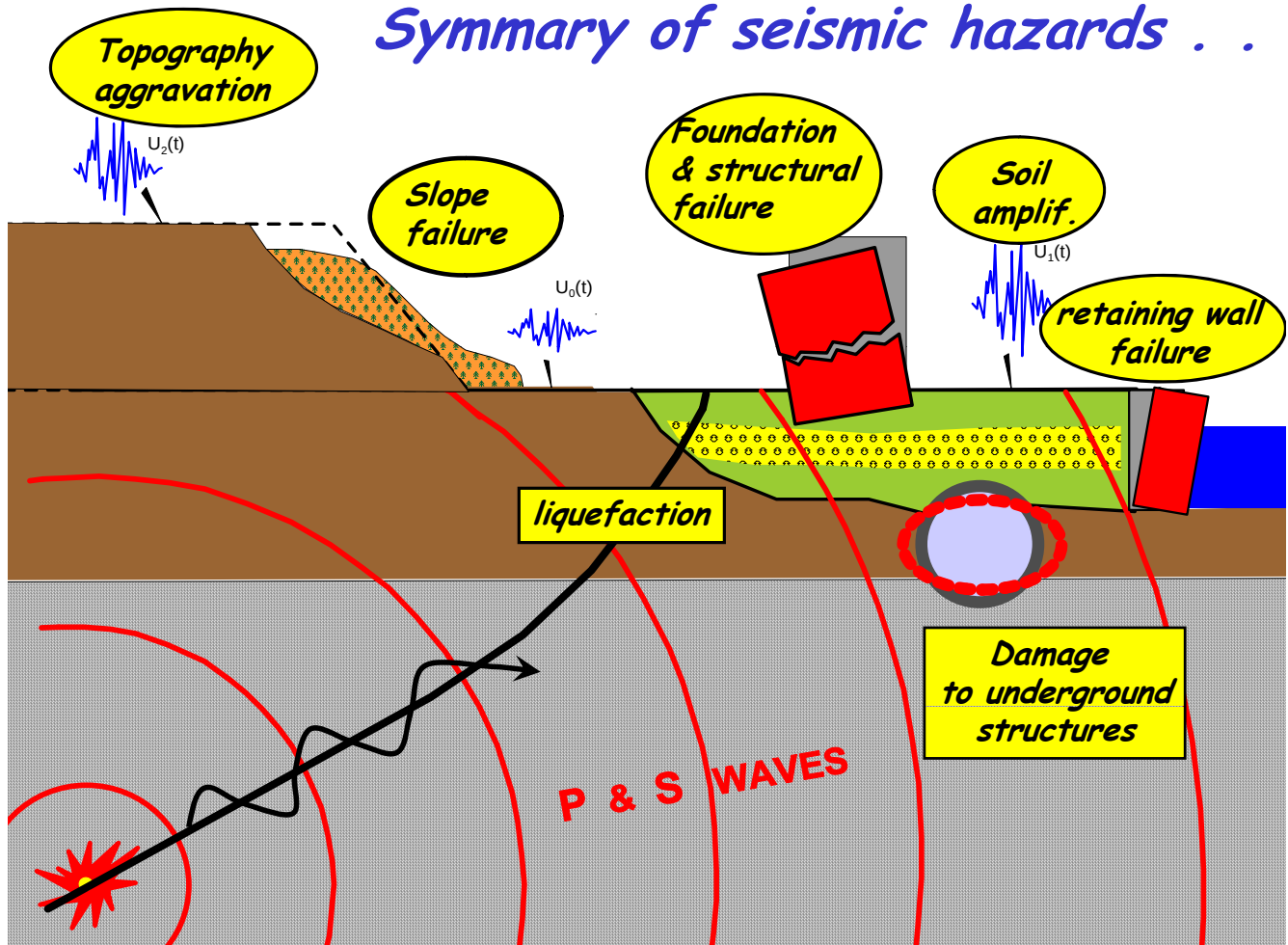
Damages due to liquefaction

(and to related lateral spreading)

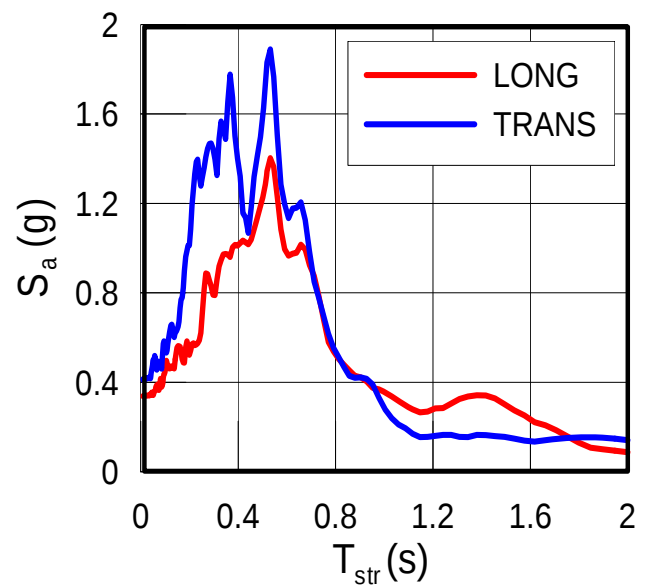
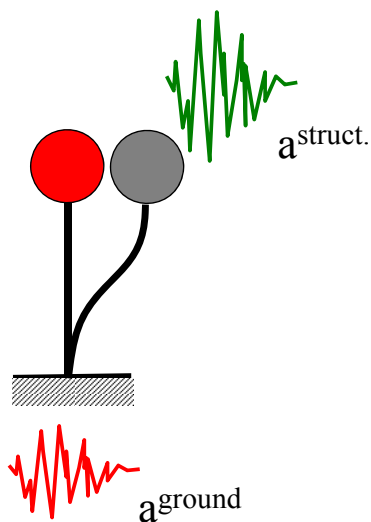


The house of the film "Lord of the rings"

Symmary of seismic hazards . .

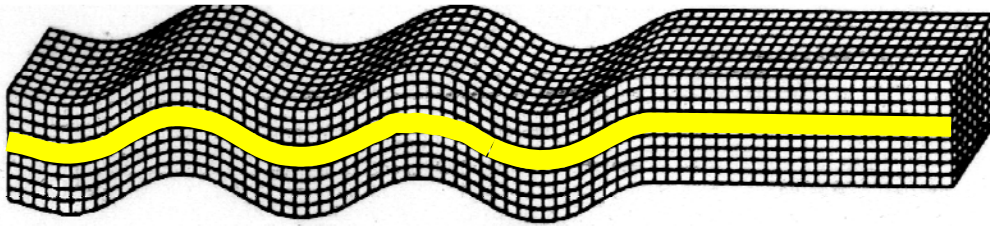


13 Lectures on GEOTECHNICAL EARTHQUAKE ENGINEERING

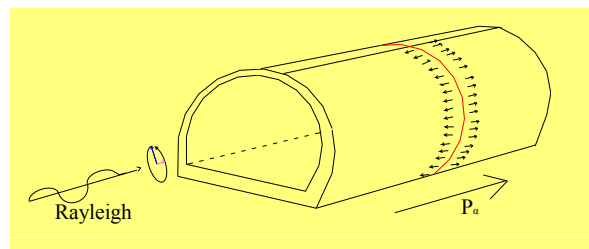


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Body (P, S)
& Surface (R, L)
Waves

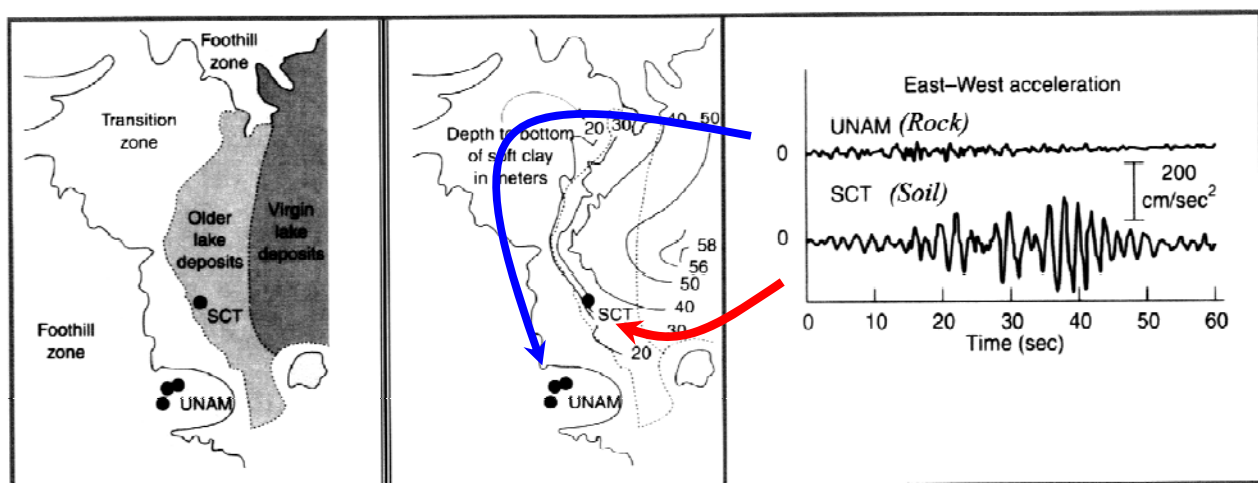


Seismic design
of underground
tunnels and pipelines



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Seismic Ground response - «Soil Amplification»



geology

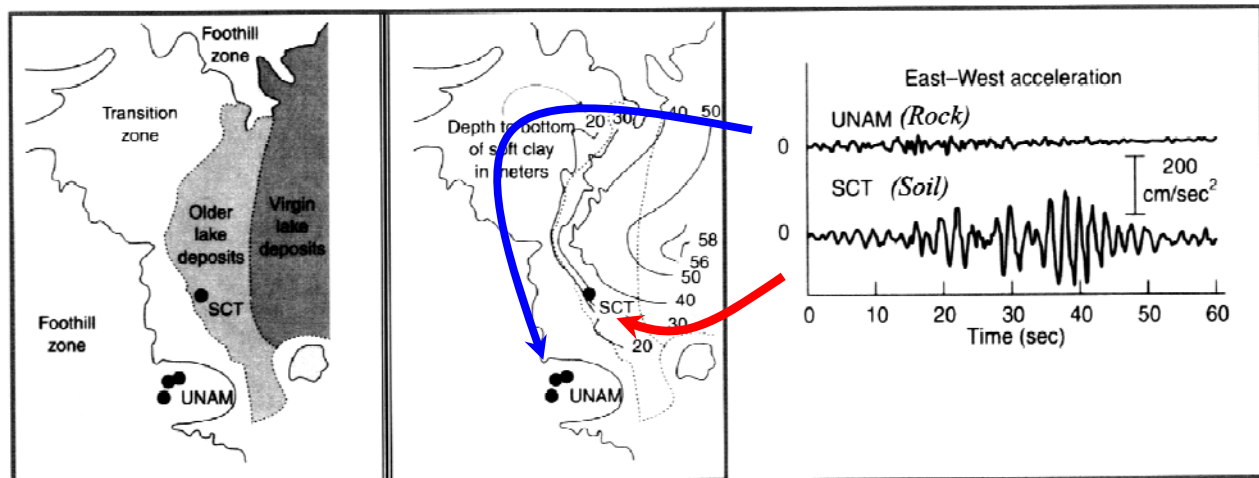
Soil thickness

Typical recordings on
SOIL & BEDROCK

Example: Mexico 1985 earthquake

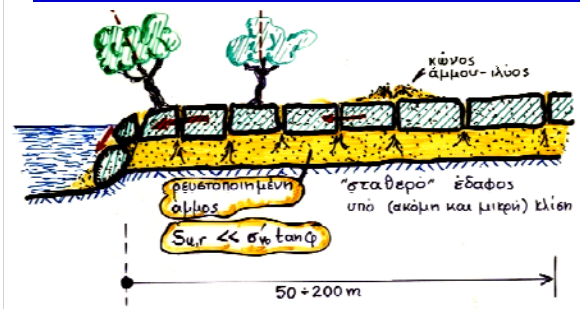
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Seismic Ground response - «Soil Amplification»



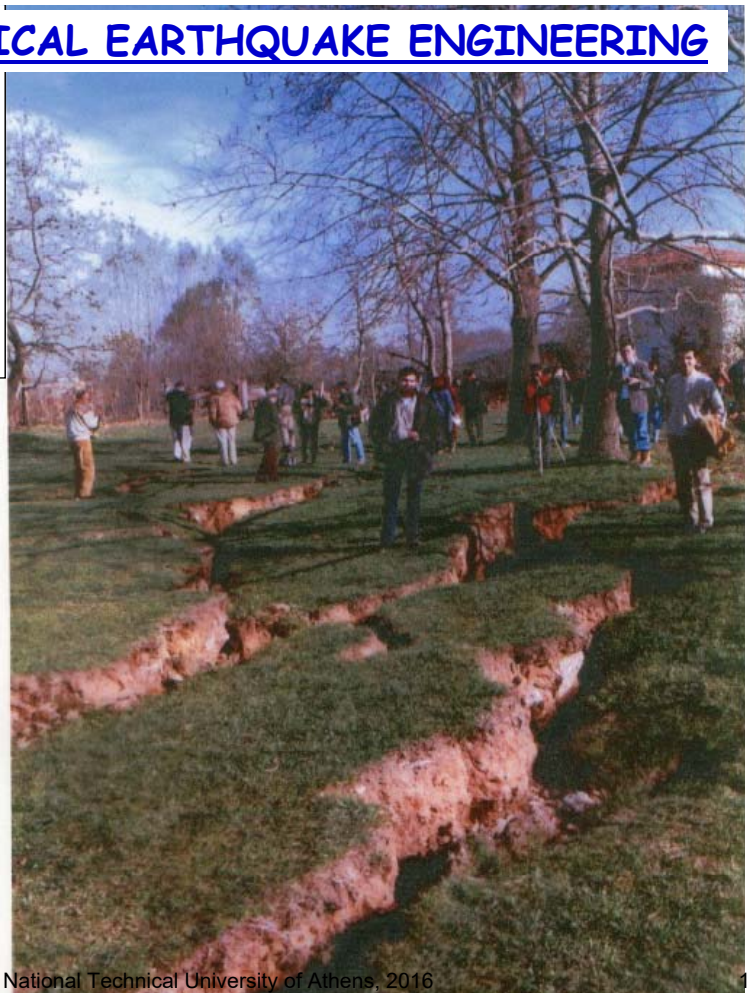
- ✚ Analytical solutions
- ✚ Equivalent-linear numerical analyses
- ✚ Non-linear numerical analyses
- ✚ Application with computer code SHAKE

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Liquefaction

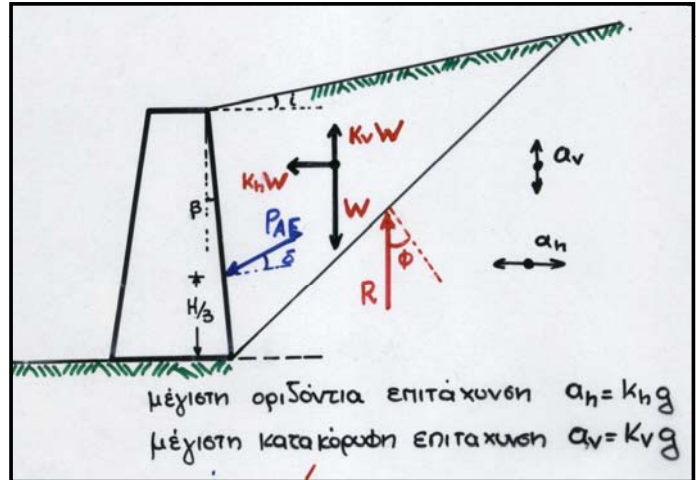
- ✚ Prediction
- ✚ Settlements
- ✚ Lateral spreading
- ✚ Ground improvement
- ✚ etc.



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Seismic design of retaining walls

- ✚ Dynamic earth pressures
Mononobe-Okabe
- ✚ Hydrodynamic pressures
Westergaard
- ✚ Flexible retaining walls



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Seismic slope failure



Displacement computation
with the "sliding block"
method

