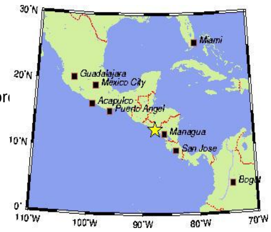
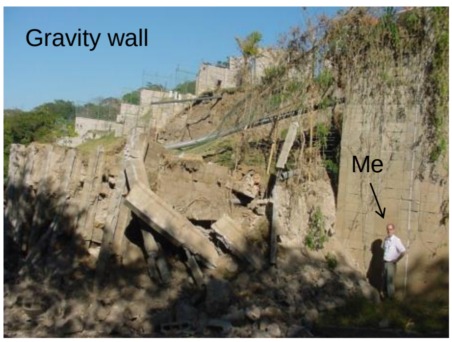
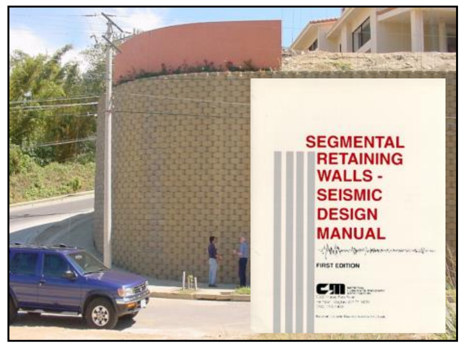
El Salvador Earthquake
13 January, 2001
Magnitude: M = 7.6
Depth: 60 km
Location: ± 60 km offshore
Rupture length: 100 km



At the location of these slides
a_{max} = 0.4 to 0.6g





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1.7-m high unreinforced section at top of wall added by owner after original construction

2001 El Salvador earthquake in Central America

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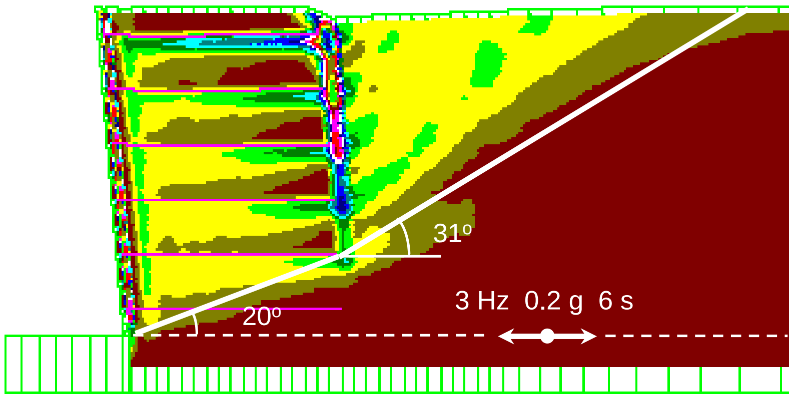
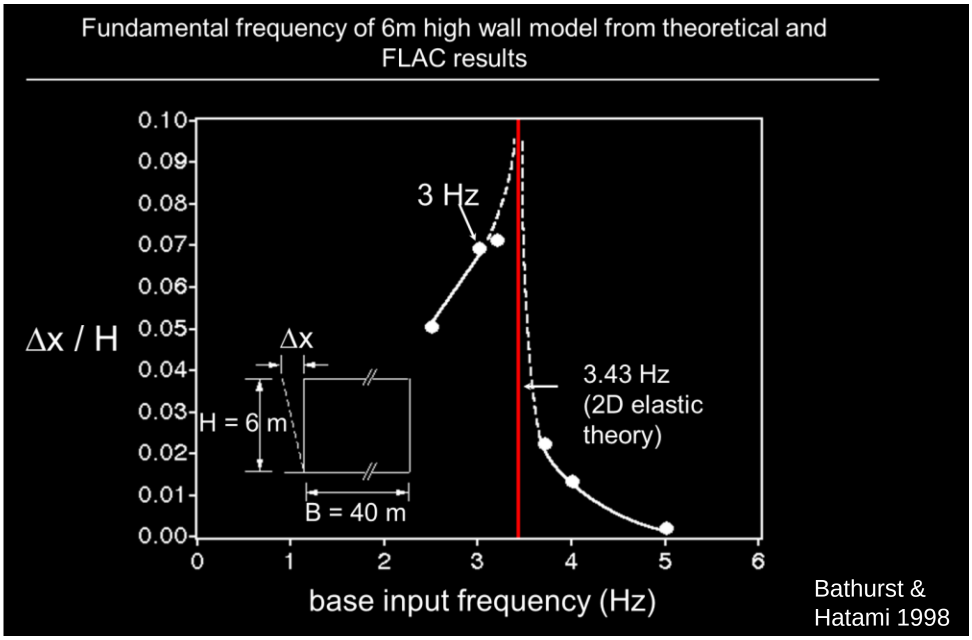
Numerical modelling (e.g. FLAC)



Bathurst, R.J. and Hatami, K. 1998. Seismic response analysis of a geosynthetic reinforced soil retaining wall. Geosynthetics International, Vol. 5, Nos. 1-2, pp. 127-166, 1998

Influence of wall fundamental frequency



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Influence of reinforcement stiffness

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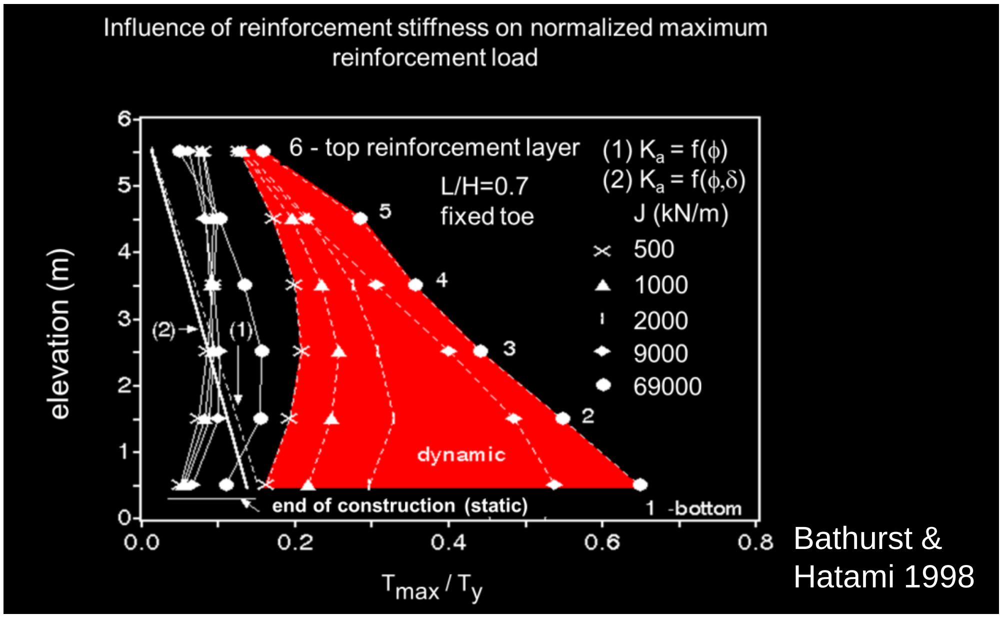

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Design guidelines

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Chapter 16

Geosynthetic-reinforced soil walls and slopes – seismicaspects

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ySchool of Civil Engineering and Environmental Science, University of Oklahoma, Norman, USA
zDepartment of Civil Engineering, University of Manitoba, Winnipeg, Manitoba, Canada

The design and analysis of geosynthetic-reinforced walls, embankments and slopes are presented earlier in this book for structures under static loading conditions. This chapter focuses on the seismic aspects of these structures. It describes the properties and behaviour of cohesionless soils, geosynthetic reinforcement and facing components under dynamic and cyclic loading, and summarises the important features of current analytical and numerical methods for the seismic analysis and design of geosynthetic-reinforced soil walls and slopes. The observed performance of reinforced soil walls and slopes during earthquakes is also presented.

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US AASHTO LRFD Design Specifications (2020) for geosynthetic and steel reinforced soil walls (MSE walls)

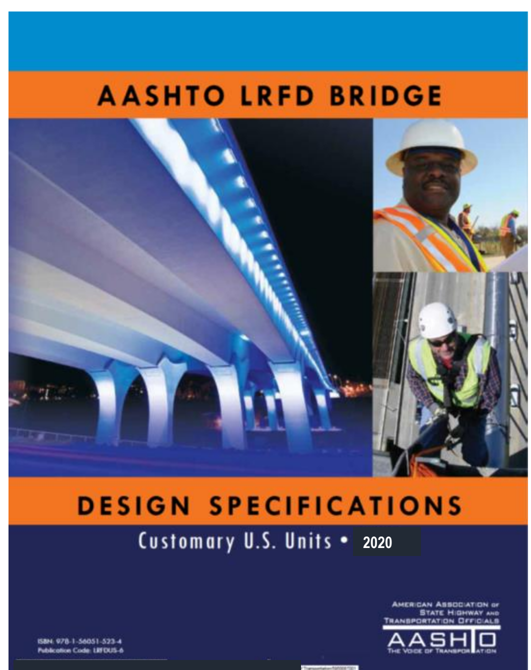
U. S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-10-024
FHWA GEC 011 – Volume I
November 2009

NHI Courses No. 132042 and 132043

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I

Developed following:
AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007, with 2008 and 2009 Interims. and *AASHTO LRFD Bridge Construction Specifications, 2nd Edition, 2004, with 2006, 2007, 2008, and 2009 Interims.*



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Tsunami

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Miyata, Y., Bathurst, R.J., Otani, Y., Ohta, H. and Miyatake, H. 2015. Influence of transient flooding on steel strip reinforced soil walls. *Soils and Foundations* 55(4): 881-894

Photograph of 10.2m-high steel strip reinforced soil wall that survived transient flooding to depth of 14.9 m during 2011 tsunami (Rikuzentakata City, Japan).

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Tsunami

Courtesy J. Otani

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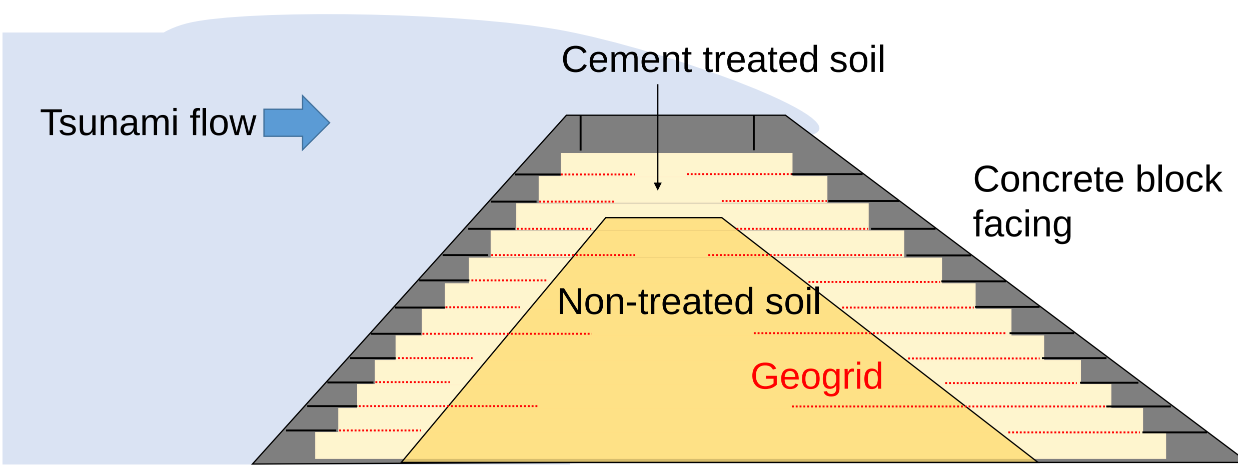
Tsunami coastal counter-measure protection



Courtesy Dr. Yoshihisa Miyata

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SEISMIC BUFFERS

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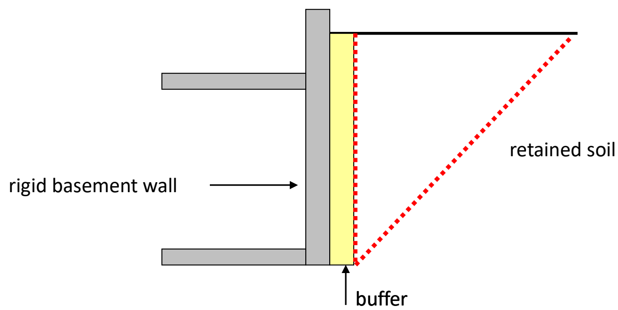
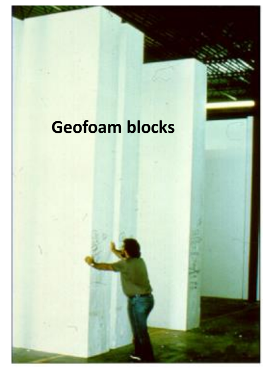
What is a wall (SEISMIC) buffer?

- A compressible inclusion placed between a rigid wall and the retained soil
- Purpose: To reduce lateral earth pressure by allowing controlled yielding of backfill (soil straining)
- Can be used for both static and dynamic loading conditions
- For static case, reduction of pressure to near "active" case (quasi-active)
- For dynamic earth pressure case, the concept of earth pressure reduction is the same except that the loads are higher
- The product of choice is expanded polystyrene geofoam (EPS)





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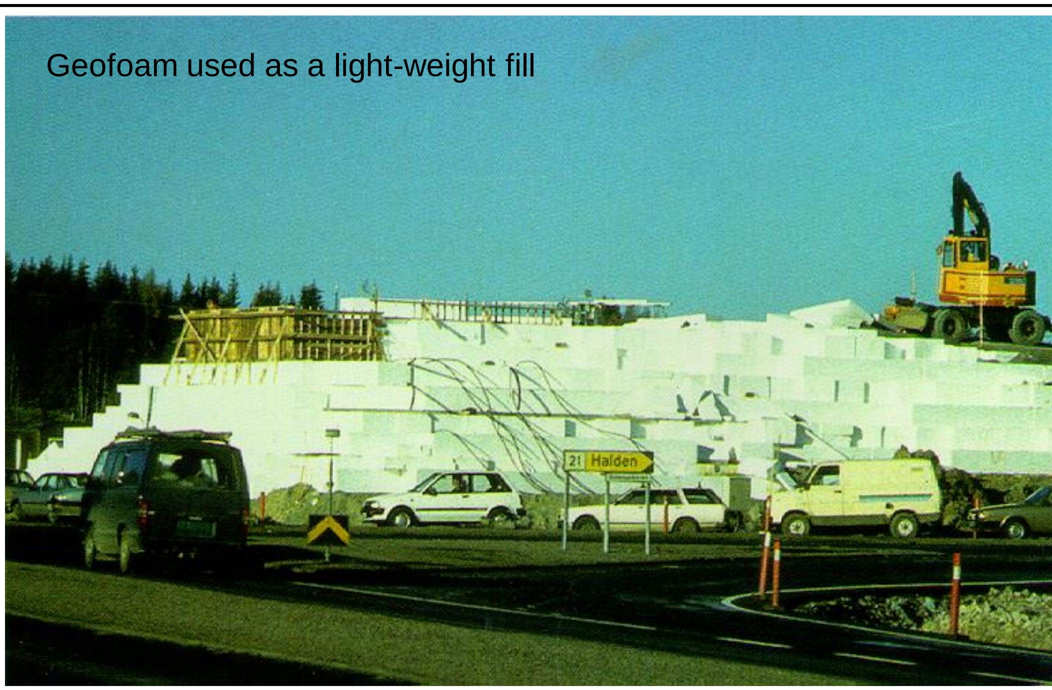

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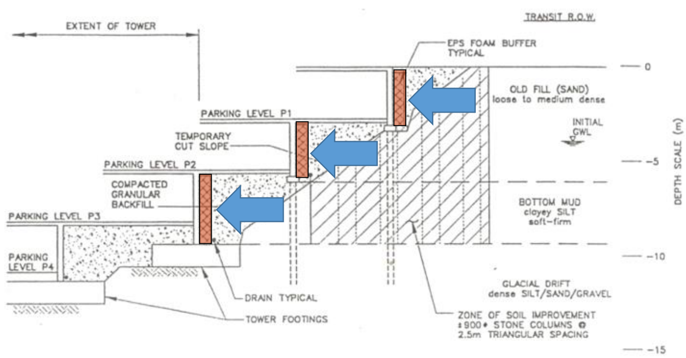
First example of EPS seismic buffer

- Inglis et al. 1996

  Deep basement in Vancouver BC Canada

Numerical analysis (FLAC) showed that the EPS seismic buffer (1 m thick) could reduce seismic forces on the rigid basement walls by up to 50%



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PROOF OF CONCEPT?

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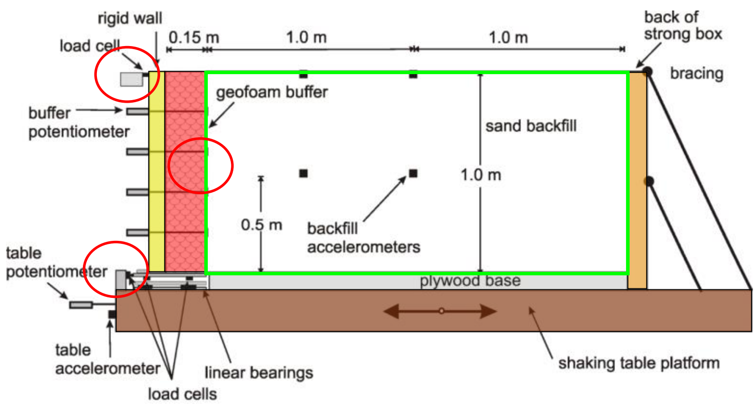
Experimental study:
General arrangement of shaking table tests

One control wall without buffer and 6 walls with different buffer densities were tested



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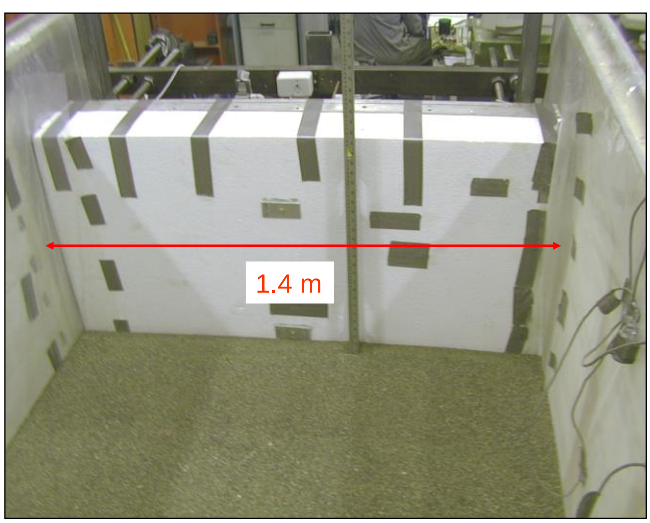
View of geofoam buffer during construction



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Properties of EPS geofoam buffer material

Wall #	EPS bulk density (kg/m^3)	EPS initial tangent Young's modulus (MPa)	EPS Thickness (m)	EPS type (ASTM C 578)
1	Control structure (rigid wall with no seismic buffer)			
2	16	4.7	0.15	I
3	12	3.1	0.15	XI
4	14	0.6	0.15	Elasticized
5	$6^{\dagger}$ (50% removed by cutting strips)	1.6	0.15	XI
6	$6^{\dagger}$ (57% removed by coring)	1.3	0.15	XI
7	$1.32^{\dagger}$ (89% removed by coring)	0.34	0.15	XI

Note: † Density of unmodified EPS geofoam = 12 kg/m^3

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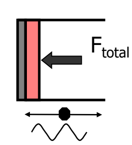
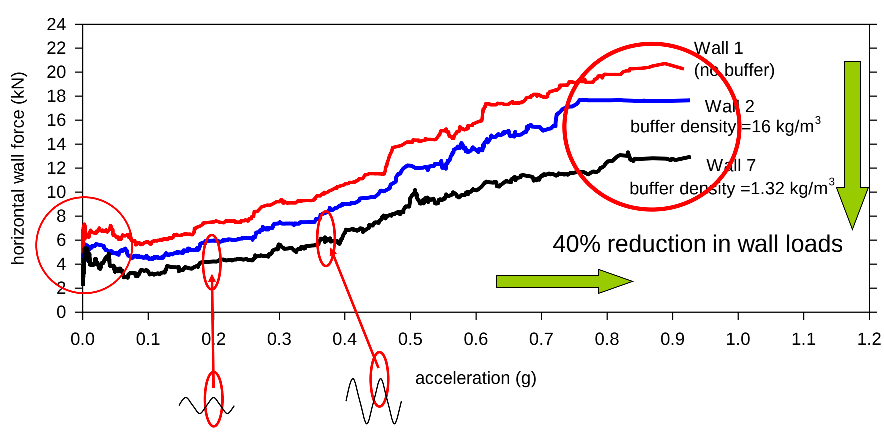
Results:
Total force versus (peak) acceleration





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