Case study:

Effects of subsurface soil layers on the excitation and response of RC buildings subjected to strong ground motion

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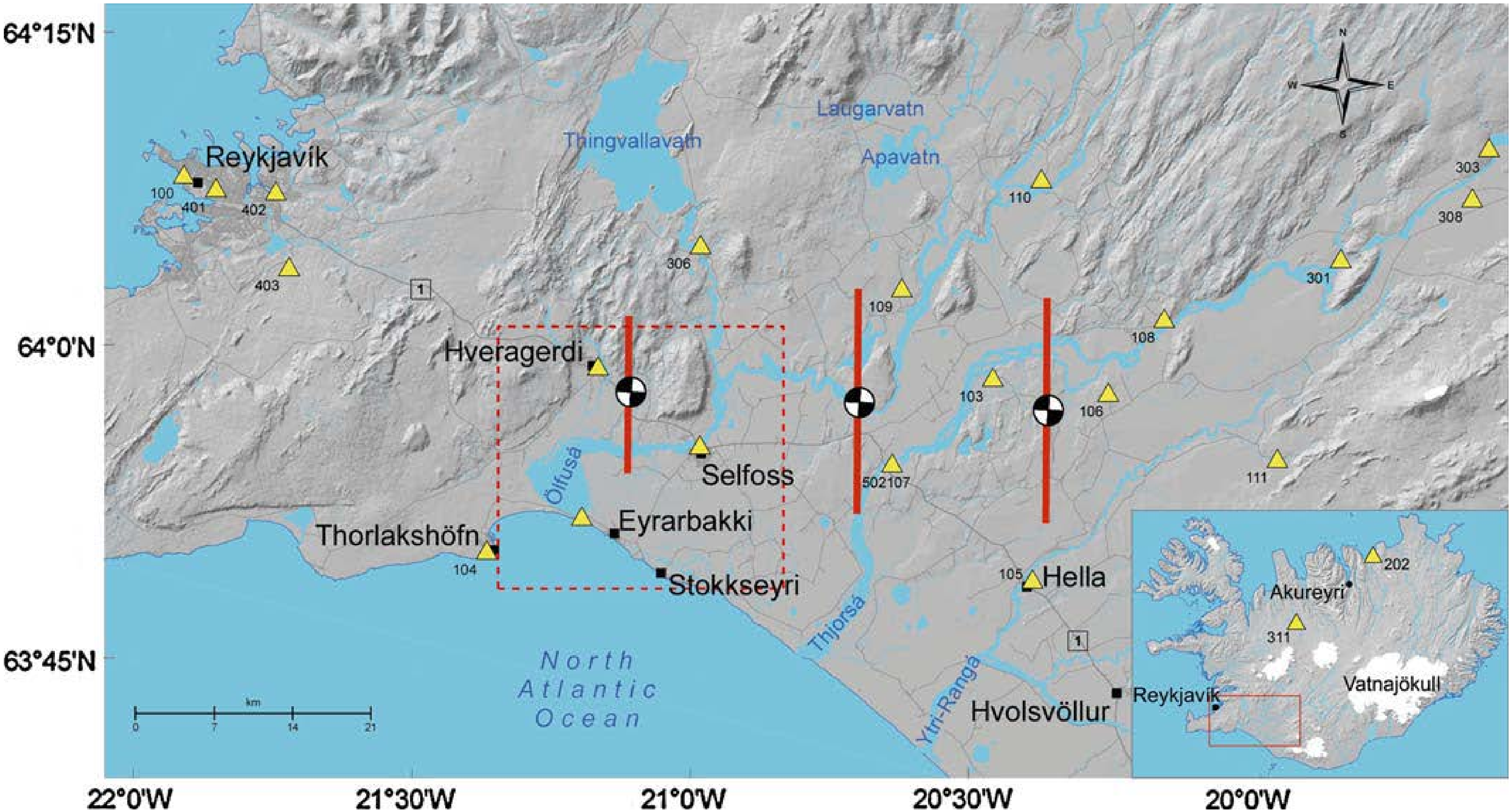
INTRODUCTION

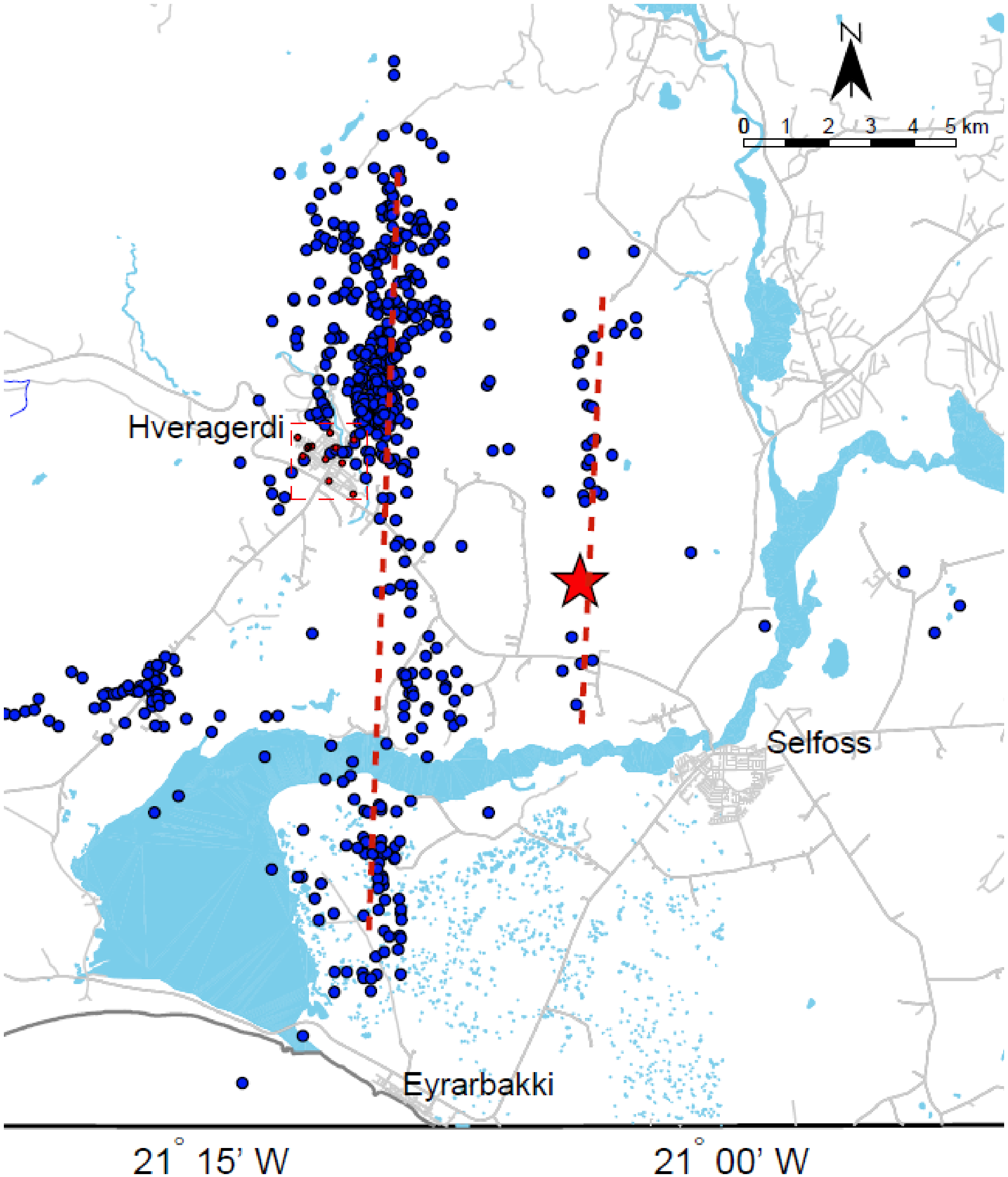
- A study of response characteristics of a specific buildings located in Selfoss, a rural town in South-Iceland, within the SISZ.
- Available data
  - Earthquake induced acceleration – ground motion and response
  - Ambient seismometer data
  - Structural analysis and finite element modelling.
- Acceleration data and structural analysis have revealed an interesting and somewhat unexpected site response phenomenon strongly influencing the structural response.
- The relevance of the geological settings for earthquake resistance of similar buildings needs to be adressed.

EARTHQUAKES IN THE SISZ IN THE LAST 17 YEARS



SELFOSS Town Hall Date of event	Magnitude	Distance from site (km)	Peak ground acceleration (%g)			Peak response acceleration (%g)		
			Vert	N-S	E-W	W: N-S	C: W-E	E: S-N
June 17, 2000	6.5	32	2.9	7.6	5.5	14.6	12.1	15.8
June 21, 2000	6.4	15	6.8	12.7	11.2	30.2	21.4	29.2
May 29, 2008	6.3	8	26.6	53.8	33.4	74.6	47.3	68.2

The 15:45 UTC 29 May 2008 Ölfus earthquake



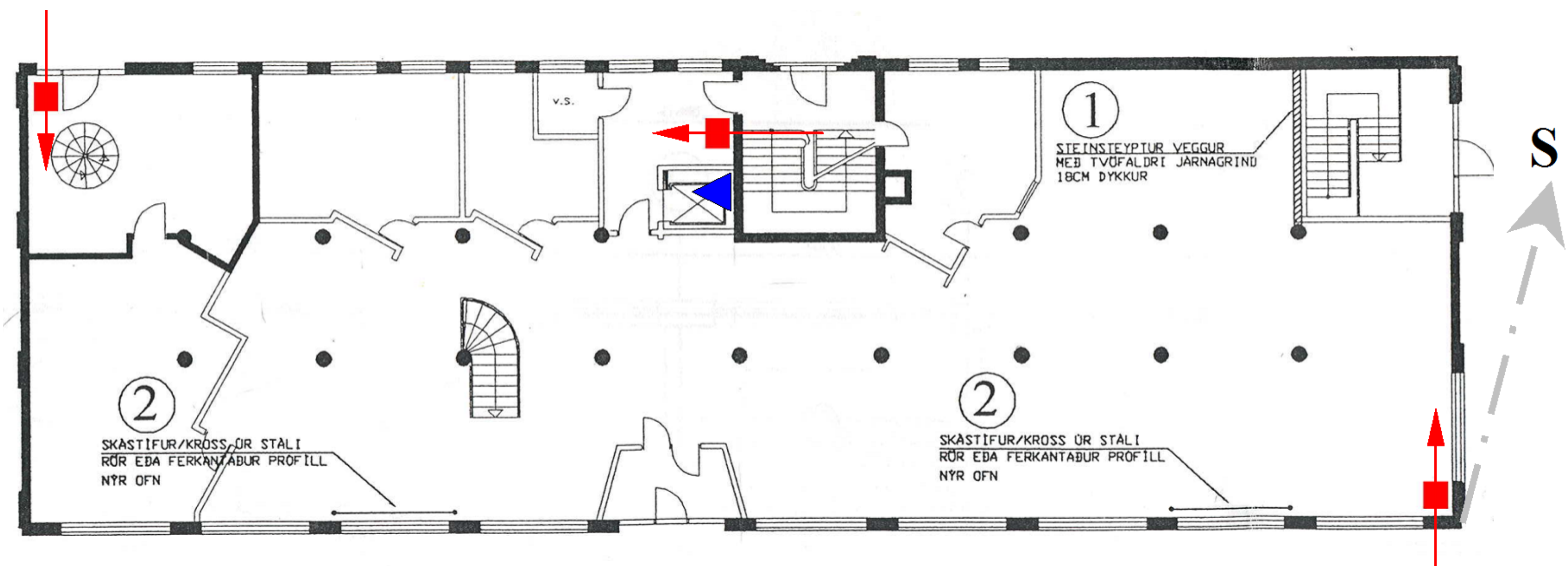
The N-S trending alignments of the seismicity distribution of aftershocks (blue circles) indicate the location of the causative faults (dashed lines).

The red pentagram shows the epicenter of the first shock.

The Town Hall at Selfoss (built in the 1940's)

< View from Northwest

v **Plan view of the ground floor. Location of uni-axial & tri-axial accelerometers is shown. The location of retrofitting elements: (1) RC wall & (2) steel cross-braces installed in spring 2000**

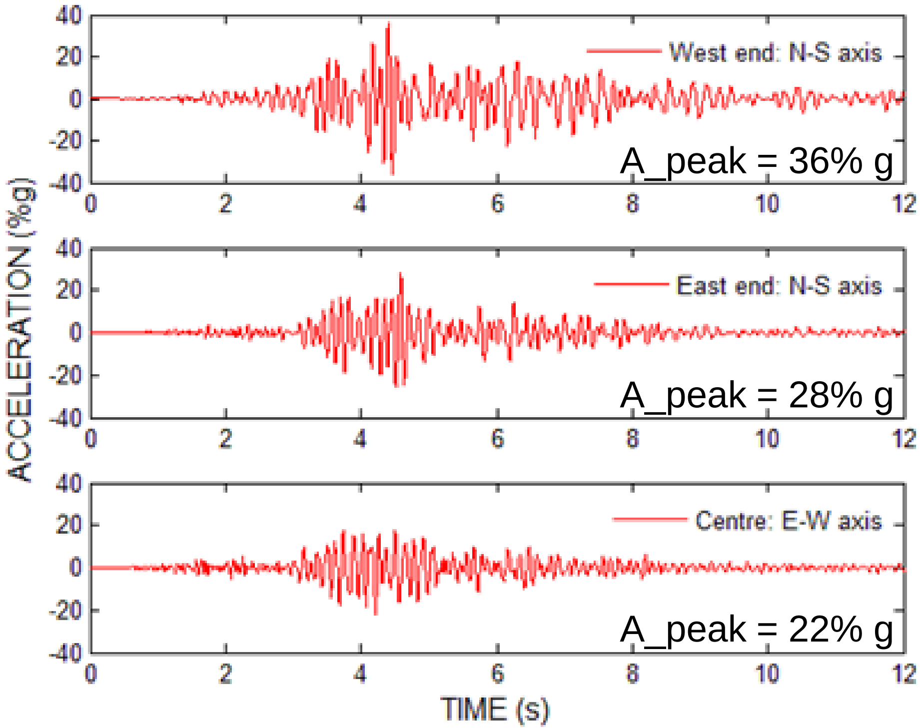


THE CASE STUDIED

- Three story reinforced office building, built in the 1940's, located within the South-Iceland-Seismic-Zone (SISZ)
- Instrumented in 1999, accelerations recorded at the basement level and on the third floor
- The focus of the study:
  - M6.4 earthquake on June 21, 2000, epicentral distance 15 km
  - M6.3 earthquake on May 29, 2008 , epicentral distance 5-8 km
- Strong dissimilarities are observed in the structural response characteristics for these two events
- It is believed that the differences can be explained by soil-structure-interaction between the building and the different soil and rock layers underneath the building

Time-series of relative acceleration response on the 3ed floor

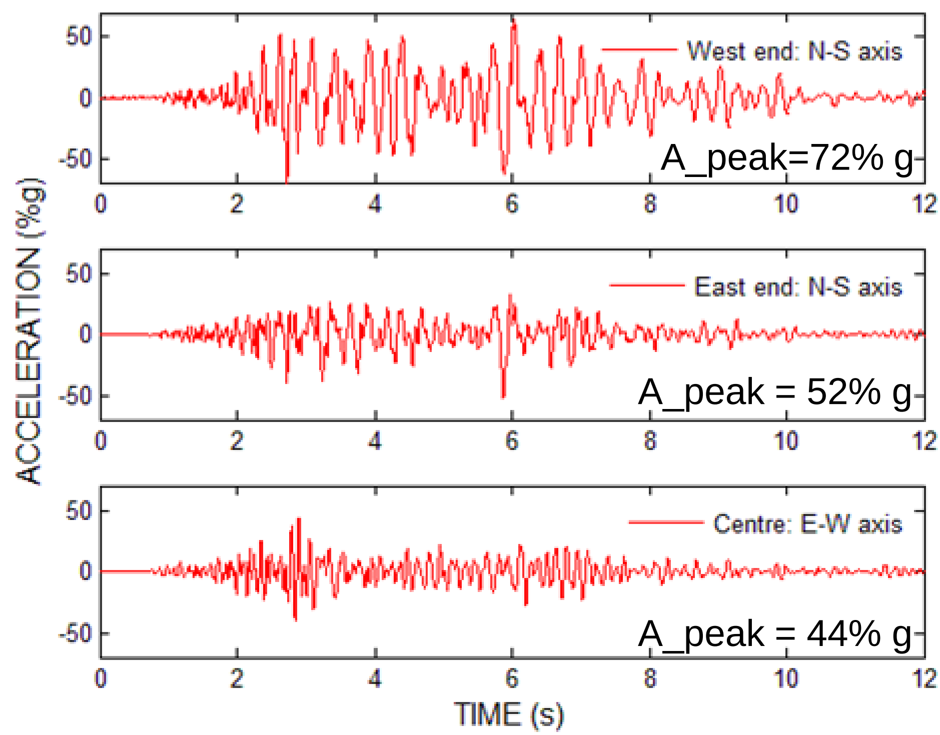
Horizontal PGA = 13 & 11%g



(a) The event on June 21. 2000

Peak values on 3ed floor ~3 times larger than in the basement

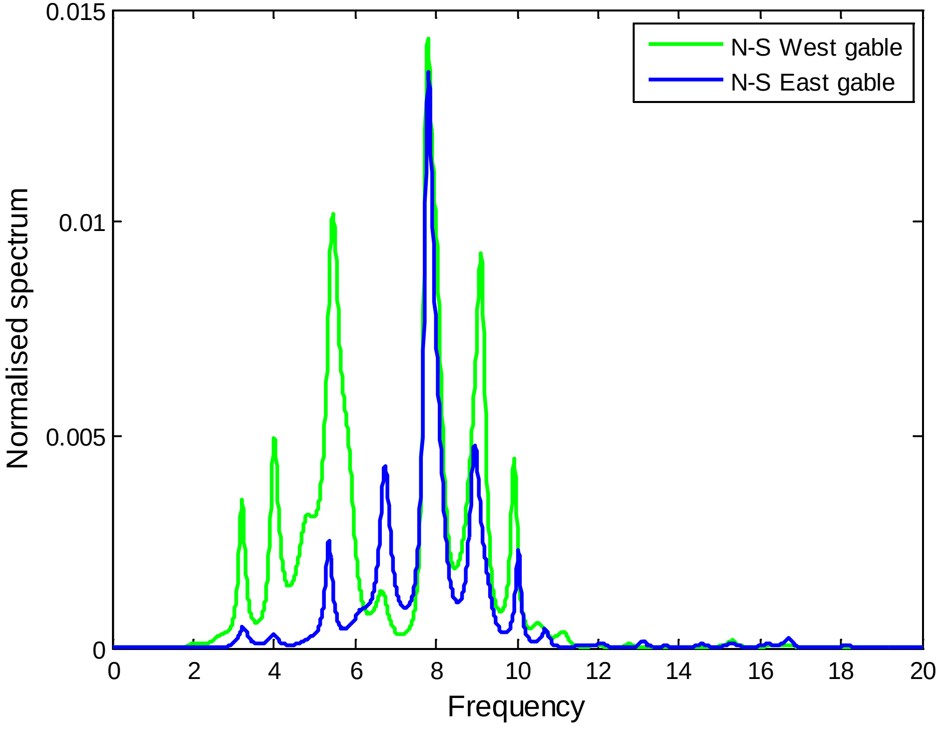
Horizontal PGA = 54 & 33%g



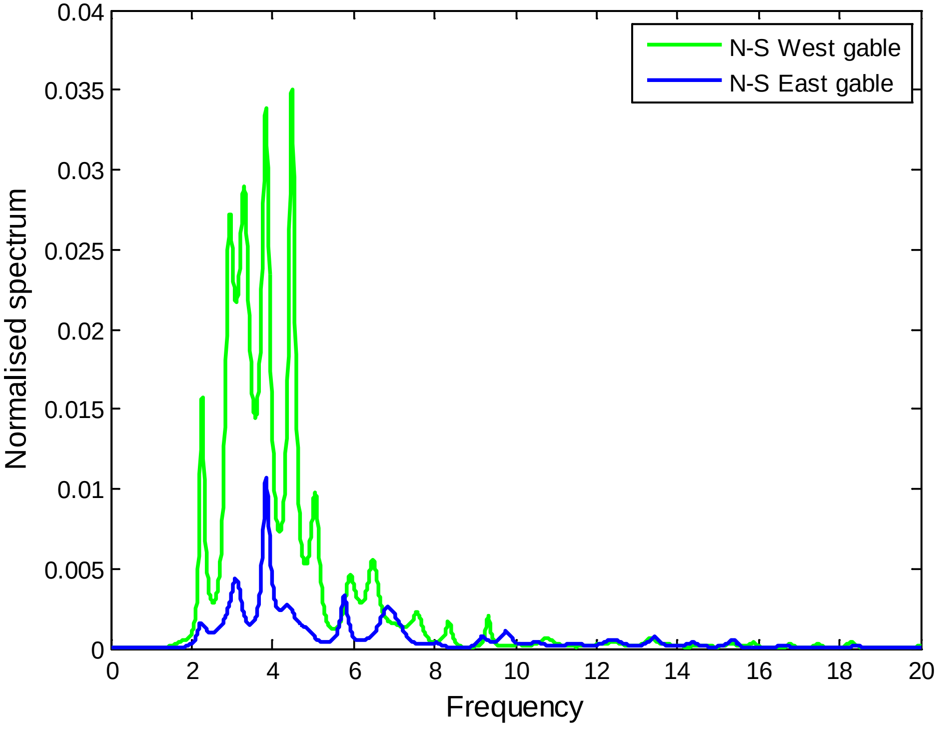
(b) The event on May 29. 2008

Peak values on 3ed floor ~1.4 times larger than in the basement

Power spectral densities of relative acceleration response on the third floor

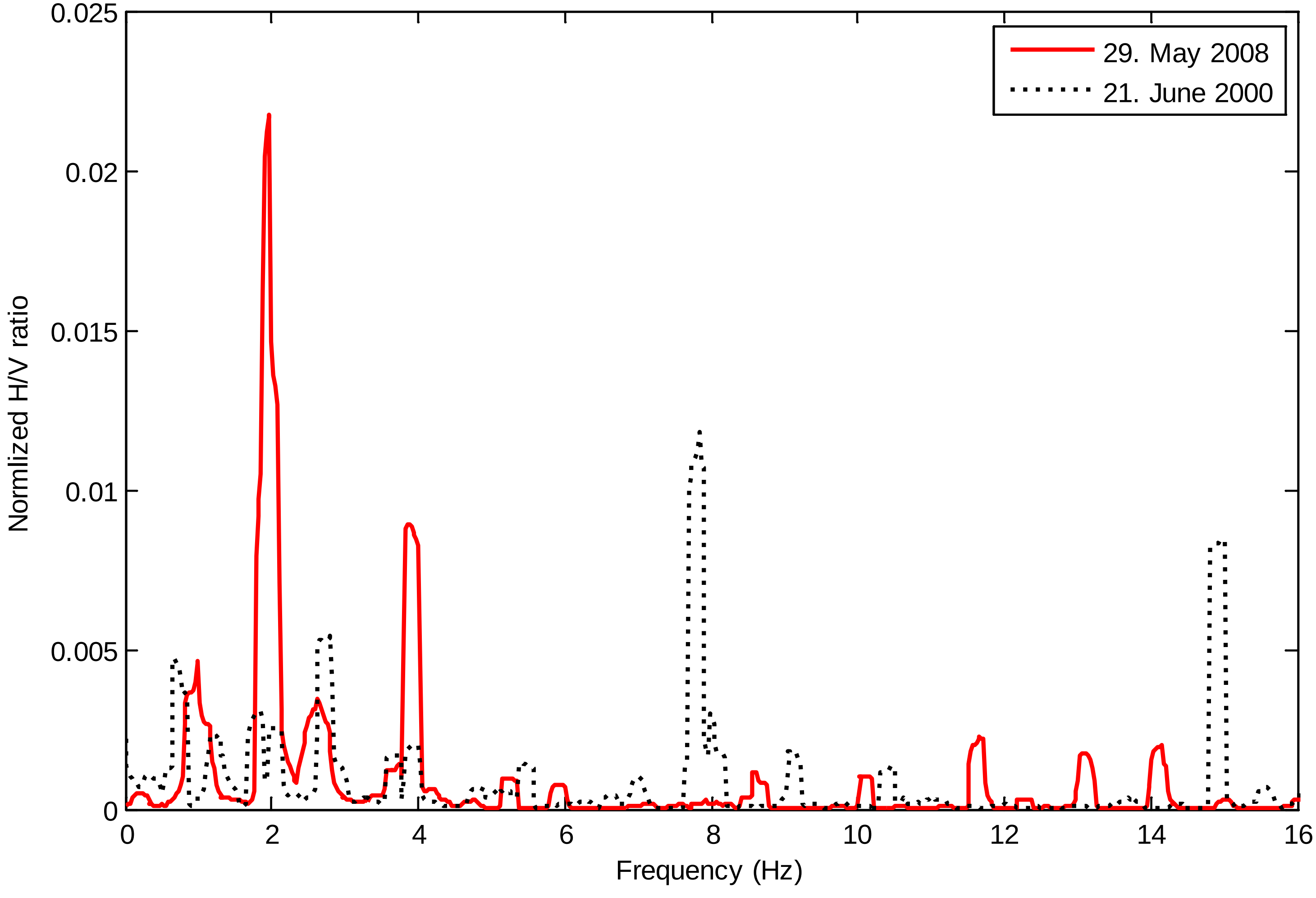


(a) The event on June 21. 2000



(b) The event on May 29. 2008

Selfoss Town Hall
Normalised H/V spectral ratio as a function of frequency for the two earthquakes in 2000 and 2008



A hypothetical rock-soil profile,
based on information from a Borehole near Ölfusá river

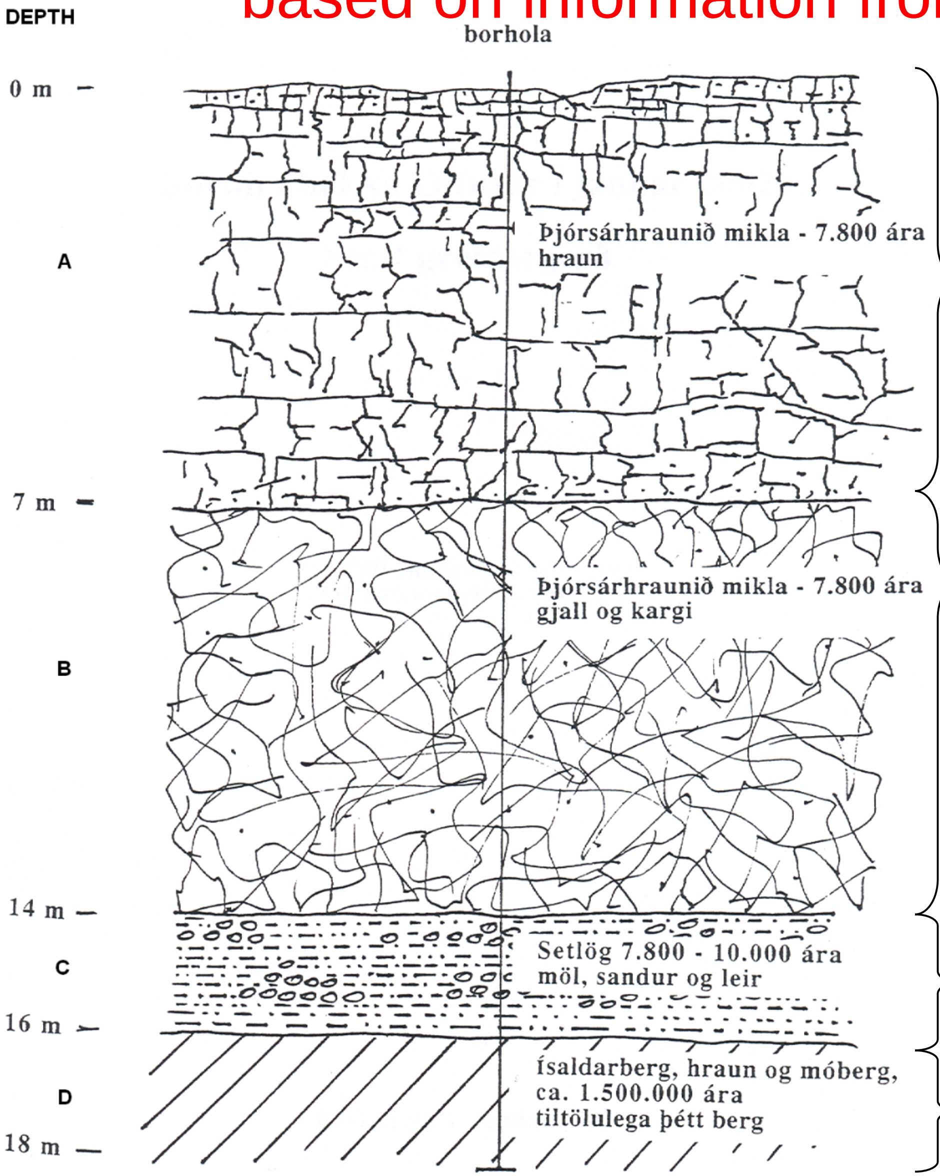


Figure: Páll Imsland

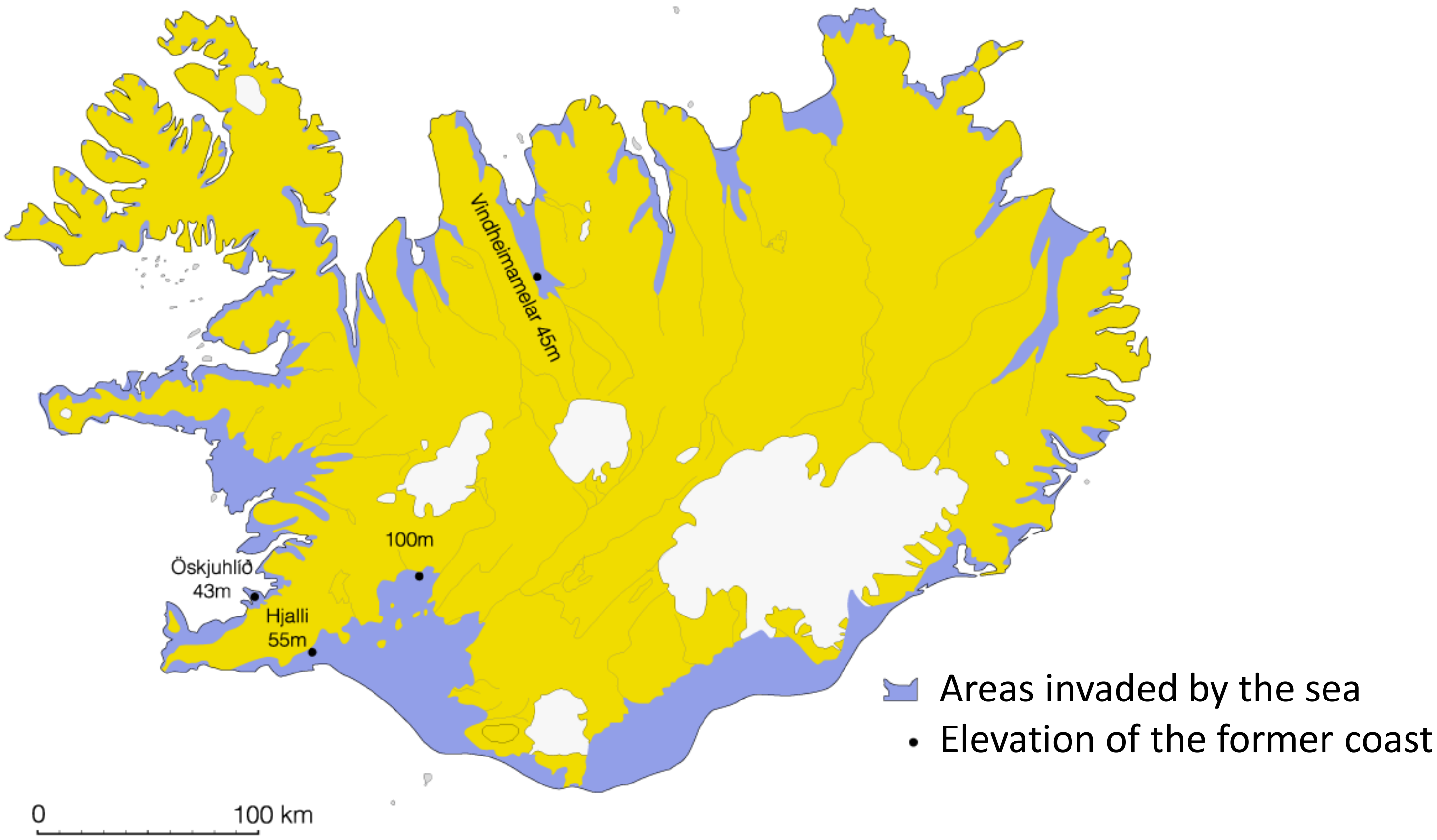
The Great Thjórsá river lava flow 8500 years old Compound lava

The Great Thjórsá river lava flow 8500 years old scoria lava

Sediments 8500 – 10.000 year old, gravel, sand and clay

Tertiary basalt formation ca. 1.500.000 years old, relatively dense rock

During the Ice Age several interglacial periods occurred,
causing the sea level to rise up to 100 m above the present coastline.



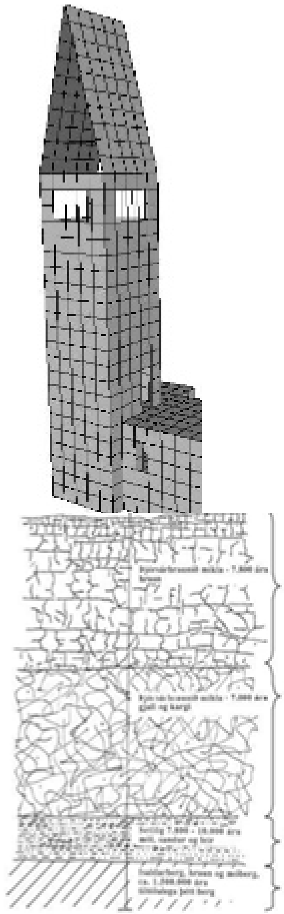
Igneous rock in Iceland, basalt and andesite

- Basaltic tuff/hyaloclastite (subglacial eruption)
- Basaltic lava flows (eruption on land) appearing mainly as two types:

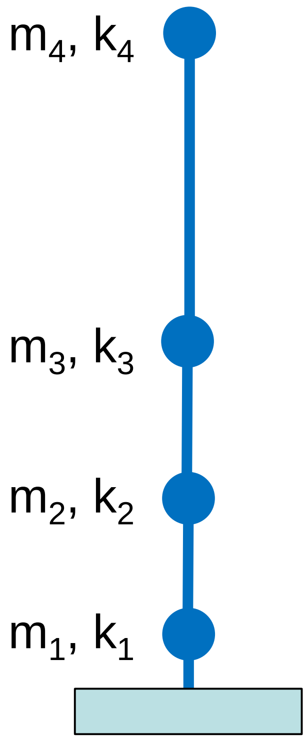
Scoria lava has a crumbly, rough surface made of loosely stacked scoria lumps. Scoria lava

Ca 10 meters thick lava pile, composed of numerous, thin flow units, each varying from 10 cm to 2 m.

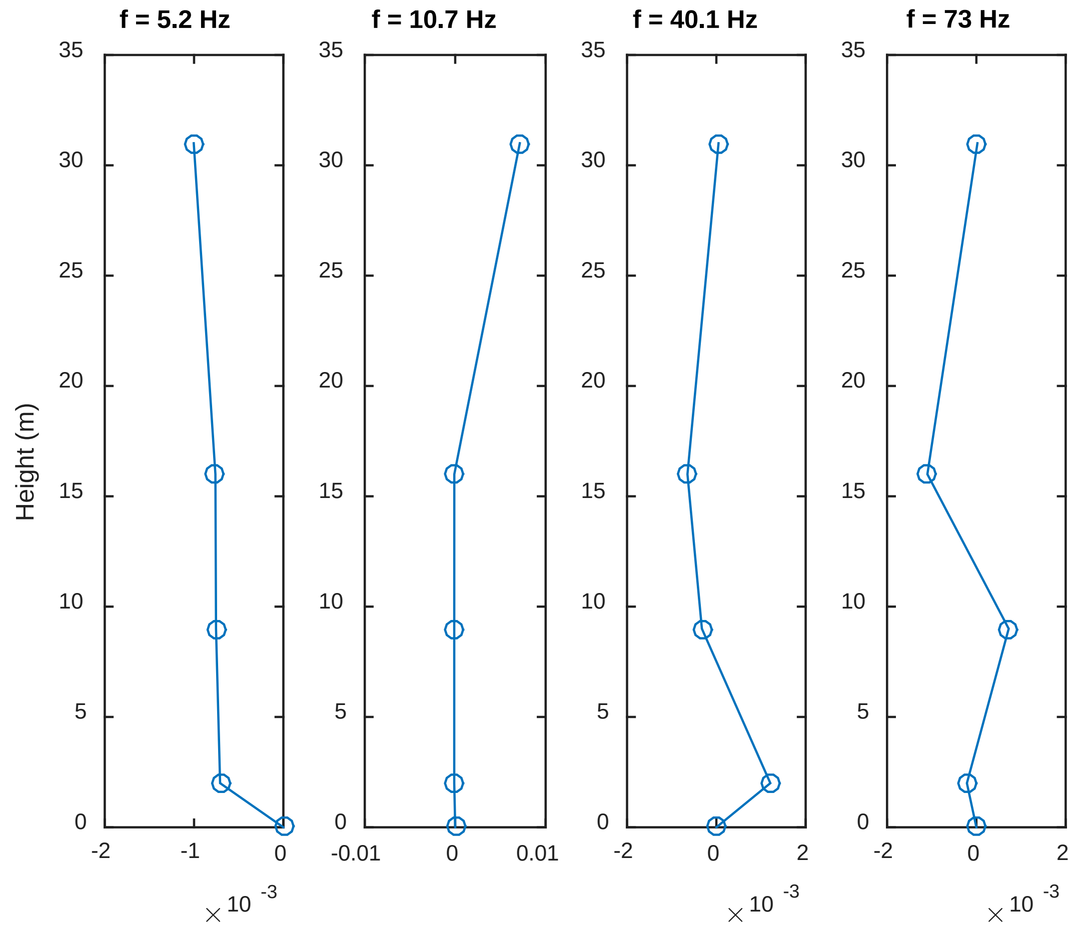
A simple dynamic soil-structure model



The tower & the propsed soil structure



A simple dynamic model, combining the soil-structure and the tower.



The modes of vibration of a simple dynamic soil-structure model.

SUMMARY

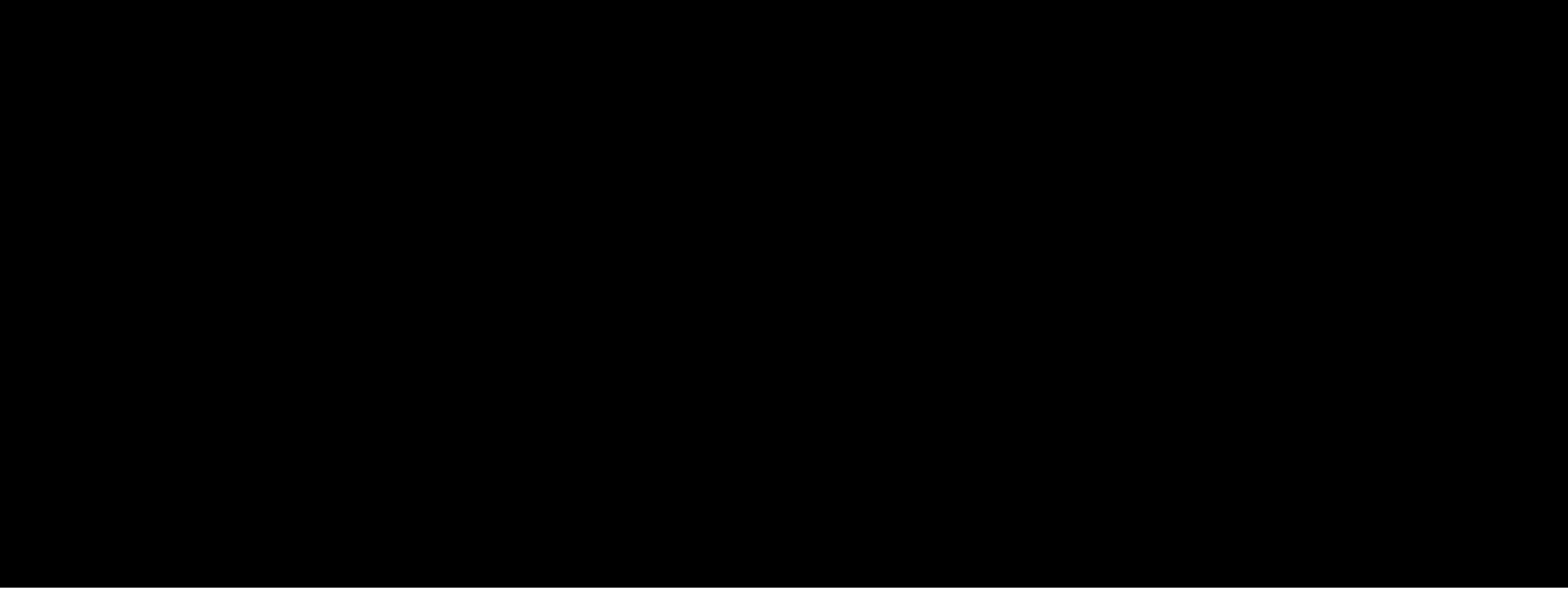
- Prior design assumption for buildings in the area
  - **Stiff soil or rock base**
- Verified by recorded EQ event in 2000
- New data recorded in EQ event in 2008, indicates
  - strong **soft soil** effect from a sub surface sediment layer
- The effects of the soft layer
  - Increases the PGA values at the surface
  - Induces increased action on building contents
  - Acts as a seismic isolation for short period structures (fn > 4 Hz)
    - Increased safety for 1 – 5 story buildings (magnification factor 1.4)
  - Acts as an exciter for longer period structures (fn ~ 2 Hz)
    - Decresed safety for 10 - 15 stories

OVERVIEW

- Data available
  - EQ.: Magnitude, epicenter/hypocenter, distance,
  - Building: Acceleration at two levels, basement and top floor.
  - Vulnerability curves for concrete buildings in the damage area.
- Analysis
  - System representation
    - FE model or a simple stick model
  - Information updating – System changes
    - Change in frequency content of excitation for building
  - Response depends on system characteristics
    - Dependency on magnitude of action / activation of soft layer
- Consequences
  - EQ. excitation estimate for structural design (soft soil vs stiff soil)
  - May effect planning decisions – height limits
  - Need for more detailed analysis of the subsurface layers

OVERVIEW ON PROPOSED CASE ANALYSIS

- Simplified model (3DOF) for building + foundation soil layers
  - Probabilistic dynamic parameters for foundation layers
- Series of buildings, with different natural frequency
- Two foundation cases: active / inactive soft layer
  - Or one case with a large variability
- Drift limits can be used to determine safe / unsafe
  - Or evaluate critical foundation condition for building type.
- For unsafe, the decision can be to:
  - Improve knowledge through borehole section analysis
  - Demand additional foundation work (piles) – added cost
  - Not to build (height limits)



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