Seismic Safety of NPP's – Targets for Research and Education (SAFIR2014/SESA)

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Background and goals

The planning of new NPP's in Finland call for re-assessment of the earthquake hazard. SESA aims to prepare background for the engineering branches faced with this challenges by a multidisciplinary approach involving all aspects of the seismic assessment: (1) evaluation of the hazard, (2) design of buildings (3) qualification of the equipment. The task is very complex. Immediate aim to map the needs of expertise for preparation of the NPP design process.

Highlighted outcomes

(1) *Facilitate collection and analysis of new data (Fig.1)*; (2) A proposal for homogenizing magnitude scale; (3) *Proposing ground motion prediction equations (GMPE's) calibrated based on Fennoscandian data (Fig 2)*; (4) *Pinpointing dominating source of hazard (scenarios) in Finland (Fig 3)*; (5) *Clarifying uncertainties concerning reactor building floor spectra (Fig 4)*; (6) Studying, and to some extent clarifying the presence of high frequency shaking in floors; (7) Improving expertise by organizing a course of 12 lectures (4 credit points) to 50+ postgraduate students and engineers in Aalto University; (8) Strengthening networks on earthquake studies in Finland.

- ML2.8 EQ 01.12.2011 triggered earthquake swarm at Kouvola area
- 19.-20.12.2011 four broad-band sensors were installed on source area with sampling rate 250 Hz
- 22.12.2011 ML2.6 earthquake → recordings from distances 1-9 km
- All events occurred at very shallow depths ~1-2 km
- Majority of events magnitude < 1

Figure 1. Facilitate collection and analysis of new data with the specific aim of supporting hazard studies

GMPE's developed based on local datasets. Selection from over 38000 3-channel seismograms in SESA databank. Original data of 1550 earthquakes; waveforms registered at 40 seismic stations. Data limited to: (1) seismograms with sampling rate of 100Hz or more (2) distance limited to 0-500 km. Earthquakes located in Caledonian terrane in Sweden, Norway and offshore excluded. Number of earthquakes 943 with 8651 registrations. M_{max}=4.1.

Peak ground acceleration (PGA), 10Hz and 20Hz GMPE equations fitted linearly to the data: (1) Simple equation from Ambraseys (A), (2) Complex form by Atkinson & Boore (A&B).
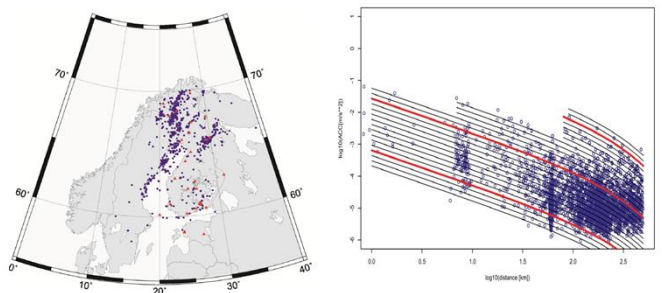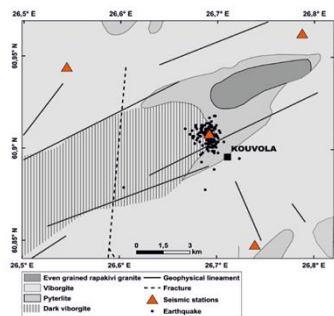

Figure 2. (a) Earthquakes used to compute the GMPE's marked with blue dots. Seismic stations depicted with red triangles. (b) Logarithm of predicted PGA from GMPE's. The lack of short distance data can be observed.

- Deagregation chart showing that the main source of hazard in from earthquakes in the magnitude range of M3-5.
- Hazard is most significant from earthquakes with the epicentral distance below 40km.
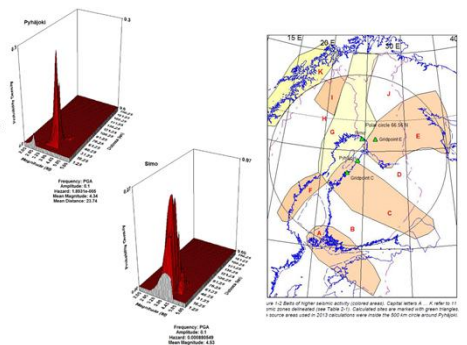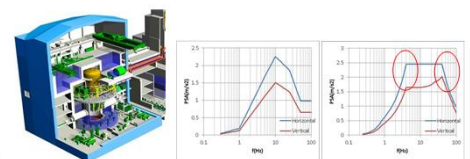
Figure 3. De-aggregation chart showing that the main source of hazard in from earthquakes in the magnitude range of M3-5, from earthquakes with the epicentral distance below 40km.

- Plan dimensions – 61x58m. Elevation – 55.76m.
- Outer walls 2m thick
- Mass ~210 000 tons.
- Prevailing mesh size ~ 0.67m

Floor	Parameter	95% of non-exceedance					
		Ax	Ay	Az	PSAx	PSAy	PSAz
2	Spectra	20%	22%	31%	3%	16%	25%
	Damping	8%	8%	20%	15%	13%	21%
	Set	10%	7%	10%	6%	6%	15%
4	Spectra	23%	44%	9%	42%	56%	10%
	Damping	6%	8%	14%	1%	3%	17%
	Set	1%	4%	13%	4%	14%	9%
6	Spectra	43%	23%	9%	50%	40%	1%
	Damping	3%	7%	12%	9%	21%	20%
	Set	8%	2%	16%	8%	12%	24%

Figure 4. Uncertainties concerning reactor building floor spectra

Conclusions / R&D directions

For small M's GMPE's fitted to Ambraseys equation is recommended, since the amount of data at short distances is too small to allow stable reliable fit using the Atkinson & Boore equation. For larger magnitudes the use of an average of GMPE's of Pezeshk et al. (2011), Atkinson and Boore (2006; 2011), Silva et al. (2002) is recommended. These models are valid only for moderate to large earthquakes, above Mw 4/5. Hazard to sites in Finland is generated from near-field, mid-magnitude seismic events. However, the predictions using attenuation relationships in the proximity of the epicenter areas is very uncertain, because the influence of the source is significant. In the future, the plan is to concentrate on earthquake source modeling using state of the art and self-developed software, in order to understand better the vibrations in the areas close to the earthquake epicenters