Assessing and Modelling Building Failures Caused by External Events at Ringhals NPP

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Introduction

- Authorities in Sweden (SSM): SSMFS 2008:17 §14: *"The nuclear reactor shall be dimensioned to withstand natural phenomena and other events that arise outside or inside the facility and which can lead to a radiological accident."*

-> New deterministic structural calculations for buildings to verify resistance against loads from external events.

- Fukushima - new focus of external events, stress tests

- Update of existing PSA modelling of external events

Approach when modelling External Events in PSA

- **Low frequent events with high impact/loads (based on deterministic calculations**)
  - e.g. extreme snow conditions with impact on building structures

- High frequent event in combination with loss of barriers
  - e.g. normal winter weather, -10 C in combination with loss of heating of intake air

Low frequent events with high impact/loads (based on deterministic calculations)

- Deterministic evaluation of building structures
  - Extreme loads, 10^-4 to 10^-6. Normally 10^-5 per year values are used.
  - Anticipated loads, 1- 10^-2, corresponding to conventional requirements *from National Board of Housing, Building and Planning.* Normally 2*10^-2 values are used.

- Typical meteorological events are analyzed for impact on building structures:
  - Wind
  - Tornado including missiles
  - Ice storm
  - Snow
  - Rain
  - Temperature
  - Earthquake

Snowfall in the town of Gävle, 1998. Depth 180 cm.

Design of Buildings

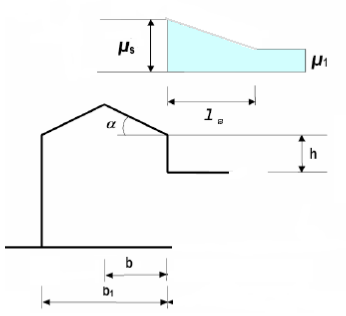
- Buildings should be designed to withstand extreme loads (1E-5 per year), existing buildings are re-qualified
- Manual actions sometimes needed to cope with loads
- Calculation for anticipated loads (2E-2 per year) very conservative based on Eurocode and the Swedish adaption by National Board of Housing, Building and Planning. (EKS10).
- Extreme loads more realistic calculations – may lead to inconsistent results

Quantification in PSA – Example Snow load

- Building cannot withstand load from snow
  - Part of roof cannot withstand load from snow
  - Part of roof cannot withstand load from snow pocket formation

- Anticipated load
  - Small exceedance of utilization factor (just above 1)
  - Conservative calculations
  - High probability for manual actions, not so severe weather

- Extreme load
  - High exceedance of utilization factor (above 1.5 or higher)
  - Realistic calculations
  - Low probability for manual actions, severe weather conditions



Utilization factor = Load/resistance of structure (ratio)

Quantification in PSA – Snow load

LOAD	No exceedance for snow load	Exceedance for snow load/snow pocket	External grid
Anticipated snow load 2*10^-2/year	No damage to building or components	Probability of damage to buildings ~ 0.5 (conservative calculations) Failure of manual actions to remove snow ~ 0.01 Conditional probability of damage to components ~1.0	Short term loss of all external grids
Extreme snow load 10^-5/year	No damage to building or components	Probability of damage to buildings ~ 1.0 Failure of manual actions to remove snow ~ 0.5 Conditional probability of damage to components ~1.0	Long term loss of all external grids

Issues related to quantification

- Utilization factor
  - < 1 – no damage, what about 0,99?
  - > 1 – damage, what probability? Depending in e.g. conservatisms in calculations

- Damage to components
  - Damage of building -> damage on components
  - Only loss of components in rooms just below damaged roof structures or will lower rooms also be affected?

- Manual actions
  - How to estimate failure, weather condition important, availability of tools and personnel
  - Meteorological warnings
  - Multi-units affected

- Multiple buildings affected
  - Probability for more than one building

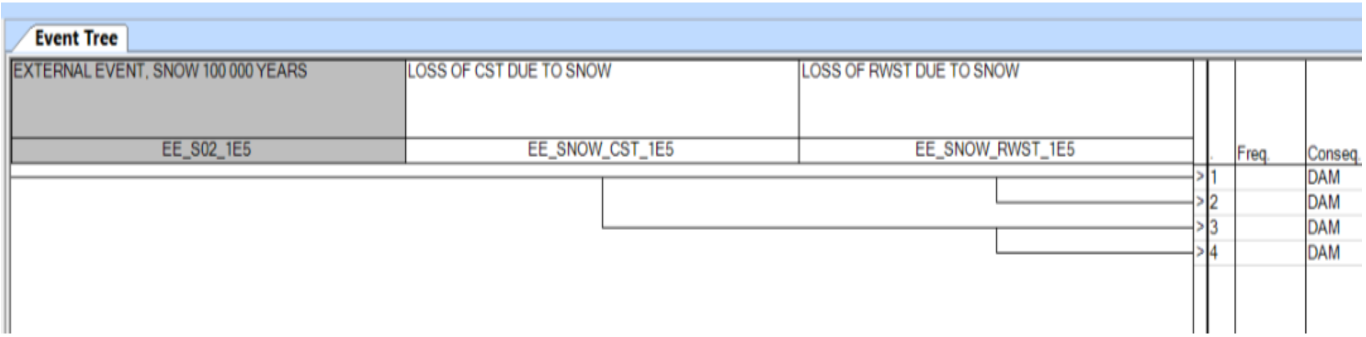
- Long term isolation of site
  - 20-24 h, longer time frame

- Modelling of components
  - Modelling components affected by external events have sometimes been simplified

Quantification in RiskSpectrum®

- Use a Event Tree structure in Risk Spectrum
  - Reduce no of analysis cases
  - Possible to do importance and sensitivity analysis for buildings
  - However, since high probabilities are included, it's important to validate the results

- An alternative is to use multiple analysis cases rather than ET structure.



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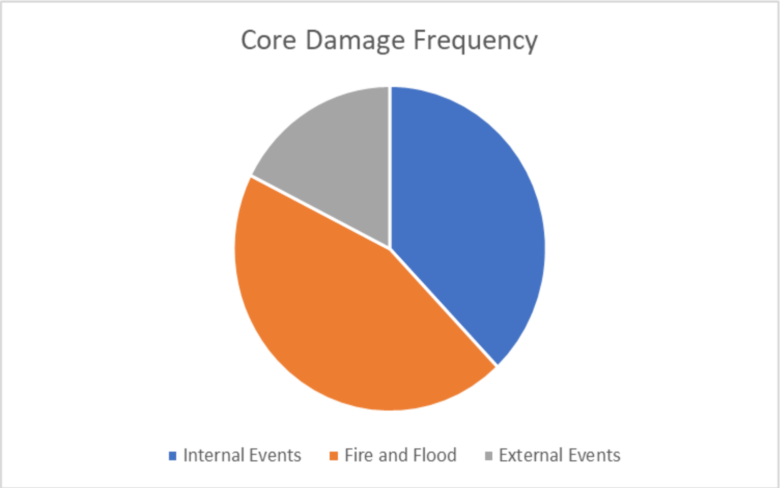
Results

- No major change in total frequency.

- The assumptions are better informed → uncertainties have decreased.
- Co-operation with experts in structural mechanics leads to better understanding of the scenarios.



Challenges

- Realistic treatment of conservative structural analysis
- SSC Damage level due to damage building structures
- Manual actions during severe weather conditions
- Multiunit issues – common buildings/components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