SITE-SPECIFIC ISSUES RELATED TO STRUCTURAL / SEISMIC DESIGN OF AN UNDERGROUND INDEPENDENT SPENT FUEL STORAGE INSTALLATION (ISFSI)

[Paper K01_5]

The 18th International Conference on Structural Mechanics in Reactor Technology (SMiRT)
August 7 ~ 12 , 2005 Beijing, China

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Introduction

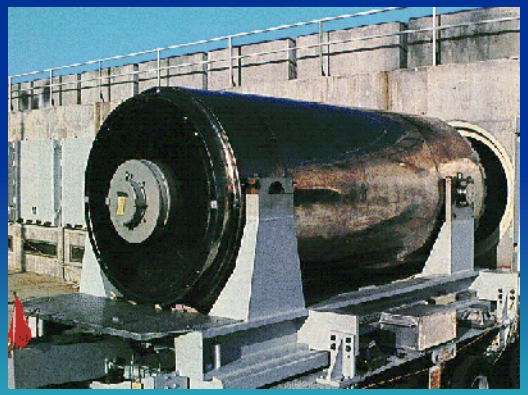
- United States Nuclear Regulatory Commission (US NRC) regulates Storage and Transportation of spent nuclear fuel
- Currently, the Independent Spent Fuel Storage Installations (ISFSIs) are mostly above ground facilities (with few exceptions)
- Utilities may choose to design and build an underground ISFSI
- Structural / Seismic analysis & design could present unusual situations

Regulations & Guidance

- Regulatory Requirements:
  - 10 CFR Part 72
- Guidance:
  - NUREG-1536 (Standard Review Plan)
  - NUREG-1567 (Standard Review Plan)
  - Regulatory Guide: RG 3.73
  - ISG (Interim Staff Guidance)
  - Other Regulatory Guides e.g. RG 1.76, etc

DCSS and Site-specific Issues

- Dry Cask Storage System (DCSS) are either Vertical or Horizontal, Steel and/or Concrete
- Structures Systems and Components (SSCs) important to safety have to withstand natural phenomena loads (NPH)
- The NPH load applications for an underground ISFSI may be different



Normal, Off-normal & Accident Condition Loads

- Handling
- Pressure
- Temperature & Radiation
- Blockage of Vent Ducts Inlet
- Snow & Ice
- Flood
- Tsunami
- High Wind, Tornado, Tornado Missiles
- Seismic
- Other Loads - as applicable

Handling, Pressure & Temperature

- During emplacement and removal of the top lid on the MPC (or storage over-pack), situations (normally not encountered for above ground ISFSI) need to be addressed
- Off-normal internal pressure conditions, ambient temperature, and soil temperature for the site-specific conditions (as in the case of above ground ISFSI) shall be adequately addressed to verify that the resulting stresses are within allowable stresses
- Solar radiation concerns are actually minimized
- Load combinations and compliance with required load factors for concrete analysis/design per ACI 349-01, NRC RG 1.142, and NUREG 1536 - as applicable - have to be met
- Potential of freezing of the nearby soil due to extreme temperatures shall be considered in the design

Blockage of Vent Ducts, Snow & Ice

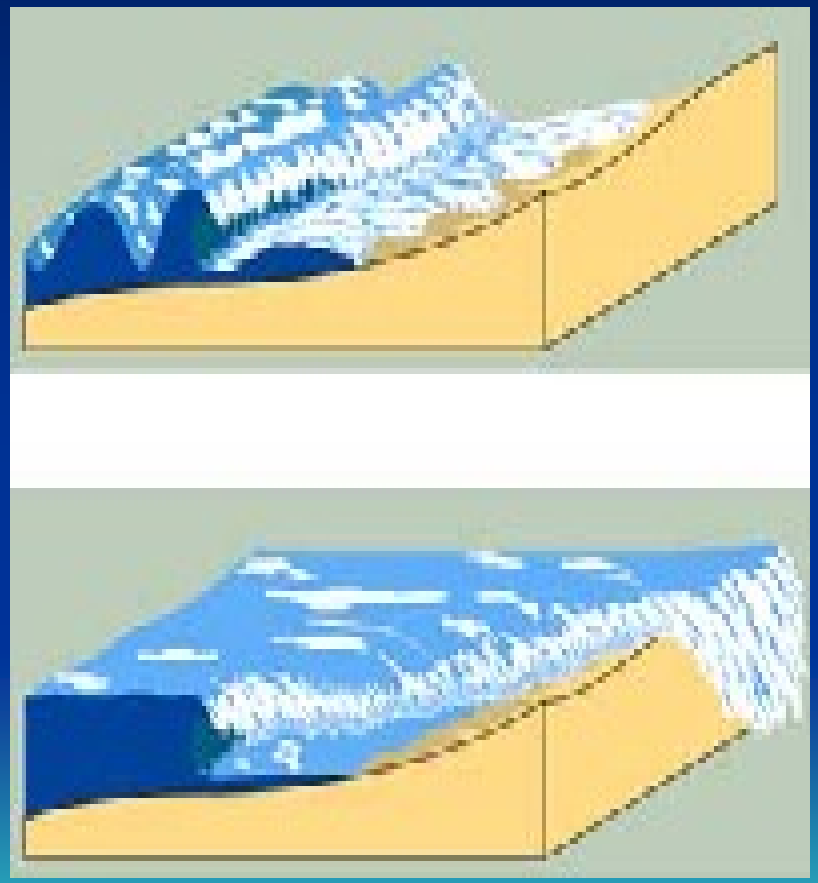
- Measures shall be taken to prevent trapped water which over time, could lead to corrosion
- Ensure that waterborne debris like sand or soil may not cause component or fuel cladding temperatures to exceed the allowable limits
- In extremely cold regions, the effects of long-term steady accumulation of snow and ice shall be considered

Flooding

- Flooding could enhance and accelerate corrosion
- Underground construction <u>may</u> create potential flooding conditions, and site-specific topography, hydrology, and existing drainage system need to be evaluated to avoid stagnant water or moisture
- Elevation of the underground ISFSI, relative to other existing structures nearby, should be carefully determined to take advantage of site-specific natural drainage

Tsunami

- Compared to ordinary breaking surf (top figure)– Typical tsunami wave has very long wavelength as shown in bottom figure
- Tsunami run-up heights <u>from near and distant tsunamis, triggered by seismic event and/or landslide</u> shall be considered for the ISFSI structures



Tsunami – Contd..

- Following scenarios shall be addressed:
- The actual run-up height of tsunami, and potential of inundation due to high and low tides including wave run-ups for storms <u>coincident with tsunami</u>
- The storage cask <u>may</u> be adequate, however, the underground ISFSI concrete structure need to be designed to withstand flowing water, water-borne debris, and other heavy objects dislodged from nearby area

Tornado & Tornado Missiles

- Due to underground location effects of tornado and tornado missiles could be less severe than those for ISFSIs above ground
- ISFSI license holder has to still ensure that site-specific licensing basis tornado rotational & translational wind, tornado differential pressures and missile impact loads are addressed - as applicable
- The portion of the concrete cavity that protrudes above ground, and the top lid of the cask need to be checked to withstand glancing blows from a low trajectory tornado missiles

Seismic

- Seismic event could lead to soil erosion, slope instability, liquefaction, sub-soil compression, short & long term settlement, inundation, etc
- Ensure that the sub-soil supporting the base mat will not liquefy suddenly, creating uneven settlement or uplift of ISFSI
- US NRC Regulatory guide 3.73 suggests to perform probabilistic seismic hazard analysis (PSHA) to account for uncertainties and alternative hypotheses
- The increased vertical load on the reinforced concrete base mat underneath the cask from a downward directed vertical seismic acceleration needs to be evaluated to ensure the structural integrity of the ISFSI

Seismic - Contd..

- Site-specific vertical ground motions and its effects on the stability of slopes nearby the underground ISFSI shall be verified
- Dr. Newmark's stick-slip sliding block concept (pseudo-static analysis) could be used to calculate seismically induced displacement on slopes
- The limiting acceleration beyond which the block (potential sliding mass on a slope during the earthquake) will start to "slip" is known as "Yield Acceleration"

Seismic - Contd..

- However, “Yield Acceleration” is not constant over time - as assumed by Dr. Newmark, and seismic vertical excitation need to be included
- Vertical ground motions could influence the seismic induced displacements of the underground structure
- Vertical acceleration when acting upward has a positive influence and will increase the value of the yield acceleration

Seismic – Contd..

- Seismically induced liquefaction of sub-soil, and its effects on all ISFSI structure need to be verified
- Per US NRC R.G 1.198, the phenomenon of liquefaction is most predominant in fluvial-alluvial deposits, Aeolian sands and silts, beach sands, reclaimed land, and un-compacted hydraulic fills
- Remedial measures should be taken, when needed to strengthen the site-specific existing sub-soil

SUMMARY

- Recapping the main points:
  - Handling, Pressure, Temperature & Radiation
  - Blockage of Vent Ducts Inlet, Snow & Ice
  - Flood
  - Tsunami
  - High Wind, Tornado, Tornado Missiles
  - Seismic
  - Other site-specific loads – as applicable

CONCLUSION

- Important to safety SSCs of an ISFSI need to be designed for site-specific environmental and NPH loads
- All analysis/design situations which could affect the overall safety shall be addressed
- Four safety goals of 10 CFR 72 under all conditions have to be met:
  - ✓ Meet radiation dose limits
  - ✓ Maintain sub-criticality
  - ✓ Ensure confinement & containment
  - ✓ Allow retrieval of spent fuel

QUESTIONS

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