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Soil Remediation for Seismic Design of ISFSI Pad

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Bhasker (Bob) P. Tripathi, P. E.
Senior Structural Engineer
DSFST/NMSS
U.S. Nuclear Regulatory Commission

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INTRODUCTION

- Liquefaction – Seismically induced
- Soil Remediation Techniques
- Soil Parameters
- Verification of Improved Soil
- Acceptance Criteria
- Analysis – SSI
- Pile supported ISFSI Pad
- Summary

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DESIGN OF ISFSI PAD AND REDUCING LIQUEFACTION

Three possible ways to reduce liquefaction hazards:

1) Avoid liquefaction susceptible soils

2) Build liquefaction resistant structures

3) Improve the soil

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REASON TO REDUCE LIQUEFACTION DURING EARTHQUAKE SHAKING

- Soil-improvement techniques reduces liquefaction hazards and avoids large increases in pore-water pressures
- Achieved by densification of the soil and/or improvement of its drainage capacity

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METHODS OF SOIL REMEDIATION

1) Dynamic Compaction (Densification)
2) Vibro-Compaction (Densification)
3) Vibro-Replacement (Stone Columns - Densification)
4) Vibro-Replacement (Stone Columns / Vibro Piers - Reinforcement)
5) Drainage and Surcharge (Densification)
6) In-Situ Soil Mixing/Deep Mixing, Wet (Reinforcement)
7) In-Situ Soil Mixing/Deep Mixing, Dry (Reinforcement)
8) Compaction Grouting (Densification)
9) Compaction Grouting (Reinforcement)
10) Cement Fracture Grouting (Compensation)
11) Chemical Grouting Silicates (Reinforcement, Reduce Permeability)
12) Jet Grouting, Etc…

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IN-SITU SOIL IMPROVEMENT

-> The (Long) soil-crete columns were driven approx. 45' below existing grade to layers of stiff to hard clay

-> Alternate rows of (Short) columns of approx. 35' length were drilled to minimize liquefaction.

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RESULTS OF SOIL IMPROVEMENT

Soil Paramctcr	Before Soil Stabilization	After Soil Stabilization
Sub-Grade Modulus	0.54 ~ 2.17 MN/m^3 (2 ~ 8pci)	8.14MN/m^3 (30pci)
Estimated Settlement	0.10 ~ 0.20m (4" ~ 8")	0.01m (0.5")
Estimated Liquefaction	30%	~ 0%
Seismic Response @Top of Pad (Max)	NS=0.26g, EW= 0.26g	NS = 0.32g, EW = 0.36g

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VERIFICATION OF IMPROVEMENT IN-SITU TECHNIQUES

- Popular because of the limitations of many laboratory techniques
- Usually performed to evaluate the liquefaction potential of a soil deposit before the improvement is attempted
- The necessary level of improvement in terms of in-situ test parameters can then be specified
- After the improvement has been completed allows one to decide if the degree of improvement was satisfactory

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IMPORTANT PARAMETERS FOR ISFSI ANALYSIS AND DESIGN

Three parameters that influence seismic response of the cask:

- 1) pad flexibility;
- 2) soil properties; and
- 3) cask arrangement on the pad

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SOIL- STRUCTURE INTERACTION [SSI] ANALYSIS

- Analyses of the ISFSI must consider the seismic response at the CG of the Dry Cask Storage System
- The ISFSI foundation analysis must include an SSI analysis and must address liquefaction potential as required by (10 CFR 72.212(b)(2)).

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SSI ANALYSIS – Contd…

- The SSI analysis needs to:
  1) compute the peak horizontal acceleration at the top of the base-mat
  2) consider non-liquefied soil conditions
  3) analyze with, and without a loaded DCSS
  4) analyze in the transverse and longitudinal directions
- These acceleration time histories should then be used to calculate the accelerations at the CG of the DCSS.

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CG OF THE CASK Vs. TOP OF THE ISFSI PAD

- If the fundamental frequency of the cask in the lateral direction lies within the resonant band of the response spectrum, higher amplification could occur at the CG of the cask.
- The seismic stability of the DCSS is based on the seismic acceleration at the CG of the cask and not based on the peak ground acceleration (PGA) at the top of the pad.

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ISFSI PAD SUPPORTED ON PILE FOUNDATION

- When the soil remediation efforts are unable to achieve acceptable accelerations, use pile foundation
- SSI does not capture 3-D effects (such as torsion)
- Consider the effects of torsion, if piles are used to support the ISFSI pad

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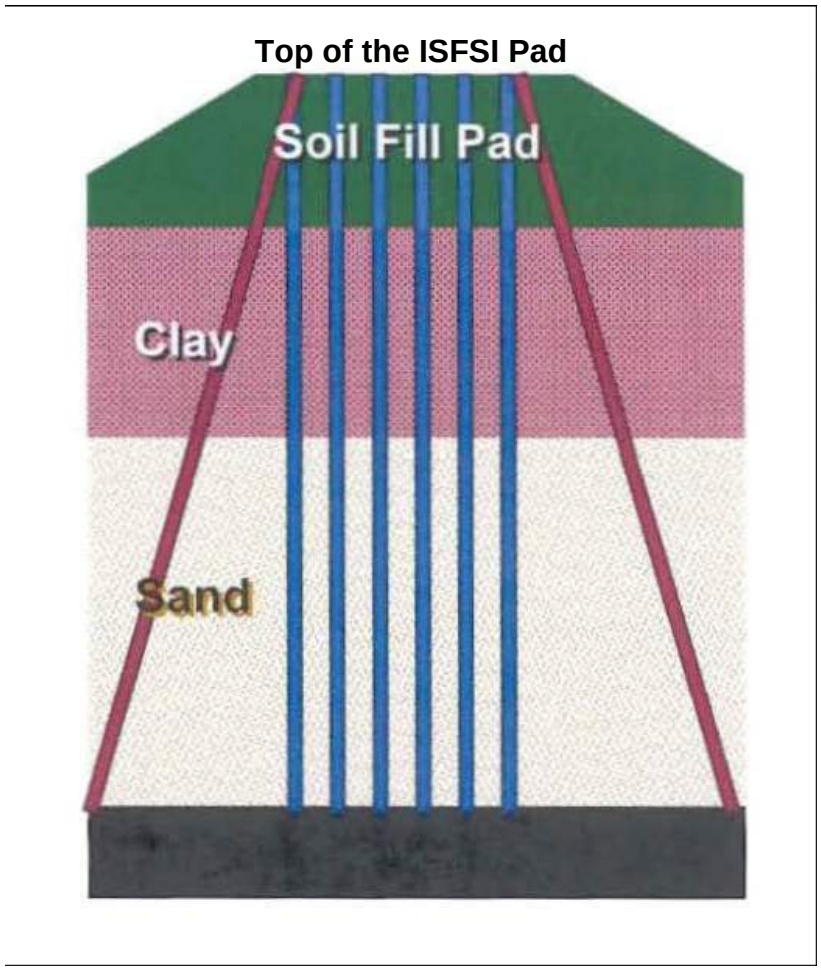
ISFSI PAD SUPPORTED ON PILES



Vertical (Blue) and Battered (Red) Piles supported on Bedrock

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ACCEPTANCE CRITERIA

- The ISFSI pad foundation must meet the Certificate of Compliance (CoC) conditions, and
- The pad foundation must meet the acceptance criteria during a safe-shutdown earthquake, or the applicable seismic criteria at a given specific site.

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SUMMARY & CONCLUSION

- In-situ soil stabilization has significant effects on the dynamic response of the structure
- Future seismically induced liquefaction potential can be reduced or even (almost) eliminated by engineering and stabilizing the sub-grade
- Soil-Structure analysis need to be considered appropriately, depending up on the type of foundation used for the ISFSI pad

❖ **ANY QUESTIONS ?**