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IAEA SAFETY STANDARDS

Geotechnical Aspects of Site Evaluation and Foundations in NPPs, NS-G-3.6

**Regional Workshop on Volcanic, Seismic, and Tsunami Hazard
Assessment Related to NPP Siting Activities and Requirements
June 13-17, Jakarta, Indonesia**

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Background

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IAEA Safety Standards Series No. NS-R-3, Site Evaluation for Nuclear Installations:

3.1. The seismological and geological conditions in the region and the engineering geological aspects and **geotechnical aspects** of the proposed site area **shall be evaluated**.

3.38. **The potential for liquefaction of the subsurface materials** of the proposed site **shall be evaluated** by using parameters and values for the site specific ground motion.

Background

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3.41. The geotechnical characteristics of the subsurface materials, including the uncertainties in them, shall be investigated and a soil profile for the site in a form suitable for design purposes shall be determined.

3.42. The stability of the foundation material under static and seismic loading shall be assessed.

3.43. The groundwater regime and the chemical properties of the groundwater shall be studied.

IAEA Safety Standards

for protecting people and the environment

Geotechnical Aspects of Site Evaluation and Foundations for Nuclear Power Plants

Safety Guide

No. NS-G-3.6



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Introduction

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- The purpose of this Safety Guide is to provide guidance on dealing with **geotechnical engineering** consideration that are important for safety of nuclear power plants.
- It provides interpretation of the Safety Requirements for site evaluation.
- It provides **guidance** on the **methods and procedures** for **analyses** that support the assessment of the geotechnical aspects of the safety of NPPs.

- This guide discusses the **geotechnical engineering aspects** of the subsurface conditions and not the geological aspects.
- It discusses the **programme of investigations that should be carried out** in order to obtain an appropriate understanding of the subsurface conditions.
- It also provides a **description of the geotechnical profiles** and the **parameters** suitable for performing the geotechnical analyses required for the design.
- It discusses also the **monitoring of the geotechnical parameters** of the site.

Contents

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- Introduction
- **Programme of investigation**
- Site considerations
- Foundation Considerations
- Earth structures
- Buried structures
- Monitoring of geotechnical parameters
- Quality insurance

Site Investigation

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- **Investigation Program**

- Selection stage
- Characterization stage
 - Verification
 - Confirmation
- Pre-operational stage
- Operational Stage

- **Sources of data**

- Historical and current documents
- In situ exploration
- Laboratory tests

- **Investigations for complex subsurface conditions**

- Prediction of complex subsurface conditions
- Detection of subsurface cavities
- Evaluation and treatment of complex subsurface conditions

Selection Stage

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- Unacceptable subsurface conditions.
- Classification of sites.
- Groundwater regime.
- Foundation conditions.

The type of soil, depth to bedrock and the properties of the deposit may be inferred. This allows a preliminary selection of acceptable foundation types to be made.

Characterization Stage

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Verification stage

- Geological hazards
- Geological and subsurface conditions
- Liquefaction potential
- Feasible foundation types
- Preliminary bearing capacity and foundation stability
- Preliminary settlement ranges
- Groundwater levels and regime
- Site preparation requirements

➤ Site investigation techniques

- ✓ Rotary borehole drilling
- ✓ In situ testing
- ✓ Seismic refraction and reflection survey



IAEA laboratory testing

Characterization Stage

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Confirmation stage

- Geological maps and profiles.
- Description of geological factors and site geology.
- Boring location plans and cross-sections.
- Boring logs and test pit logs.
- Results of in situ testing.
- Results of laboratory testing.
- Results of geophysical surveys.
- Description and results of analyses.
- Detailed description of groundwater regime

The purpose of this stage is to determine the site characteristics and select parameters that are to be used for final analysis and design for individual facilities.

Pre-operational and Operational Stages

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–Pre-operational stage :

Complete and refine the assessment of site characteristics by incorporating geotechnical data newly obtained during foundation excavation and construction.

– Operational Stage :

Settlement of structures should be measured and used to confirm its safety and integrity by comparing with prediction analyses

Foundations considerations

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- Foundation work
 - Preliminary foundation work
 - Improvement of foundation conditions
 - Choice of foundation system and construction
- Soil-structure interaction
 - Static Analysis , Dynamic Analysis , Analysis methods
- Stability
 - Bearing capacity, Overturning, Sliding
- Settlements and heaves
 - Static analysis , Dynamic analysis
- Induced vibration effects



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Preliminary Foundation Work

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- Prototype testing (including test fills, verification of foundation material improvement techniques)
- Excavations for foundations or foundation systems
- Dewatering and its control
- Dental work in rock
- Mapping of excavations
- Foundation materials improvement (including such items as material modification, drainage, etc)
- Structural backfill placement
- Mud mat placement or any type of protection layer

Summary of available methods

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- Dissipation of excess pore pressure
 - Gravel drains
 - Sand drains
 - Wick or paper drains
- Densification through vibration and compaction
 - Sand compaction piles
 - Deep dynamic compaction
 - Vibration/ vibro flotation
 - Stone columns
 - Preloading
 - Compaction grouting
 - Timber displacement piles
- Restraining effect through inclusions
 - Deep soil mixing
 - Diaphragm walls
- Stiffening through chemical cement addition
 - Jet grouting
 - Chemical grouting

Ground Improvement Design program

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The following steps can be followed to design the ground improvement program:

1. Select potential improvement methods
2. Develop and evaluate remedial design concepts
3. Choose methods for further evaluation
4. Perform final design for one or more of the preliminary designs
5. Compare final designs and select the best one
6. Field test for verification of effectiveness and development of construction procedures
7. Develop specifications and QA/QC programs

Monitoring of

Geotechnical Parameters

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- Purpose of Monitoring
 - **Provide parameters** and site characteristics suitable for **predicting the performance of foundation** systems under various loading conditions.
 - The monitoring of actual loads and deformations permits a **field check of the predicted behavior** of the foundations and earth structures
- Guidelines for Monitoring
 - The soil behavior should be monitored during excavation, backfilling and building construction.
 - The groundwater regime under buildings and in adjoining areas should be monitored
 - The monitoring devices should be **carefully chosen** so that the monitoring system provides the expected information **for the life duration of the installation**. The choice and number of the devices should rely on feedback experience with regards to their expected failure ratio.

QUALITY ASSURANCE

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- A Quality Assurance program should be established to control the execution of the site investigations and assessments and engineering activities being performed during the different stages of the site evaluation activities for the NPP.
- This program should cover the organization, planning, work control, personnel qualification and training, verification and documentation of the activities.
- This program should be established at the earliest possible time consistent with the site evaluation activities for the NPP .
- The process of establishing site related parameters and evaluations involves technical and engineering analyses and judgments which requires extensive experience and knowledge .

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Thank you for your attention



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