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# Management of the geotechnical section for NPP siting requirements

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## 1. Introduction

Siting is known as the process of finding out the most suitable site for the specific facility. Siting for a nuclear installation is a multifaceted process that includes safety considerations. Nuclear Power Plant (NPP) siting stages can be divided into survey stage, site selection stage, site assessment stage, and pre-operational and operational stages. At first, the potential regions and sites are investigated by screening analysis, and the candidate sites are identified at the stage of site survey. And then, the candidate sites are assessed for the preferred candidate sites and final selection through further screening and ranking at the stage of site selection. At these two stages, the initial environmental data should be collected and analyzed. And, at the stage of site assessment, justification of the acceptability of the site is performed based on the detailed site investigation, and the derivation of the site related design basis resulted from the characterization of the site are applied to Preliminary Safety Analysis Report (PSAR) and Environmental Impact Assessment (EIA) for Early Site Permits (ESPs) and Combined Licenses (COLs). Site characteristics shall be within the site parameters specified in Standard Design Certifications (DCs) for the reactor to be safe at the site. There are so many site parameters and site characteristics. They should be not only accurate for the safe NPP design but also satisfactory for the siting requirements of PSAR and EIA. Moreover, they are so specialized and profound that a siting management team of a nuclear power project has difficulty managing the contractors to get appropriate results for PSAR an EIA. For this reason, it was needed to understand the site parameters and site characteristics in terms of effective siting management. This paper deals with only the geotechnical section to help NPP siting management although there are also other main sections such as meteorology and hydrology.

## 2. Site parameters for geotechnical section

Necessary site parameters for soil and rock properties and the related standard test methods will be stated as below.

In general, core samples are collected from more than twenty boreholes by means of ground drilling and transported to the laboratories for the tests on the following soil and rock properties.

### *2.1. Soil Classification*

Soils are typically classified as either coarse grained or fine grained, cohesionless or cohesive, but the most common description is “sandy” or “clayey”. Soil classification is used to help describe soil behavior.

Grain Size Distribution (GSD) Curve is used for the classification of coarse grained and fine grained soil with the value of Fines Content (FC = Weight of fines ÷ Weight of soil sample × 100%) as per the result of the sieve analysis (ASTM D422) and the hydrometer analysis (ASTM D422). The Atterberg limits is used to calculate the Plasticity Index (PI = LL – PL) through the plastic limit test (ASTM D4318) and the liquid lmit test (ASTM D4318).

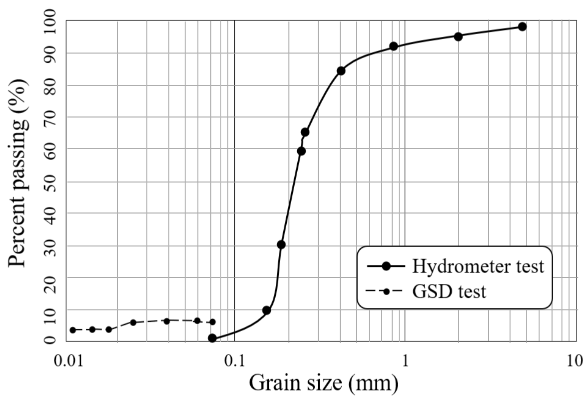


Fig. 1. GSD curve

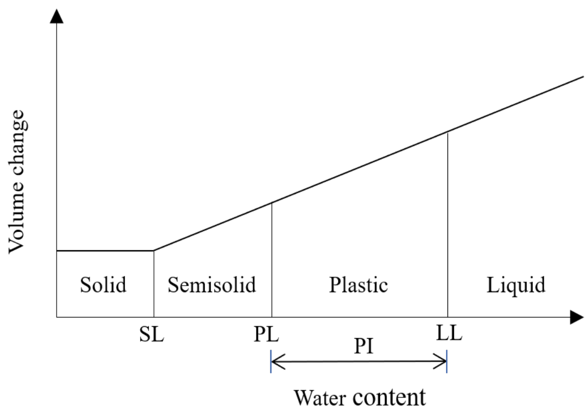


Fig. 2. Atterberg limits

### *2.2. Index Properties for Soil*

Index properties are the properties of soil that help in identification and classification of soil. Water content, specific gravity, particle size distribution, in-situ density (Bulk unit weight of soil), consistency limits and relative density are the index properties of soil. These properties are generally determined in the laboratory. The following parameters can be derived from the index properties.

Maximum index density and unit weight ($\gamma_{max}$) of soils uses vibratory table (ASTM D4253). Minimum index density and unit weight ($\gamma_{min}$) of soils and calculation of relative density (ASTM D4254) uses three alternative methods such as using a funnel pouring device or a hand scoop to place material in mold, depositing material into a mold by extracting soil filled tube, and depositing material by inverting a graduated cylinder.

*2.3. Soil Compressibility*

An increase in stress mainly caused by construction of foundations compresses soil layers. The compression is caused by deformation of soil particles, relocation of soil particles, and expulsions of air and/or water from void spaces. Soil compressibility is the capability of the soil to decrease in volume with applied mechanical load. The process to describe the soil volume decrease by the external load is compression. Consolidation refers to compression of saturated soil. Compression of unsaturated soils is compaction. Soil settlement caused by loads is generally divided into three following status such as immediate settlement ($S_e$ : caused by elastic deformation), primary consolidation ($S_c$ : volume change in saturated cohesive soils due to expulsion of water), and secondary compression ($S_s$ : observed in saturated cohesive soils where there is no change in stress, also known as creep).

$C_r$ (Slope of recompression/rebound line), $C_c$ (Slope of virgin compression line), and $C_\alpha$ (Index of secondary compression) are derived from the consolidation curve, which can be drawn by means of the consolidation tests (ASTM D2435, ASTM D4186).

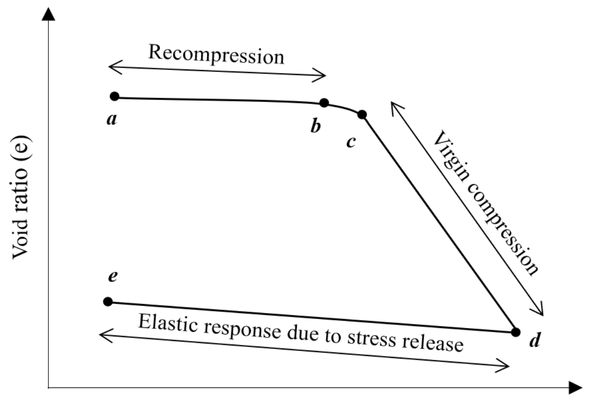


Fig 3. Consolidation curve

*2.4. Shear Permeability*

Soils are permeable due to the existence of interconnected voids through which water can flow through points of high energy to low energy. Hydraulic conductivity of soil is a function of several factors such as fluid viscosity, pore-size distribution, void ratio, roughness of particles, and degree of saturation.

*K* (Hydraulic conductivity) can be derived from the falling head permeability test (ASTM D5084, ASTM D7664) at the laboratory or pumping tests (ASTM D7242) in the field.

*2.5. Shear Strength of Soil*

The strength of soil is shear strength which is the maximum internal resistance to applied shearing forces. According to the Mohr-Coulomb failure criterion, shear strength consists of two components, cohesive and frictional. Failure Envelopes are different between drained and undrained conditions. In case of drained condition, Effective stress analysis is applied for construction on sandy soil, embankments constructed slowly (in layers over clayey soils), and excavation in clay. In case of undrained condition, total stress analysis (one depth only, conservative) or undrained strength analysis (effective stress before shearing, also known as strength normalization only for clays) is applied.

*C* (Cohesion) and $\phi$ (Friction angle) are the measures of shear strength. These parameters are subdivided according to the three types of triaxial tests. They are denoted as $C_d$ and $\phi_d$ by CD (Consolidated drained) triaxial test (ASTM D7181-11), $C_u$ and $\phi_u$ by CU (Consolidated undrained) triaxial test (ASTM D4767-11), and $S_u$ ($\phi = 0$) by UU (Unconsolidated undrained) triaxial test (ASTM D2850-03a).

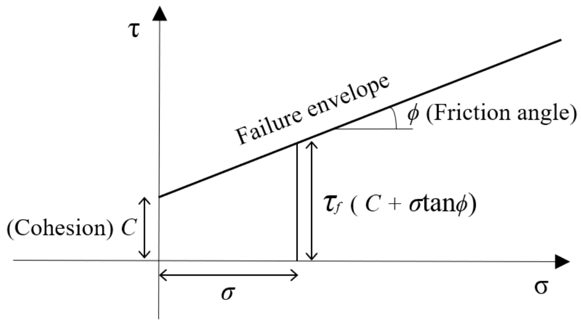


Fig 4. Mohr-Coulomb failure criterion

*2.6. Rock*

Properties of rock mass are discontinuity, anistropy, and heterogeneity. The factors influencing rock mass behavior are discontinuity, degree of weathering, initial stress, and groundwater. The investigation of rock quality is important for the foundation of NPP. The rock core is used for the investigation of the rock quality. Many rock borehalls are needed to take the rock core samples.

Rock Quality Designation (RQD) is a simple measure of rock quality. Rock Mass Rating (RMR) has various value to classify a rock quality. RMR classification table determines a rock mass quality. There are also rock quality iundicdes (*Q*, *Q'*) that are useful to establish rock mass blasterbility and its variation.

Table I: RQD description

| RQD(%) | Rock Quality |
|---|---|
| < 25 | Very Poor |
| 25 ~ 50 | Poor |
| 50 ~ 75 | Fair |
| 75 ~ 90 | Good |
| 90 ~ 100 | Excellent |

Table II: RMR description

| RMR | Rock Quality |
|---|---|
| 0 ~ 20 | Very Poor |
| 21 ~ 40 | Poor |
| 41 ~ 60 | Fair |
| 61 ~ 80 | Good |
| 81 ~ 100 | Very Good |

### *2.7. Dynamic Characteristics*

Main seismic waves are P (primary, push-pull) waves and S (secondary, shear) waves. And, P waves are characterized by having a particle motion in the direction of propagation, whereas S waves have particle motion transverse to the direction of propagation.

Dynamic site characterization such as P wave velocity ($V_P$), S wave velocity ($V_s$), and Modulus Reduction and Damping (MRD) curves are derived through geophysical testing method such as the spectral analysis of surface waves test. MRD curves make simple and torsional shear tests. The test results usually show $G/G_{max}$.

## 3. Conclusions

NPP siting projects take several years and cost a lot. The good siting is the very beginning of the successful NPP construction. If the siting fails, NPP construction can be delayed a lot more or canceled due to the change of the circumstances during the delay. This paper cannot cover all the geotechnical section for NPP siting management. However, it is expected to help understand the importance of the siting management for successful NPP projects. The papers for the management of meteorology and hydrology sections for NPP siting requirements are expected to be written later on.

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