Low-grade Soil Materials with Non-plastic Fines as an Alternative Geomaterial for Embankment Structures

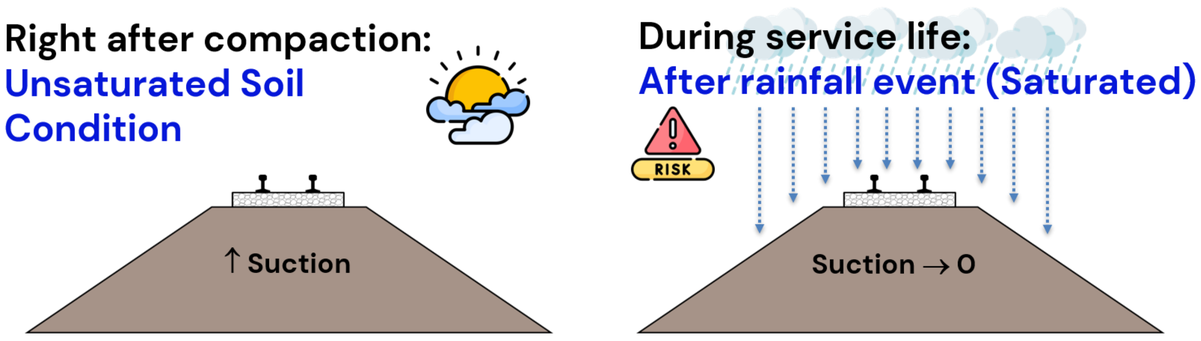
盛土建設の代替材料としての非塑性細粒分を含む低級盛土材料の活用

ROSAL Maria Demi Faye Quinto
(Outline of Master Thesis, July 2024)
Department of Civil Engineering, The University of Tokyo, Japan

THE UNIVERSITY OF TOKYO
GEOTECHNICAL ENGINEERING LAB.

Research Background

The increasing global demand, but insufficient supply of high-quality soil materials has led to the importance of exploring alternative geomaterial such as low-grade soils for embankment structures that could satisfy the requirements ensuring a stable foundation.



The simplest way to utilize such soil material is to increase the compaction energy level (CEL) and at the drier conditions. High stiffness and shear strength are correlated with high matric suction, but the extent of its influence has yet to be fully understood. These three concerns arises after the event of rainfall:

- Decreased shear strength
- Collapse (sudden deformation)
- Risk of increased axial strain due to traffic load

Objectives

1. To understand the strength properties of soil when compacted at the drier side of the compaction curve for low-graded soil material with fines content from 20% to 30%.
2. To understand the deformation characteristics when low-graded soil materials highly compacted at the drier side of the compaction curve is soaked during and after rainfall.

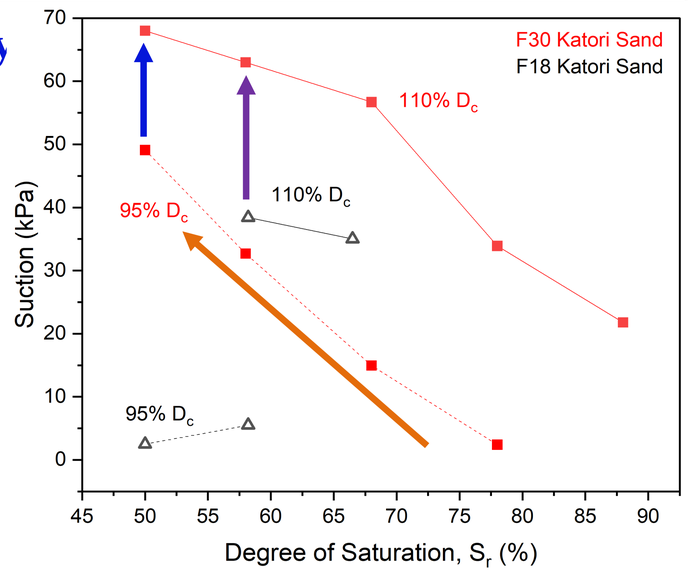
Factors affecting suction

Effect of Compaction Energy
- ↑ ρ_d, ↑ Suction

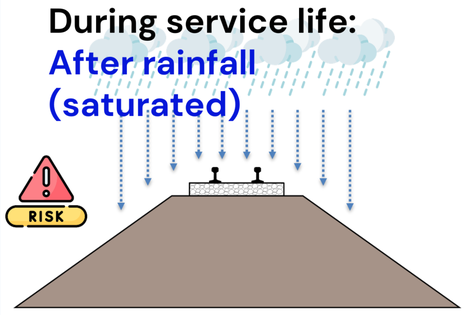
Effect of Saturation,
- ↓ S_r, ↑ Suction

Effect of Fines Content,
- ↑ F_c, ↑ Suction

How does the increase of suction affect the mechanical properties of the soil?

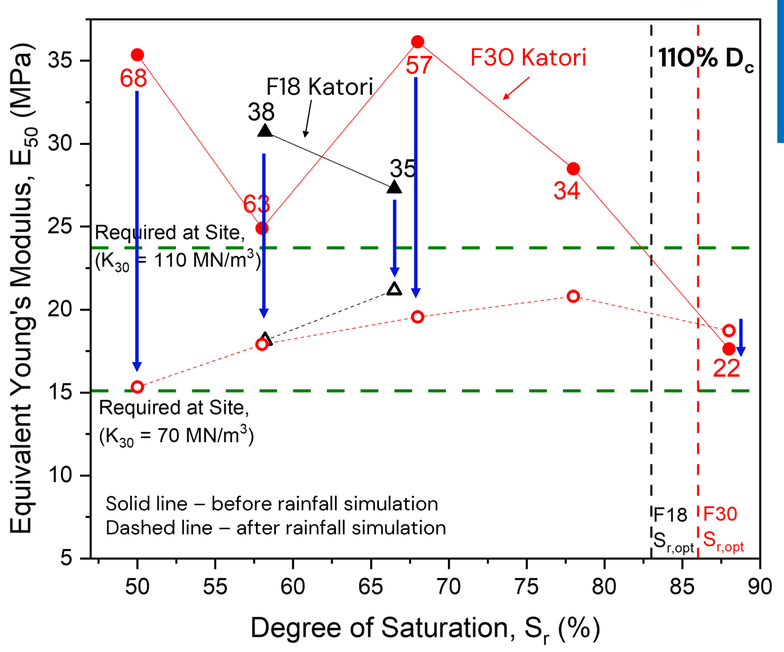


Strength (q_{max}) & Stiffness (E_{50}) after rainfall



May lead to **over-estimation** of **measured on-site stiffness due to loss of mobilized suction after rainfall event**

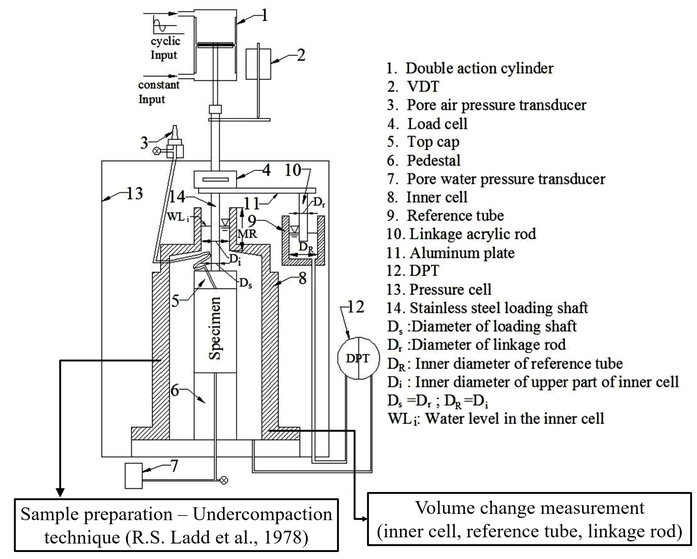
Equivalent Young's Modulus, E_{50}



Methodology

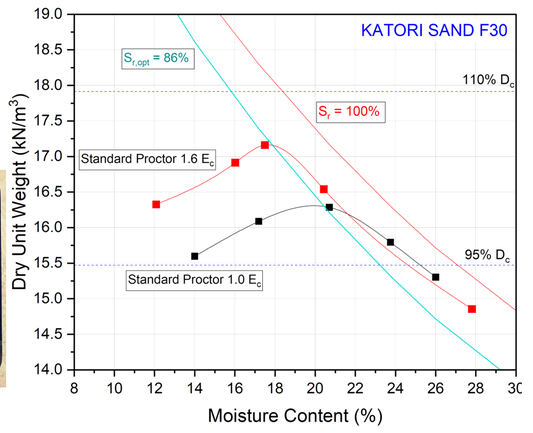
Linkage Double Cell Triaxial System

- This system is used to test unsaturated test conditions under different loading conditions (monotonic loading and cyclic loading).
- Suction can be measured and controlled.
- A separate series of soaked condition tests to mimic rainfall are performed.



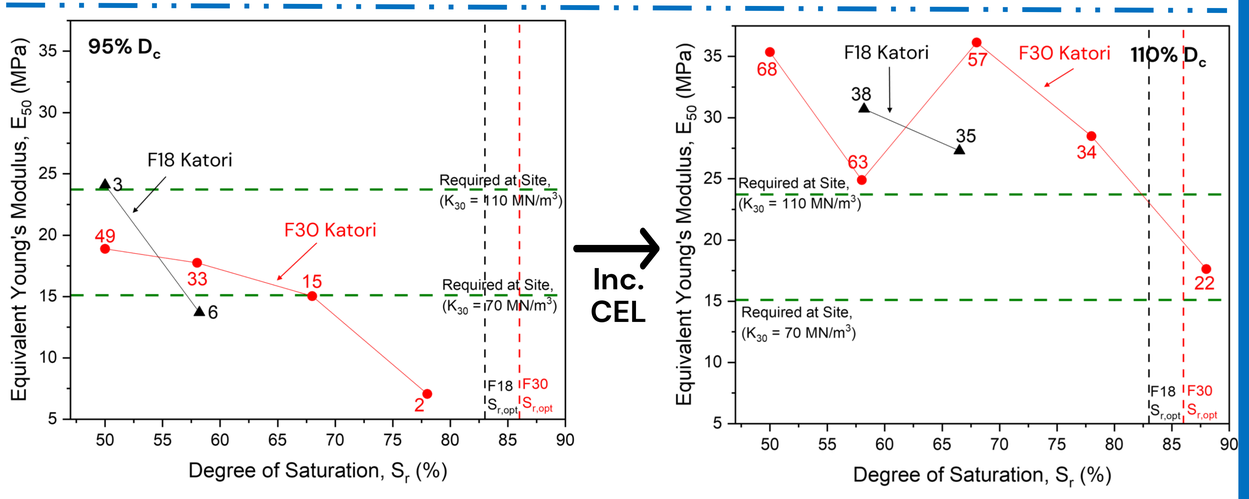
Materials

- Katori Sand (F_c = 18.8%)
- Model Katori Sand (F_c = 30%)

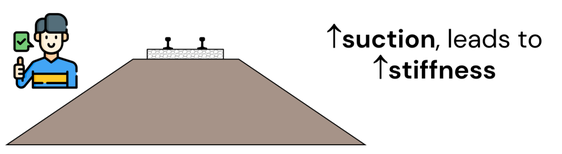


Strength and Deformation Properties

Equivalent Young's Modulus, E_{50}



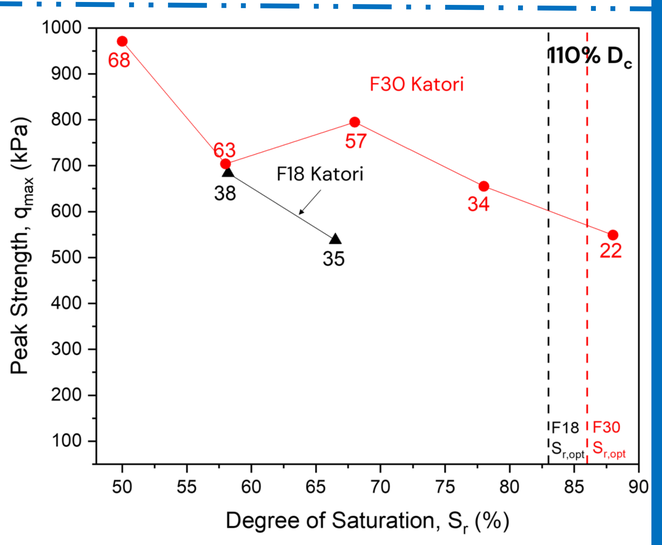
Right after compaction:
Unsaturated Soil Condition



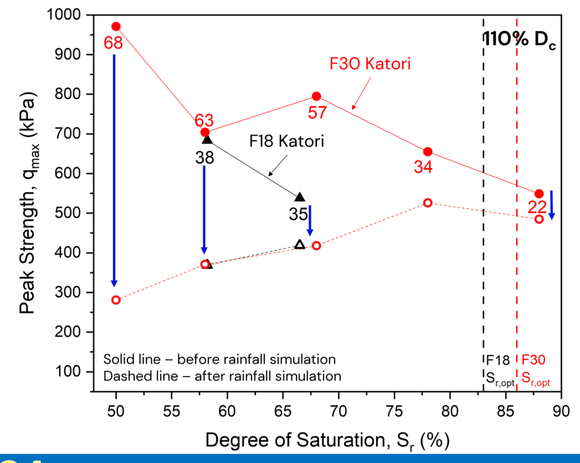
At higher CEL (110% D_c),

- Stiffness value is **well within the required K_{30}** even when compacted near the $S_{r,opt}$
- E_{50} and q_{max} dramatically increases with the decrease in S_r while suction also greatly increases

Peak Strength, q_{max}



Peak Strength, q_{max}



Effect of rainfall:

- **Near $S_{r,opt}$,** huge reduction of E_{50} and Q_{max} **does not occur**.
- E_{50} and Q_{max} **decreases significantly after rainfall** when highly compacted at much **drier conditions** due to the **loss of suction**.
- Soil with higher F_c showed larger effect of rainfall.

Effective compaction method for utilizing low-grade material with non-plastic fines content for railway embankment

(非塑性細粒分を含む低級盛土材料の鉄道盛土への有効活用のための効果的な締固め管理方法)

東京大学 THE UNIVERSITY OF TOKYO

BHARGAVI CHOWDEPALLI

(Outline of Doctoral Thesis, March 2023)

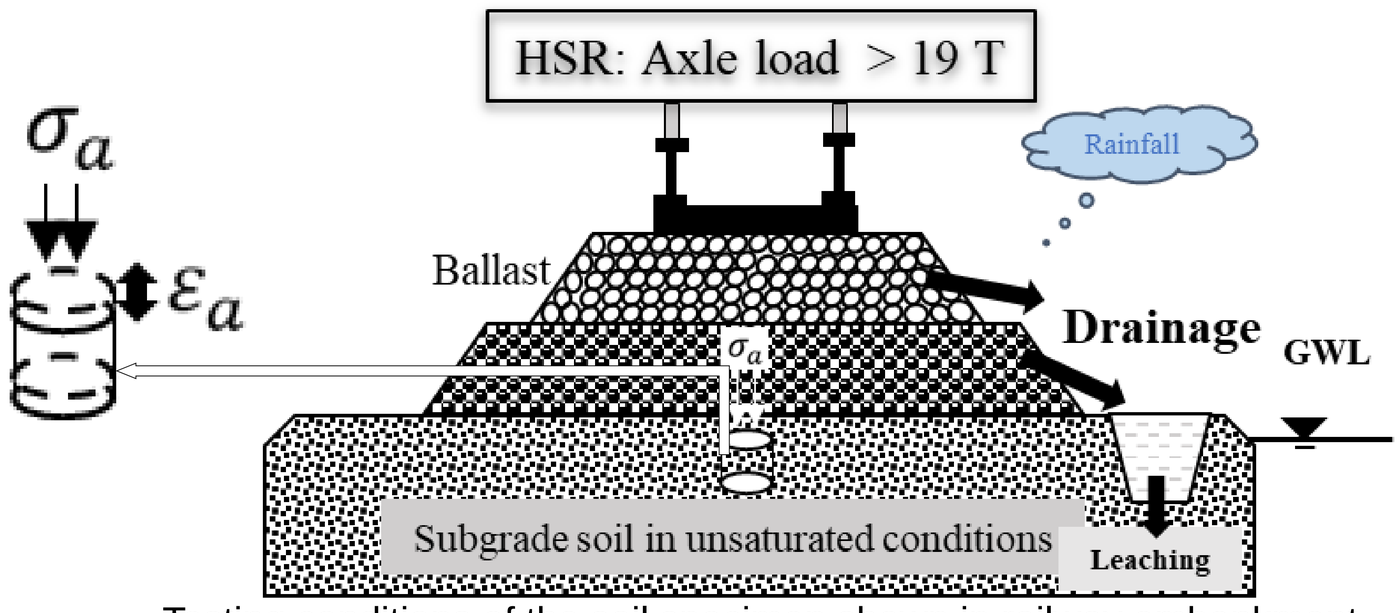
Department of Civil Engineering, The University of Tokyo, Japan

THE UNIVERSITY OF TOKYO GEOTECHNICAL ENGINEERING LAB.

Research Introduction

Engineering problems associated with unsaturated soil conditions on high-speed railway embankment (HSR) –

- Lack of good quality material
- No guideline for heavy axle load performance structure which considers both the external loads (**Traffic vehicle loading**) and environmental conditions (**Heavy rainfall**)

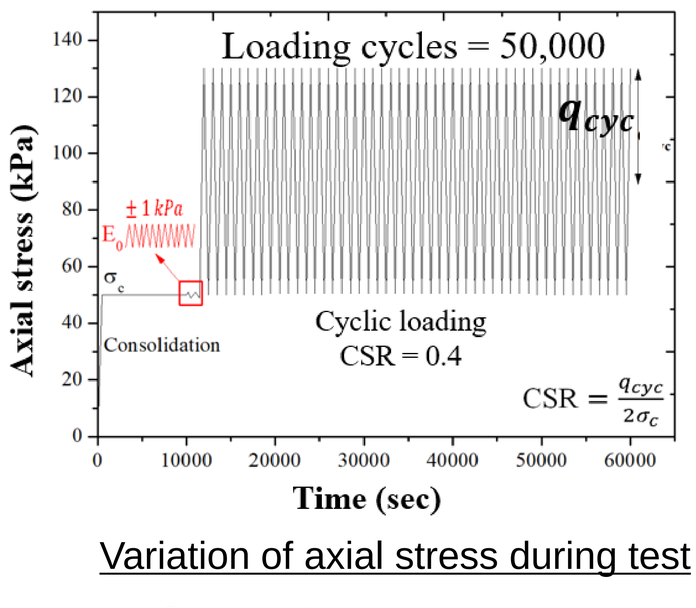


Testing conditions of the soil specimen shown in railway embankment

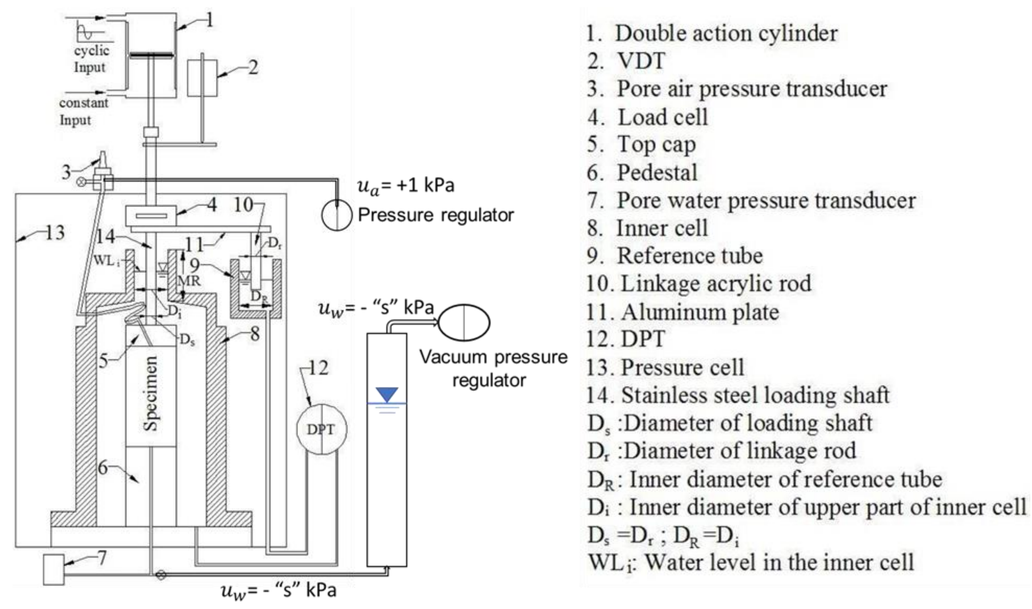
Testing apparatus and methodology

To understand the deformation behaviour of the soil –

- Suction-controlled drained cyclic triaxial tests were conducted.
- Linkage double cell triaxial apparatus was used to conduct these tests as it has the ability to measure/ control the suction during cyclic loading.



Variation of axial stress during test



Linkage double cell triaxial apparatus

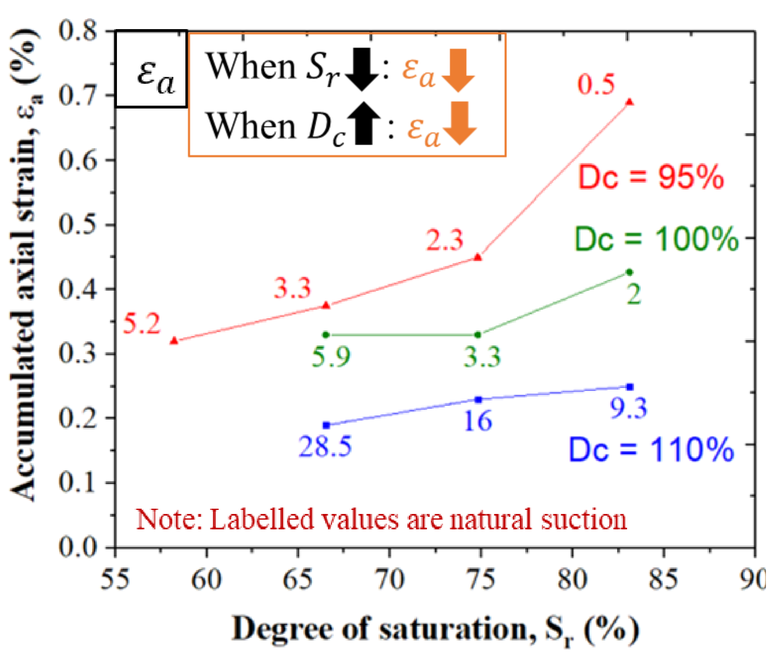
Evaluation of Accumulated axial strain (ε_a)

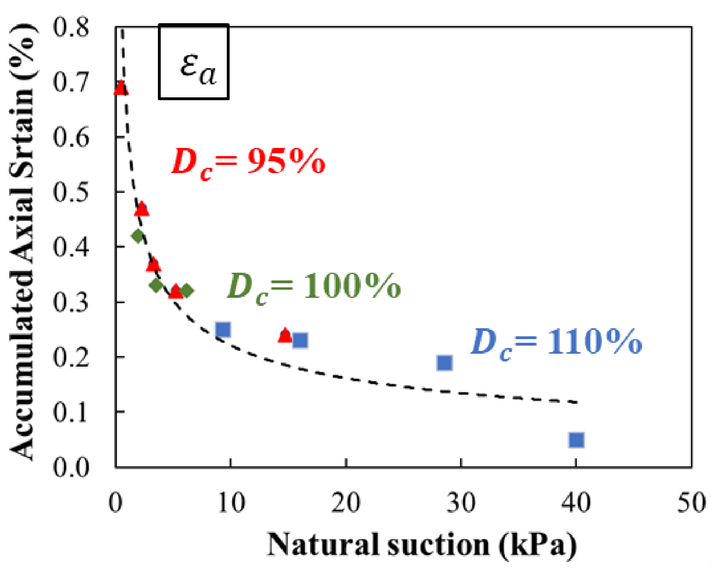
Effect of compaction and saturation on ε_a

- Accumulated axial strain during cyclic loading by varying the compaction and saturation is evaluated.
- Relationship between the accumulated axial strain and natural suction in unsaturated conditions is investigated.

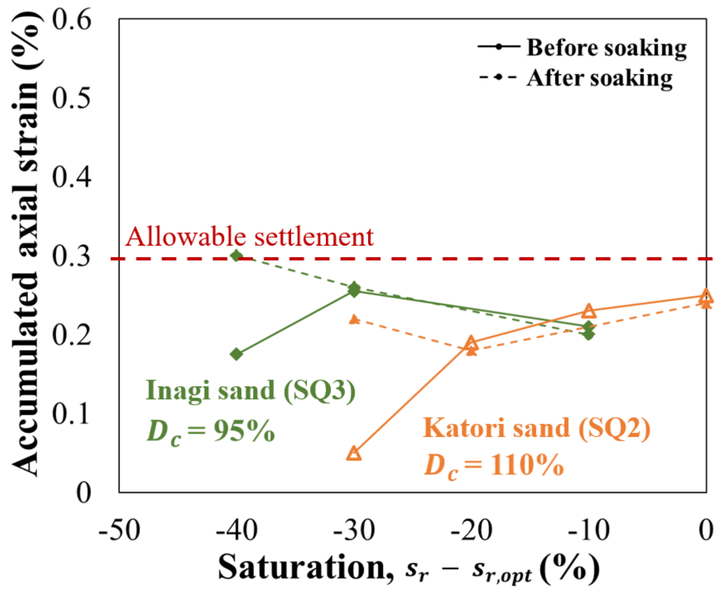
Effect of fines content on ε_a

- Allowable settlement for slab track on railway embankment, taking into account the current testing conditions and serviceability criteria, was found to be less than 0.33%.
- Variation of accumulated axial strain for different fines content was investigated and compared it with the allowable settlement criteria.





Variation of accumulated axial strain with respect to the compaction, saturation and natural suction.



Variation of accumulated axial strain with respect to the normalized saturation before soaking (unsaturated) and after soaking for the soils with different fines content.

- ✓ Positive effect of suction on accumulated axial strain was confirmed in unsaturated conditions.
- ✓ Negative effect of suction on accumulated axial strain at low saturation after soaking was clearly observed.
- ✓ Increase in accumulated axial strain was significantly seen with increase in fines content.

Requirements for utilization of low-grade material (Katori sand):

- Increase in compaction (D_c)
- Precise control of water content (W_c) considering the positive effect of suction in unsaturated conditions and by avoiding negative effect of suction while soaking.

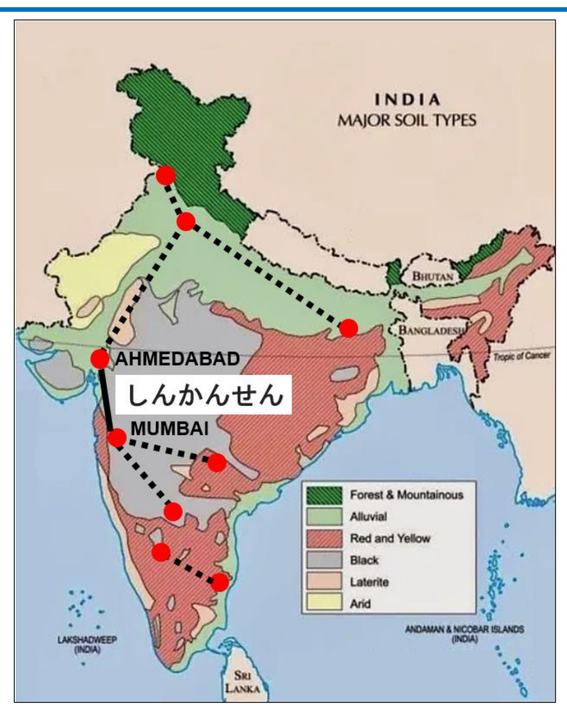
Effective compaction method for utilizing low quality banking material for railway embankment

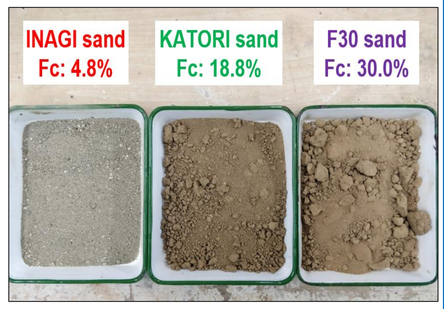
Akshay Singh Rathore
(Outline of Master Thesis, August 2020)
Department of Civil Engineering, The University of Tokyo , Japan

Introduction

- Indian Railways have planned construction of many high-speed rail projects in near future. An earth embankment is the cheapest railway structure and for its construction, a good quality soil having low fines content (F_c%) is the most important requirement, so that the railway embankment exhibits minimum deformation during its design life. As per the geology of India, the availability of good quality soil is low.

- In this research, an effort has been made to utilize a slightly lower quality soil having more fines content, in a railway embankment by doing better compaction. The importance of moisture control in an embankment is also studied.

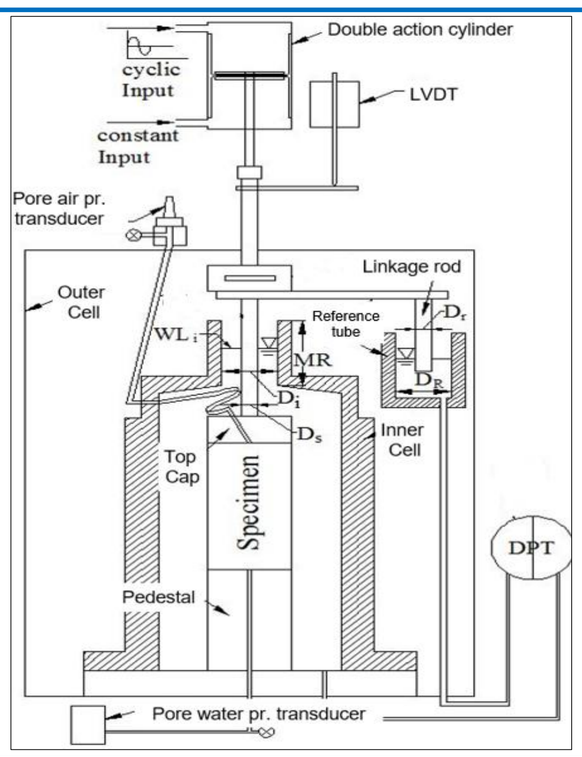




Methodology

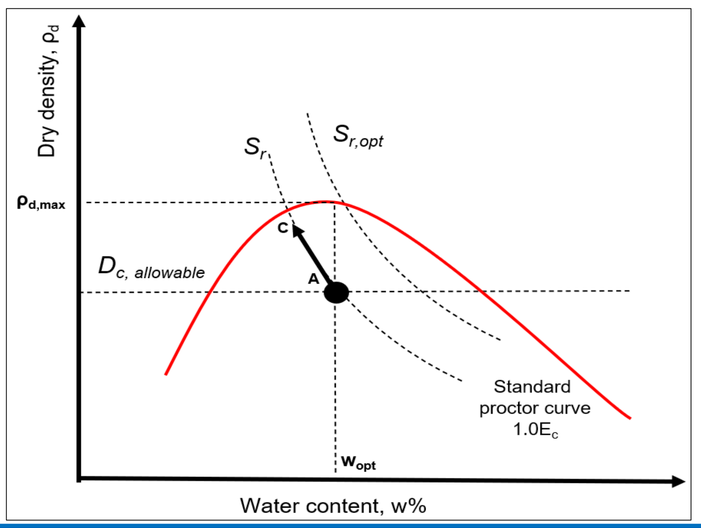
- Special apparatus called the Linkage double cell triaxial apparatus capable of unsaturated soil testing was used.

- Inagi sand (F_c:4.8%), Katori sand (F_c:18.8%) and F30 sand (finer version of Katori sand with F_c:30.0%) were tested under cyclic compressive loading.



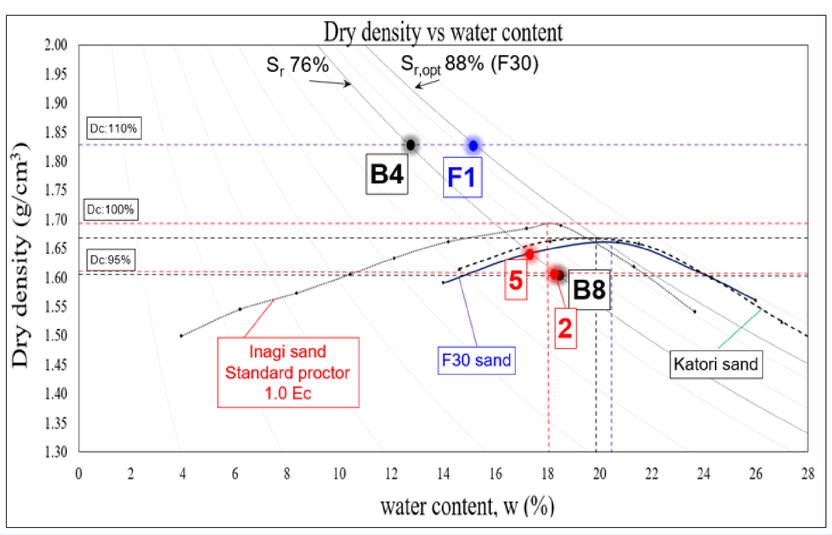
Saturation degree (Sr) for moisture control

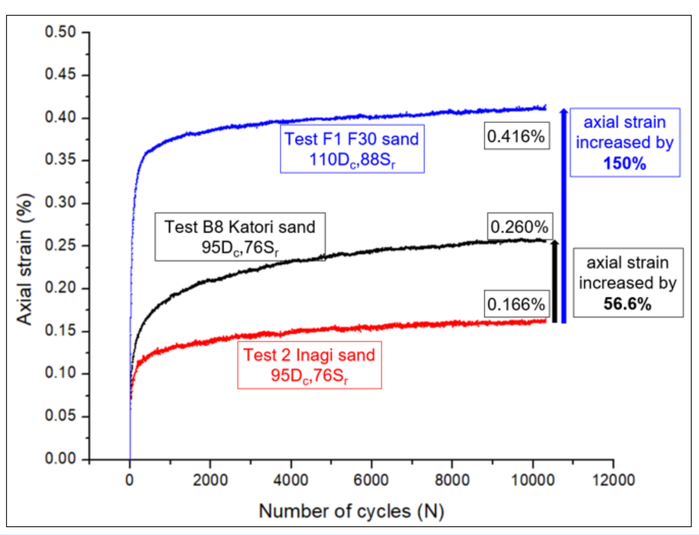
- Compaction of lower quality soils by using Saturation degree (S_r) for moisture control is an important index for effective compaction.



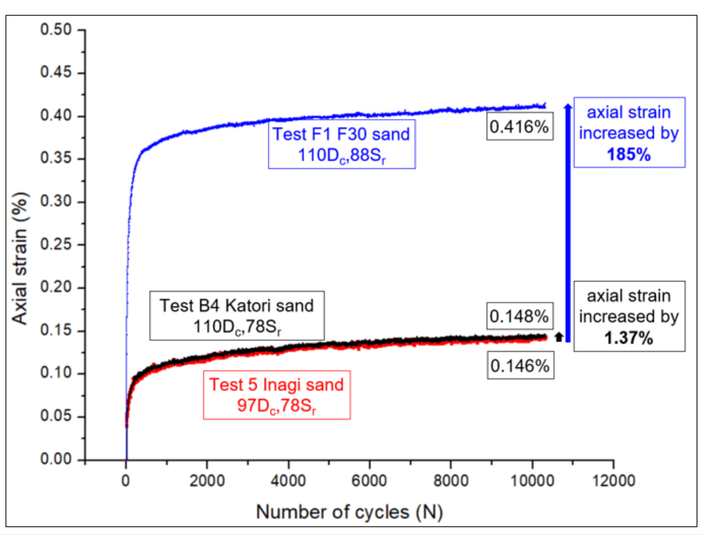
Effect of better compaction on lower quality soil

At similar compaction level for all soils, the accumulated axial strain is lowest for good quality Inagi sand, but with better compaction of lower quality soils, Katori sand with 18.8% fines performed similar to Inagi sand. However, F30 sand with 30% fines could not perform even with better compaction.





With Better compaction



Importance of moisture control in compacted soil

Soil samples compacted in dry conditions under low saturation degree show highest stiffness, still their performance in terms of lower deformation is not better. Such soils may satisfy the compaction parameters but may pose a potential risk of more deformation in future.