Structural Health Monitoring using Optical Fiber and Electrical Methods

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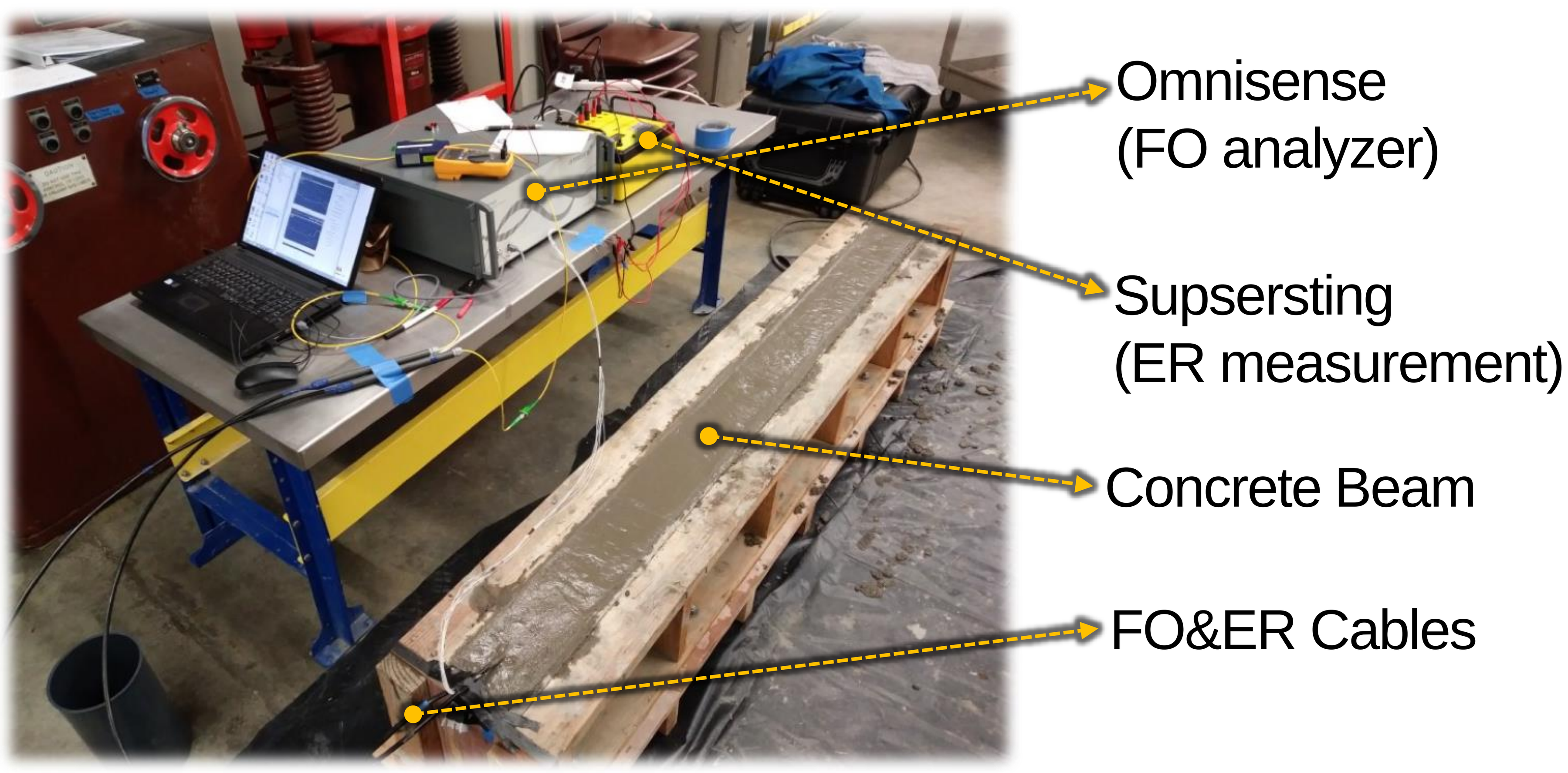
Project Overview

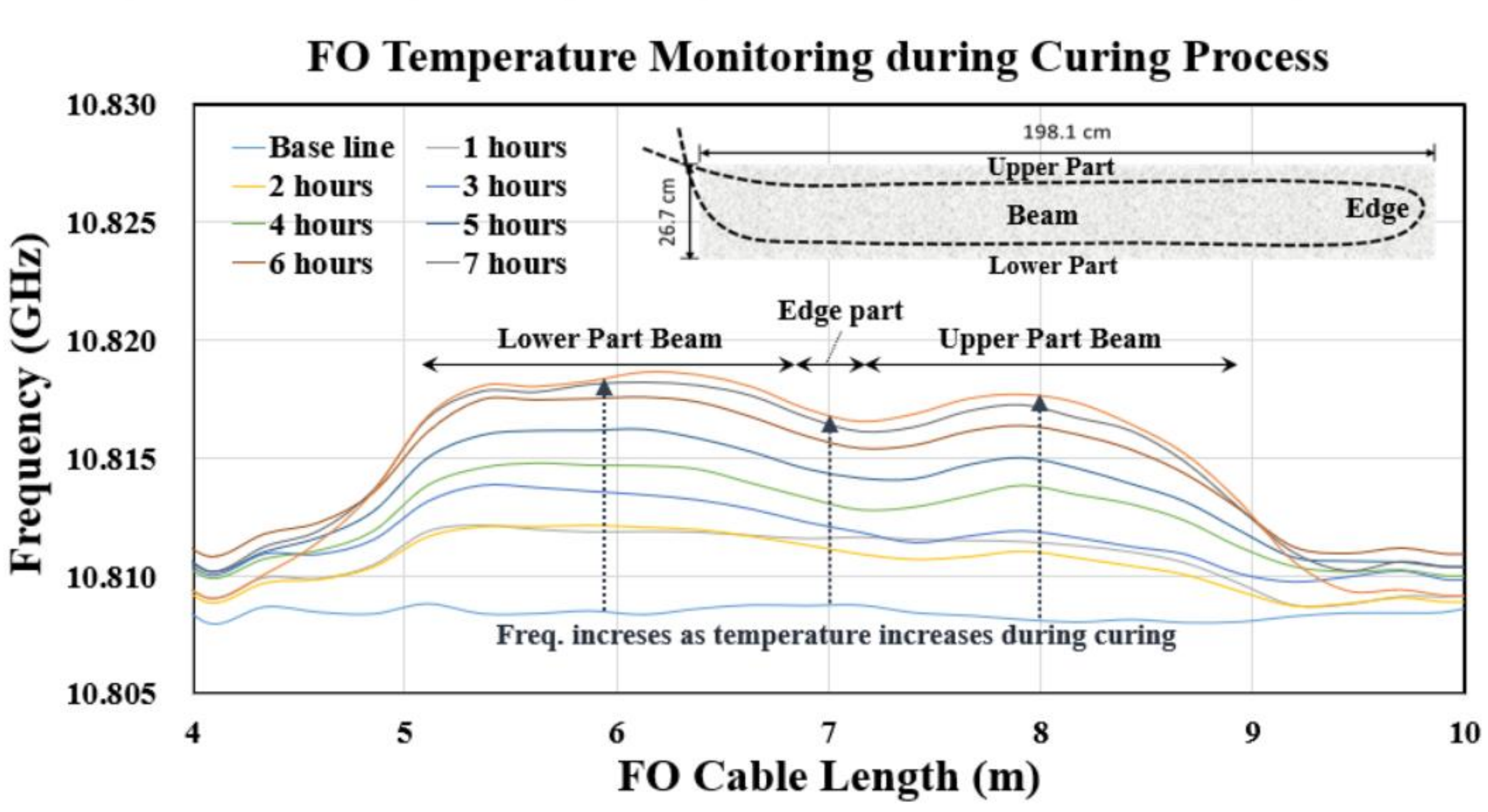
- Distributed **Fiber Optical** technique and **Electrical Resistivity** are both extensively used for infrastructure monitoring.
- This project aims to investigate the **complementary information** and **potential benefits**, which can be provided by using the two techniques (FO and ER) together.

Lab Test 1: Beam Curing Process Monitor

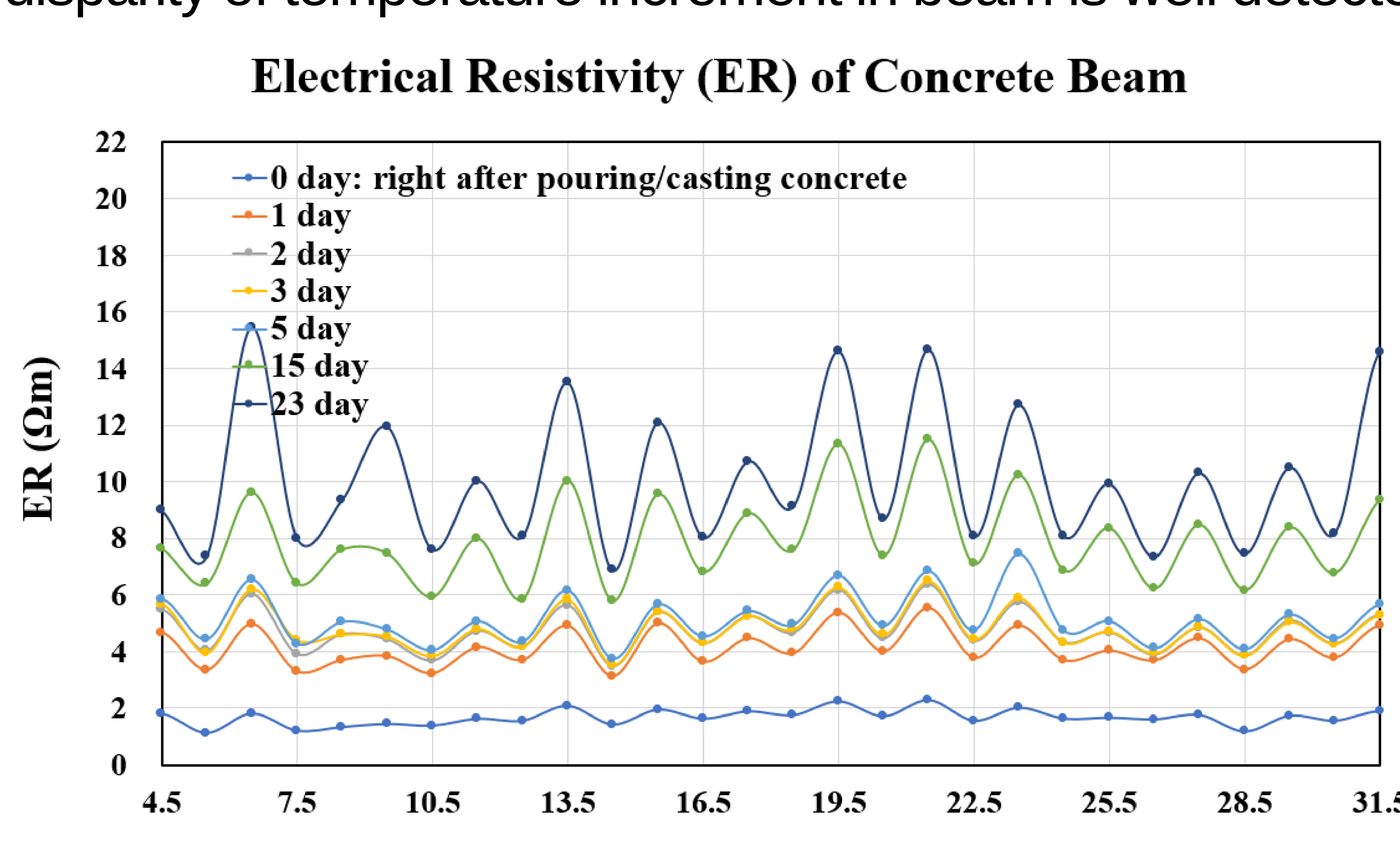
- Temperature FO and ER cables are embedded in the bottom and upper part of the concrete beam.
- **Omnisense** is used as the FO analyzer and Supersting is used to measure the ER of the concrete during curing process.



❖ Temperature (using FO) and ER monitoring results:



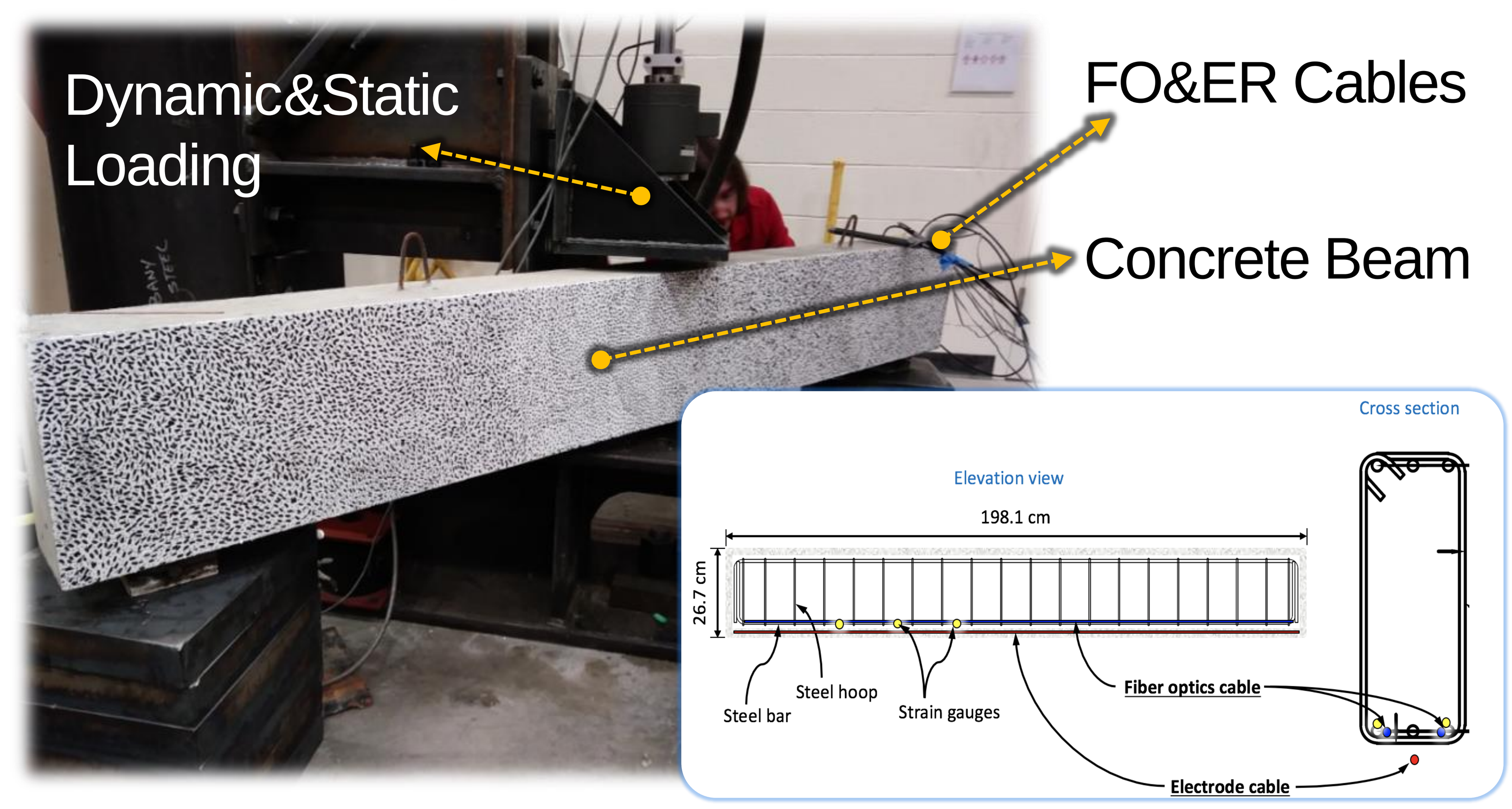
➢ Frequency increases during the initial curing process and spatial disparity of temperature increment in beam is well detected by FO.



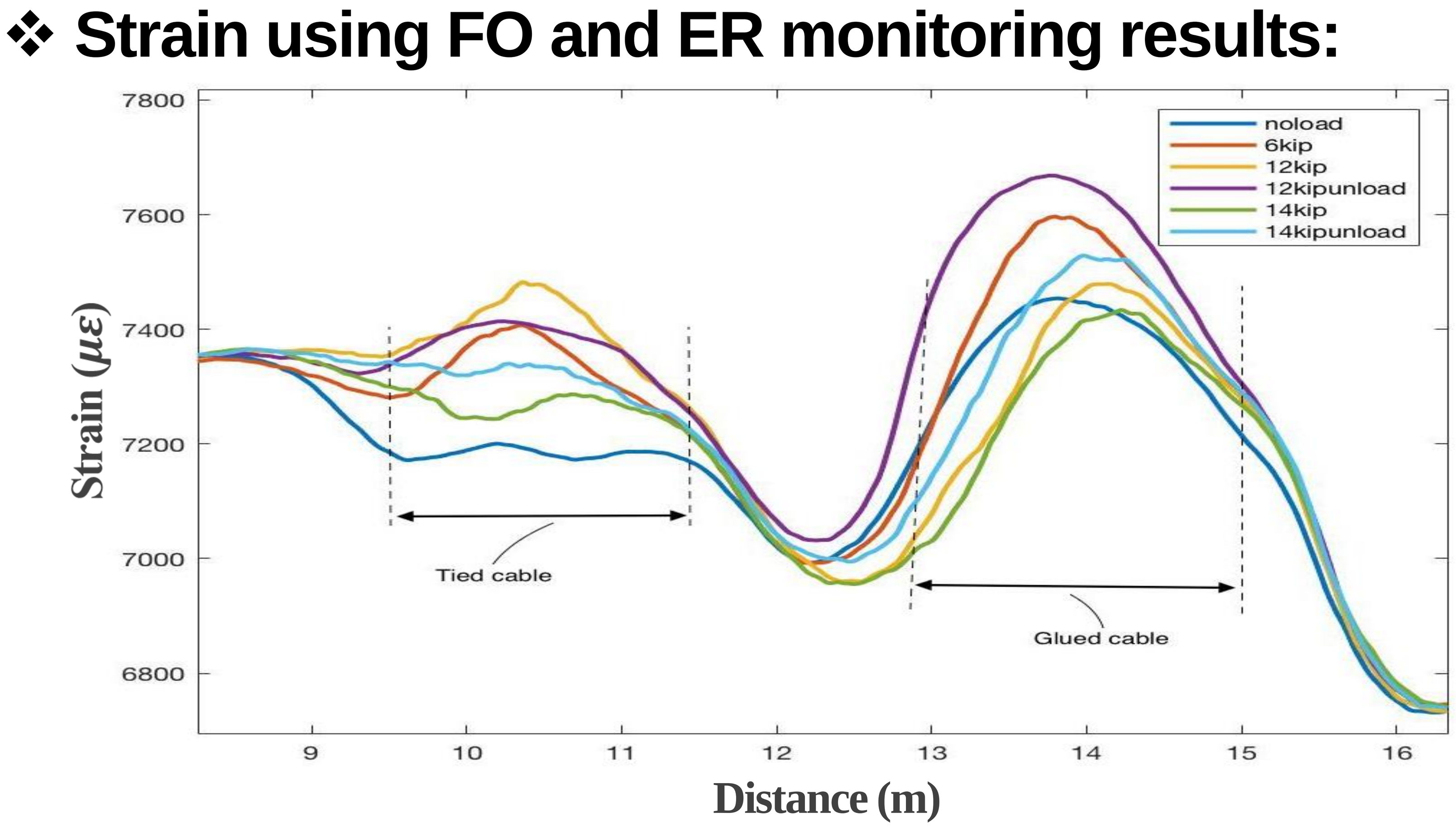
➢ ER gradually increases, but highly increased during active curing/hydration process (for 1 day). Steel hoop installed with uniform spacing induces the fluctuation of ER along the beam.

Lab Test 2: Beam Bending Test

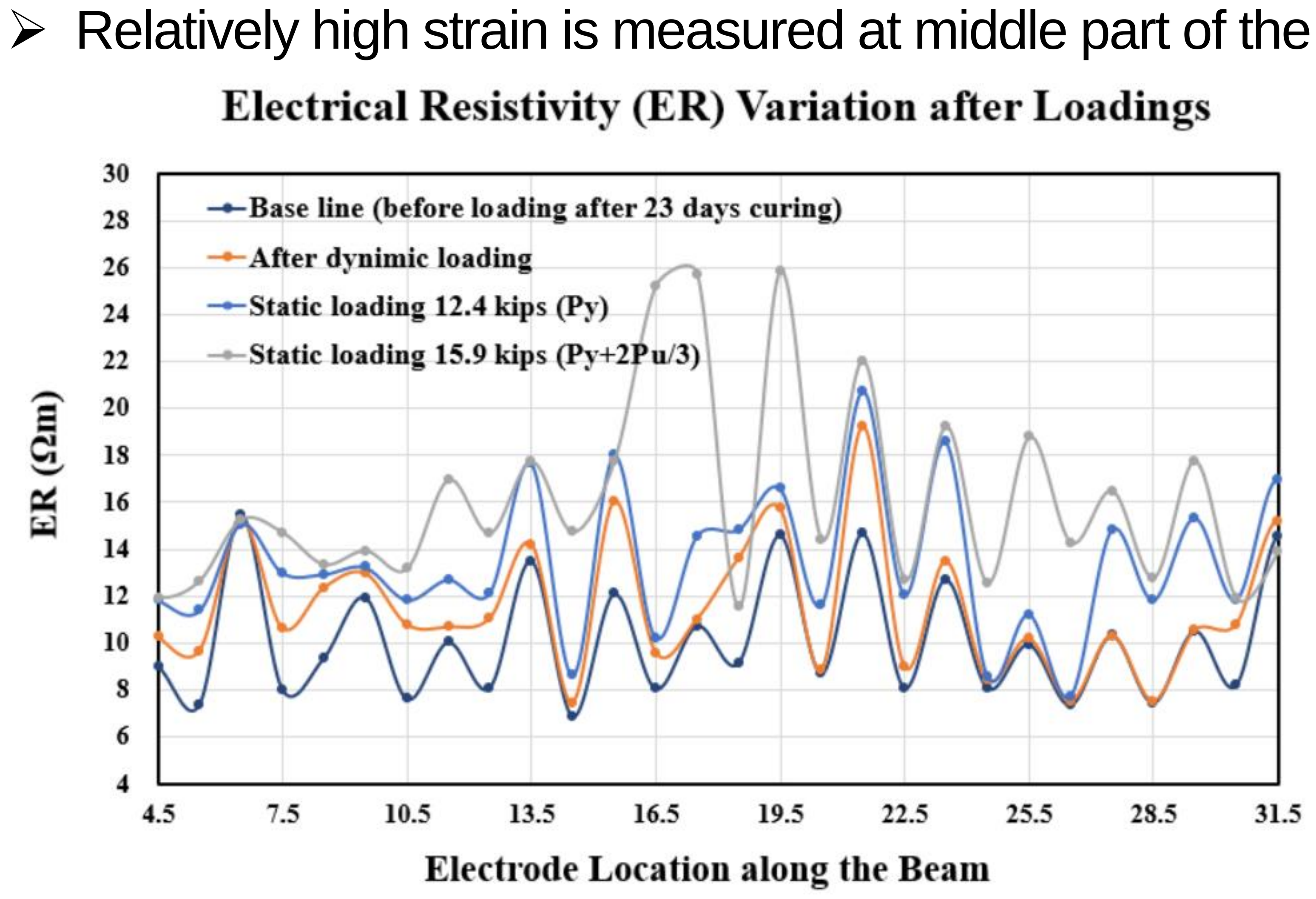
- Three-point bending with dynamic and static loading.
- The beam is eventually loaded till breakage.
- FO cable are tied or glued to the rebar and ER cable is embedded in the bottom part of the beam.
- Newly developed dynamic FO analyzer, **Alicia** is used for strain monitoring



❖ Strain using FO and ER monitoring results:



➢ Relatively high strain is measured at middle part of the beam.



➢ ER increases after dynamic loading. Higher load induces higher ER increment and detachment between steel hoop and concrete may cause the ER increment.

Acknowledgement

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Real-time Ground Monitoring ahead of Mechanized Tunneling Face using Electrical Methods

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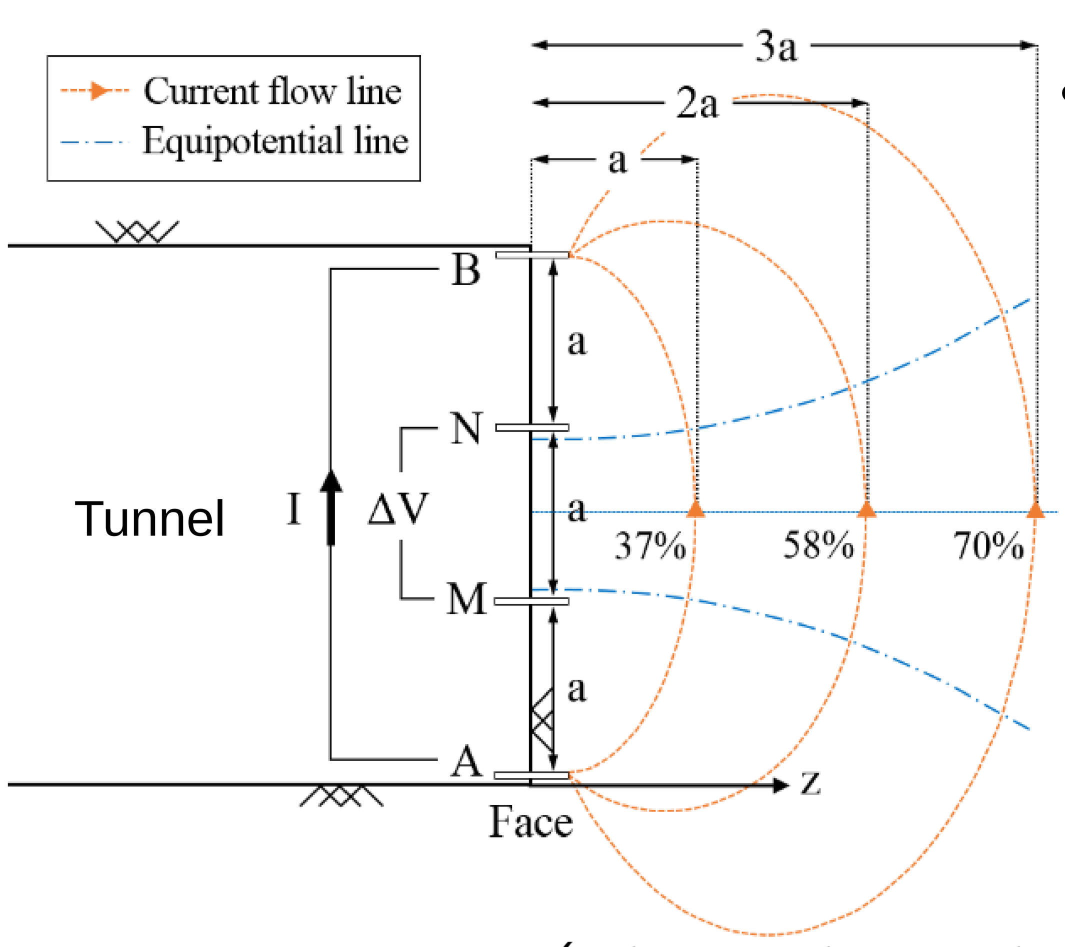
1. Introduction

- An accurate determination of the ground condition ahead of a tunnel face is key to stable excavation of tunnels.
- The effectiveness of using the **electrical resistivity (ER)** along with **induced polarization (IP)** is investigated for identifying hazardous ground conditions in front of tunnel boring machine (TBM)

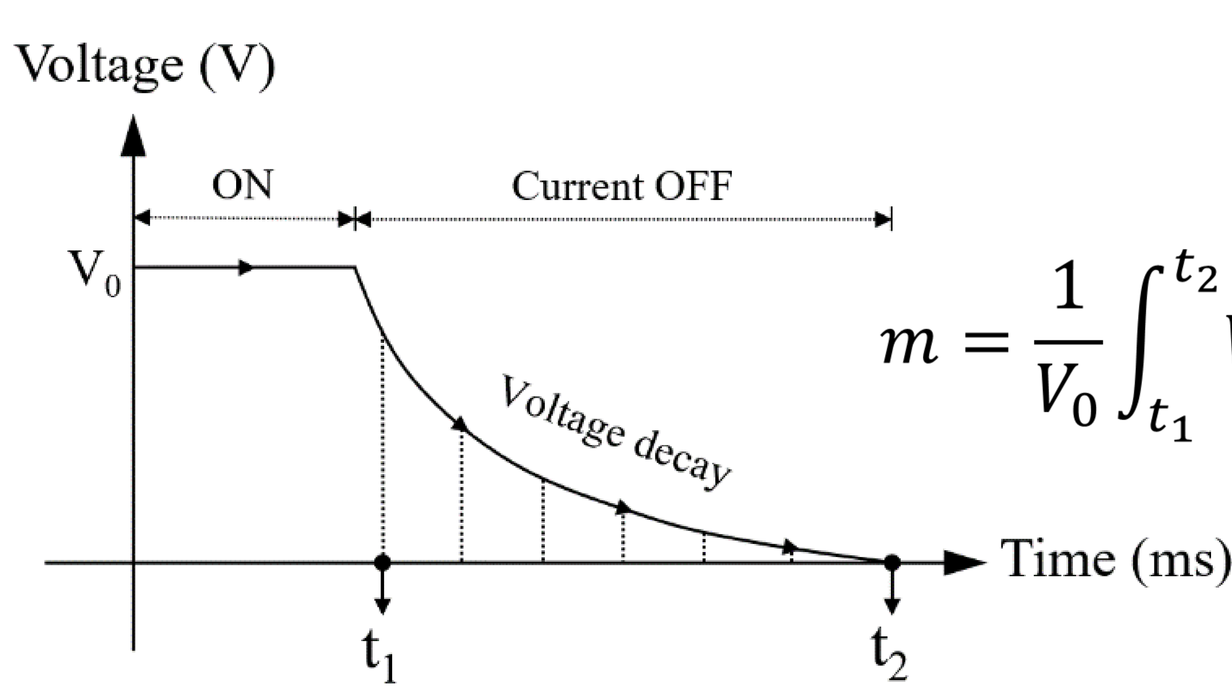
2. Background: ER and IP



- An electric current (I) is injected between electrodes A and B, and the resulting electric potential (ΔV) is measured between electrodes M and N. **The ER (ρ) (Ωm)** is then calculated as

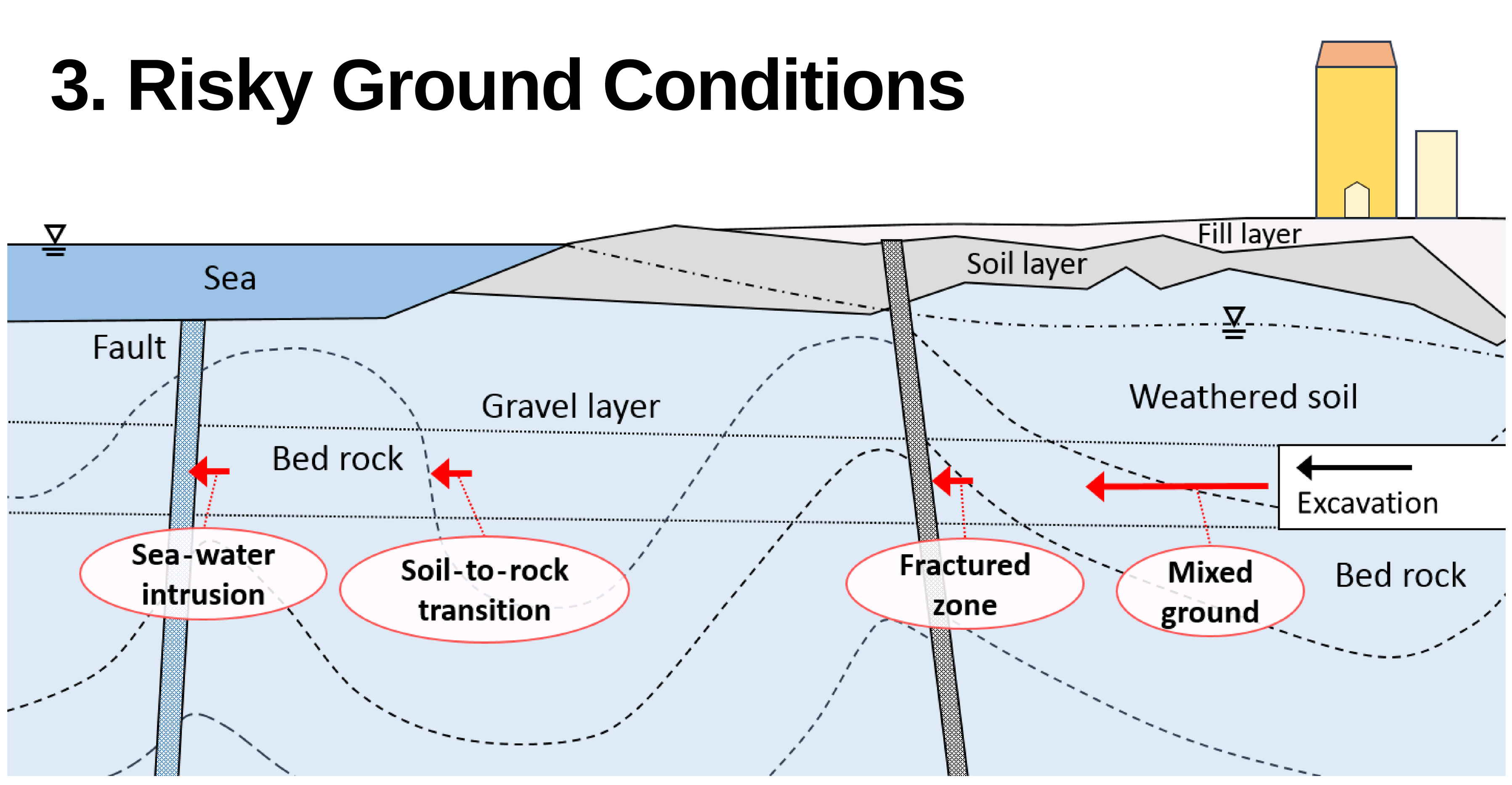
$$\rho = 2\pi \left(\frac{1}{AM} - \frac{1}{MB} - \frac{1}{AN} + \frac{1}{NB} \right)^{-1} \cdot \frac{\Delta V}{I}$$

- In the **Time-domain IP method**, the direct electric current that flows into the ground is abruptly turned off.
- The attenuating voltage (V) is then measured for a given time to estimate the apparent **chargeability (m)** (ms)



$$m = \frac{1}{V_0} \int_{t_1}^{t_2} V(t)\, dt$$

3. Risky Ground Conditions

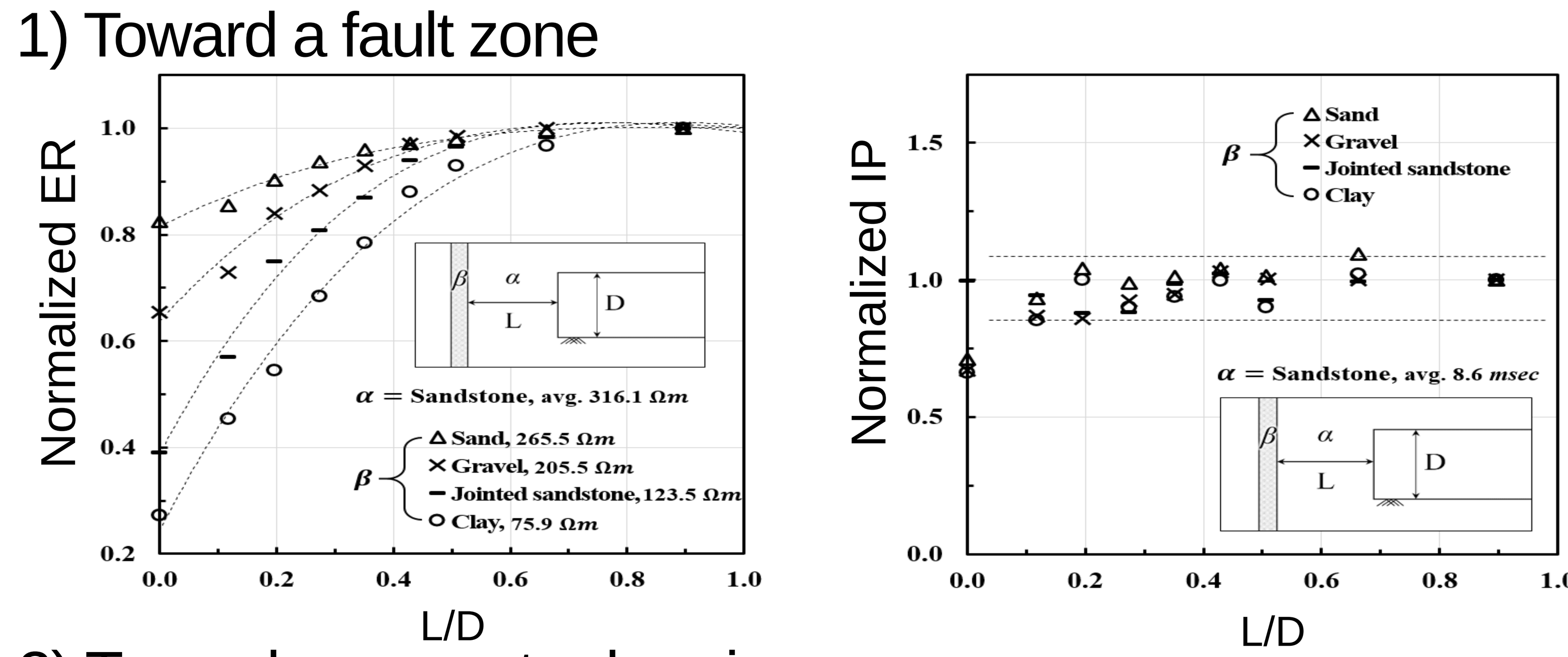


- Prediction of **fractured zone**, **seawater bearing zone**, **soil-to-rock transition zone**, and **mixed ground** in the early stages will be beneficial for improving constructability

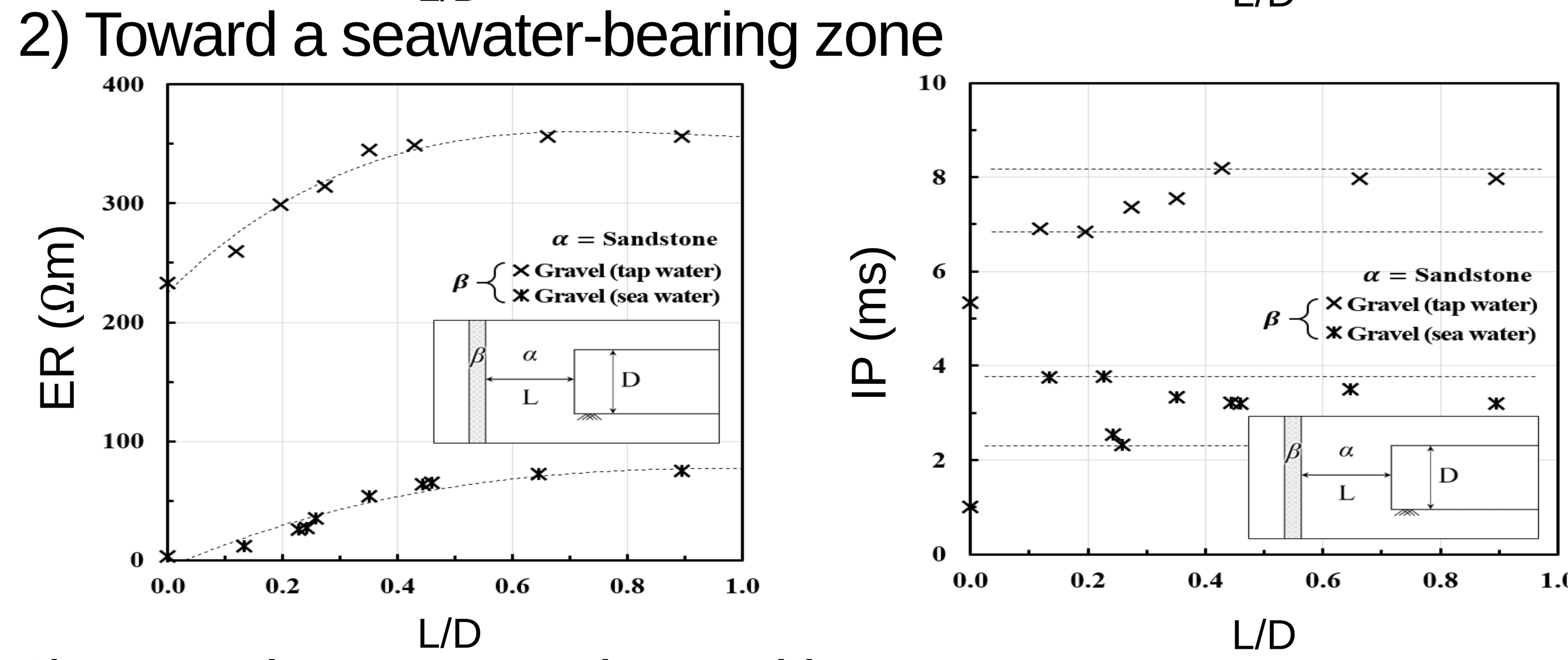
4. Experiment and Results

- The advancement of the TBM toward risky grounds is **artificially modeled in laboratory-scale experiments.**

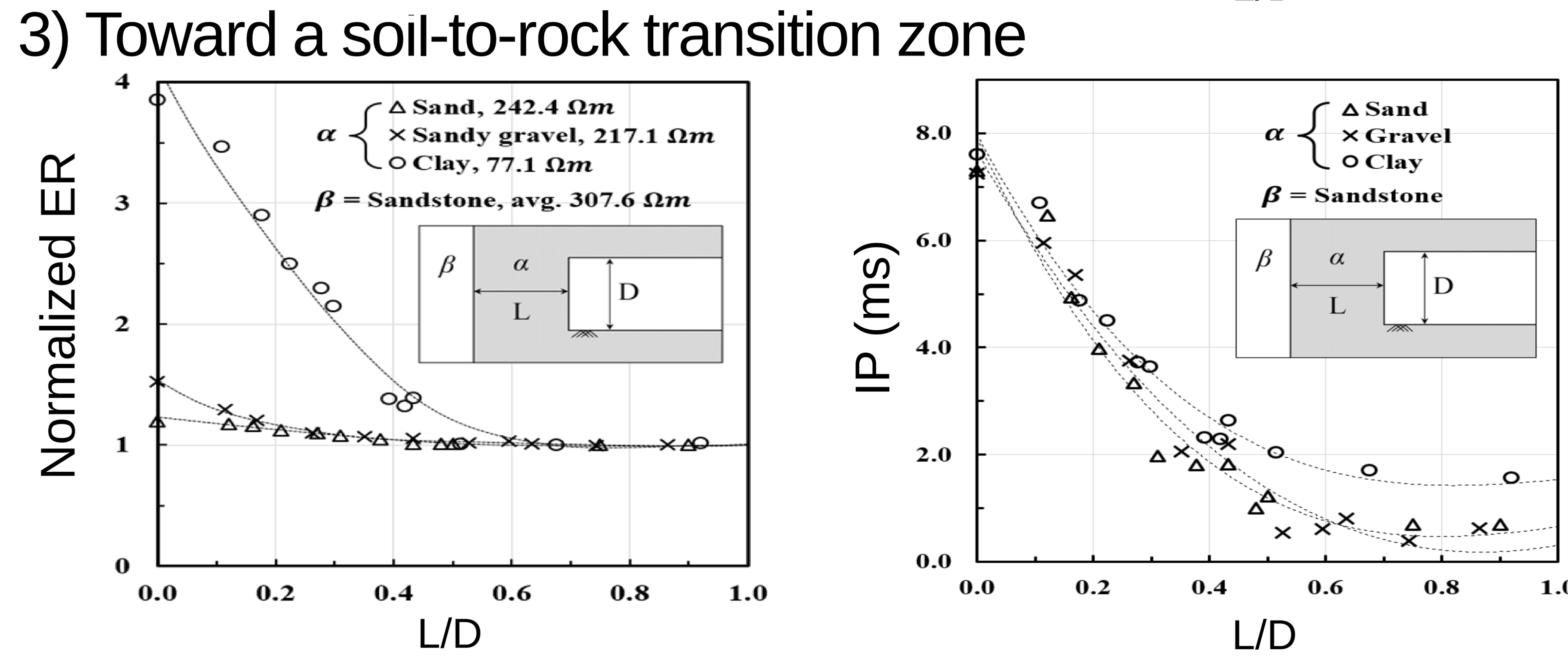
1) Toward a fault zone



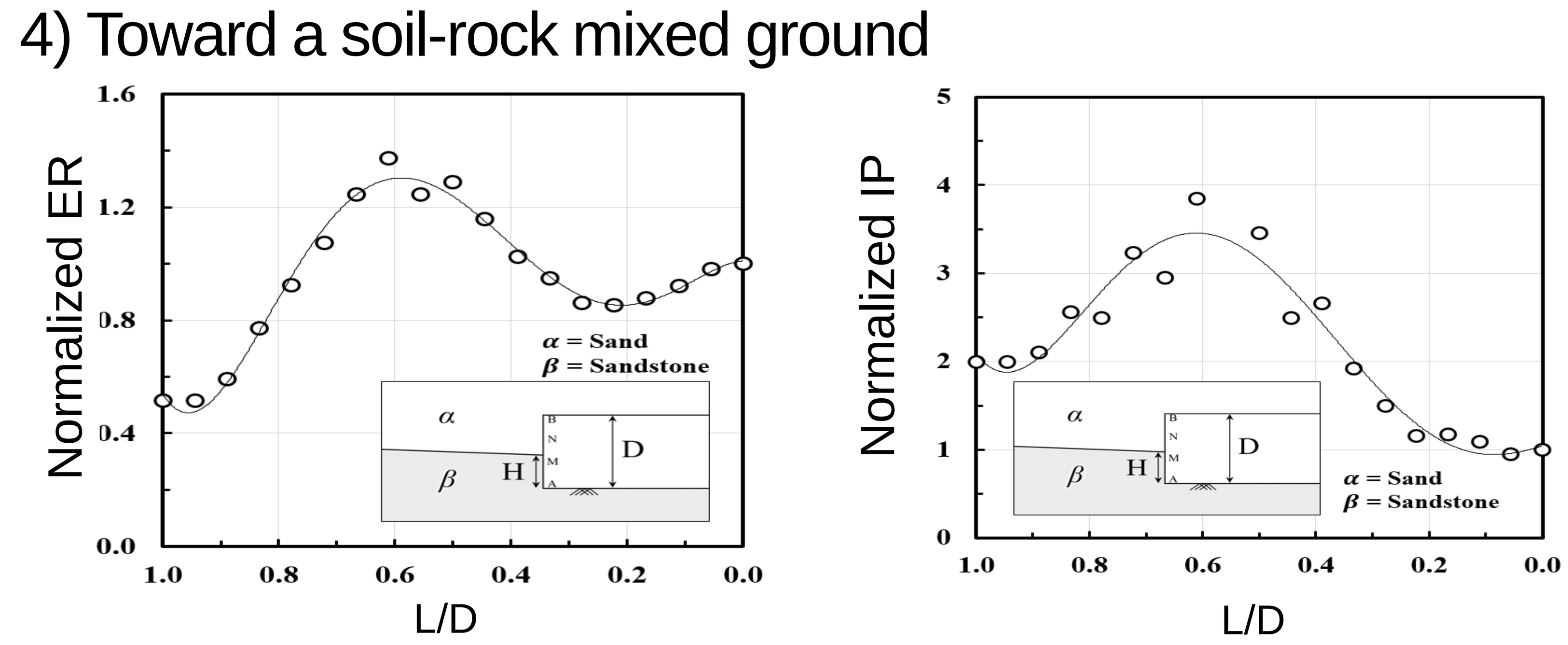
2) Toward a seawater-bearing zone



3) Toward a soil-to-rock transition zone



4) Toward a soil-rock mixed ground



5. On-site Prediction Guide

- Table shows the variation of the ER and IP at a glance, as the TBM advances toward each type of risky ground.

Risky grounds / Measurement	Fault zone (Case 1)	Seawater bearing zone (Case 2)	Soil-to-rock transition zone (Case 3)	Soil-rock mixed ground (Case 4)
Electrical resistivity	Decrease ↓	Decrease ↓	Increase ↑	Fluctuate ↓↑
Chargeability (IP)	Constant →	Constant with small value →	Increase ↑	Fluctuate ↑↓

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