Climate Change Effects on Geotechnical Structures

Part - 1

Important Notes

1. Introduction

Climate change is increasingly influencing the performance, safety, and durability of geotechnical structures. Changes in temperature, rainfall patterns, sea level, and extreme weather events directly affect soil behavior and ground–structure interaction. Geotechnical engineers must now account for long-term climate variability and extreme conditions in design, construction, and maintenance.

This document provides a structured and engineering-focused explanation of how climate change impacts geotechnical structures, linking soil mechanics fundamentals to real-world infrastructure challenges.

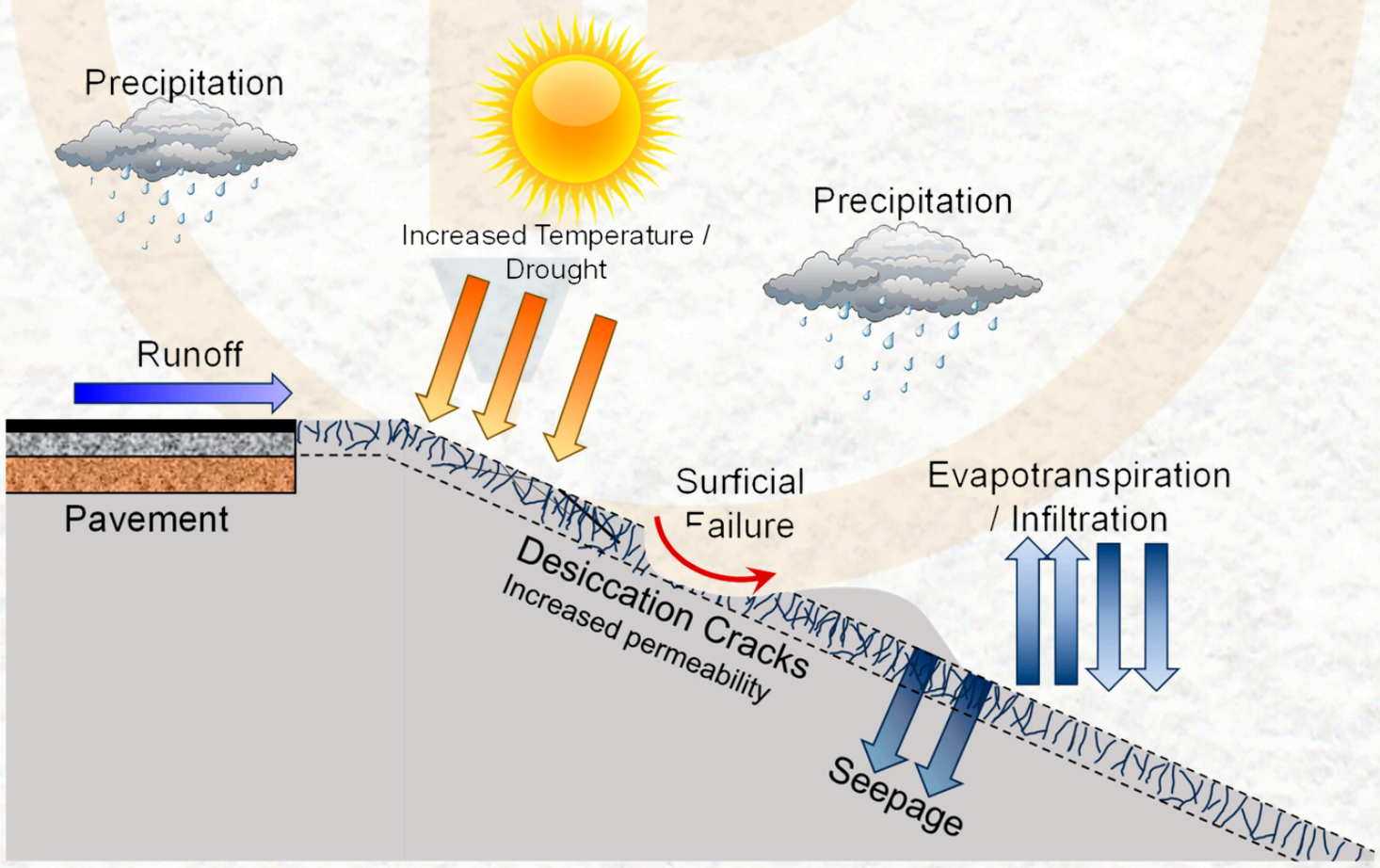

Figure - Climate Change Effects on Geotechnical Structures, Source - MDPI

2. Changes in Rainfall Patterns and Infiltration

Climate change is associated with more intense rainfall events and longer dry periods.

Soil behaviour changes:

- Rapid infiltration increases pore water pressure
- Reduction in effective stress
- Softening of clayey soils
- Increased erosion and surface instability

Key relationship:

Effective stress: $\sigma' = \sigma - u$

Increased pore pressure (u) during heavy rainfall directly reduces soil strength.

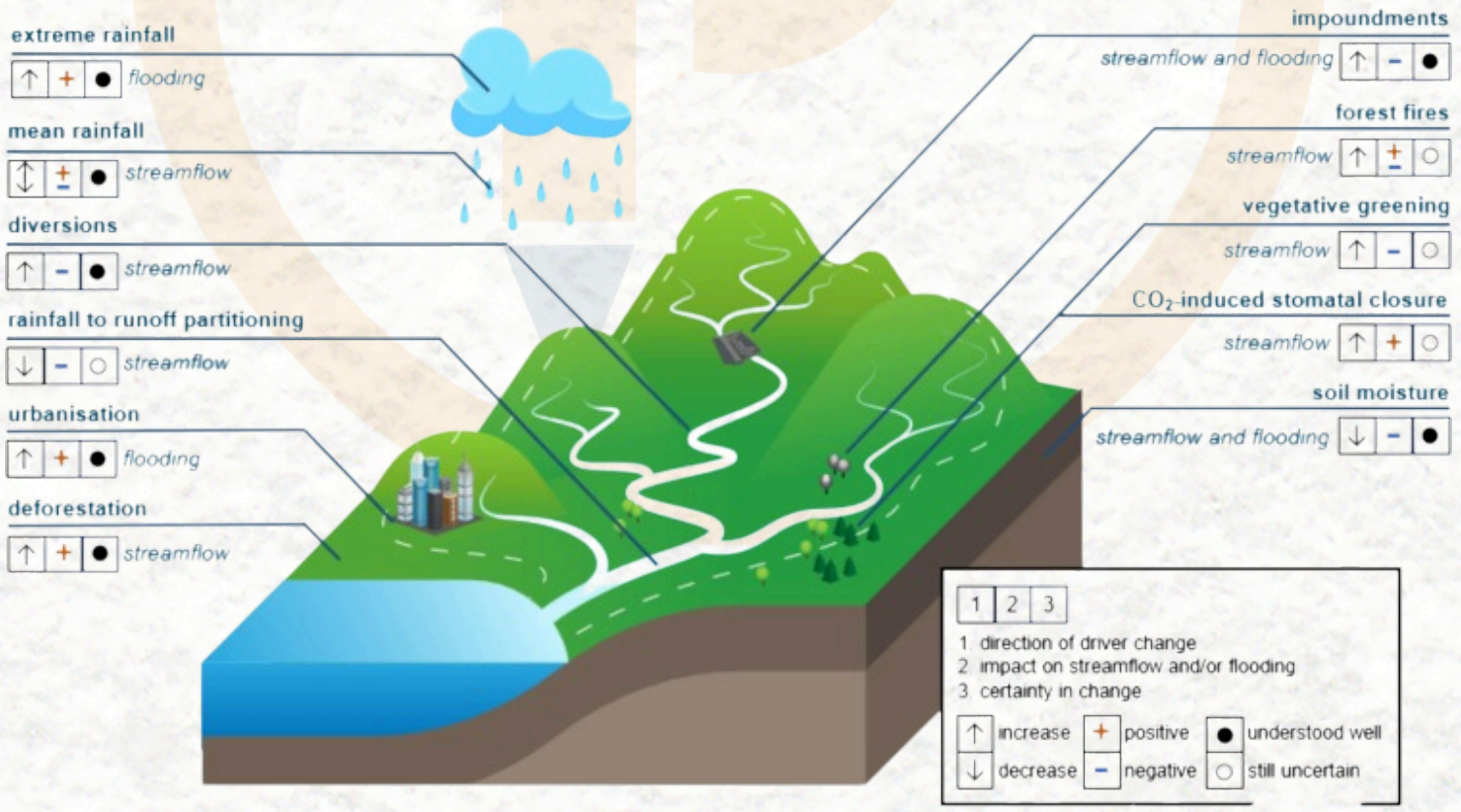

Figure - Climate Change Effects on Geotechnical Structures, Source - MDPI

3. Impact of Temperature Variations on Soils

Rising and fluctuating temperatures influence soil properties, especially near the ground surface.

Geotechnical effects:

- Thermal expansion and contraction of soils
- Changes in pore water pressure
- Alteration of soil structure in sensitive clays
- Degradation of frozen ground and permafrost

Engineering concern: Thermal cycles can induce differential settlement and cracking in foundations and pavements.

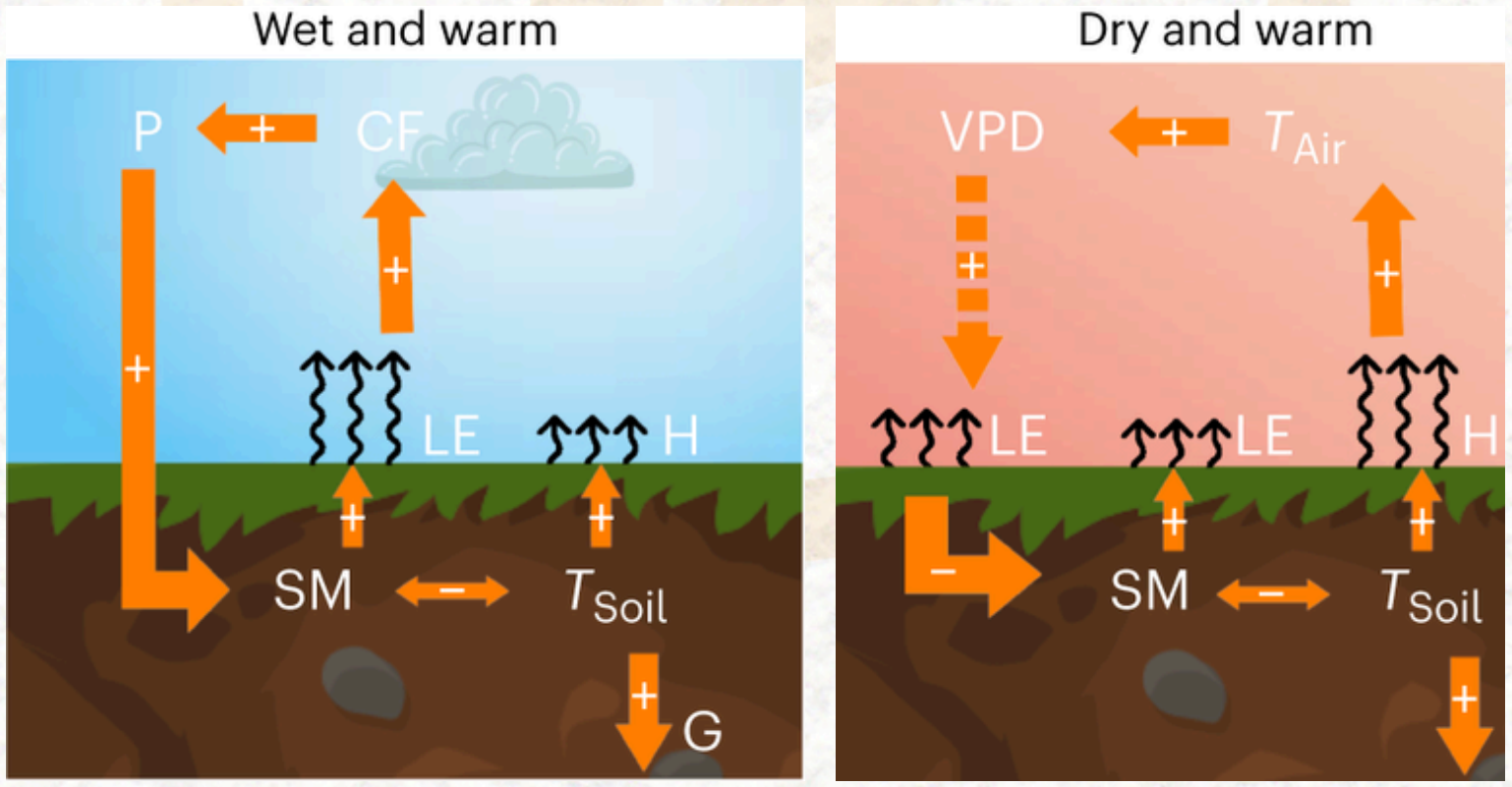

Figure - Temperature Variations on Soils, Source - ResearchGate

4. Climate Change and Geotechnical Engineering

Climate change affects geotechnical systems primarily through:

- Increased temperature variations
- Changes in precipitation intensity and frequency
- Rising groundwater levels
- Sea-level rise and coastal flooding
- Increased frequency of extreme events (storms, droughts)

These factors alter soil moisture, effective stress, strength, and deformation behavior.

5. Slope Stability and Landslides

Slopes are highly sensitive to climate-induced changes.

Climate-driven triggers:

- Prolonged rainfall
- Rapid drawdown in reservoirs
- Freeze–thaw cycles

Geotechnical implications:

- Reduction in shear strength
- Increase in driving forces
- Higher probability of shallow and deep-seated failures

Shear strength relationship:

- $\tau = c + \sigma' \tan \varphi$

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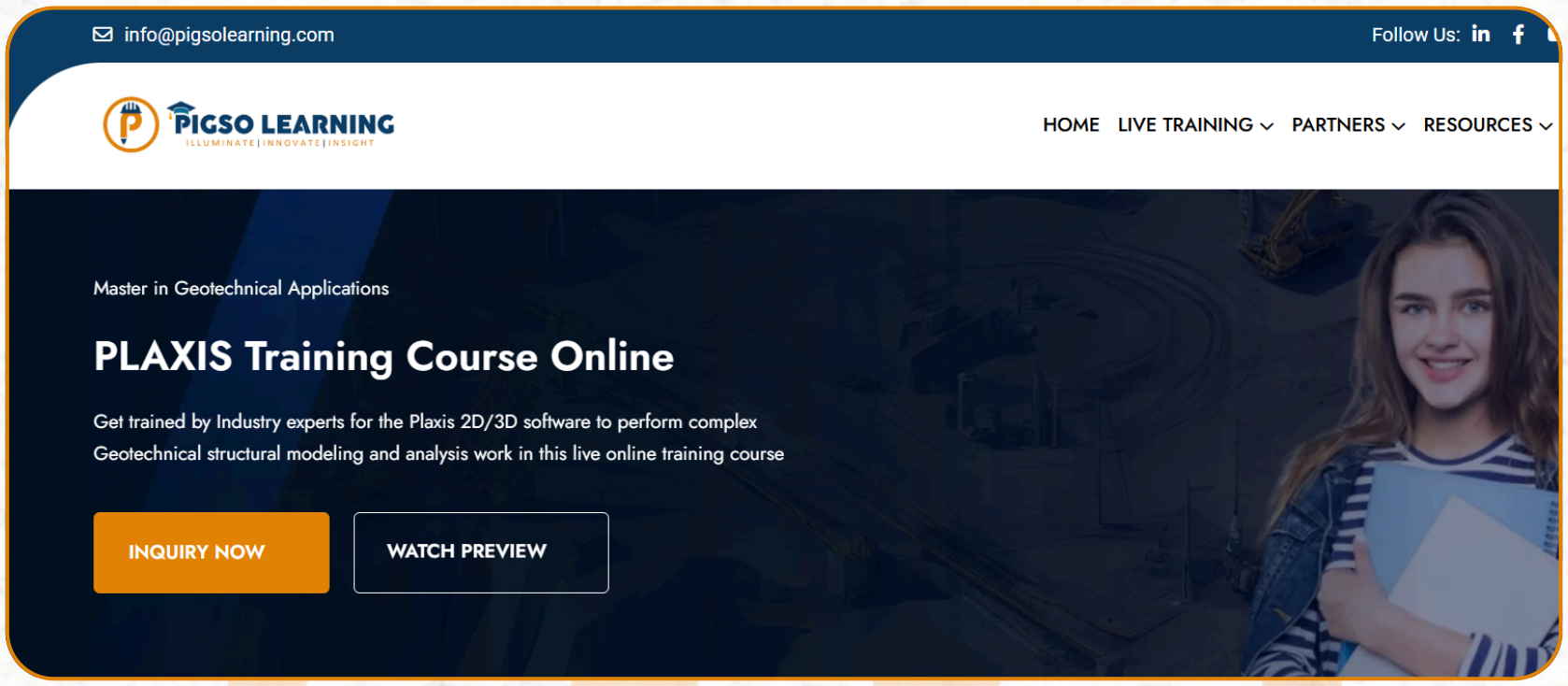

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6. Effects on Foundations

Climate change alters both shallow and deep foundation performance.

Observed impacts:

- Increased settlement due to softening soils
- Loss of bearing capacity in saturated soils
- Changes in skin friction for piles

Engineering concern: Design assumptions based on historical climate data may no longer remain valid over the structure's life.

7. Expansive and Shrink-Swell Soils

Expansive soils are particularly vulnerable to climate variability.

Climate influence:

- Longer dry seasons cause shrinkage
- Intense rainfall causes rapid swelling

Geotechnical consequences:

- Heave of foundations and pavements
- Cracking of structures
- Serviceability failures

Proper moisture control and soil treatment are essential in climate-resilient design.

8. Permafrost Degradation and Cold Regions

In cold regions, rising temperatures cause permafrost thaw.

Geotechnical risks:

- Loss of soil strength
- Excessive settlement
- Failure of pile foundations

Infrastructure in polar and high-altitude regions is especially vulnerable to climate warming.

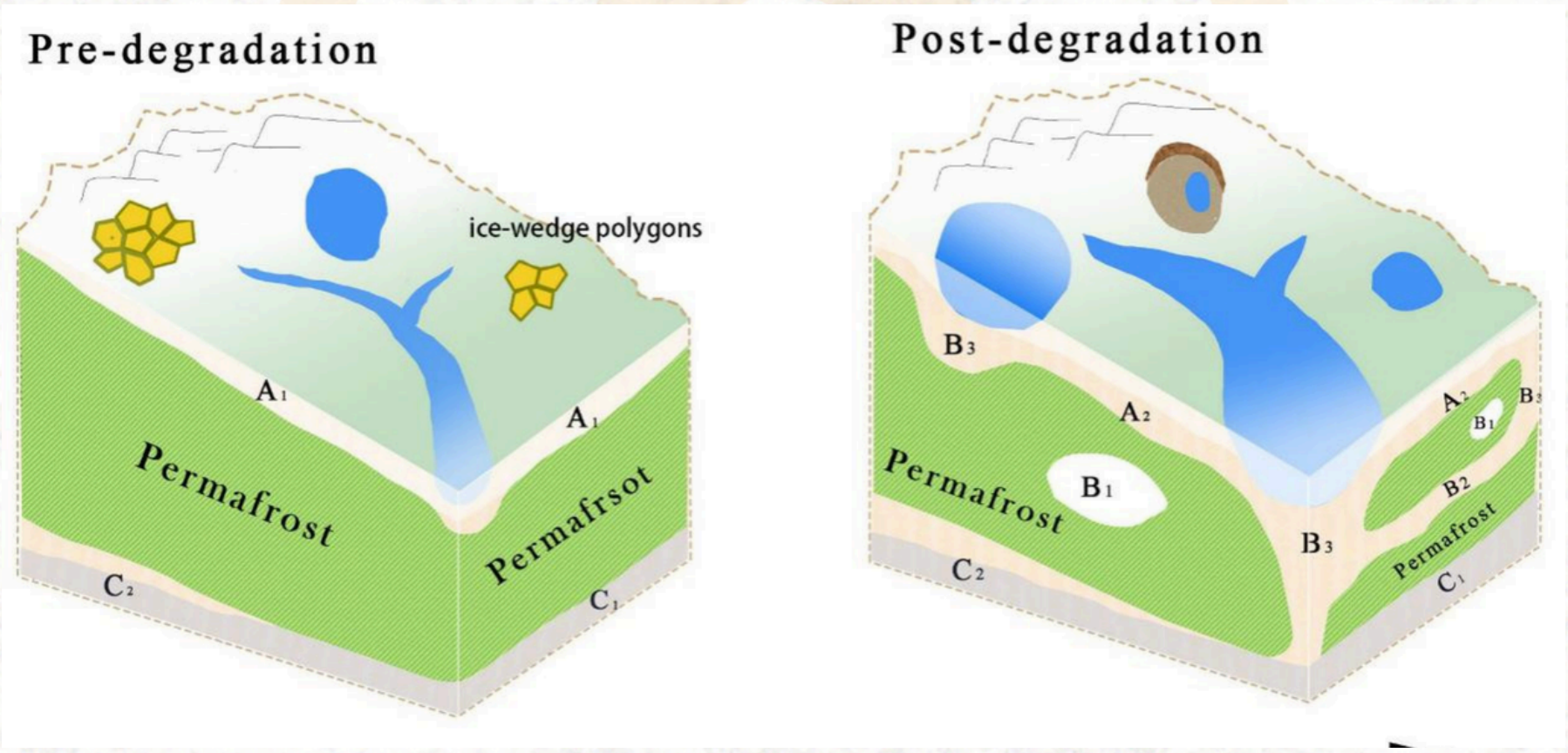

Figure - Permafrost Degradation and Cold Regions, Source - MDPI

Reference Links

- IPCC Climate Change Reports: https://www.ipcc.ch/
- FHWA - Climate Resilience in Geotechnical Engineering: https://www.fhwa.dot.gov/
- Engineering LibreTexts - Geotechnical Engineering: https://eng.libretexts.org/Bookshelves/Civil_Engineering/Geotechnical_Engineering
- US Army Corps - Climate Preparedness and Resilience: https://www.usace.army.mil/
- NPTEL - Advanced Geotechnical Engineering: https://nptel.ac.in/

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