

Cite this as: Jianjian HE, Xihao JIANG, Yubing WANG, 2025. Hydraulic conductivity of sand influenced by temperature and porosity in centrifugal tests. *Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)*, 26(3):177-193.

<https://doi.org/10.1631/jzus.A2400216>

Hydraulic conductivity of sand influenced by temperature and porosity in centrifugal tests

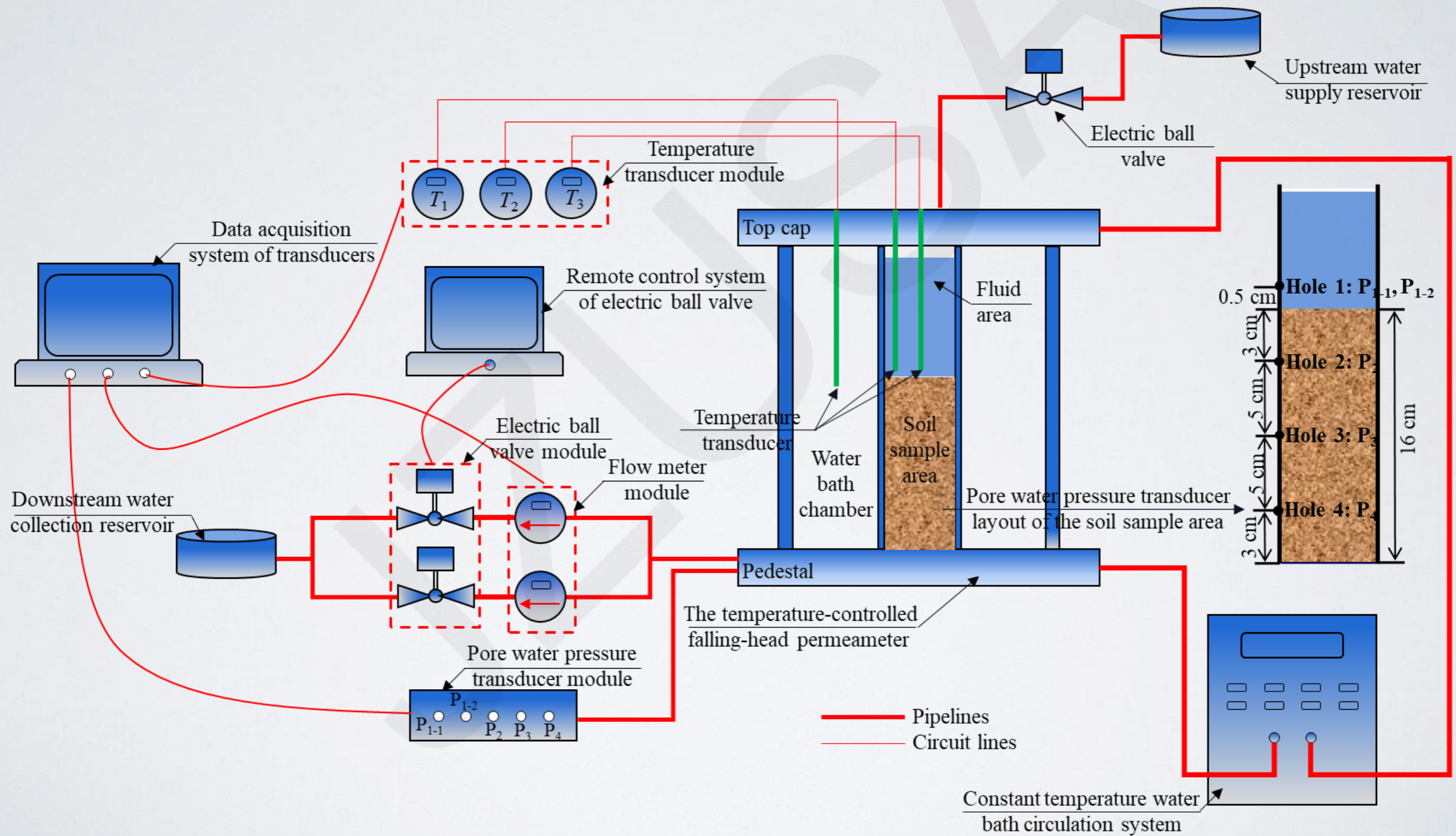
Key words:

Hydraulic conductivity of sand, Temperature, Porosity, Centrifugal acceleration, Kozeny-Carman equation



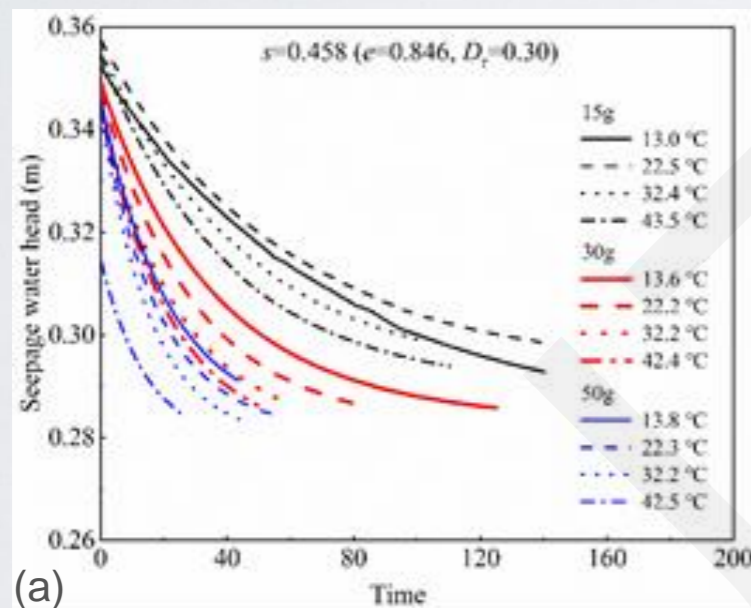
Self-designed apparatus

- A hypergravity temperature-controlled falling-head permeameter apparatus

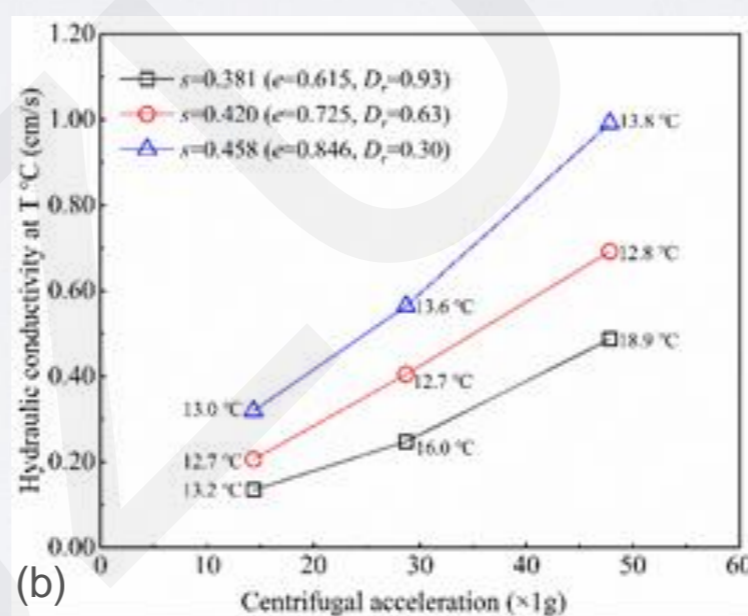


Qualitative analysis of test results

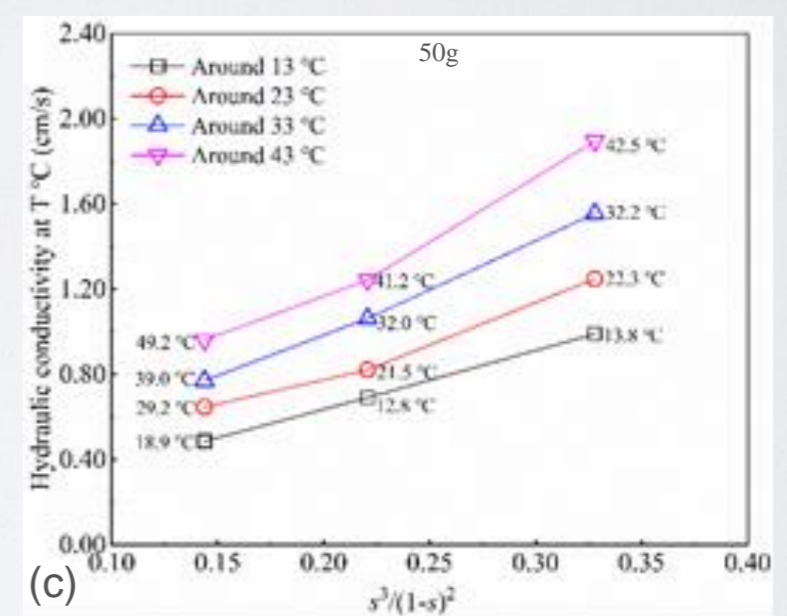
- (a) The seepage of the samples under each test condition was stable and the results of each test were reliable.
- (b) In a similar seepage temperature range, no matter how dense the sand, the hydraulic conductivity of the sand was linearly correlated with centrifugal acceleration
- (c) The hydraulic conductivity of sand showed a nearly linear growth in relation to its porosity function



(a)



(b)



(c)

- (a) Seepage water head process line
- (b) The hydraulic conductivity of sand samples with different porosity varies with centrifugal acceleration in a similar temperature range
- (c) The relationship between the hydraulic conductivity and porosity function

Prediction of centrifugal hydraulic conductivity of sand

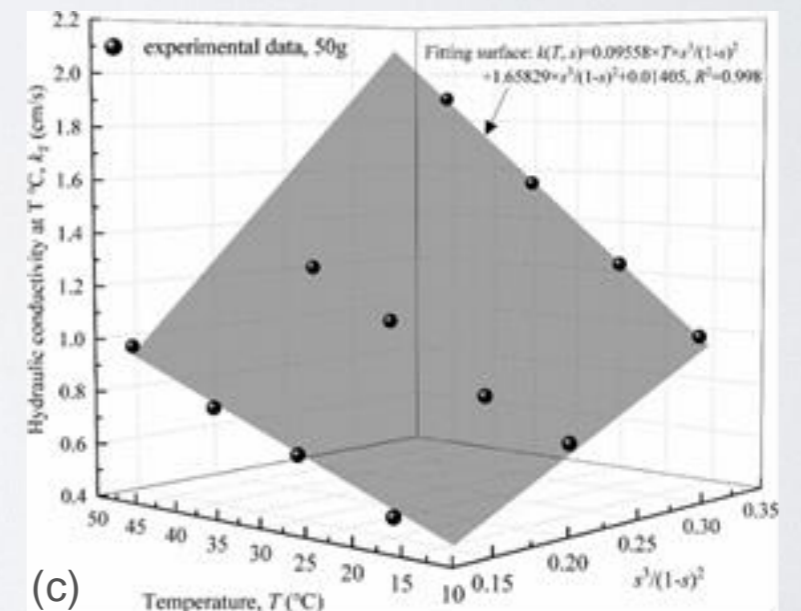
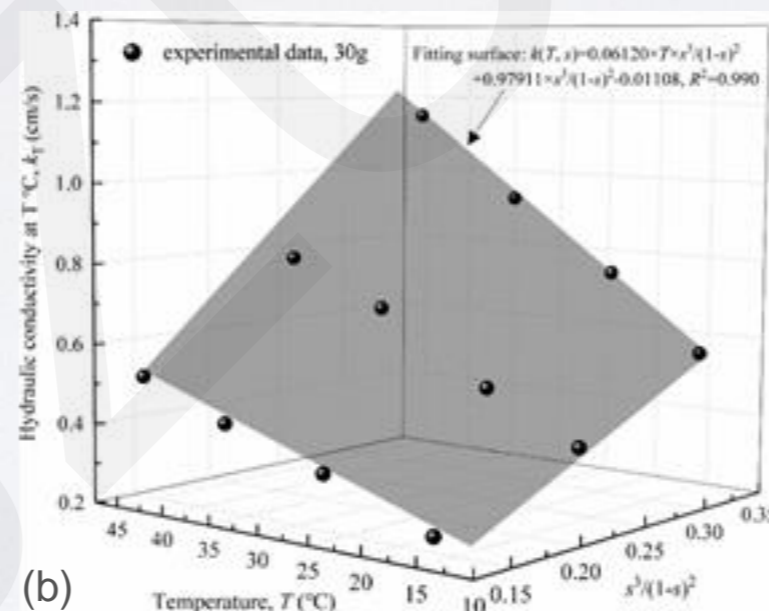
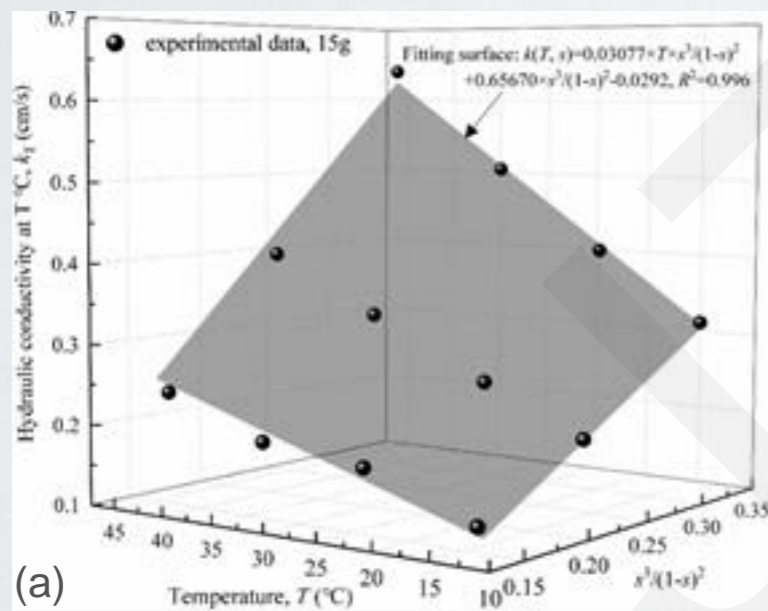
➤ Pathway I: Establishing $k(n, T, s)$ based on $k(T, s)$

➤ First, $k(T, s)$ was established considering the impact of porosity and temperature:

$$k(T, s) = cT[s^3/(1-s)^2] + d[s^3/(1-s)^2] + b \quad (\text{Eq. (7)})$$

➤ Then, $k(n, T, s)$ was established based on $k(T, s)$:

$$k(n, T, s) = 0.00193nT[s^3/(1-s)^2] + 0.00410T[s^3/(1-s)^2] + 0.03023n[s^3/(1-s)^2] + 0.18255[s^3/(1-s)^2] - 0.0292 \quad (\text{Eq. (10)})$$



➤ Using Eq. (7) to fit the hydraulic conductivity at real temperatures under different centrifugal accelerations: (a) 15g; (b) 30g; (c) 50g

Prediction of centrifugal hydraulic conductivity of sand

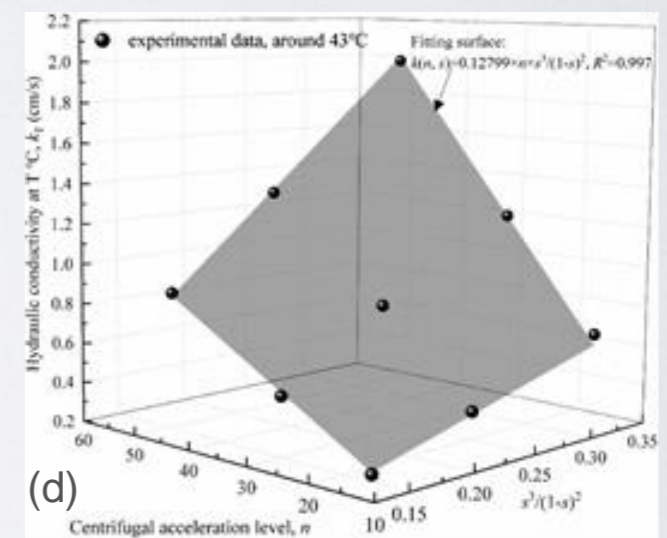
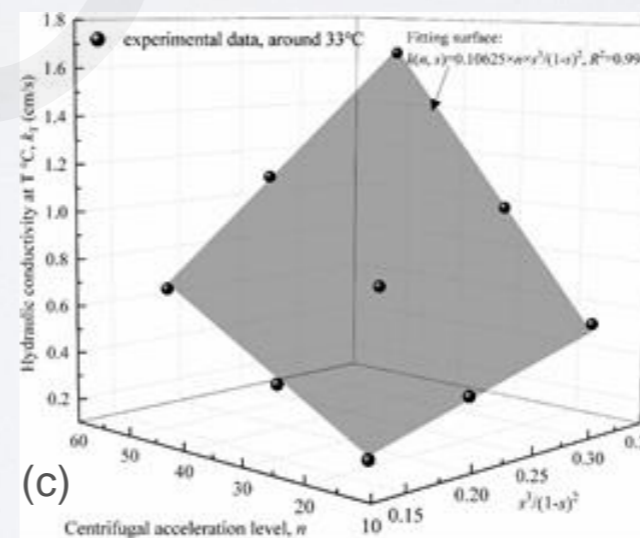
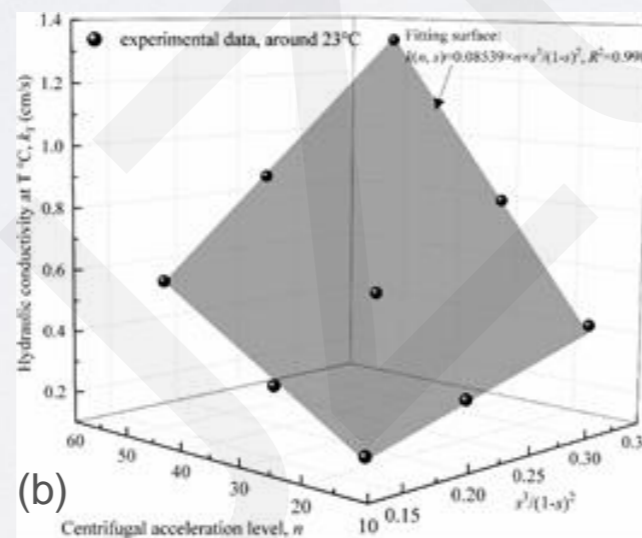
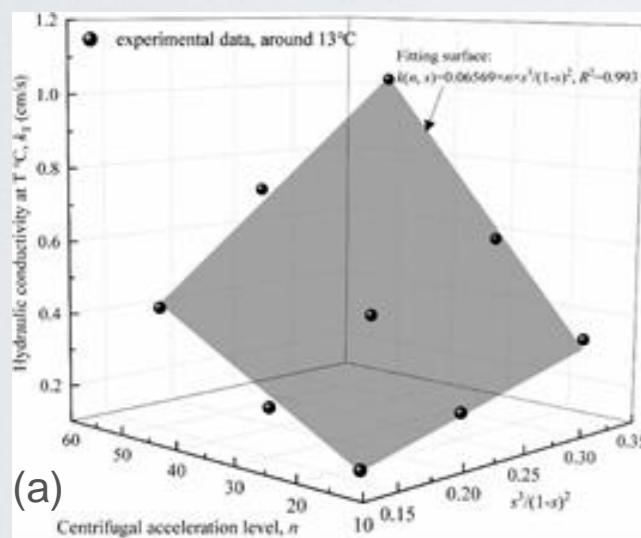
➤ Pathway II: Establishing $k(n, T, s)$ based on $k(n, s)$

➤ First, $k(n, s)$ was established considering the impact of porosity and centrifugal acceleration:

$$k(n, s) = b_1 n [s^3 / (1-s)^2] \quad (\text{Eq. (13)})$$

➤ Then, $k(n, T, s)$ was established based on $k(n, s)$:

$$k(n, T, s) = 0.00208 n T [s^3 / (1-s)^2] + 0.03400 n [s^3 / (1-s)^2] \quad (\text{Eq. (15)})$$



➤ Using Eq. (13) to fit the hydraulic conductivity at real temperatures: (a) around 13 °C; (b) around 23 °C; (c) around 33 °C; (d) around 43 °C

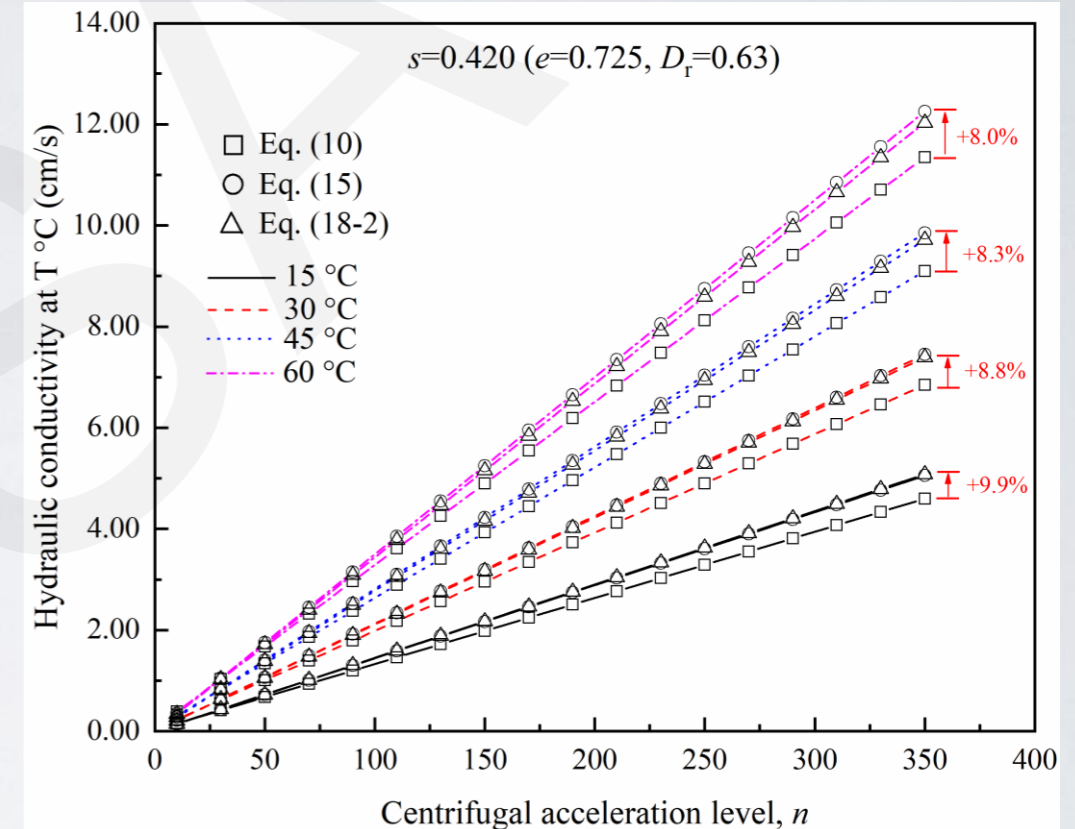
Prediction performance in more extreme environments

- The Kozeny-Carman equation can accurately estimate the hydraulic conductivity of sand in centrifuge modeling under the various conditions of this study:

$$k(n, T, s) = 0.00200nT[s^3/(1-s)^2] + 0.03573n[s^3/(1-s)^2]$$

(Eq.(18-2))

- At higher temperatures and greater centrifugal accelerations
 - When the centrifugal acceleration is less than 50g, the above three equations are highly reliable for forecasting the hydraulic conductivity of sand.
 - When the centrifugal acceleration exceeds 50g, it is advisable to give priority to the use of Eq. (10). Eqs. (15) and (18-2) can still be used, but their associated errors must be considered.



- The variation of hydraulic conductivities calculated by Eqs. (10), (15), and (18-2) with centrifugal acceleration level

Perspectives and Research Priorities

Research Priorities:

- The effect of temperature on hydraulic conductivity of cohesive soil in a centrifugal environment.
- Developing an advanced experimental device to facilitate the study of complex multifield coupling processes in a centrifugal environment (e.g. thermo-hydro-stress-biochemical interactions in soil).
- The influence of temperature on centrifuge modeling involving seepage at a larger model scale.

The temperature effects on soil seepage characteristics in a centrifugal environment remain poorly understood, including the need for appropriate experimental devices and the impact of temperature on the hydraulic conductivity of both cohesive and non-cohesive soils. Because accurately revealing and characterizing the influence of temperature on the hydraulic conductivity of soil in a centrifugal environment is crucial for using centrifuge modeling to depict the coupled THM behavior of soil and is also important for addressing multifield coupling problems involving seepage in geotechnical engineering.