### Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)

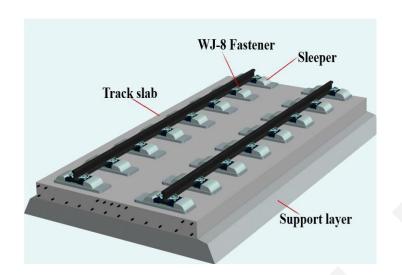
# Multi-field, time-varying behavior, and cracking mechanisms of early-age concrete in balastless track beds

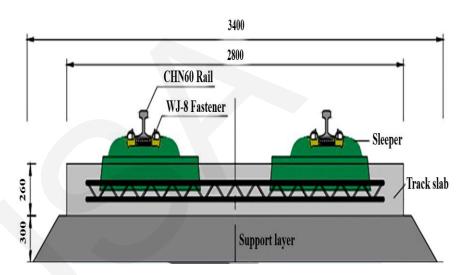
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### 1. Research subjects





Double-block ballastless track structure



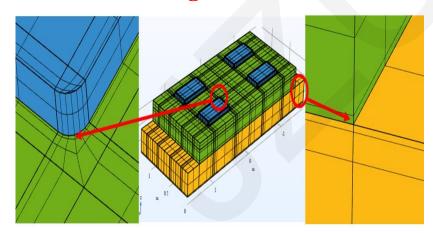
Concrete track bed cracks

### 2. Risk prediction model for early-age concrete cracking

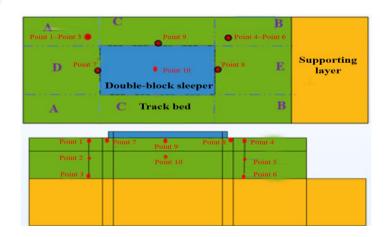
#### **Various calculation methods:**

- the hydration field of early-age concrete in track beds:  $\frac{\partial \alpha}{\partial t} = A_{25}\beta_{\varphi}\beta_{T}$
- temperature field of double-block track:  $(\rho C)_{eff} \frac{\partial T}{\partial t} + \nabla \cdot (\lambda \nabla T) + \frac{\partial Q_h}{\partial t} = 0$
- humidity field of double-block track:  $\frac{dw_e}{dt} + \frac{dw_n}{dt} + \nabla \cdot D_w \zeta_{\varphi} \nabla \varphi + \nabla \cdot \delta_p \nabla (\varphi P_{sat}) = 0$
- mechanical field of early-age track bed:  $\dot{\sigma} = D_c(\alpha)$ :  $\dot{\varepsilon}_e = D_c(\alpha)$ :  $(\dot{\varepsilon} \dot{\varepsilon}_c \dot{\varepsilon}_{\varphi} \dot{\varepsilon}_T)$

#### **Numerical modeling:**

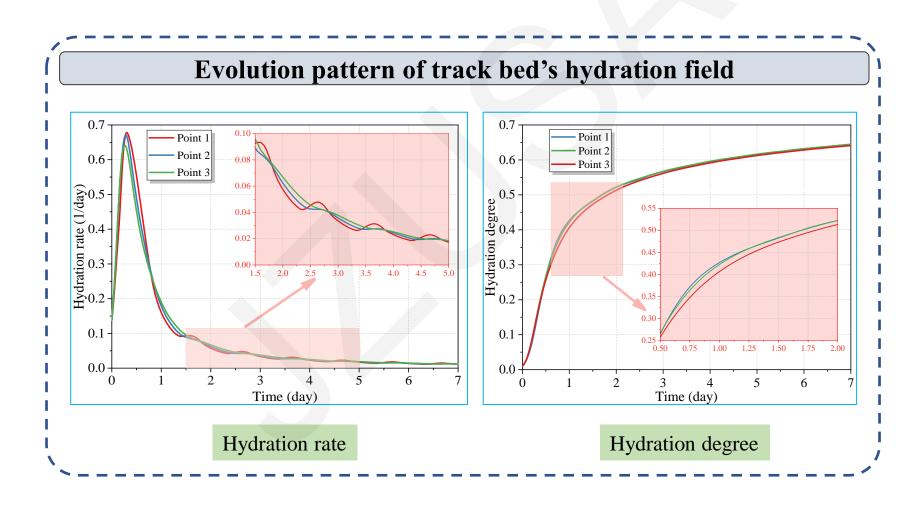


Multi-field coupling model of double-block ballastless track in early age

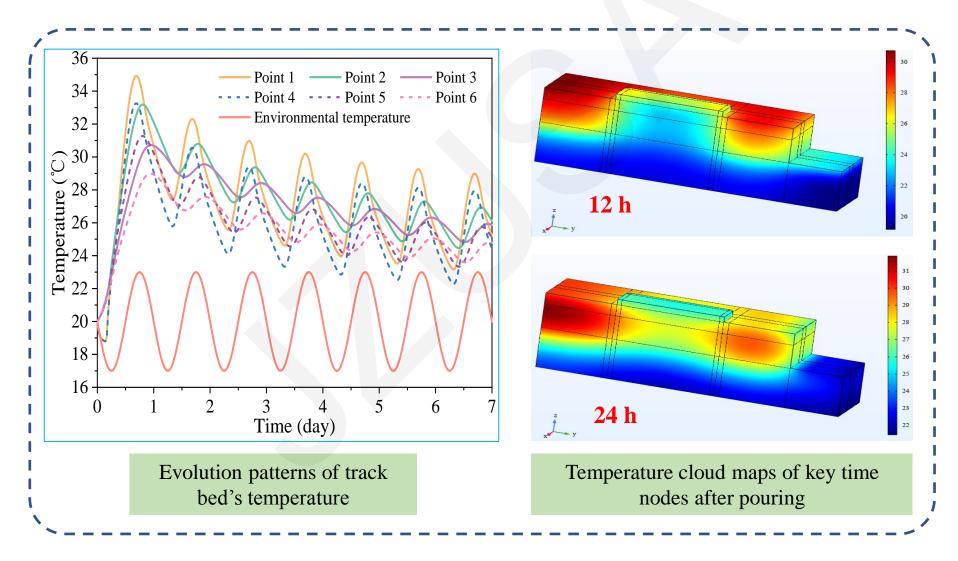


Schematic diagram of the layout of model numerical monitoring points

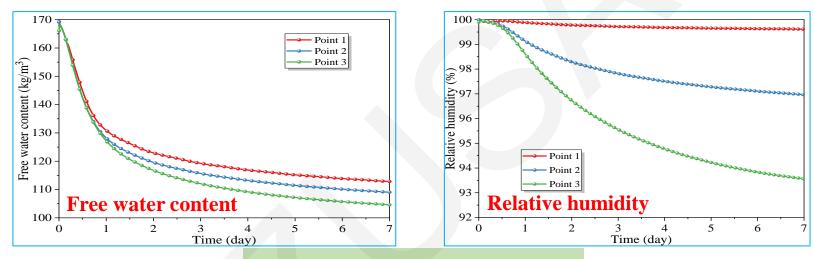
#### 3.1 Time-varying development of hydration degree:



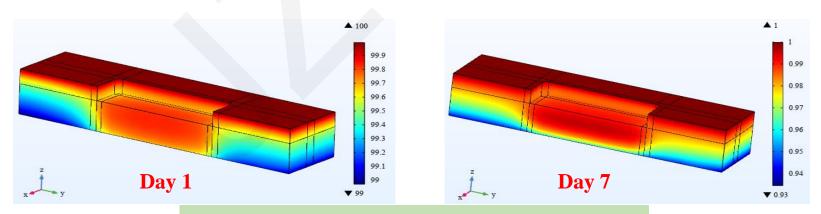
### 3.2 Time-varying development of temperature field:



#### 3.3 Time-varying development of humidity field:

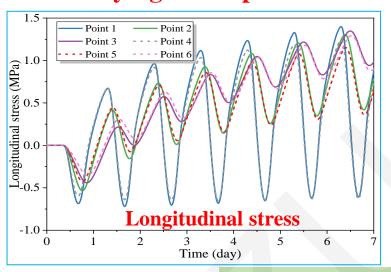


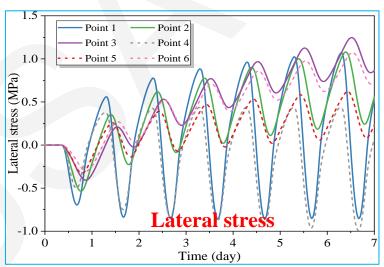
Temporal evolution of humidity field



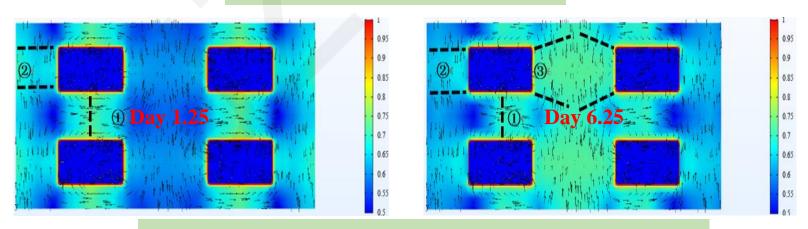
Spatial distribution of relative humidity in track bed

### 3.4 Time-varying development of stress field:





Stress evolution pattern of track bed



Distribution diagram of cracking risk coefficients and principal

### 5. Conclusions

- ➤ In the hydro field, track bed's max hydration rate is around 7h after pouring, final set at 9.5h. Max diff ratio of hydration rate under sleeper due to 1st-day temperature is roughly 14%. In temperature field, early-age track bed temperature is higher than ambient, with daily cyclic change. Concrete surface max temperature is 16h after pouring, which is about 15° C above molding temp. In chemo (humidity) field, near double-block rail sleeper, humidity is uneven. Small water loss is due to drying, and hydration mainly reduces water content.
- ➤ When measuring track bed's early cracking risk, on day 1.25, the cracking risk coefficient of old-new concrete interface around sleeper exceeds 1. By day 7, the track bed slab's splay crack risk near the rail sleeper hits the threshold, with a risk coefficient of about 0.75. Temperature deformation drives surface stress, while humidity deformation triggers tensile stress at the track bed bottom.

### 5. Conclusions

- In terms of material property factors, the risk of cracking increases with the maximum heat of hydration. The risk of cracking and the heat release peak time are in a concave relationship. In terms of environmental and atmospheric factors, cracking increases linearly with the temperature differences between day and night. The cracking risk increases linearly with the average daily cooling rate. Solar radiation intensity has the greatest influence on the cracking risk of the surface layer, and the risk of cracking on the surface layer increases linearly with the radiation intensity. As for the construction technique factors, the cracking risk increases linearly with the molding temperature.
- In terms of comprehensive risk control measures for the cracking of early-age track beds, the recommended measures are (most to least): reducing hydration heat, optimizing heat release peak time, enhancing insulation measures, selecting appropriate molding time, and controlling the molding temperature.