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Decomposition method for existing tunnel lining displacement induced by undercrossing: a case study

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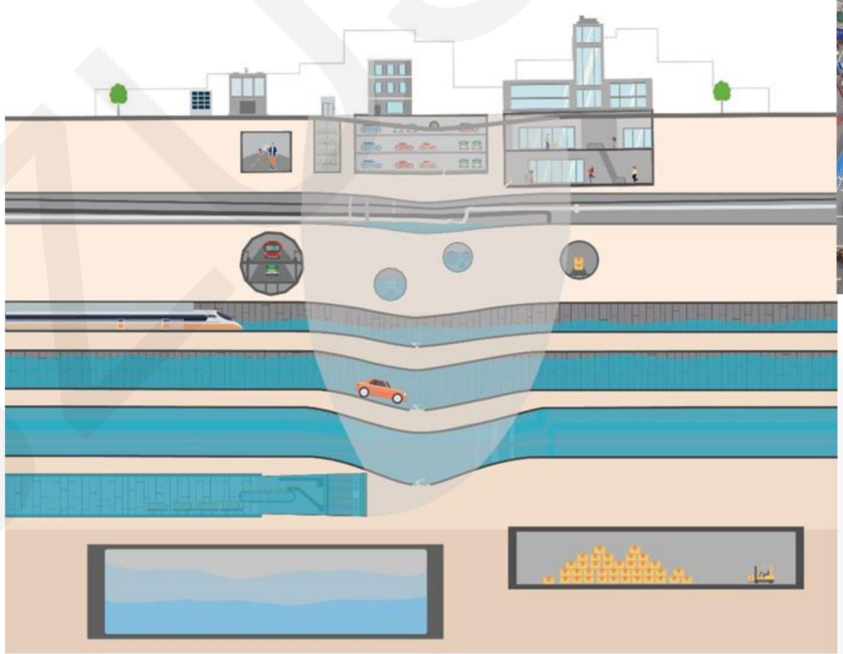
Project overview

- The conflict between the need to protect densely built-up areas in city centers and the disturbances caused by rail transit construction is becoming increasingly prominent.

穿越构筑类别	穿越构筑名称	穿越方式	备注
隧道	9号线	下穿	正交穿越
	7号线	下穿	正交穿越
	1号线	下穿	正交穿越
	14号线	下穿	小角度斜穿
	2号线	下穿	平行穿越
	北环电缆隧道	下穿	
	皇岗快速路改造工程	上穿	
桩基	皇桥立交桩基	侧穿	小净距穿越
建筑物	岗厦北站附属结构	下穿	
	巴登村5-7F	下穿	
	中山大学附属第八医院	侧穿	
	6号线科学馆站	下穿	
	7号线华强南站	下穿	
	中学附近民房2-7F	下穿	
	华海综合大楼	侧穿	
	福田中学	下穿	中学正在改造施工
河道	福田河	下穿	



“穿”出，数名施工人员正在现场拆除盾构机。目前，广西规划馆站—庆歌路站区左线已实现贯通。

南宁轨道交通集团建设分公司土建三部项目主管刘松地介绍，广西规划馆站位于五象片区，平乐大道与宋厢路的交叉口。7月11日，车站全部完成封顶，区间左线盾构于2016年4月26日在庆歌路站始发，并于近期在广西规划馆站完成接收，历时120天实现了全线首个区间贯通。区间长度是727米，管线拼装了489环。

克服复杂地质条件确保盾构顺利掘进

该盾构区间在掘进过程克服了施工“拦路虎”。轨道交通3号线 02标指挥部副指挥长兼总工程师艾厚军介绍，广西规划馆站—庆歌路站区间为两条单洞单线圆形盾构隧道，采用盾构法施工，该区间地质条件复杂，主要为泥岩、灰岩、黏土层及岩溶地层，盾构掘进过程中岩面变化快，需穿越上软下硬地层和溶洞，姿态控制难度较大，掘进施工过程中盾构机如控制不当会引起盾构姿态向上或向下超限。

针对岩溶地层，南宁轨道交通集团和施工单位在盾构施工前对区间沿线进行地质补勘，确定溶洞位置及范围后采用地面注浆的方式填充溶洞，随后对填充效果进行取芯检测，并加强地面监测，确保盾构机掘进的安全性。同时，根据该区间全断面中风化泥灰岩、黏土层、上软下硬不均匀地层等复杂地质条件，多次邀请专家组织刀盘选型评审会，为盾构机刀盘配置高强度滚刀，合理设置刀盘开口率，并增配了刀盘喷水功能，加强渣土改良效果，做到降低刀具磨损程度的同时进一步减少泥饼产生，确保盾构机顺利掘进。

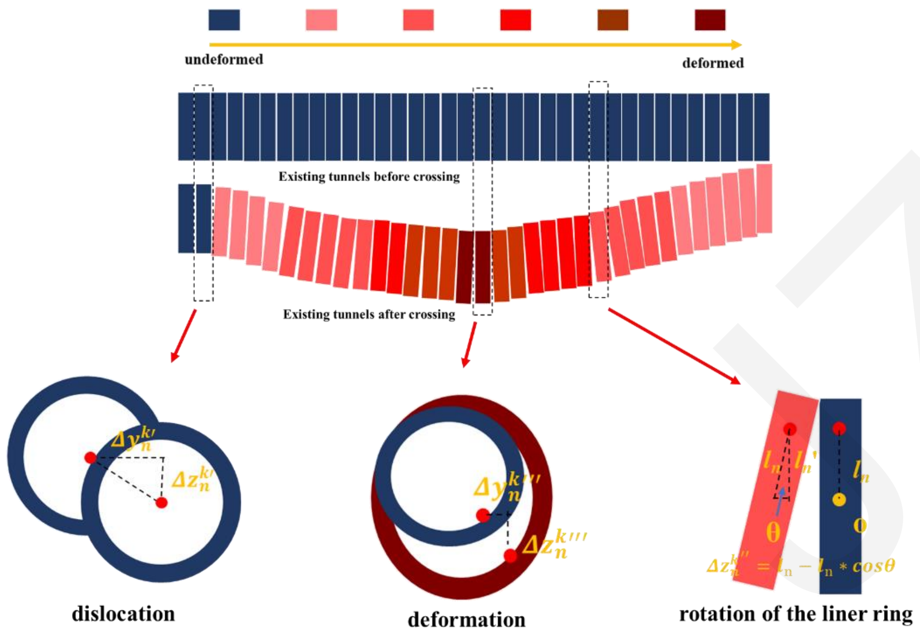
Displacement decomposition method

The **key principles** of the decomposition:

1 the **continuity of longitudinal deformation**;

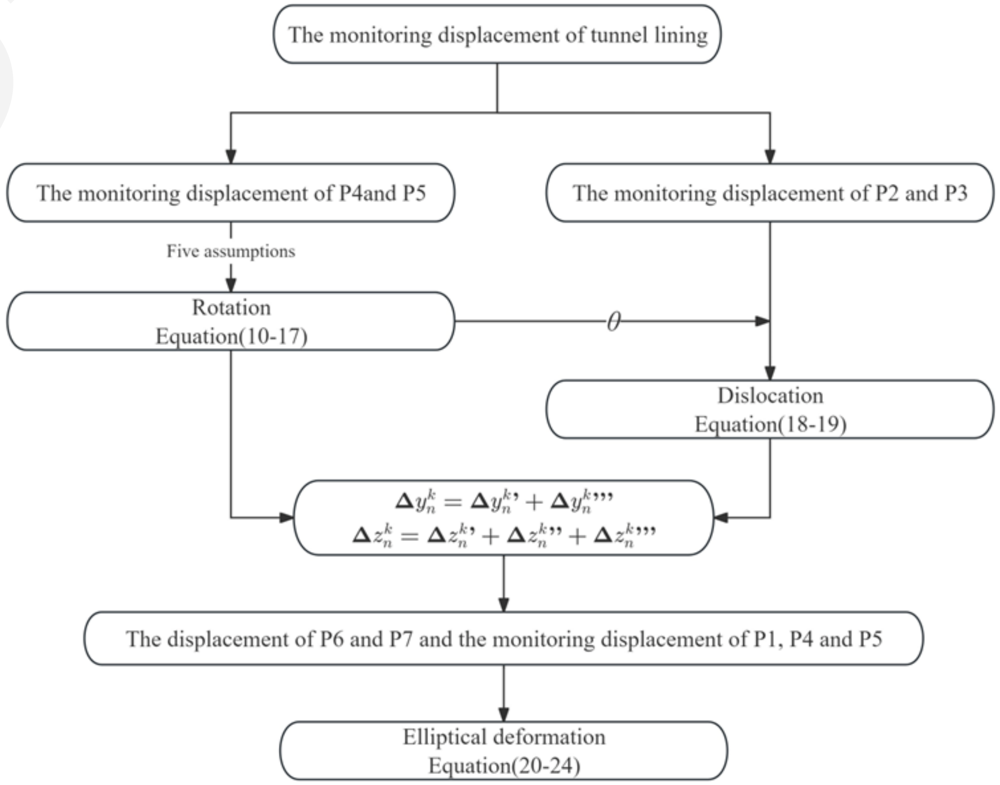
2 the **sinusoidal functional relationship** between the rotation angle and the longitudinal distance to the cross point;

3 neglecting the **longitudinal joint deformation**.



Displacement decomposition

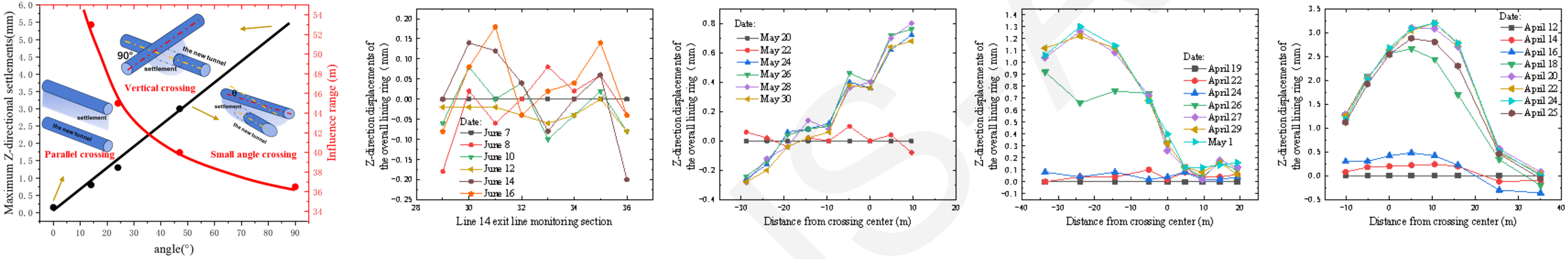
Calculation Steps



Flowchart of the Displacement Decomposition Method

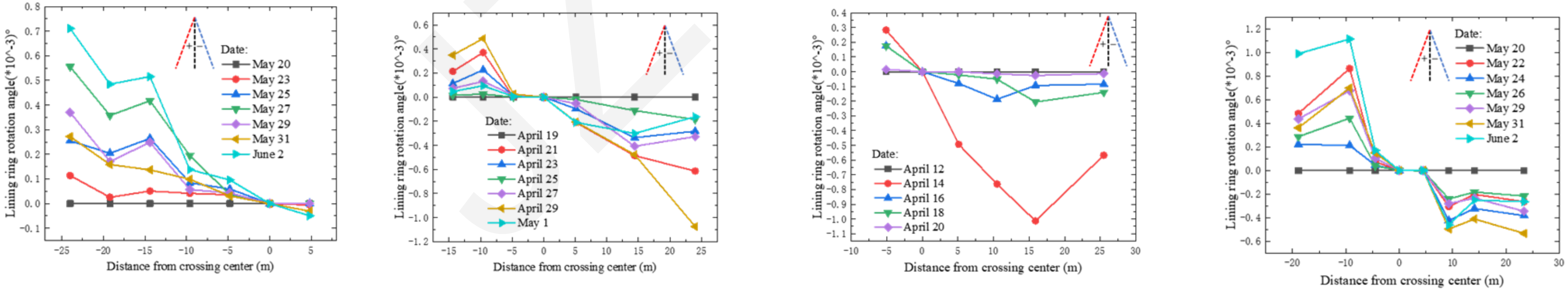
Displacement decomposition results

Vertical displacement is the primary factor influencing lining ring behavior, increasing linearly with crossing angle while the affected zone decreases **nonlinearly**. During undercrossing, vertical settlement exhibits an initial rapid increase followed by gradual recovery due to construction measures such as grouting.



Settlement at the bottom of the lining ring

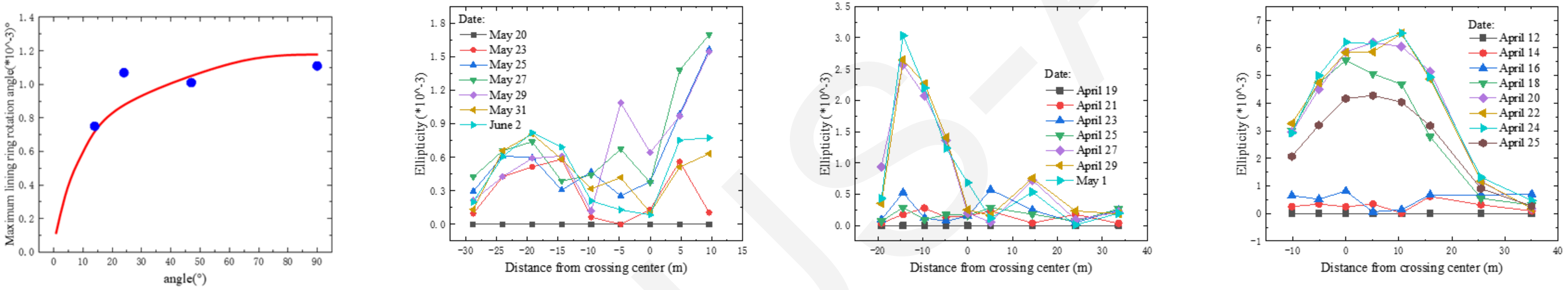
The maximum lining ring rotation angle occurs during 90° undercrossing and decreases **nonlinearly** with smaller crossing angles. **Spatially**, the rotation angle first increases and then decreases with distance from the crossing center; **temporally**, it follows a pattern of initial increase followed by gradual reduction.



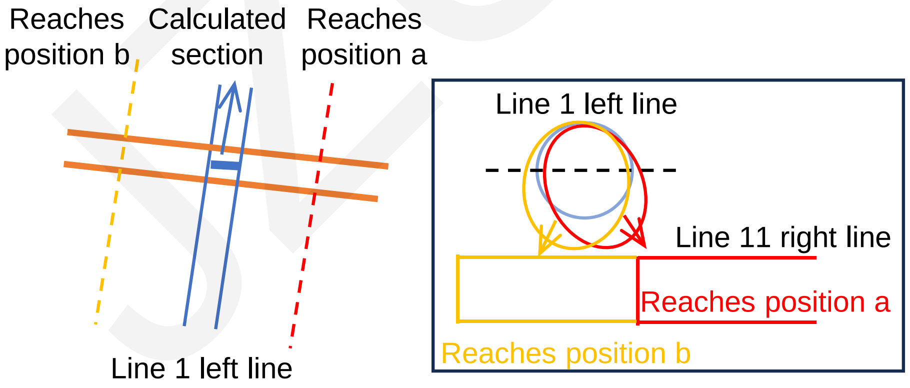
Lining Ring Corner

Displacement decomposition results

Ellipticity **increases** with crossing angle but decreases **with distance from the crossing center**. **Two temporal patterns were observed**: under small crossing angles, ellipticity increases rapidly then fluctuates significantly during stabilization; under large crossing angles, it increases sharply then stabilizes with minor fluctuations. Additionally, the major axis of elliptical deformation consistently points toward the excavation face of the new tunnel.



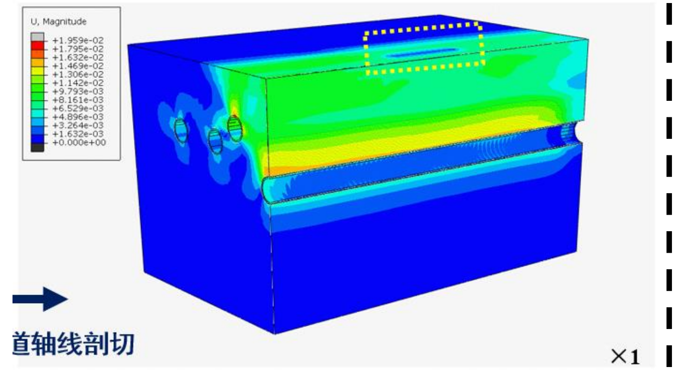
Lining Ring Ellipticity



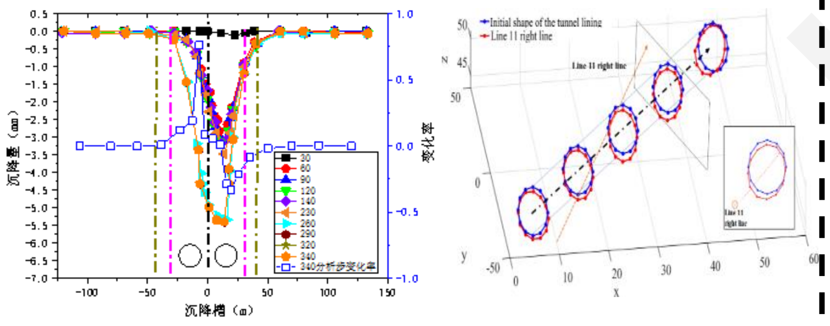
Long axis of the tunnel section ellipse points

Related research - three-dimensional detailed model

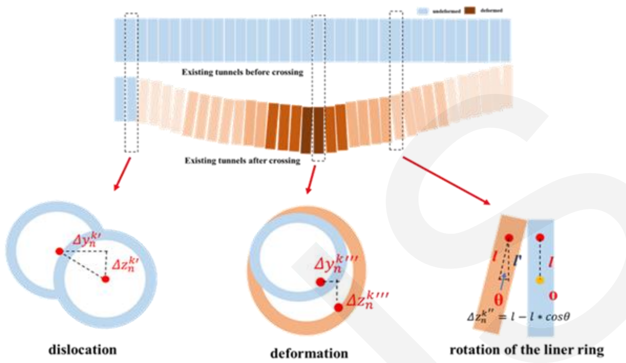
The Shenzhen Metro Line 11 project established **a three-dimensional detailed model** considering the entire shield tunneling process. By integrating construction-phase monitoring data, it revealed the spatiotemporal distribution patterns of settlement and structural deformation induced by shield tunneling through complex geological strata, dense clusters of piles, dense clusters of old residential buildings, and existing rail lines. **A displacement monitoring decomposition model** was proposed to elucidate the mechanisms and patterns of **ring-to-ring misalignment, ring rotation, and intra-ring ellipticity** induced by construction. For isolation piles and grouting reinforcement techniques, the isolation effect of **pile foundations** and **the deformation control range of soil reinforcement** were clarified.

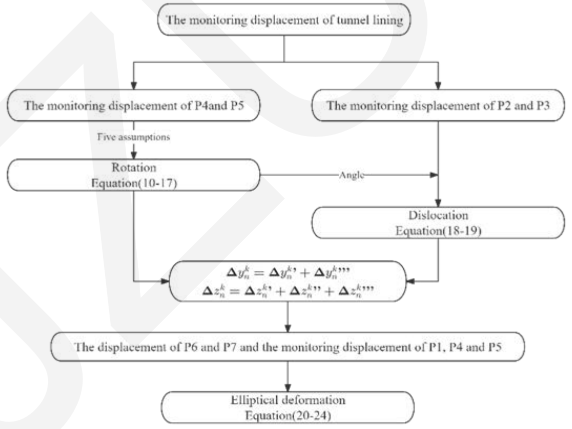


Three-dimensional high-precision numerical model

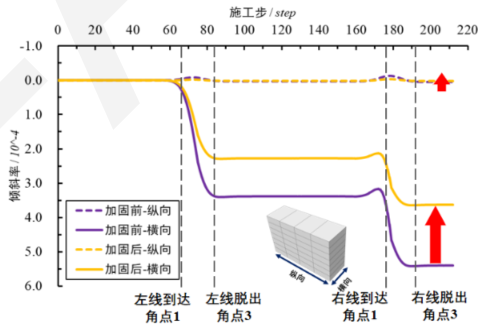


Deformation Patterns of Existing Lines Crossing Building Complexes

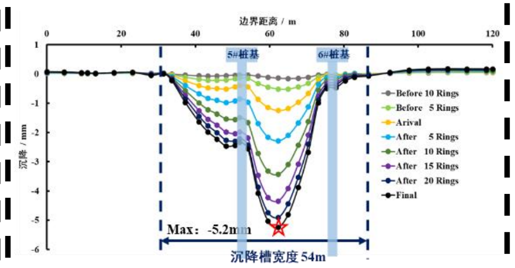




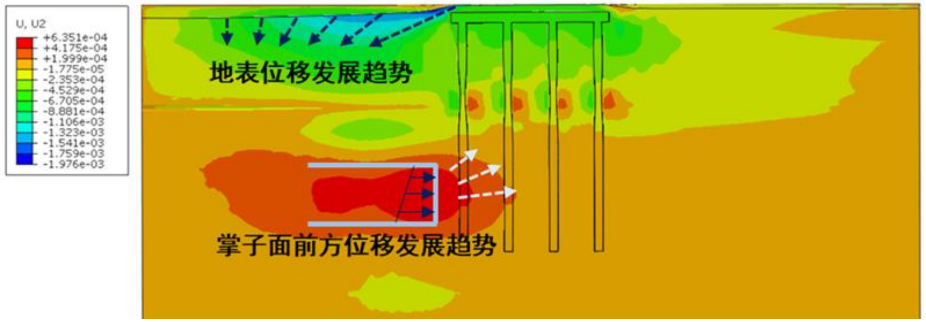
Deformation Patterns and Mechanisms Induced by Crossing in Existing Lines



Impact of Formation Reinforcement



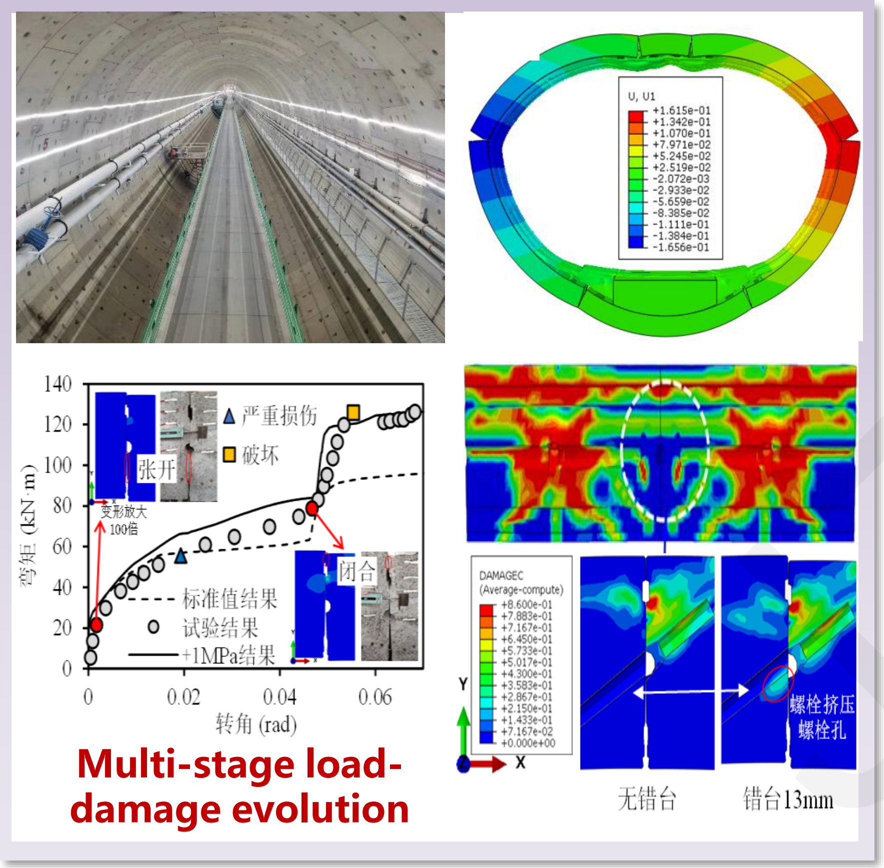
The isolation effect of pile foundations



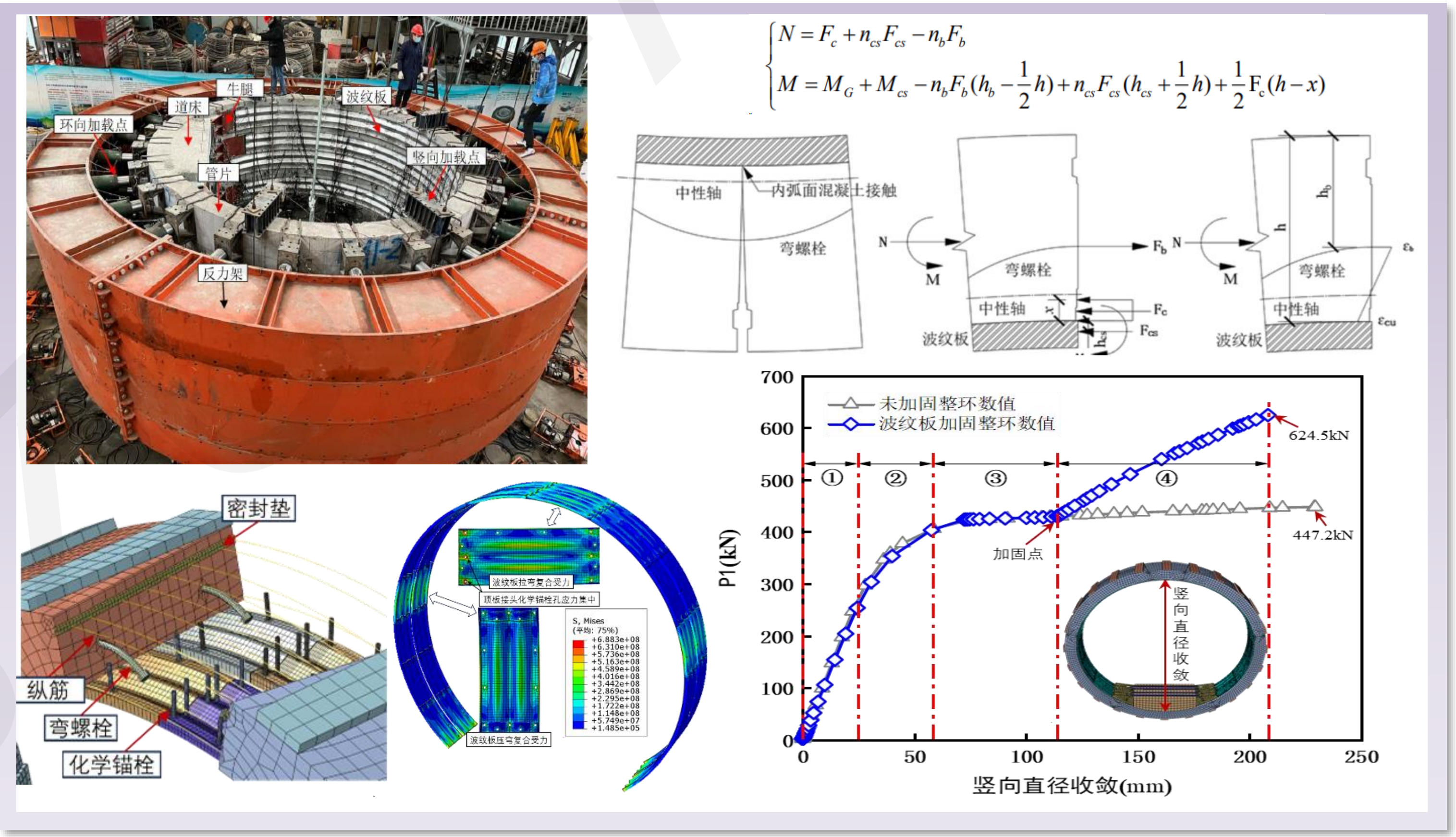
Disturbance Patterns Through Pile Foundations

Related research-National Natural Science Foundation of China

Research conducted under major projects of the **National Natural Science Foundation of China** has revealed **the multi-stage load-bearing mechanisms and failure characteristics of shield lining structures under joint opening and large deformations**. This work has developed rapid reinforcement techniques using corrugated steel and fiber-reinforced concrete-based technologies to enhance lining toughness, thereby improving the structure's rapid response capability during catastrophic events.



Multi-Structure Load-Failure Mechanism of Lining Structures



Disaster Prevention and Control Technology for Corrugated Steel Tunnel Structures