

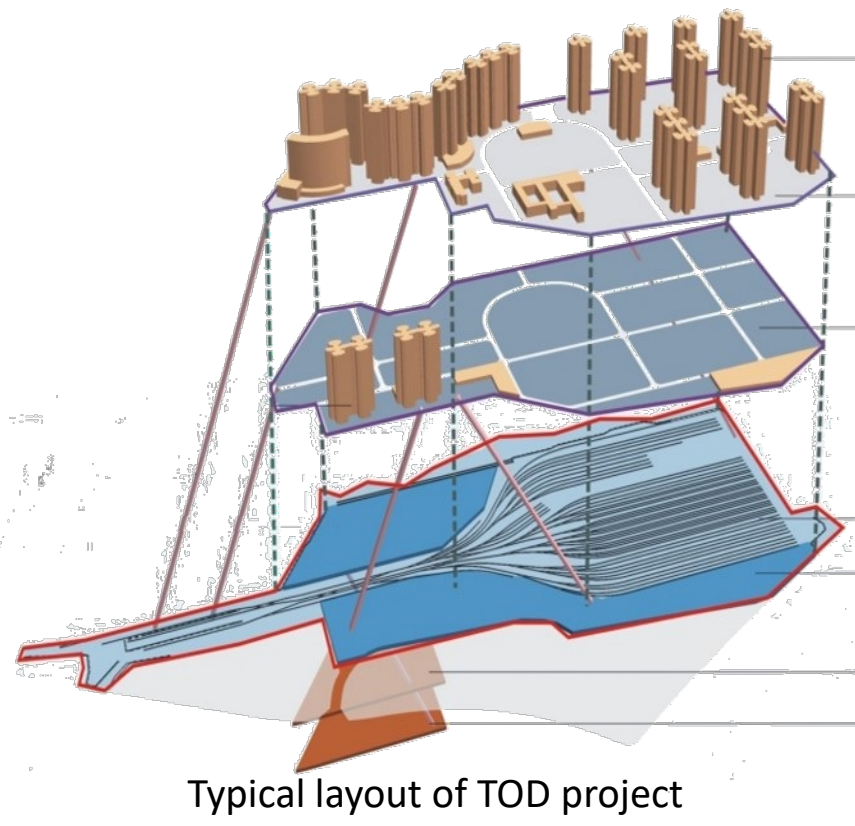
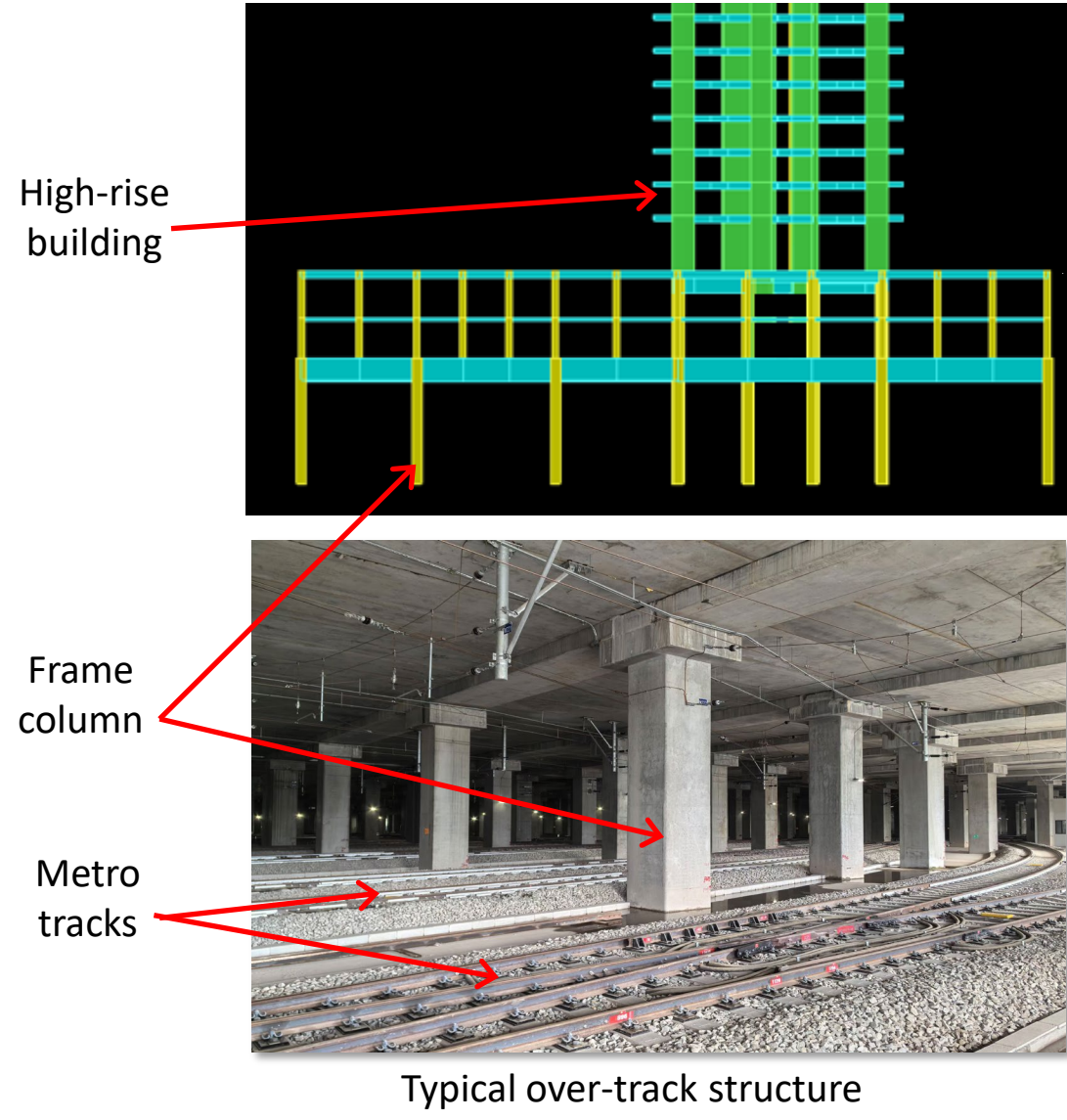
Innovative Isolation for Vibration-Seismic Dual Control of Fully Frame-Supported Over-Track Structure: A Demonstrative Application on the Chisha TOD Building in Guangzhou

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Owner: Yuexiu Property Co., Ltd.; Manufacturer: QuakeSafe Technologies Co., Ltd.



Technical Requirements and Challenges

- The transit-oriented development (TOD) projects, characterized by the boom of over-track buildings, suffer from metro-induced vibration and noise
- The seismic performance of the fully frame-supported structure also needs to be improved.
- The high-rise buildings require large-sized isolator due to the high vertical load.

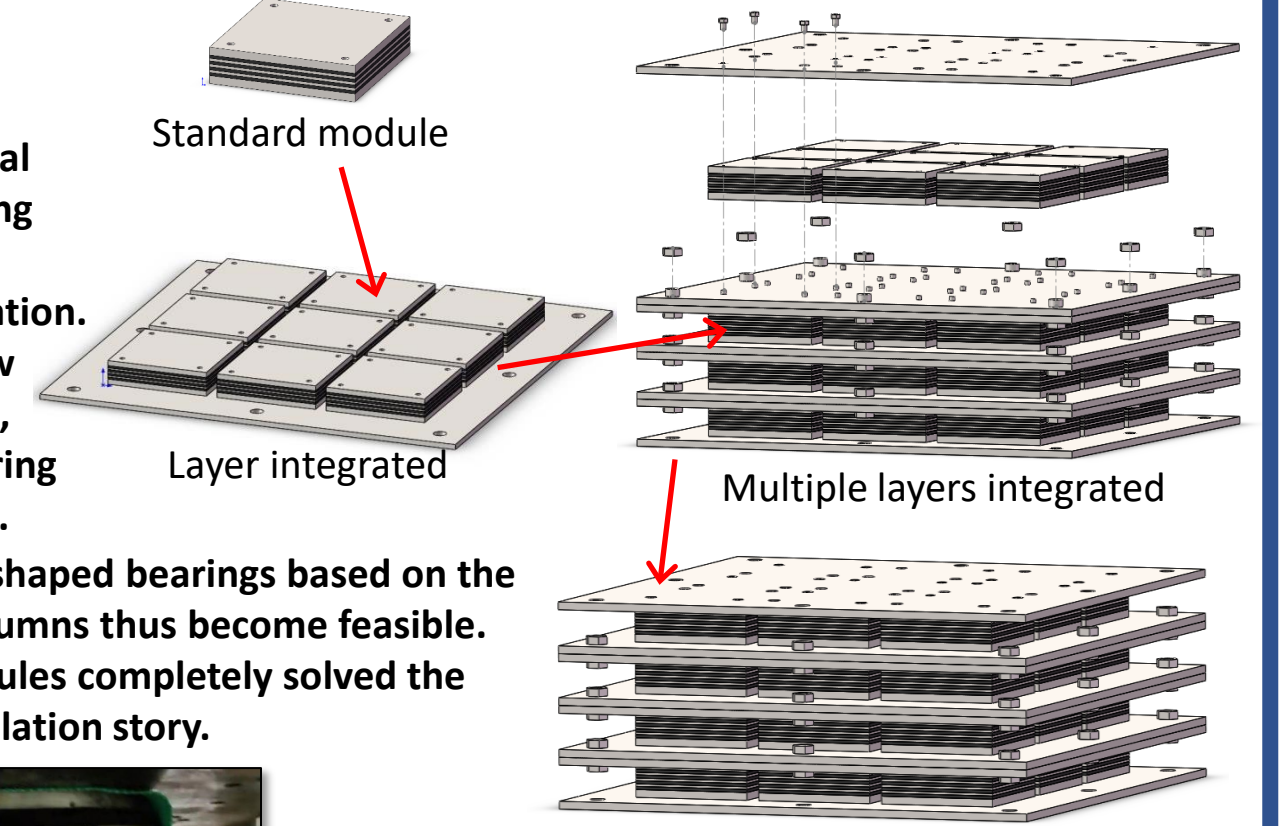


Typical layout of TOD project

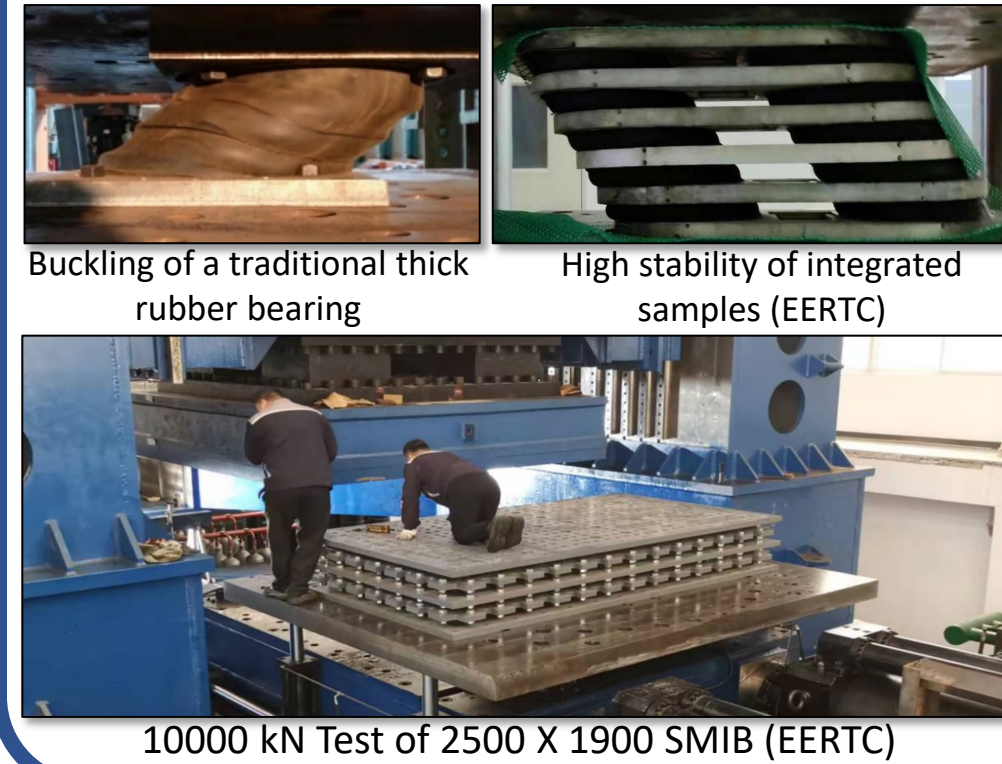
- The vulcanization process for extra large-sized rubber bearings is impossible and extremely costly.
- Traditional thick rubber bearings cannot achieve both the low vertical stiffness and high compressing-shearing stability.
- Inconsistent vertical deformations of various traditional isolators in the same story is hard to control.
- The presence of lead cores and traditional dampers acts like acoustic bridges, causing the loss of vibration isolation.

Novel Standard-Module Integrated Isolator

- A novel Standard-Module Integrated Bearing (SMIB) is developed.
- Compared to traditional thick rubber isolators, the SMIB features low vertical stiffness and high compressing-shearing stability, and thus enable the high performance of vibration-seismic isolation.
- The novel design results extremely low requirements of vulcanization process, avoiding the bottleneck in manufacturing large-size bearings and quality control.
- The production of large and specially shaped bearings based on the cross-sectional shape of the frame columns thus become feasible.
- The usage of consistent standard modules completely solved the problem of uneven deformation of isolation story.



A Typical SMIB isolator (36 Standard Modules)



10000 kN Test of 2500 X 1900 SMIB (EERTC)

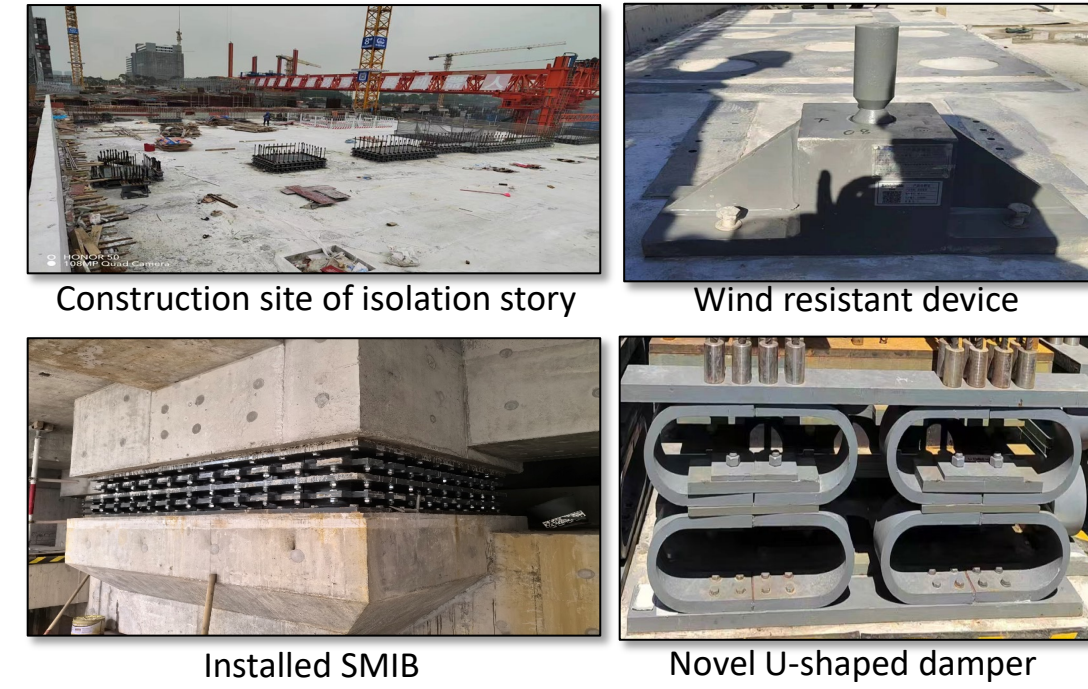
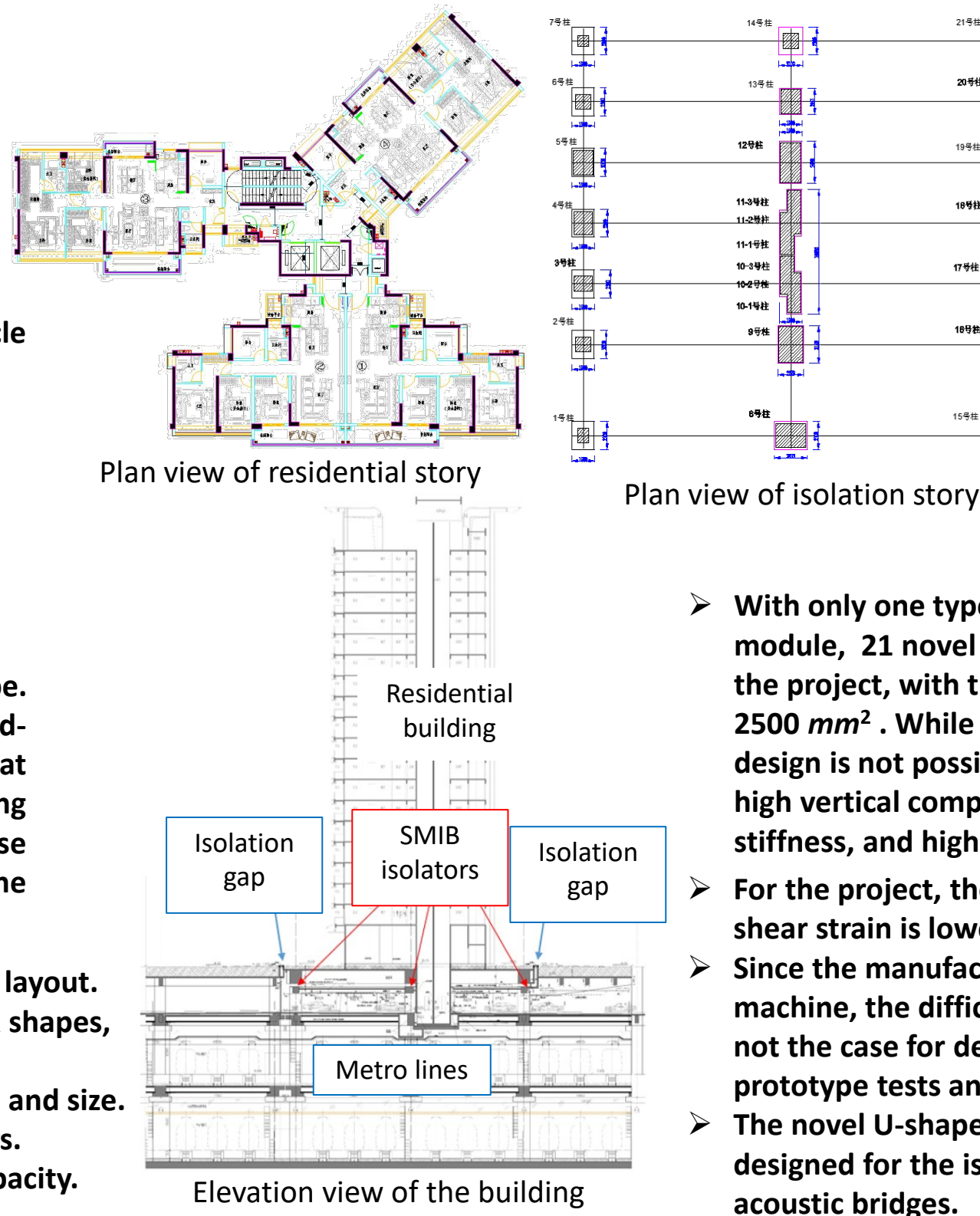


2800 X 2500 'L' shape SMIB isolator (EERTC)

The Chisha TOD Building: A Design of Highrise and Inter-story Vibration-Seismic Isolated Structure

- The Chisha TOD isolated building which exceeds 92.5 m in height, employs an inter-story isolation design and is currently the tallest building in China utilizing isolation for seismic-vibration dual control.
- The bottom three stories are a RC frame-structured railway and vehicle base, with the tallest story height reaching 11.9 m. The fourth floor serves as the vibration isolation story. The 5th to the 23rd story is residential and RC shear-wall structured.
- The total building area reaches 25,600 m², with the standard story features an irregular butterfly shape.
- For the first time that a fully framed-supported structure be realized at this height in China, the building exceeds the limits of Chinese national code, especially in the following five aspects:

1. Torsional irregularity and eccentric layout.
2. Irregular plan with concave-convex shapes, resembling an hourglass.
3. Abrupt changes in vertical stiffness and size.
4. Discontinuity in structural members.
5. Abrupt changes in load-bearing capacity.

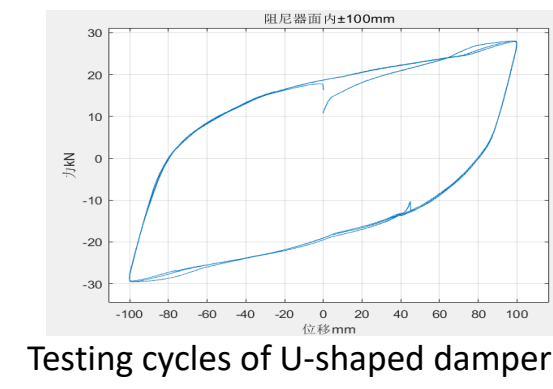


Construction site of isolation story

Wind resistant device

Installed SMIB

Novel U-shaped damper



Testing cycles of U-shaped damper

- With only one type of the present standard module, 21 novel SMIB isolators is proposed for the project, with the largest one reaches 2800 X 2500 mm². While by traditional isolator, the design is not possible to simultaneously achieve high vertical compressive capacity, low vertical stiffness, and high shear deformation capabilities.
- For the project, the SMIB design load is up to 10 MPa, vertical natural frequency is near 7Hz, the shear strain is lower than 300%.
- Since the manufacturer only needs to use the same small mold and low-tonnage vulcanization machine, the difficulty associated with production and quality control is significantly reduced. This is not the case for design schemes that utilize traditional bearings. As a result, all bearings pass both prototype tests and routine tests in one go.
- The novel U-shaped damper with vibration isolation gap and wind-resistant device have also been designed for the isolation story, replacing lead cores and traditional dampers, and thus avoiding the acoustic bridges.



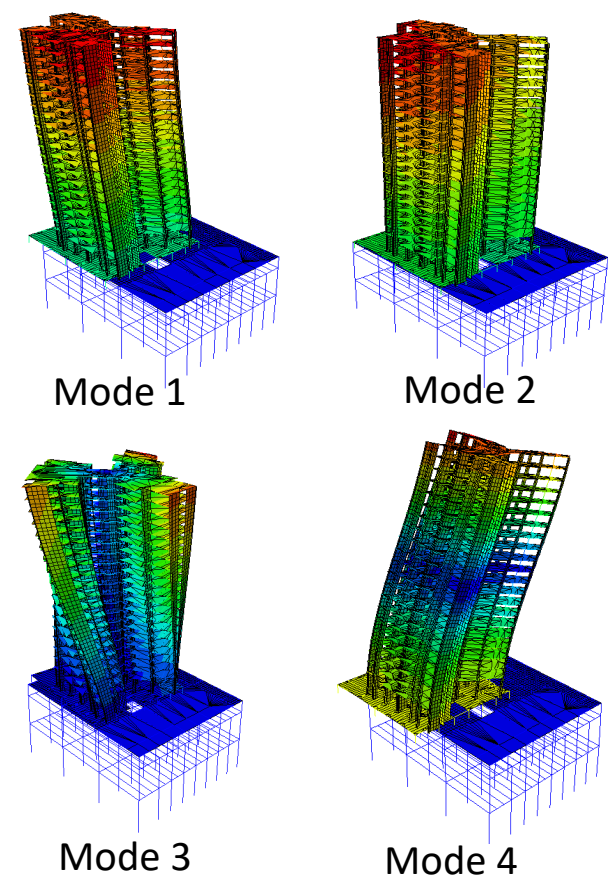
Completed building in 2024

Seismic Response Reduction

- Time-history analysis and response spectrum analysis are conducted using YJK and ABAQUS software.
- According to China code, the fundamental period of the isolated building under moderate-scale earthquake is near 3.0s.
- The shear force at the base reduces over 50% by the isolation design, this allows the structural measures for the superstructure can be reduced by one level.
- Both the seismic performance of the lower frame and the upper shear-wall structure have been improved by isolation design, effectively addressing the five unfavorable issues that originally existed in the over-limited structure. And thus the project passed the inspection of structure anti-seismic expert committee.



Inspection meeting of expert committee in 2022

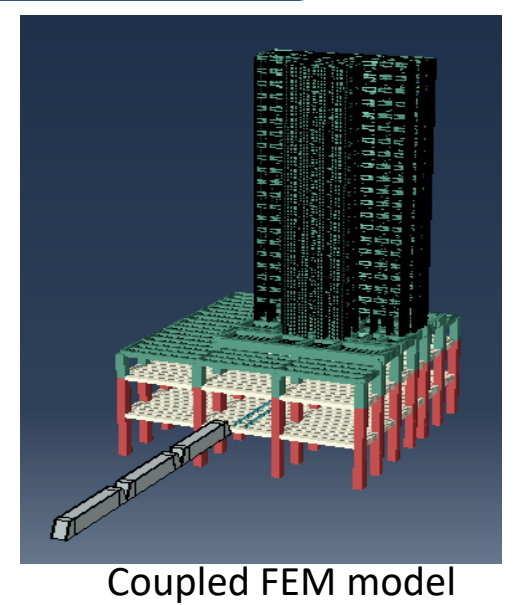


Base shear force ratio of the residential tower

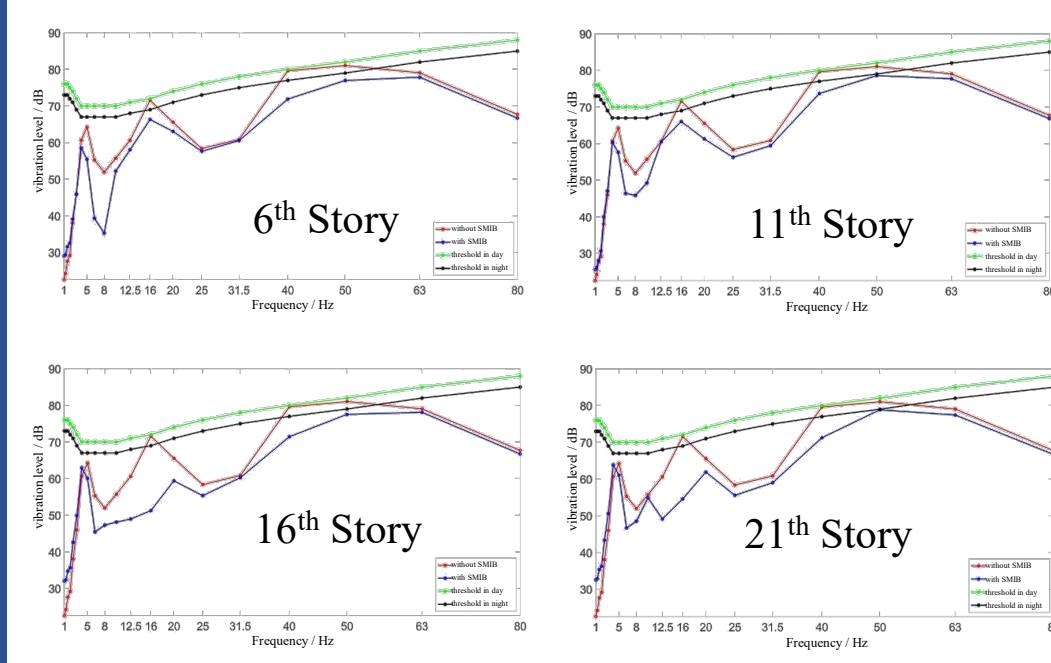
Input level	Method	Input direction	Fixed	Isolated	Isolated/Fixed
Design earthquake	CCQC	X	15960.87	6962.75	0.44
		Y	18604.79	6174.01	0.33
	YJK	X	18572.9	7763.28	0.42
		Y	17768.6	6681.85	0.38
Rare earthquake	ABAQUS	X	18572.9	7763.28	0.42
		Y	17768.6	6681.85	0.38
	CCQC	X	35113.91	15793.00	0.45
		Y	40930.53	13656.38	0.33
YJK	X	40860.38	20000.00	0.49	
	Y	39090.92	18470.00	0.47	

Vibration Response Reduction

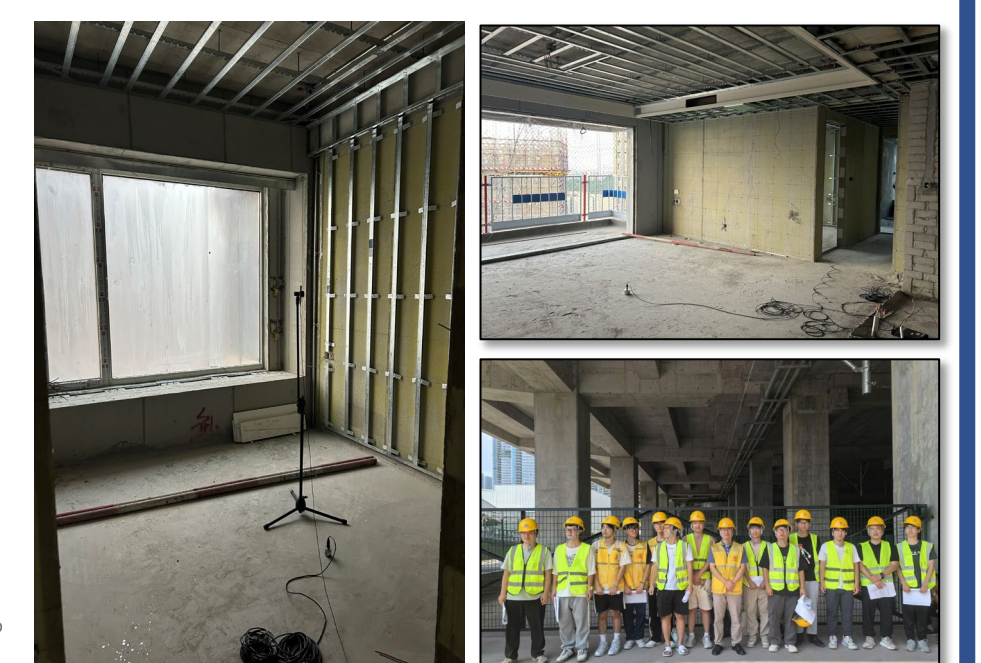
- A coupled model integrating metro train, tracks, foundation, substructure, and superstructure was established by using ABAQUS.
- Considering the unfavorable scenario where the first and second stories of the structure have trains running simultaneously with a speed of around 20 km/h, the vibration response of the upper structure was analyzed.
- The vibration threshold is specified by the China code GB-10070
- The analysis indicates that without the isolation design, the Z-vibration level and sub-frequency vibration levels of the residential building will exceed the China code limits. The isolation design, totally reduce the maximum Z-vibration level by 5dB, keeps both within the limits specified by the Chinese code.
- The field test in 2024 evidences the vibration level satisfies the China code.



Coupled FEM model



The simulated sub-frequency vibration levels



Field test of traffic-induced vibration in 2024