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Design and AESS Quality Control of Fused Diagrid Structures of Guangzhou SANY Twin Towers

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Abstract To improve the seismic performance, the SANY twin towers in Guangzhou, China have utilized friction devices at the offset nodes of the diagrid system. Slip is designed to occur at about 85% of the moderate earthquake shear demands. Dynamic elasto-plastic analyses in rare earthquakes show that most friction nodes slip and dissipate energy as expected. The seismic energy dissipated in the diagrid system with the friction nodes is over 50% of the total nonlinearity energy dissipation. The diagrid structure is exposed and designed to the AESS 4 standard. Performance based fire safety design has made it possible to leave the CFT members free of fireproof. Strict quality management has been carried out by the architect and the project management team to ensure the high quality of the exposed steel structures. The construction has finished, and the twin towers were be opened in 2025.

Keywords: Friction Node, Energy Dissipation, Diagrid Structure, High-rise Steel Structures, AESS

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1. Introduction

The SANY twin towers project is located in Pazhou District of Guangzhou, China. The project consists of two towers. The P125 Tower is 40-story tall, 204m high to the top of the parapet. The P126 Tower is 36-story tall, 181.5m high to the top of the parapet. The structural systems for the two towers are similar, each with a central concrete core and an exterior hexagonal diagrid (also called hexagrid hereinafter) concrete filled tube (CFT) frame. This paper mainly presents the structural designconsidering friction devices considering friction devices and AESS (Architecturally Exposed Structural Steel) quality control of tower P125.

2. Architectural Design

The SANY twin towers are envisioned as an emblem for the company's growth and innovation. The two towers are united by a striking structural design: an external diagrid system rising in a diamond grid pattern, as shown in Figure 1. The structural system allows the floors to be suspended from the structure, eliminating cumbersome interior columns. Landscaped terraces punctuate the towers at five-floor intervals. Rather than a solid podium base, an elevated podium bridges the two towers, allowing the ground to become an inviting public plaza with gardens.

Native landscaping permeates through the base of the towers, continuing up to the podium and wrapping



Figure 1. Architectural rendering of the project.

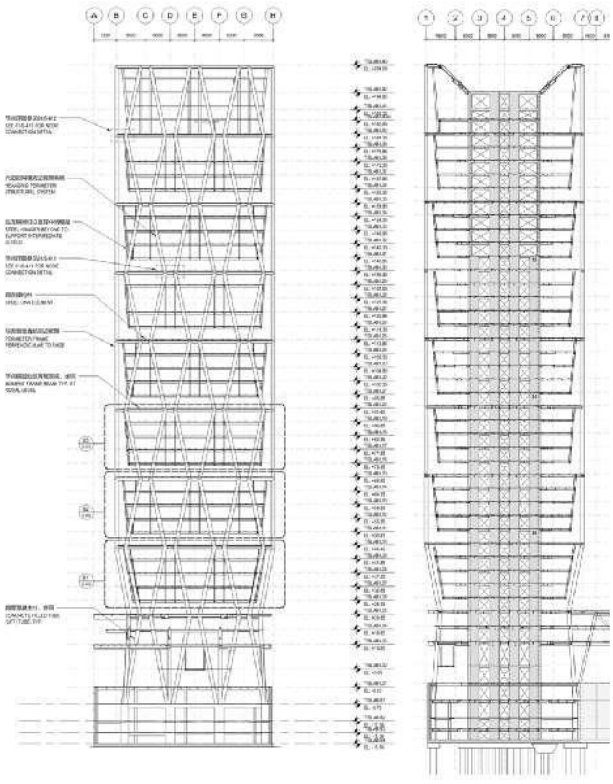


Figure 2. Elevation and section of P125.

around balconies above. Two transparent lobbies frame the plaza to create a unifying ground floor experience. The design is sensitive to local climate, landscape, and context, integrating nature to create a more inviting and connected workplace. Passive strategies include natural ventilation from operable vents, sliding glass terrace doors, perforated metal ceilings that accommodate air intake and exhaust, and inward-sloping facade modules which shade the building.

The most crucial design feature and construction challenge is its AESS system. This system integrates sustainable design principles across multiple disciplines. The surface material of the external frame deliberately avoids metal cladding systems. Compared to conventional aluminum-clad facades, exposing the structural steel reduces embodied carbon in the building envelope by approximately 10%, achieving the project's sustainable and low-carbon design goals.

3. Design of Friction Fused Diagrid Structure

Figure 2 shows the elevation and section of P125 tower. Above L10, the tower consists of two alternating sets of 5-story hexagrid modules. Each module consists of a nodal floor and four intermediate floors below with varying dimensions, hung from the nodal floor above using steel hangers. Figure 3 shows the rendering of two typical hexagrid modules that are 10-story tall.

3.1. Structural system

Guangzhou is in an area of moderate wind and moderate seismic intensity. Tower structural design is mainly governed by seismic actions. The lateral system is a dual system with a reinforced concrete core and the hexagrid exterior frame. The hexagrid consists of round CFT columns, H-shaped beams with typical spans of 12.7 m, and 3.2 m-long steel offset nodes with a friction device in the center, to introduce ductility into the diagrid. The gravity system typically utilizes 125 mm thick composite slabs at intermediate floors and 150 mm thick composite slabs at nodal floors, supported by and acting compositely with rolled steel H shaped beams at 3.2 m on center.



Figure 3. Two typical 5-story modules.

Friction devices are widely studied (Morales et al., 2012) and tested in structural experiments (Mualla, 2000) as an effective means to dissipate seismic energy in building structures (Pall et al., 2004). A Chinese code (MOHURD, 2013) also provides guidelines on using friction devices in building structures. For this project, friction devices are arranged at the center of the offset node of the hexagrid providing ductility and energy dissipation in moderate and rare earthquakes. Figure 4 shows an exploded view of an offset node with the friction device. The oval-shaped central steel plate with standard holes has a friction pad bonded to each side. The left half and right half of the node each have an oval plate with vertically slotted holes. The three parts are assembled with high strength bolts. The friction devices slip at the predefined shear threshold around 80% to 85% of moderate earthquake shear demands, introducing improved ductility into the diagrid frame.

As part of a performance-based design approach in JGJ3 code in China (MOHURD, 2010), both the core shear walls and frame columns in bottom strengthened zone (Level 10 and below) are considered critical elements and are designed to remain elastic under moderate earthquakes, and non-yielding in shear under rare earthquakes.

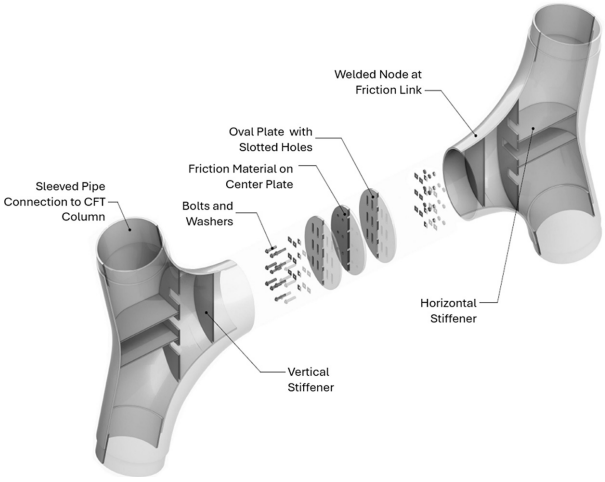


Figure 4. Exploded view of the friction node.

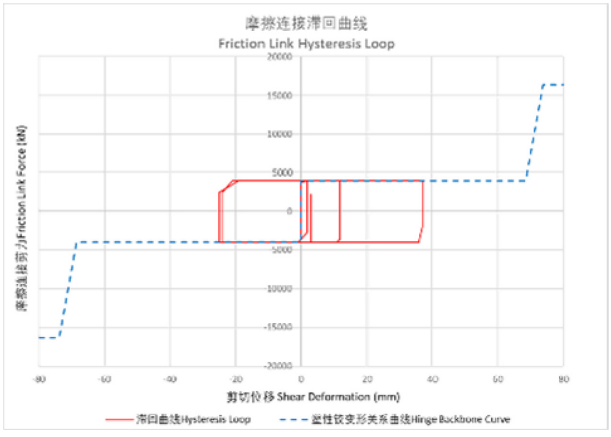


Figure 5. Shear-deformation curve for ductile friction link.

Table 1. Global analysis results of Tower P125

First 3 Periods	4.20s / 3.64s / 2.64s (X dir. / Y dir. / Torsion)	
	X dir.	Y dir.
Seismic shear / weight ratio	1.28%	1.56%
Seismic drift	1/1365	1/1154
Wind drift	1/1425	1/1760
Ratio of shear in frame	38%	24%
Ratio of moment in frame	32%	25%
Story stiffness ratio	0.95	1.01
Torsion drift ratio	1.15	1.09

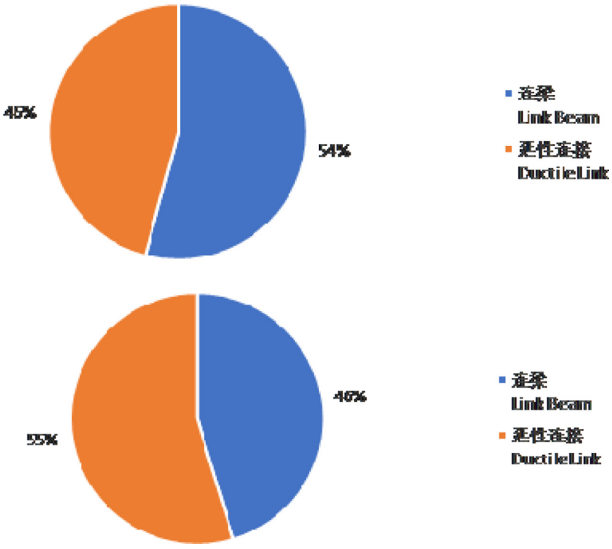


Figure 6. Energy dissipation in X (above) and Y (below) inputs.

3.2. Elastic Analysis

The primary structural analysis software is ETABS v18. The main elastic results are listed in Table 1. As shown by the small lateral drifts, the diagrid frame provides much higher lateral stiffness in both X and Y directions than a traditional moment frame with vertical columns.

3.3. Elasto-plastic Analysis

Elasto-plastic time-history analyses have been done in rare earthquake load cases, which corresponds to 2% exceedance probability in 50 years. Seven sets of earthquake records including five natural records and two simulated ones are scaled to have a peak ground acceleration (PGA) of 220 cm/s^2. Time histories are then applied in three directions, including the H1, H2 and V (100% + 85% + 65% of peak PGA). Figure 5 shows the defined behavior of the ductile link, and the hysteresis loops from one time history analysis.

In rare earthquakes, most of nodes see their bolts sliding in the slot and dissipate energy, and none of the deformation exceeds the life safety (LS) limit state (ASCE41, 2013), which is acceptable. All the CFT columns and steel moment frame beams remain elastic. Most link beams of the RC core yield as expected. Figure 6 shows that in the average of rare earthquake cases, the friction devices dissipate about half of the inelastic seismic energy, greatly improving the structural performance in rare earthquakes. In comparison, a typical frame-core structure usually has over 90% of the inelastic energy dissipated in link beams and results in large deformation and potentially severe damage.

4. Architecturally Exposed Structural Steel

4.1. AESS Categories

The complexity of the AESS system lies in surface treatment and craftsmanship standards. The finishing processes for the SANY project reference the AISC Code of Standard Practice for Steel Buildings and Bridges (AISC 303), which identifies AESS surface quality into five categories: Standard steel structure (SSS) and AESS

Table 2. AESS category matrix.

	Category	AESS 4	AESS 3	AESS 2	AESS 1	SSS
ID	Characteristics					
1.1	Surface preparation to SSPC-SP 6	√	√	√	√	√
1.2	Sharp edges ground smooth	√	√	√	√	√
1.3	Continuous weld appearance	√	√	√	√	√
1.4	Standard structural bolts	√	√	√	√	√
1.5	Weld spatters removed	√	√	√	√	√
2.1	Visual samples	Optional	Optional	Optional		
2.2	One-half standard fabrication tolorances	√	√	√		
2.3	Fabrication marks not apparent	√	√	√		
2.4	Welds uniform and smooth	√	√	√		
3.1	Mill marks removed	√	√			
3.2	Butt/plug welds ground smooth and filled	√	√			
3.3	HSS welds oriented for reduced visibility	√	√			
3.4	Cross sectional abutting surface aligned	√	√			
3.5	Joint gap tolerances minimized	√	√			
3.6	All welded connections	Optional	Optional			
4.1	HSS seam not apparent	√				
4.2	Welds contoured and blended	√				
4.3	Surface filled and sanded	√				
4.4	Weld show-through minimized	√				



Figure 7. AESS Samples, from left to right are SSS, AESS 1 to 4.

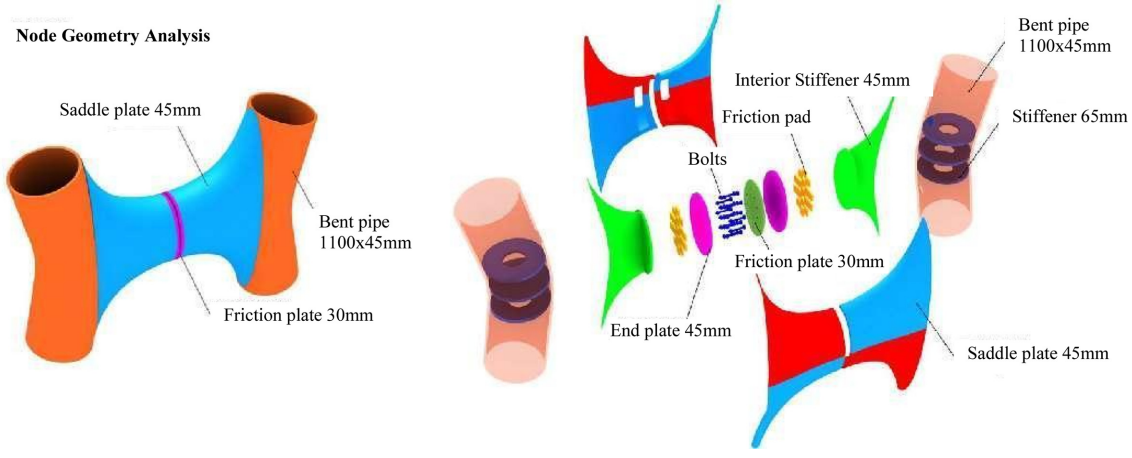


Figure 8. Parts of the friction node.

1 to 4. The standard outlines progressively stringent requirements for weld appearance, base steel preparation, surface painting, and mock-up validation. The SANY project's external frame adheres to the highest level, AESS 4. The detailed requirements are listed in Table 2. The requirements must be confirmed through the use of mock-ups, as shown in Figure 7.

4.2. AESS Fire Protection Design

According to the Chinese fire code (GB 50016-2014), Grade-I fire-resistance-rated buildings require columns to achieve a 3-hour fire resistance duration, and non-intumescent fireproof coatings (typically 25 to 40 mm thick) are typically applied to the exterior of structural steel with cladding outside. To enhance the visual quality of AESS, the project conducted a performance-based fire engineering analysis based on the Chinese code GB 51249-2017. This analysis optimizes fire protection design while ensuring safety and aesthetic integrity. The external diagrid frame comprises three key components: steel beams, CFT columns, and saddle-shaped steel nodes. Fire load analysis was conducted at three distinct locations - both planar facades and corners - to evaluate temperature impacts on structural integrity under fire exposure. Based on analysis, the round 1100 × 30 CFT column satisfies the 3-hour fire resistance without



Figure 9. Fabrication process and AESS quality control of the node.



Figure 10. Photo of the completed building.

fireproofing as its capacity under fire is higher than the most unfavorable load. For steel beams and the nodal zones within 1.5 times the beam depth above and below the beam flange, fireproof coating with a 2-hour resistance is required to achieve the full 3-hour resistance. An intumecent fire paint is used to maintain the AESS quality as much as possible and achieve the 2-hour fire rating.

4.3. Aesthetic Quality Control of AESS

The difficulty of fabricating the nodes, the smoothness of welding and polishing, and the completion of the fire-resistant coating and topcoat have become the core challenges of the project. After comparison of multiple schemes, the saddle-shaped nodes are decomposed into bent tubes, segmented steel plates, and internal stiffeners for fabrication, as shown in Figure 8. Tubes were bent via medium frequency induction hot bending, followed by precision validation of curvature tolerances. Segmented plates were thermoformed using steel molds, with 3D verification via wooden mold before welding. Multi-layer welding at tube-plate interfaces optimized the surface continuity, and precision grinding achieves substrate smoothness. The intumescent coating is applied with meticulous surface preparation ensuring flawless topcoat adhesion. Figure 9 shows some photos of the fabrication process.

Benefiting from the architect's high participation in the optimization of the structural node mock-up, comparison and selection of fabricating methods, and high acceptance criteria for quality control, a high-standard, high-completion exposed external structural frame system that meets the design requirements was finally realized. It is a high-quality realization of the design for the AESS system for the iconic building facade.

5. Conclusions

The analysis results show that the structural system performs well in resisting wind loads and seismic actions. In rare earthquakes, the ductile links with friction devices slip and dissipate a significant portion of the inelastic seismic energy. The AESS quality of the diagrid system is in a high standard thanks to the strict quality control during the fabrication and construction process.

In the construction drawings design stage, the client re-evaluated the budget of the project and reduced the number of frictions devices to the twenty nodes on Level 15 and Level 20 The updated analyses by the engineer of record still showed significant energy dissipation by the friction nodes. The project was opened in 2025. Figure 10 is a photo of the completed twin towers.

Acknowledgments

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