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New Facilities in Laboratory of CSCEC for Large and Full Scale Structure Test

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ABSTRACT
This paper introduces the structural engineering laboratory of China State Construction Engineering Corporation (CSCEC) which is under construction and its facilities to researchers. The laboratory is located in Shunyi District, Beijing and its dimension is about 130m×36m. A reaction wall and strong floor system and a Facility for Advanced Structural Testing (FAST) are the main facilities in this laboratory. A stepwise elevation of the L-shape reaction wall is arranged as 25.5m, 25.5m, 21m and 15m high respectively with the widths of 16.7m, 21.5m, 18m and 10.5m. The reaction wall and strong floor system can meet the requirement of eight-floor full-scale test for reaction equipment. The FAST is a 6-degree-of-freedom testing facility and can apply vertical, longitudinal and lateral load, and three directions of moment on a specimen, which allows FAST to test a variety of specimens with realistic loading conditions. The maximum allowable value of vertical, longitudinal and lateral forces are 108MN (static), 6MN (static) and 9MN for static test (6MN for dynamic test with the velocity of 1570mm/s), respectively. The dimension of the space for test is 9m×5m×10m (longitudinal×lateral×vertical). The strokes of vertical, longitudinal and lateral actuators are 250mm, ±1500mm and ±500m, respectively.

KEYWORDS: *Laboratory, Facility for Advanced Structural Testing, Reaction wall and strong floor system.*

1. GENERAL INSTRUCTIONS

With the rapid development in economy and expansion of construction scale, more and more projects with the characteristics of high, huge, special and novel are constructed in China. According to statistics of the Council on Tall Buildings and Urban Habitat (CTBUH), 97 tall buildings of 200 meters' height or greater were completed in 2014 around the world. And 58 tall buildings, which account for 60% of the global, were located in China [1]. The typical tall buildings have the features of greater heights, large span, more complicate system, higher material strength, larger sectional dimension and more complicated node. Such as the Z15 Tower has the height of 528m with 115 floors and its floor area is 0.427 million square meters [2]. The height of PINGAN IFC is 660m with 118 floors [3].

Due to the absence of similar project and technical experience, the experimental technique with large test facilities is needed to verify the key technique in design and construction. However, most of the large test facilities in the world have the limit of loading capacity and relatively simple function. The Multi-Axial Testing System (MATS) of National Center for Research Earthquake Engineering [4] is a 6-degree-of-freedom testing facility which can apply vertical, lateral, and transverse loading, and three directions of moment on a specimen. MATS can test a variety of specimens with realistic loading conditions, such as VE dampers, steel bracing members, LRBs and RC columns. However, its load frame is constructed with reinforcement concrete which reduces the test efficiency because of the lower efficiency of specimen replacement. Caltrans Seismic Response Modification Devices Test Facility of University of California, San Diego [5] and Bi-axial Bearing Test System of University of Pavia (*http://www.eucentre.it/trees-lab-experimental-methods/bi-axial-bearing-tester-system*) focus on tests of bearing devices and not suitable for tests of structural component. 40000kN Multifunctional

Electro-hydraulic Servo Load System of Beijing University of Technology [6] can conduct tests of columns, beam to column connections and LRBs.

The reaction wall and strong floor system can provide an efficient interface to evaluate the seismic behavior and performance of large or even full scale structures and components. Testing methods, such as quasi-static tests, pseudo-dynamic tests and real-time hybrid testing, can be realized in this integrated system. The reaction wall and strong floor system is an important test facility in structural engineering laboratory.

The structural engineering laboratory of CSCEC is constructed for large and full scale tests, which can provide theoretical support for the design and construction of structures with characteristics of high, huge, special and novel. This paper introduces the structural engineering laboratory of CSCEC which is under construction and its facilities to researchers.

2. INTRODUCTION OF STRUCTURAL ENGINEERING LABORATORY OF CSCEC

CSCEC is one of the most integrated construction and real estate conglomerates in China with the longest history of specialized operation and market-oriented management. It is the largest transnational construction company in the developing countries and the top home builder in the world, taking the long lead of China's international contracting business. Established in both domestic and international markets, CSCEC operates in more than 20 countries and regions around the world and, in China its business spreads all over the territory. The main business of the company covers such fields as building construction, international contracting, real estate development and investment, infrastructure construction and investment, prospecting and design, all in the leading position in their respective fields.

China State Construction Engineering Corporation Technical Center (Figure 2.1), which is located in Shunyi District, Beijing, China, is the subordinate technical center of CSCEC and responsible for providing technical service to projects of CSCEC. The structural engineering laboratory introduced in this paper is one of the three laboratories of CSCEC Technical Center. Its dimension is about 130m (length) ×36m (width) ×35m (height). An L-shape reaction wall as shown in Figure 2.2 and the FAST shown in Figure 2.3 are the main facilities in this laboratory. The reaction wall and strong floor system can meet the requirement of eight-floor full-scale test for reaction equipment. The FAST is a 6-degree-of-freedom testing facility and can apply vertical, longitudinal and lateral loading, and three-direction moment on the target specimen, which allows FAST to test a variety of specimens with almost realistic loading conditions. With the L-shape reaction wall and strong floor system and FAST, large scale and full scale structure model tests can be conducted in the structural engineering laboratory of CSCEC, which can provide theoretical support for the design and construction of tall buildings and long-span structures.

Figure 2.1 China state construction engineering corporation technical center

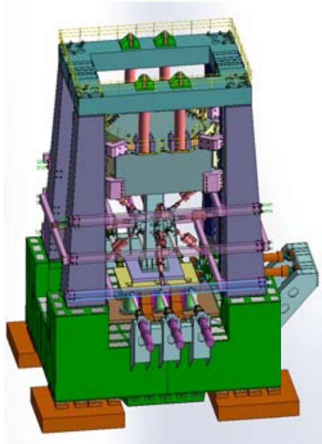
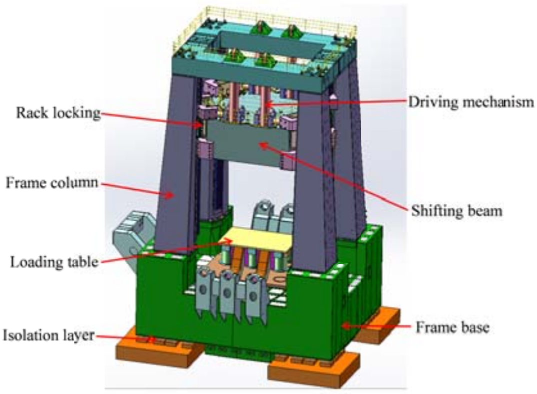


Figure 2.2 L-shape reaction wall   Figure 2.3 Facility for advanced structural testing

3. FACILITY FOR ADVANCED STRUCTURAL TESTING

FAST is a 6-degree-of-freedom testing facility and is adequate for specimens with different height. Its aim is to study the response and failure mode of large rubber bearings and structural components under the action of static or dynamic loads. The dimension of the test space is 9m×5m×10m (longitudinal×lateral×vertical) and the dimension of loading table is 6m×4m (longitudinal×lateral), while the adjusting ranges of the loading table are ±1500mm of longitudinal direction, ±500m of lateral direction and 0~250mm of vertical direction, respectively. The load capacities are 108MN in vertical direction, 6MN in longitudinal direction and 9MN with low velocity (or 6MN with the velocity of 1570mm/s) in lateral direction, respectively. The shifting beam can adjust from 0.5m to 10m continuously which can test specimens from 0m to 10m height efficiently. An isolator layer, which consists of 52 spring elements with dampers, is used to mitigate the adverse influence on the surroundings caused by the vibration of the FAST.



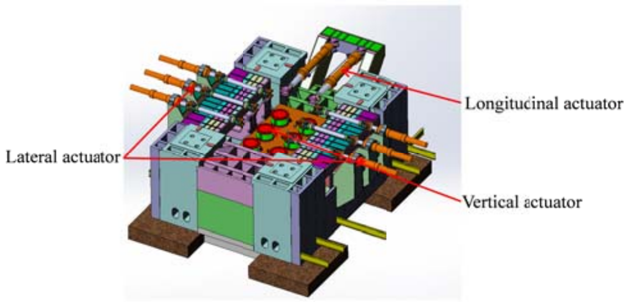


Figure 3.1 Load frame system   Figure 3.2 Hydraulic and control system

With the FAST, compression test, compression-shear test, compression-shear-torsion test of columns with different heights and cross sections, and compression-shear test of shear walls with different height can be carried out. Test of rubber bearing, which is an important function of FAST, can also be conducted with larger velocity or displacement. The main functions of FAST refer to the description in Table 3.1. The maximum compression force for compression test can achieve 108MN with the maximum specimen dimension of 2m×2m×10m. The load capacities of bidirectional compression-shear test are 60MN in vertical direction, 6MN in longitudinal direction and 9MN in lateral direction, respectively. The maximum displacement and velocity, which is usually used for rubber bearing test, are ±1500mm and 1570mm/s, respectively, with the load capacity of 6MN. In addition, complex joint test can also be conducted in this test system as shown in Figure 2.3.

Table 3.1 List of Main Functional Parameters of FAST

Testing Type	Vertical Force (MN)	Longitudinal Force (MN)	Longitudinal Displacement (mm)	Lateral Force (MN)	Lateral Displacement (mm)	Roll (°)	Pitch (°)	Yaw (°)	Height of Specimen (m)
Compression Test of Column	108	/	/	/	/	/	/	/	10
Unidirectional Compression -Shear Test of Column	80	6	±255	/	/	/	/	/	10
	80	6	±330	/	/	/	/	/	9
	80	6	±405	/	/	/	/	/	8
	80	6	±480	/	/	/	/	/	7
	80	/	/	9	±135	/	/	/	6
	80	/	/	9	±245	/	/	/	5
	60	/	/	9	±410	/	/	/	10
	60	/	/	9	±500	/	/	/	9
Bidirectional Compression -Shear Test of Column	60	6	±125	9	±125	/	/	/	7
	60	6	±250	9	±250	/	/	/	6
	60	6	±380	9	±380	/	/	/	5
	50	6	±205	9	±205	/	/	/	7
	50	6	±355	9	±355	/	/	/	6
	50	6	±500	9	±500	/	/	/	5
Compression, Shear and Torsion Test of Column	60	/	0	/	0	±1.4	±1.4	±10	10
	60	/	0	/	0	±2	/	/	10
	60	/	0	/	0	/	±2	/	10
	60	/	±250	/	±250	±1.4	±1.4	±5	10
	60	/	±450	/	±450	±1.4	±1.4	0	10
	60	/	±450	/	±450	±2	/	/	10
	60	/	±450	/	±450	/	±2	/	10
Compression-Shear Test of Shear Wall	60	6	±500	/	/	/	/	/	10
Unidirectional Compression-Shear Test of Rubber Bearings(high-speed)	60	/	/	6	±500	/	/	/	2
	20	/	/	6	±500	/	/	/	2
Unidirectional Compression -shear Test of Rubber Bearings(low-speed)	60	6	±1500	/	/	/	/	/	2
	20	6	±1500	/	/	/	/	/	2
	60	/	/	9	±500	/	/	/	2
Bidirectional Compression-Shear Test of Rubber Bearings(low-speed)	60	6	±500	9	±500	/	/	/	2

Note: the frequency of high-speed is 0.5Hz.

FAST consists of load frame system (see Figure 3.1) and hydraulic and control system (see Figure 3.2). The load frame system mainly includes: shifting beam, driving mechanism for beam movement, loading table, frame columns, frame base and so on. The shifting beam, loading platform, frame columns, frame base and so on can form an enclosed system with self-balanced internal force. The shifting beam and the loading table can form a loading space subject to continuous adjustment from 0.5 to 10m in height, which is suitable for specimens with different height. A rack locking mechanism is employed to realize this function of FAST.

The hydraulic and control system includes hydraulic actuators, oil source, hydraulic accumulators, oil distributors and hydraulic valves, hydraulic accessories as well as digital servo controller, electrical control system, software and so on. It is the core of FAST which can determine the function of the test system. The loading table, which six hydraulic low friction bearing actuators of 18MN attached to, slides over the frame base. Together with eight horizontal actuators connected to the loading table, the test system can apply vertical, lateral, and longitudinal loading, and three directions of moment on a specimen. The horizontal actuators consist of two actuators of 3MN and six actuators of 15MN for static test (10MN for dynamic test). The friction in the test can be minimized to an acceptable level with the six hydraulic low friction bearing actuators. To improve stability of the test system, four hydraulic low friction bearing actuators are used. Oil source of 2800L/min and hydraulic accumulators with the maximum instantaneous flow of 44364L/min are used to ensure the hydraulic power supply. The oil source also is used to provide hydraulic power supply for the reaction wall and strong floor system. Tests can be carried out collaboratively with FAST and the reaction wall and strong floor system in the laboratory.

4. REACTION WALL AND STRONG FLOOR SYSTEM

The reaction wall and strong floor system is another important test facility of the structure laboratory of CSCEC. It can provide an efficient interface to evaluate the seismic behavior and performance of large or full scale structures and components. Testing methods, such as quasi-static tests, pseudo-dynamic tests and real-time hybrid testing, can be realized in this integrated facility. Bidirectional tests of full-scale structures, which can up to eight-floor, can be executed with reaction wall and strong floor system (see Figure 4.1).

As shown in Figure 2.2, the reaction wall, which is used to provide horizontal reaction force for the hydraulic actuators, is L-shaped. A stepwise elevation of the L-shape reaction wall is arranged including 25.5m, 25.5m, 21m and 15m high respectively with the widths of 16.7m, 21.5m, 18m and 10.5m. The 6.5m wide box cross section, which consists of two reinforced concrete plates of 1.5m thick and an opening of 3.5m, is chosen as the cross section type of reaction wall. Pre-stressing tendons are employed at the vertical direction to prevent the reaction wall from cracks and deflections during tests. The strong floor (see Figure 4.2), which is about 4000m^2, is used to mount specimen for against the slide of specimen during test. Thickness and the dimension of strong floor are 0.8m and 130m×36m, respectively. Reaction holes are assembled throughout the reaction wall and strong floor. There is a 0.5m thick rib at every 2.5m underneath the strong floor to enhance its bearing capability. The bearing capacity of single reaction hole is 1300kN and bearing capacity of the strong floor in the scope of 3m×3m is 1500kN.

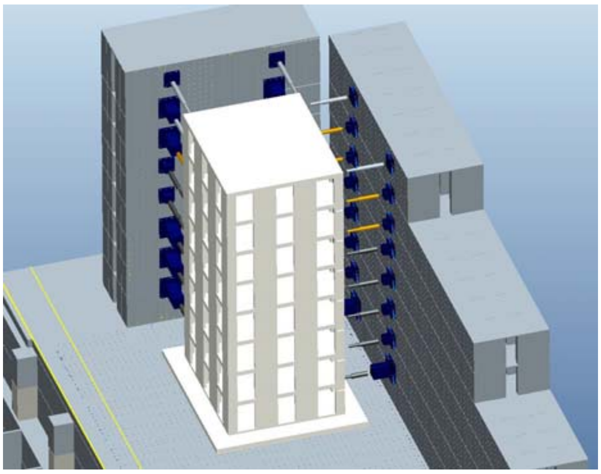


Figure 4.1 Schematic of eight-floor full scale structure test

Figure 4.2 Strong floor

Table 4.1 Configuration of hydraulic actuators

Types of Actuators	Load Rating(kN)	Stroke(mm)	Velocity(mm/s)	Quantity
Static and Single Ended	±2000	±1000	/	2
	±2000	±500	/	4
	±1500	±500	/	6
	±1000	±1000	/	4
	±1000	±500	/	12
	±500	±500	/	2
	±500	±300	/	2
Dynamic and Double Ended	±500	±500	1500	2
	±500	±500	1000	2
	±1000	±500	500	2

The reaction wall and strong floor system has 32 sets of static hydraulic actuators and 6 sets of dynamic hydraulic actuators. The configuration of hydraulic actuators is shown in Table 4.1. The hydraulic hard lines including pressure pipes, return pipes and oil distributors are installed inside the reaction wall and underneath the strong floor, as shown in Figure 4.3. With the arrangement of hydraulic hard lines, tests can be carried out conveniently in any place of the laboratory.

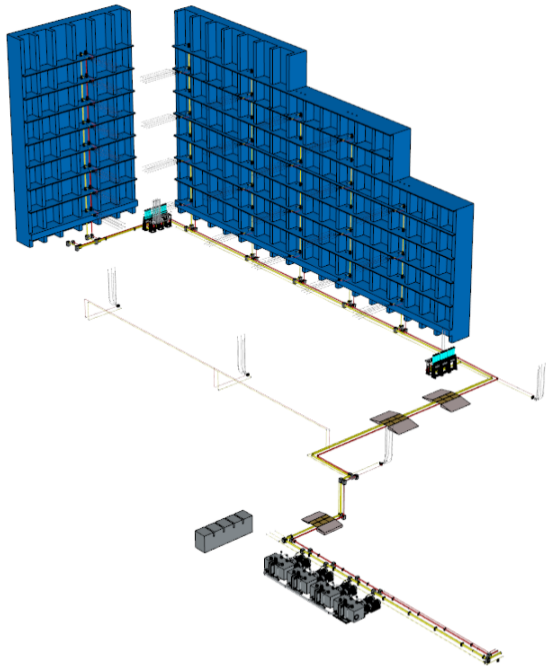


Figure 4.3 Arrangement of hydraulic hard lines

5. CONCLUSIONS

The structural engineering laboratory of CSCEC and its two main facilities were introduced in this paper. The laboratory aims to provide theoretical and testing support for the design and construction of tall buildings and long-span structures through large scale even full scale test. The laboratory hall occupies the area of 130m×36m. A reaction wall and strong floor system and the FAST are main facilities in this laboratory. A stepwise elevation of the L-shape reaction wall was arranged including 25.5m, 25.5m, 21m and 15m high respectively with the widths of 16.7m, 21.5m, 18m and 10.5m. The reaction wall and strong floor as the reaction equipment system can meet the requirement of eight-floor full scale test. The FAST is a 6-degree-of-freedom testing facility and can test a variety of specimens with realistic loading conditions. The maximum allowable value of vertical, longitudinal and lateral forces are 108MN (static), 6MN (static) and 9MN for static test (6MN for dynamic test with the velocity of 1570mm/s), respectively. The dimensions with 9m×5m×10m in the FAST are available for the test and the area of 6m×4m can be used for specimen arrangement. The strokes of vertical, longitudinal and lateral actuators are 250mm, ±1500mm and ±500m, respectively.

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