Advanced Materials Research Vols. 133-134 (2010) pp 1219-1224

doi:10.4028/www.scientific.net/AMR.133-134.1219

The Structural Analysis of The Historical Constructions of West China Campus-Sichuan University

LUO L L[1,a], XIE Z T[1], WU T[1], WANG Y W[1], XIAO C B[1] and LING C J[1]

[1]Sichuan Institute of Building Research, Chengdu, China

[a]lluo516@yahoo.com.cn

Abstract A group of buildings in West China Campus-Sichuan University (The Atherton Building for Biology and preventive Medicine, The Lamont Library and Harvard-Yenching Museum, and The Whiting Memorial Administration Building) featured both in Chinese and Western styles were built by five western churches together in 1910, under the name of "Private West China United University". To protect the buildings, the authors tested the strength of materials taken from the buildings and inspected the buildings in site to evaluate the structure of the historical constructions. The authors suggested protective measures which were adopted in the rehabilitation to the buildings and evaluated the repair effect by the method of Field Vibration Test. Through the test, inspection, analysis and evaluation of the buildings, lots of information data of historical constructions have been accumulated.

Keywords: Historical constructions, detections, analysis;, evaluation, protection, dynamic properties.

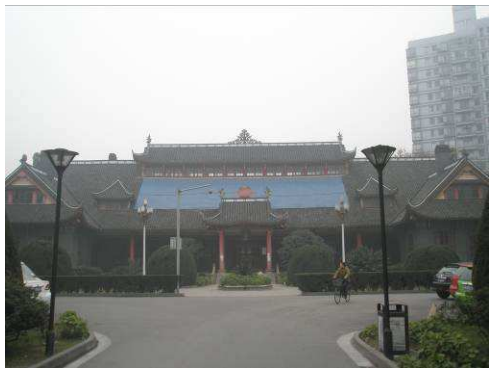
Backgrounds

A group of buildings in West China Campus-Sichuan University featured both in Chinese and Western styles were built by five western churches together in 1910 under the name of "Private West China United University". The buildings were designed by western architect according to the style of architecture originated from ancient China and constructed with timber and brick. Subjected to hundred years usage, the buildings are in negative condition, and some damage was caused by Wenchuan Earthquake on May 12th, 2008. To protect the buildings, the authors tested the strength of materials taken from the buildings and inspected the buildings in site to evaluate the structure behaviour of the buildings. Protective measures suggested by authors were adopted in the rehabilitation to the building. After the rehabilitation, field structural dynamic vibration test was carried out to evaluate the repair effect. Through the test, inspection, analysis and evaluation of the buildings, lots of information data of the historical constructions have been accumulated

Table 1 : Introduction of the historical constructions of west campus-Sichuan University

Name	*Area and Age*	*Structural type*	*Function*	*Elevation photos*
Atherton Building for Biology and preventive Medicine	Construction area is 3450 m^2. Built in 1924. Experienced maintenance and reconstruction.	The three storey building were constructed with timber and brick, which is 56.05 m in length, 30.93m in width, 16.17m in height(from outdoor level ground to ridge crest elevation)	Classroom	

Table1 : Introduction of the historical constructions of west campus-Sichuan University (cont.)

Name	*Area and Age*	*Structural type*	*Function*	*Elevation photos*
Lamont Library and Harvard-Yenching Museum	Construction area is 2688 m^2. Built in 1926. Experienced maintenance and reconstruction	The three storey building (partial three storey) were constructed with timber and brick ,which is 53.87m in length, 47.84 in width, 15.74 in height for two storey part, 12.93m in height for three storey part(both measured from outdoor level ground to ridge crest elevation)	Classroom	
Su-Tao Pu Memorial	Construction area is 3600 m^2. Built in 1941. Experienced maintenance and reconstruction	The three storey building (loft from the fourth floor)were constructed with timber and brick, which is 56.48m in length, 27.55m in width, 10.45m in height(from outdoor level ground to eaves elevation)	Classroom	
Whiting Memorial Administration Building	Construction area is 2618m^2. Built in 1915. Experienced maintenance and reconstruction.	The two storey building were constructed with timber and brick, which is 55.45m in length, 27.88m in width, 12.890m in ridge crest height, the indoor floor level is 0.8 m above outdoor ground level.	Office	
No. 5 Classroom	Construction area is 3000m^2. The eastern part was built in 1928, the western part was built in 1948. Experienced maintenance and reconstruction	The three storey building were constructed with timber and brick(loft from the fourth floor), which is 53.3m in length, 30.8m in width, 11.1m in height(from outdoor ground level to eaves level)	Classroom	

In Situ Inspection

Atherton Building for Biology and preventive Medicine Uneven settlement hasn't been found either on surrounding ground or on foundation of this building; load-bearing wall is built of flashed bricks, Two types of flashed bricks are sampled for test with the size of 230x110x51mm and

226x105x50mm. We tested compressive strength of flashed bricks and mortar with such results: average compressive strength of flashed brick is 9.6MPa, minimum compressive strength is 4.1MPa; average compressive strength of mortar is 3.06MPa.

Parts of this building's wall are damp: plaster gets hollowing, efflorescence and shedding, surface of the flashed bricks are moist and efflorescence. Vertical and oblique cracks appear in the corner of some windows and under window sills. After taking off plasterer coat, we observed that brick wall cracks. U-crack appears in the top of brick arches of many doors and windows. Top brick lintels of few arches are broken and caving. Oblique cracks are observed in the joints of few pillars. Photos are showed as follows:

Figure 1: Damp and saltpetering on the surface of wall *Oblique crack in the top of pillar*

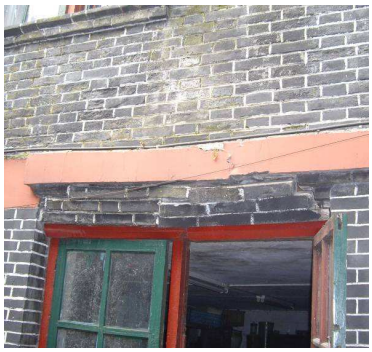


Figure 2: Crack on top of brick arch Broken top of brick lintel arch Vertical crack in the joint of walls

The walls' thickness are 470 mm, 350mm, 230mm. separate brick pillars of 470*710mm and 470*470mm are set up in some place. No obvious deformation and movement is observed in walls and separate pillars. Some wood elements of roof are damp and decayed, but the joint parts are mainly in good condition.

Lamont Library and Harvard-Yenching Museum Uneven settlement hasn't been found either on surrounding ground or on foundation of this building. Load-bearing wall is built of flashed bricks. Two types of flashed bricks are sampled for test with the size of: 231x104x54mm and 233x108x55mm. We tested the compressive strength of flashed bricks and mortar with such results: average compressive strength of flashed brick is 13.5 MPa, minimum compressive strength is 6.8 MPa, with standard deviation of 4.4MPa. Average compressive strength of mortar is 2.69MPa.

Parts of the building's wall are damp, plaster gets hollowing, efflorescence and shedding, surface of the flashed bricks are moist and efflorescence. Vertical and oblique crack appears in the corners of some windows and under window sills, maximum width of the crack is about 1.5mm. U-crack appears in the top of arch of doors and windows on the 1st and 2nd floor. After taking off plasterer coat, we find some arch crack extend along the vertical mortar gap, a few brick crack width reach 2.5mm. Photos are showed as follows:

Figure 3: Arch vertical crack *Arch vertical crack*

The walls' thickness are 470mm, 370mm, 230mm, 470x350mm separate brick pillar is set up in some place. No obvious deformation and movement is observed in wall and separate pillars. Wood elements of roof haven't been decayed, wormed or deformed evidently, and the joint parts are mainly in good condition.

Su-tao Pu Memorial Uneven settlement hasn't been found either on surrounding ground or on foundation of this building. Load-bearing wall is built of flashed brick. Two types of flashed bricks are sampled for test with the size of: 227x110x56mm and 231x112x54mm. We tested the compressive strength of flashed bricks and mortar with such results: average compressive strength grade of flashed brick can reach to MU10, average compressive strength of mortar is less than 2.0MPa.

Part of this building's walls are damp, plaster gets hollowing, efflorescence and shedding, surface of the flashed bricks are efflorescence. Crack appears in parts of wall, maximum width of the crack is about 0.35mm. Crack appears in part of top arch of doors and windows. After taking off plasterer coat, we find some arch crack extend along the vertical mortar gap, a few brick crack width reach 0.3mm.

Figure 4: Wall damp and effloresce *Arch vertical crack*

The walls' thickness are 480mm,360mm,230mm. Separate brick pillar of 600x600mm, 480x480mm, 360x360mm are set up in some place. No obvious deformation and movement is observed in wall and separate pillars. Wood elements of roof are damp, decayed or deformed in some parts, some roof trusses are desiccation fissure, few roof ties even fall off from the joint; and some rafter is getting downwarping or even broken.

Whiting Memorial Administration Building Uneven settlement hasn't been found either on surrounding ground or on foundation of this building; load-bearing wall is built of flashed brick. Flashed brick of 235x105x50mm was sampled. We tested the compressive strength of flashed bricks and mortar: average compressive strength of flashed brick is 8.36MPa, minimum compressive strength is 6.8MPa; Average compressive strength of mortar is 4.20MPa.

Parts of this building's wall are damp: plaster gets shedding, surface of flashed bricks is efflorescence. Verticl crack appears in some joint parts of wall. Crack appears in part of top arch of doors and windows, and maximum width of the crack is about 0.30mm.



Figure 5: Wall crack *Vertical crack along juncture of walls* *Arch vertical crack*

The walls' thickness is 470mm, 360mm, 240mm, no obvious deformation and movement is observed in wall. Wood column of 460mm diameter is used. Wood elements of roof are damp and decayed, few roof ties even fall off from the support saddle as wide as 3.0mm. A few columns are broken on the top or malposed or even deflected. Some roof trusses are desiccation fissure, and steel plate and bolt in joints have corroded because of severe rust, few rafters even breakdown.

Evaluation and Protective Measures

Evaluation of Structures. The compressive strength data of flashed bricks and mortar samples are adopted in the calculation of the load bearing capacity for the structural members, it's concluded that unqualified walls exist in all above buildings.

In site inspections show all above building walls are damp and effloresce, some walls even crack, and most cracks appear in the corners of doors, windows and top bricks arch, some wood elements of roof are damp and decay, a few even get broken.

Through the in site inspections and the load-bearing capacity calculation based the test data of compressive strength of flashed bricks and mortar samples, we find unqualified walls exist in all above buildings, and some structural members are senescent and decay. Therefore, we suggested that proper treatment measures should be adopted immediately.

Protective Measures Recommended

(1) Reinforce unqualified walls;

(2) Reinforce cracked walls and brick arches;

(3) For effloresce and decay walls, clean off superficial rotten parts first, then coat proper protective materials according to exterior decoration.

(4) For the rotten, wormed or damaged timber members, replace with new ones.

Evaluation of Treatment Effect

The recommended protective measures according to the inspection and evaluation have been adopted to repair the above five historical constructions. In order to evaluate the treatment effect, our group carried out dynamic structure characteristic test in Whiting Memorial Administration Building and No.5 Classroom before and after the treatment, thus the treatment effect is evaluated by analysing the change of building dynamic properties.

According to dynamic structure test data and measures adopted in the rehabilitation, it's concluded:

[1] The rehabilitation measures emphasis on repairing, no change or strengthening to the original structural system while only a few structural members being replaced, thus there is no essential change of longitudinal and transverse autooscillation frequency after repairing.

[2] The rehabilitation of Whiting Memorial Administration Building greatly improved its longitudinal stiffness with little improvement to its transverse stiffness. Because of the full-scale

rehabilitation to the roof and floors, building's mass has been improved significantly, which leads to the increase of longitudinal autooscillation frequency and decrease of transverse autooscillation.

[3] The rehabilitation of No.5 Classroom improved its transverse stiffness evidently with little improvement to the longitudinal stiffness. Because of the full-scale rehabilitation to the roof and floors, building's mass has been improved significantly, which leads to the increase of longitudinal autooscillation frequency and decrease of transverse autooscillation

Table2: Building dynamic properties

Construction name	*Whiting Memorial Administration Building*		*No.5 Classroom*			
			Half timber part		*Timber part*	
	Before restore	*After restore*	*Before restore*	*After restore*	*Before restore*	*After restore*
Frequency of longitudinal autooscillation (Hz)	*3.321*	*3.907*	*5.079*	*4.102*	*6.055*	*5.079*
Frequency of transverse autooscillation (Hz)	*4.883*	*4.688*	*3.711*	*4.297*	*5.274*	*5.665*

Conclusions

Based on the in site inspection and evaluation to the five historical constructions of west china campus-Sichuan University such as Atherton Building for Biology and preventive Medicine, Lamont Library and Harvard-Yenching Museum etc. We found that material degradation widespread in the structural members of the timber and brick buildings: bricks get crack and effloresce, some wood members are decay and broken with a few members broken. Immediate maintenance to the buildings is suggested and carried out, and routine check is also suggested to monitor the building in good condition.

The compressive strength tests of bricks and mortar from the five historical building indicates that the flashed bricks and mortar have relatively high compressive strength which could be referred for the treatment to the similar contemporaneous buildings

Dynamic structural characteristic test is done before and after restoring Whiting Memorial Administration Building and No.5 Classroom. The variant results confirmed that it's reasonable to evaluate the treatment effect using dynamic structural characteristic test.

References

[1] Ray, W C, and Joseph, P (1995). "*Dynamics of Structures*." Computers and Structures Inc.

[2] Saluwu (1997). "Detection of Structural damage through in frequency review." *Engineering Structures.* , 19(9), 718-723.

[3] Tomson, W T(1972). "*Theory of Vibration with Application*." Prentice-Hill Inc.