Seismic Retrofit of Historic Wing Sang Building

By Dudley R. "Rusty" Morgan and Lihe "John" Zhang

The Wing Sang Building at 51 East Pender Street, Vancouver, BC, Canada, is the oldest standing building in Chinatown. It actually consists of two buildings. The front (south) building was first built as a two-story brick masonry structure in 1889 by Yip Sang.

Born in Shengtang, China, in 1845, Sang immigrated to San Francisco, CA, in 1864. In 1882 he settled in Vancouver, where he was in charge of hiring some 7000 Chinese laborers for construction of the Canadian Pacific Railway. Also, he started the Wing Sang Company which dealt in Chinese silks, utensils, trinkets, curios, and dry goods. His business thrived; and in 1901, he added a third story to the Wing Sang Building. Figure 1 shows the south building facing East Pender Street. The family also thrived and Sang ended up with four wives and 23 children. To house them all, he built a six-story brick masonry building at the back (north) of the existing Wing Sang building in 1912. The story goes that each wife and her children had a separate floor.

Fig. 1: Wing Sang Building, south building facing East Pender Street

Building Upgrade

The buildings had deteriorated over the years and, being of exterior simple brick masonry construction with interior timber framing and flooring, were highly deficient by modern seismic standards. This is where Bob Rennie, a highly successful Vancouver realtor, came to the rescue. The two buildings are now being seismically retrofitted as new offices and a private art gallery for Rennie.

Reinforced shotcrete plays a major role in the seismic retrofit of these two buildings. It is being used for strengthening all the exterior walls and the parapets of the north building and in both exterior and interior walls in the south building. The reinforced shotcrete construction for the north building is now almost complete, and this article is limited to a description of this work in the north building.

Design Concepts

In addition to installing new internal bracing and reinforced concrete floors, a major component of the seismic retrofit of the building is tying back all the exterior brick masonry in the north building to a new reinforced shotcrete wall and pilaster system. A typical wall detail is shown in Fig. 2. The brick wall varied in thickness at the different floor levels, being about 22 in. (558 mm) thick at the lower elevations, stepping back to 17 in. (432 mm) thick at intermediate floor levels, 13 in. (330 mm) thick at the upper floor levels, 8 in. (203 mm) thick at the roof parapet. The reinforced shotcrete wall, however, was not stepped back. It was kept in one plane at a thickness of 10 in. (254 mm) over the full height of the walls. Insulating foam of varying thickness was used to enable this to be accomplished. The exception is the parapet where the reinforced shotcrete wall was only 8 in. (203 mm) thick (refer to Fig. 2 and 3 for details).

After preconstruction shotcrete mock-up tests, but before the start of construction, a modification was made. To avoid having to remove existing brick masonry in constructing the deepened columns, it was decided to make the columns project out from the plane of the wall as pilasters,

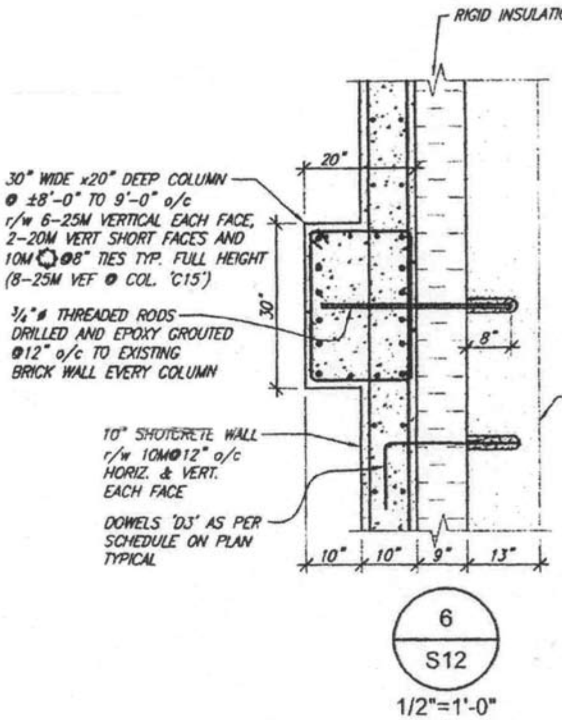

Fig. 2: Typical wall and pilaster section detail in north building exterior wall

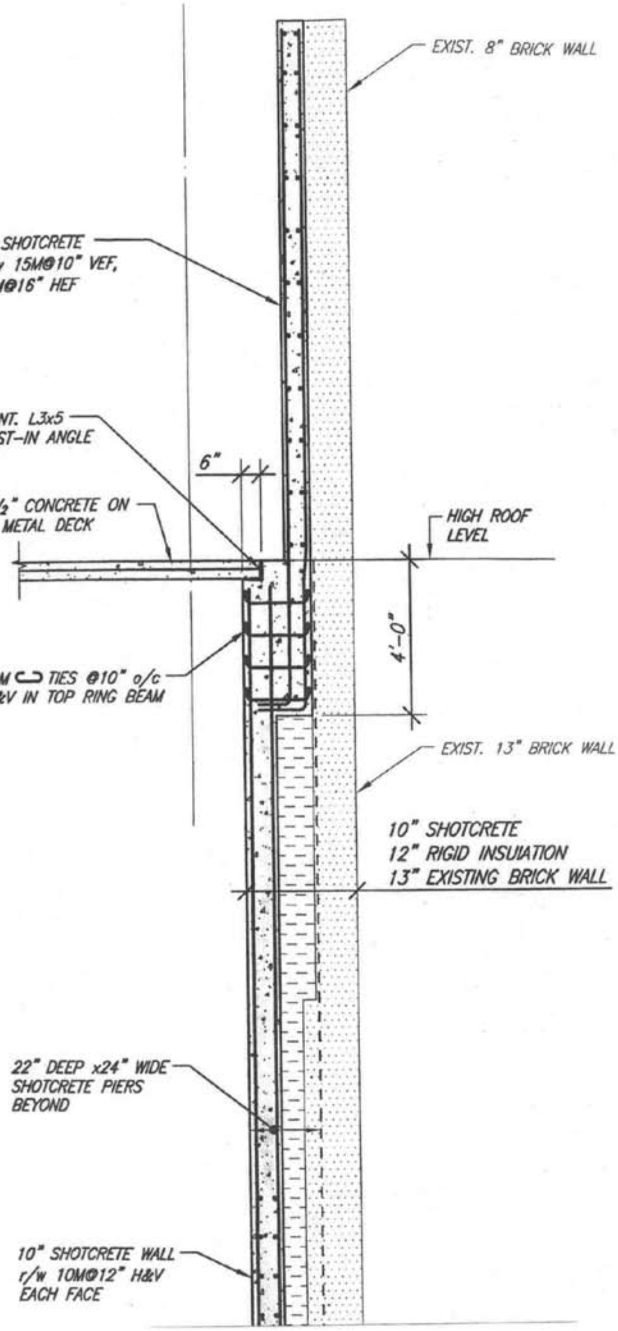

Fig. 3: Section detail of ring beam at roof level and reinforced shotcrete wall and parapet

as shown in Fig. 2. There were typically eight pilasters in the north wall, six in the south wall (with some thickened sections), and three pilasters in each of the east and west walls.

It took between 20 to 26 yd^3 (16 to 20 m^3) of shotcrete to shoot either the north or south walls at one floor level, with the quantity of shotcrete required depending on the number of openings in the wall (that is, windows and doorways).

A key item in the seismic design was the mechanical anchoring of the exterior masonry using grouted L-bar dowels installed in the brick masonry at approximately 2 ft (610 mm) on center vertically and horizontally and encapsulating them in the reinforced shotcrete walls (refer to Fig. 2). Anchors were also placed in the pilasters. Additional strengthening was achieved by sealing many of the windows on the north and south walls with reinforced shotcrete (refer to Fig. 4).

Nozzleman and Shotcrete Prequalification

Nozzlemen proposed for shooting on the project had to be ACI certified to ACI CP-60 (02) for wet-mix vertical shotcreting. In addition, nozzleman had to shoot preconstruction mock-ups of wall and pilaster sections. Figure 5 shows shooting of a pilaster mock-up. Figure 6 shows the stripped back face of the pilaster mock-up. Note the good dense quality of the shotcrete, with freedom from voids, shadows, rebound, or any other defects. Figure 7 shows five cores extracted from the pilaster mock-up at the location of reinforcing steel. Note the excellent encapsulation of the five 1 in. (25 mm) diameter vertical bars. All cores had an ACI 506 core rating of either Grade 1 or 1.5, that is, near perfect encapsulation. In addition, a standard ASTM C1140 test panel was shot to prequalify the mixture. With an average 7-day compressive strength of 4900 psi (33.8 MPa), the shotcrete readily met the specified strength of 4350 psi (30 MPa) at 28 days.

Table 1: Shotcrete Compressive Strength

Set No.	Compressive Strength			
	7 days		28 days	
	psi	MPa	psi	MPa
1	5308	36.6	7789	53.7
2	5308	36.6	7382	50.9
3	4250	29.3	10,457	72.1
4	5236	36.1	6744	46.5
5	4134	28.5	7643	52.7
6	5555	38.3	7368	50.8
7	4670	32.2	6701	46.2
8	5918	40.8	7382	50.9
9	4453	30.7	6266	43.2
10	4859	33.5	6121	42.2
11	4656	32.1	4946	34.1
12	3713	25.6	5395	37.2
13	5482	37.8	5178	35.7
14	4525	31.2	6106	42.1
15	5105	35.2	5743	39.6
Average	**4877**	**33.6**	6746	46.5

Fig. 4: View of upper level of north building, note windows filled with reinforced shotcrete

Fig. 5: Shooting pilaster mock-up

Shotcrete Supply and Testing

The shotcrete was delivered by concrete truck in 5.2 to 7.8 yd^3 (4 to 6 m^3) loads. The Ocean Construction Supplies Y79 mixture supplied was a fly ash-modified shotcrete with a 5/8 in. (14 mm) maximum size aggregate that has been widely used in the Vancouver market for shoring construction and in structural shotcrete and other applications. The mixture has a specified 28-day compressive strength 4350 psi (30 MPa) and is commonly supplied at an air content of 5 to 8%, making it suitable for use in both interior and exterior applications.

Standard ASTM C1140 test panels were shot for approximately every 39 yd^3 (30 m^3) of shotcrete supplied. After curing at the site for 2 days, the test panels were transferred to AMEC's testing laboratory where they were moist-cured at 73 °F (23 °C). Two pairs of 3 in. (75 mm) diameter cores were extracted at both 7 and 28 days for compressive strength testing. Test results for the first 15 sets of cores tested are shown in Table 1. Average 7-day strengths were 4877 psi (33.6 MPa) and average 28-day strengths were 6746 psi (46.5 MPa). No individual 28-day strength test results fell below the specified 4350 psi (30 MPa) compressive strength requirement.

The shotcrete was typically supplied in the 2.5 " 1 in. (60 " 25 mm) slump range and shot well, having a good plastic consistency for encapsulating the reinforcing bar, yet was resistant to sagging and sloughing.

Shotcrete Construction

A typical shotcrete crew comprised eight people: a superintendent, certified shotcrete nozzleman, trainee nozzleman, blow pipe operator, two finishers, and two laborers. The certified nozzleman shot the pilasters and at least half of the walls. The trainee nozzleman relieved the certified nozzleman and was permitted to shoot the less congested wall sections, under the direct supervision of the certified nozzleman. AMEC provided an engineer for part-time inspection and monitoring of shotcrete production. At least two inspection visits were provided at each floor level with diary reports of observations.

Figure 8 shows a typical wall section, with L-bar dowels, reinforcing bars, and pilaster edge forms installed. Figure 9 shows shooting of a wall using the bench gunning technique. Figure 10 shows shooting of a pilaster, and Fig. 11 shows finishing of a wall.

The most challenging part of the work was the consolidation of shotcrete around reinforcing bars at splice zones in the pilasters, where the vertical reinforcing bar from the floor beneath had to be spliced with the reinforcing bar for the next floor level. This first occurred at the second-floor level

Fig. 6: Stripped back-face of shotcreted pilaster mock-up. Note good consolidation of shotcrete

Fig. 7: Cores extracted from reinforcing bar locations in pilaster mock-up—all core Grades 1 or 1.5

Fig. 8: View of a typical wall section with L-bar dowels, reinforcing bars, and pilaster edge forms installed

Fig. 9: Shooting of a wall using the bench gunning technique

Fig. 10: Shooting of a pilaster

Fig. 11: View of a wall being finished

in the splice zone on the lower 4 ft (1.2 m) of the pilasters. The reinforcing bars in the splice were tied side-by-side, as is done in conventional concrete forming; and this resulted in a congested detail for shooting (refer to Fig. 12). A decision was made to form the front face of the lower 4 ft (1.2 m) of the pilaster at these splice locations and pump in the shotcrete and consolidate it with an immersion vibrator. Whereas this method worked well, it was not as efficient as being able to shoot the entire pilaster.

Fig. 12: View of reinforcing bar in splice zone at bottom of pilaster

At higher elevations, a decision was made to tie reinforcing bar in the splice zone in pilasters in a back-to-back (rather than side-by-side) configuration, relative to the direction of shooting. This made the reinforcing bar detail much more "shootable" and this method was used with good efficiency. Good shotcrete consolidation was achieved, as was evident in the stripped sides of pilasters.

A key to a good structural shotcrete project is being able to recognize when a reinforcing steel detail is not amenable to good shotcrete consolidation. This was apparent in the ring beam near the roof elevation, as shown in Fig. 3, as well as in some beams above wall openings appearing at other floor levels. At such locations the beams were formed and the shotcrete was pumped in and consolidated with an immersion vibrator, just like conventional concrete.

The Yip Sang Legacy lives on in Vancouver. In July 2008 some 375 Yip Family members, the progeny of Yip Sang, held a reunion in Vancouver. Bob Rennie provided them with 375 red hard hats and a tour of the still under construction Wing Sang building. With the structural seismic upgrade and refurbishing, in which shotcrete is playing a major role, it is expected that Yip Sang's legacy will live on in the Wing Sang building for at least another century.

Acknowledgments

Architect: Walter Francl Architect Inc.
Developer: Jameson East Development
Structural Engineer: J.M. Engineering
Contractor: n.Wallace & Company Ltd.
Shotcrete Subcontractor: Bel Pacific Shoring & Foundations
Shotcrete Supply: Ocean Construction Suppliers Ltd.
Shotcrete Construction and Quality Control Inspection and Testing: AMEC Earth & Environmental, a division of AMEC Americas Limited.

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