Test Report

"Airbag Testing of a One-way Out-of-plane Unreinforced Masonry (URM) Wall"

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Laboratory: Civil Test Hall, The University of Auckland

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Airbag Testing of a One-way Out-of-plane Unreinforced Masonry (URM) Wall

Introduction: This report presents details of airbag testing performed in the Civil Test Hall, The University of Auckland. This test was the first one of its own kind being conducted in the Test Hall. It is expected that the results from the testing give some guidance for the improvement of the test procedure for future airbag testing. A complete report of the observations and also preliminary results of the test are included in this report.

1. Setup Description

A setup shown in Figure 1(a) was used to apply uniform pressure on the surface of a URM wall acting in one-way condition. The wall, with a height, width, and thickness of 3500 mm, 1200 mm, and 220 mm, respectively, was restricted at top and bottom for movements perpendicular to its plane. For this purpose, steel angle sections with a length equal to the length of the wall were used on both sides of the panel at the ground and top elevations. Although it was expected that the wall would crack from the mortar joint immediately above or below these support levels, the assemblage of the steel sections proved to allow for rotation of the wall at the support levels. Zero axial load was assumed throughout the testing.

Two Bigfoot vinyl airbags with a thickness of 0.25 mm were used to generate the loads. The air used to inflate the airbags was supplied from the main compressed air supply at the Test Hall. A manually operated pressure control system shown in Figure 1(b) was used to reduce the air pressure from 8 PSI to the applicable pressure range, starting from zero and increasing up to about 1.15 kPa. By selecting the same type and length of hoses and connections for each airbag, it was ensured that both of the airbags were inflated up to a same pressure level. It is noteworthy that at the beginning, a total of four airbags have been arranged in a system to apply cyclic loads to the specimen. During the half cycle testing an observation was made, which prevented the cyclic test to be initiated. The problem was the slow deflation of the airbags in the opposite side, when the wall was being tested from one side (refer to Observation of the Test). It was then concluded that the setup needed to be improved in future to allow for cyclic testing being performed.

Figure 1: (a) Test Setup (b) Data Acquisition System and Pneumatic Unit

A very thin layer of low-strength, highly flexible polyurethane foam (1 mm thickness) was used between the airbag and the masonry surface to prevent airbags damage, though it was noticed during the test that the damage was not an issue and the testing could be performed without using the foam layer. The load was generated and increased by inflating airbags being confined between the wall surface and a sheet of plywood attached to the backing frame. It was transferred from the backing frame to the reaction frame by means of four S-type 1000 N load cells (Figure 2). It was important to ensure that all of the load was transferred through the load cells, not any other connection. For this purpose steel rollers were used underneath of the plywood backing frame. The displacements were measured by a linear variable displacement transducer (LVDT) placed at mid-height (1750 mm elevation) of the wall. The deflected shape of the wall had been assumed to be linear up the height of the wall, with a maximum at about mid-height. Therefore, the LVDT was placed at about the point of maximum displacement.

A National Instrument data acquisition (DAQ) system with 24 channels (Figure 1(b)) was used to accommodate for 8 cables from the load cells and one cable from the LVDT. Because of the severity of the electromagnetic noises being recorded by the NIDAQ machine, it was decided to record the test data with a frequency of 50 Hz. A post-processing code was then prepared to apply a low-pass filter to the records resulting in removal of data with frequency of more than 4 Hz.

2. Material Properties

Solid bricks and mortar type “O” with sand-cement-lime ratio of 9:2:1 were used to build the two-leaf wall. Bricks were used in a “common bond” pattern, with headers every fourth course. The results of the material testing performed according to ASTM standards are given in Table 1.

Table 1: Mean mortar strength

Test	Compressive strength, (MPa)	Flexural strength of bond wrench, (MPa)
Test Method	ASTM C 780 – 02	ASTM C 1072 – 00a
Mean	3.95	0.44
CoV	0.13	0.19

3. Observation of the Test

The testing was started with applying load from one side (Figure 2). The airbags pressure was slowly and uniformly increased from zero to the maximum value (about 1.15 kPa, point A in Figure 4, 5, and 6). At about the maximum load, a crack was started to be opened in a fashion suggesting that either it had already existed before or it was initiated without too much energy being released at once. At about the same instance of time as when the crack appeared, the pressure inside the airbags automatically started to decrease as the wall was deforming and the displacements were significant. The displacement of the wall at the crack was allowed to reach about 135 mm (0.61t), at which point the cracked wall looked nearly unstable (Figure 3). The supplying air hose was then stopped, and the airbags pressure was reduced by opening the release valves. As the pressure started to decrease, the weight of the wall acted as a stabilizing force, returning the wall to its first situation. The crack was no longer visible, when closed. No other damage than the above mid-height crack was observed in the wall specimen. The testing duration was approximately 15 minutes.

It had been planned to perform a cyclic testing following the above half-cycle test, but it was realised that performing such test was not possible. The problem was that after the half-cycle testing, there was still a large amount of air left inside the airbags, though with zero pressure, which prevented the wall from deflecting when pushed from the opposite side. In this situation (inflating airbags in one side and, at the same time, expecting the air to come out from the airbags at the opposite side), the load values recorded are not the true strength of the wall and are in part due to the pressure developed in the opposite airbags. This pressure develops because of the slow rate of deflation from the airbag when compared with the higher rate of inflation of the airbags in the opposite side. The same phenomenon can be observed at point C in Figure 5, though this was not a cyclic test and the increase in the load values is due to the wall weight only. Performing the cyclic test required removal and installation of the airbags for several times, which was not convenience. The cyclic test was therefore abandoned, and it was decided that the setup should be improved to make the future cyclic testing possible.

The second phase of the test was commenced, which comprised the half-cycle testing being repeated two times for testing from each side of the wall. Unfortunately, unknown errors have occurred during the acquisition of displacement records from the test, and erroneous data have been obtained from the testing. Therefore, the results from these segments of the test are not included here.

Figure 2: A single horizontal crack began to develop 350 mm above the wall mid-height; the supports at top and bottom of the wall allow for rotation of the wall, and therefore no crack was formed at the support levels. Four load cells connecting the backing frame to reaction frame at each side, and the single LVDT arrangement can be observed in the figure.

(a) (b)

Figure 3: (a) wall at maximum displacement position (135 mm at the crack level); after this point the inlet air was stopped, and the airbags connections were opened to allow for airbag deflation. The wall stabilized to its resting position by its own weight. (b) mid-height crack

4. Test Results

The displacement and load histories and the force-displacement curve derived from the results from the testing can be found in Figure 4 through 6. Figure 7 includes a linear approximation of the force-displacement curve.

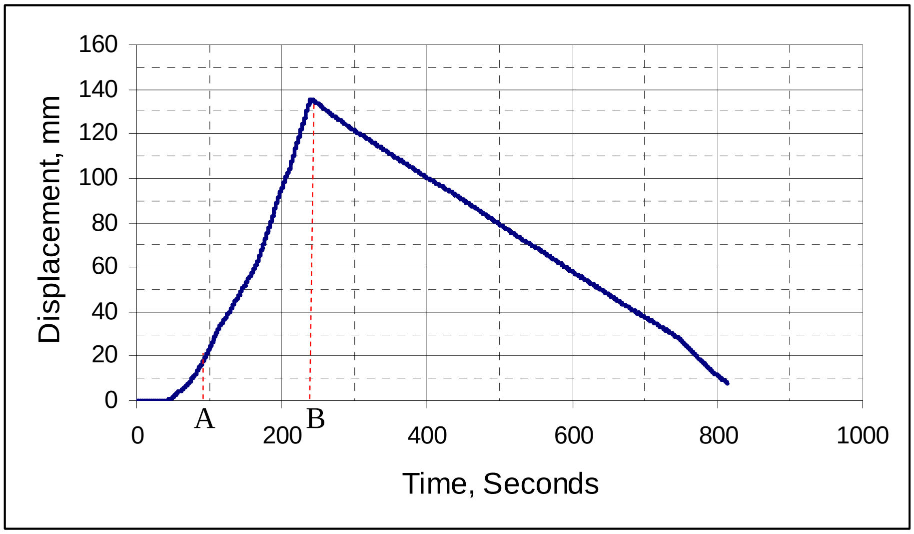

Figure 4: Displacement history for the crack elevation, with a maximum of 135 mm; Point A corresponds to the maximum pressure (1.15 kPa)

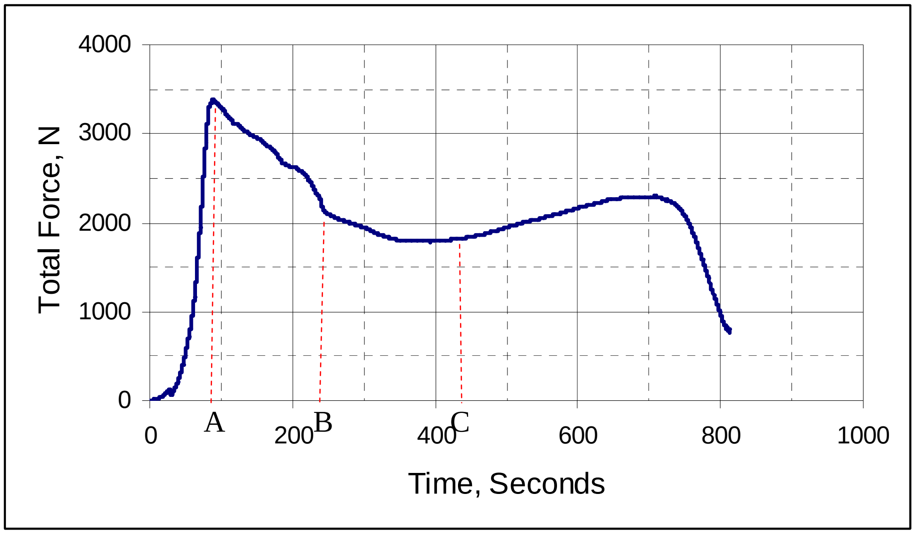

Figure 5: Load history, with a maximum of 3395 N at point A; Point B corresponds to maximum displacement, and point C is the start of increase in airbags pressure because of the wall weight returning the wall to its initial situation

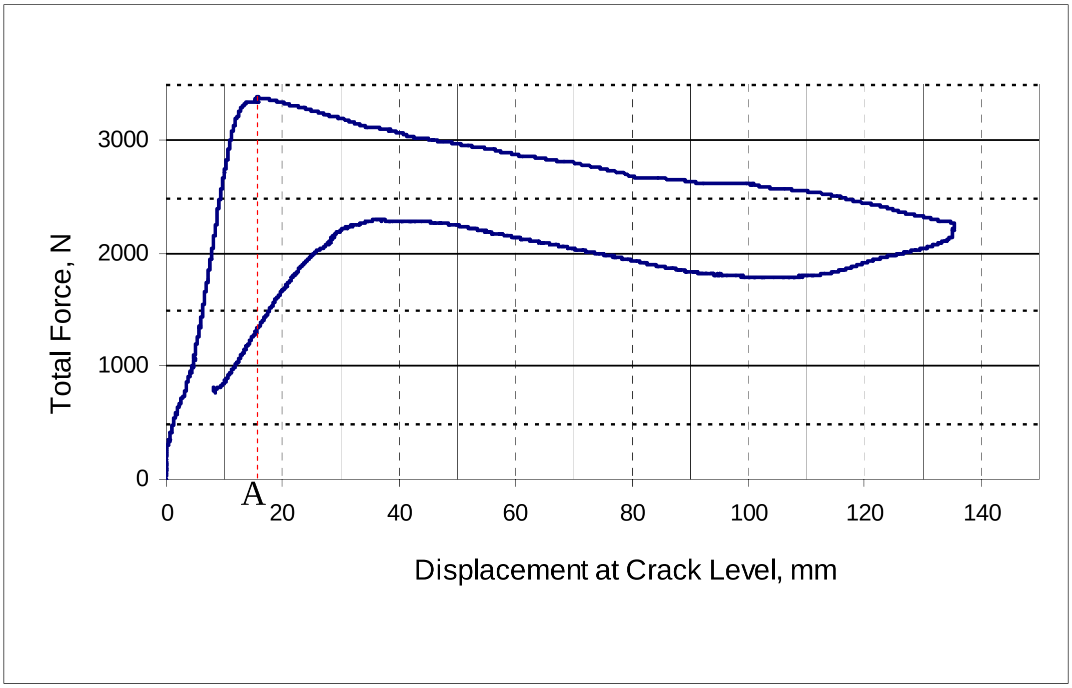

Figure 6: Force-Displacement Curve

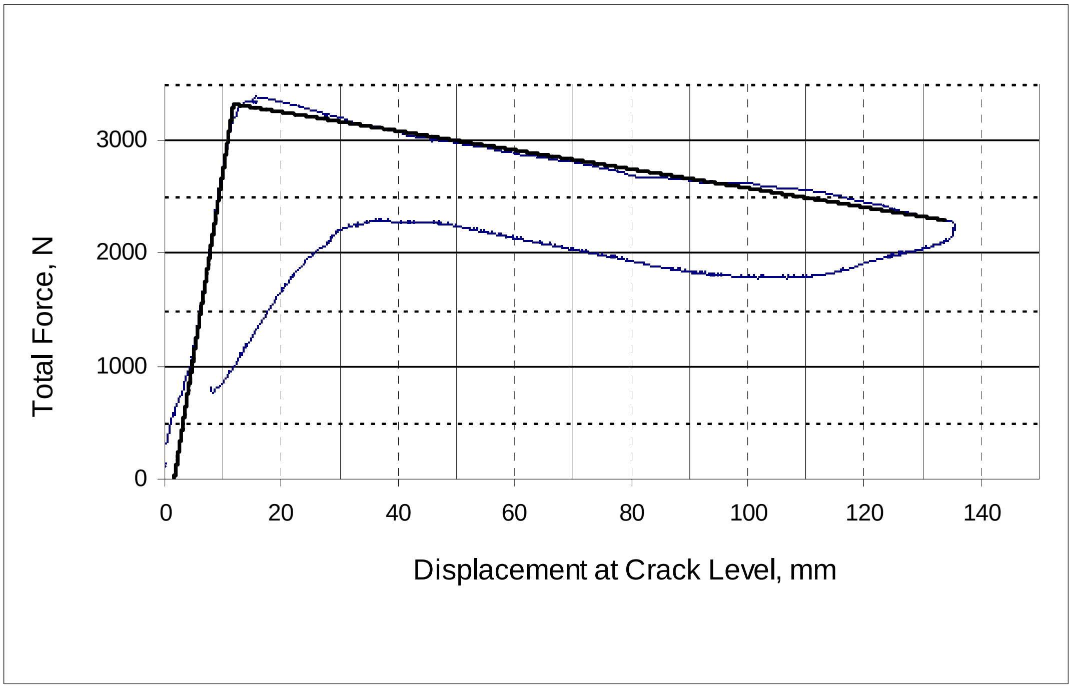

Figure 7: Linear model representing the actual force-displacement curve