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Strength Assessment of a Brick Masonry Building of 1895

Détermination de la résistance d'un bâtiment en maçonnerie de 1895

Widerstandsbestimmung eines Backsteingebäudes von 1895

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1. Introduction

Recent severe damage to old brick masonry buildings in Japan as a result of even moderate earthquakes has emphasized the need to retrofit such buildings to enhance their seismic performance. This paper describes a collaborative project to investigate the seismic performance and appropriate retrofit measures for a famous 3–story brick masonry building, 130m long, 45m wide and 15m high and containing many interior walls. The building was completed in 1895 and is the only remaining masonry structure in a Tokyo business district where it is part of a government office complex.

This paper consists of two parts. Part 1 provides detailed information on the strength of the brick walls. Part 2 examines the seismic performance of the building by using earthquake response spectrum methods and the strength results.

2. Test program

To evaluate the seismic resistance of the masonry, flexural, shear and compressive monotonic loading tests were conducted on the walls. The walls were constructed of bricks 240*115*65 mm with 10 mm thick bed joints. And tests, as follows, were conducted

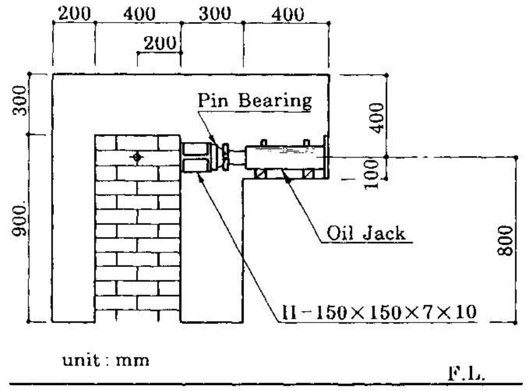

Fig.1 In–plane flexural test

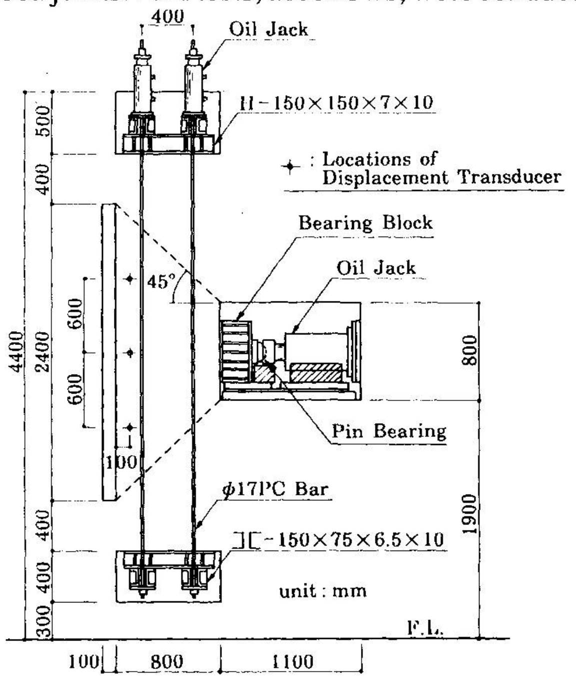

Fig.2 In–plane shear test

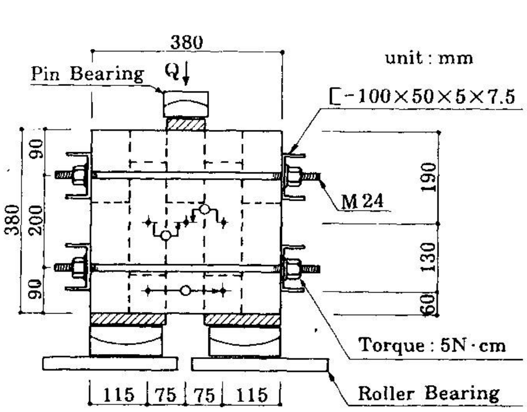

Fig.3 Double shear test

on the actual brick walls and on 380 mm cubic specimens cut from the walls:

a. In–plane flexureal and shear tests of the walls (Fig.1 and 2) ;
b. Double shear tests on cubes loaded parallel to the horizontal joints (Fig. 3) ;
c. Compressive tests on cubes loaded perpendicular to the horizontal joints ; and
d. Compressive, splitting and modulus of rupture tests on individual bricks

3. Test results

The setup for the two in–plane shear tests is shown in Fig. 2. The loading jack was inserted in a 800*1100 mm hole cut in the wall and the area between that jack and a 2400*100 mm slot also cut in the wall was preloaded to a mean vertical stress of 0.4 Mpa. Horizontal load, Q , versus horizontal center displacement, δ , relationships obtained from this test are shown in Fig. 4. The slope of the curves, which represents the stiffness of the walls, gradually decreased as the loading increased. The load carrying capacities degraded asymptotically once severe diagonal shear cracks initiated along the joints. For specimen B–1 the maximum load was 230 KN at a horizontal displacement of 9.9 mm.

In the double shear tests, displacements were measured parallel(slip) and perpendicular (separation) to the horizontal joints. Fig. 5 are the resultant load – displacement relationships for specimen C–1. Slips and separations were not observed until immediately after the maximum load of 98 KN was reached. Then large plastic displacements occurred without significant reduction in load carrying capacity. The other three specimens exhibited similar behavior but their capacities and stiffnesses were slightly smaller than for C–1. The mean shear strength at the joints derived from this test was 0.28 Mpa.

Shown in Fig. 6 is a comparison of the stress–strain relationships from the compressive tests. The vertical strains at the peak load for each specimen differ due to differences in the maximum strengths of the fragile joint mortar. The initial stiffness for the walls, defined as the secant modules at one third of the maximum strength, averaged 2800 Mpa .

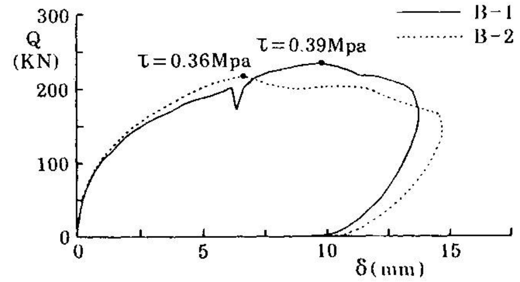

Fig.4 Load – displacement relationships for In–plane shear test

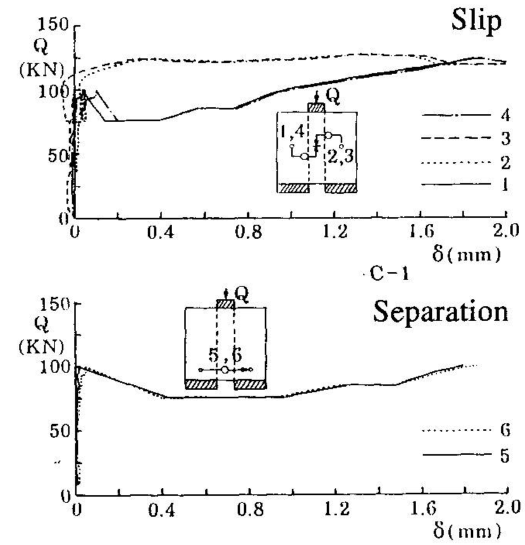

Fig.5 Load – displacement relationships at the joints

4. Summary and conclusions

The test results showed that the strength of the joint mortar had a significant effect on the behavior of the brick walls. That strength was reduced by long term deterioration effects. The following conclusions were drawn as to mechanical properties of the brick walls:

1. Flexural strength σt=0.15 Mpa ;
2. Shear strength τu=0.38 Mpa ;
3. Compressive strength σu=6.4 Mpa ; and
4. Modulus of elasticity Ew=2800 Mpa

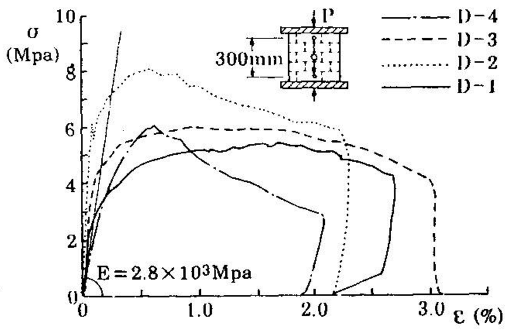

Fig.6 Stress – strain relationships from compressive tests