INELASTIC EARTHQUAKE RESPONSE ANALYSIS
OF BRICK INFILLED FRAMES

Wei Lian[I] Wu Qiyun[II]
Tian Jiahua[III] Dai Gueying[II]

SYNOPSIS

The behaviour of the brick infill framed element under the monotonic and cyclic lateral loads and the restoring force characteristic parameters for this kind of element are given in the paper. The post earthquake simulation for a seven-story brick infill framed building was done by applying the story-shear model and the related formulae in this paper. The calculated time-history response agree fairly with practical earthquake records.

INTRODUCTION

Brick infilled frame is a kind of structure composed of reinforced concrete and brick, two sorts of material with different natures. As a result of brick walls liable to crack under lateral loading, the elastic seismic response analysis for brick infilled frame structures seems to be inadequate. However, owing to the complicacy of the behaviour of such structures, no definite specifications about them were provided in aseismic design code in our land up to the present.

Relying on an experimental study, formulae for evaluation of stiffness and strength of infilled frame elements in different working stages are given in the paper.

A post earthquake simulation to a 7-story brick infilled frame building in Tianjin area was done by carrying out the inelastic response analysis on the structure and showed quite satisfactory results.

BRIEF DESCRIPTION ON EXPERIMENTS

An experimental study on three group of nine pieces of frame element models of about ½ scale under monotonic and reversed cyclic loading was performed. Among each group there was a relevant empty frame model for comparison (Fig. 1). All joints between the 12 cm thick brick infill walls and circumscribed frames laid solidly.

I Director Engineer, II Engineer
Research Institute of Building Earthquake Engineering, Chinese Academy of Building Research
III Lecturer, Beijing Polytechnical University

Fig. 2 shows the comparison of P - Δ curves of brick infill frame models and corresponding empty ones.

Test results showed that the brick infill frames exhibited much higher bearing capacity, while keeping almost the same deformability as that of empty frames. However, premature cracks in brick walls were observed.

The entire process of deformation of the elements under lateral loading might be approximately summarized into three stages. Within the first stage, starting from applying load to appearance of cleavage on perimeter of infilled wall, the model works elastically in the main just like a composite plate. The second stage covers from wall perimeter cleavage to wall diagonal cracking. In this stage, stress distribution in both frame and wall changes uninterruptedly with the increasing load, causing obvious decrease of stiffness of the model. The third stage is from wall diagonal crack to the formation of plastic hinges in frames, a through horizontal fissure in the middle part of the wall or lower then occurs. Finally, the infilled frame collapsed because of the concrete in compressive zone of a critical column section crushed (Photo 1).

One of the measured hysteretic loops of brick infilled frame element under reversed cyclic lateral loading is given in fig. 3. It is seen that the action of a reversed load holding equi-displacement repeated for three times does not bring about any perceptible descent of strength capacity, but a slight dwindling of stiffness will take place.

FORMULAE FOR EVALUATION OF STIFFNESS AND STRENGTH OF BRICK INFILL FRAME ELEMENTS

Based upon the test results an idealized degenerated trilinear mode restoring force characteristic curve shown in fig. 4 is suggested, representing the P - Δ relationship of the infilled frame element in different working state. Related formulae are given as follows:

1. Stiffness

$$K_1 = \alpha_1 K_0 = \alpha_1 E_W F_W \Big/ 2.35H\left(\frac{1}{1-\gamma} + \frac{\tilde{F}_W H^2}{7 J_c}\right) \qquad (1)$$

$$K_2 = 0.25 K_0 \qquad (2)$$

where, $\alpha_1 = 0.55 + 0.15\ (L/H' - 1)$ (3)

E_W — modulus of elasticity of brickwork

$\tilde{F}_W$ — transformed area of cross-section of brick wall ($= 1.1\ F_W$, $F_W = B\ L$)

J_c — transformed sectional inertia moment of the combined plate

a — length of opening

γ — coefficient of opening influence
($= \alpha B/F_W$ opening near the middle)
B — thickness of brick wall

As the effect of bending deformation becomes innegligible, the stiffness of the elements should be calculated according to special formulae for a wide column.

2. Strength
Crack shear strength (4)

$$Q_c = R_\tau F_W (1 + 2b/L)$$

Yield strength (5)

$$Q_y = R_\tau \widetilde{F}_W + (M_{ub} + \xi M_{uc})/H$$

where,

$$R_\tau = R_j \sqrt{1 + \sigma_0 / R_j} \qquad (6)$$

$$\xi = 3.5 + 0.5 (L/H' - 1) \qquad (7)$$

R_j — shear stress strength of brickwork

σ_0 — average compressive stress in brick wall

M_{uc}, M_{ub} — sectional yielding moments of frame column and beam respectively. The effect of axial compression on M_{uc} should be considered

MATHEMATICAL MODELS FOR INELASTIC EARTHQUAKE RESPONSE ANALYSIS OF MULTI - STORY BRICK INFILL FRAMES

Three kinds of mathematical models are proposed below for the inelastic earthquake response analysis of multi-story brick infill frames.

1. Generally, the simple shear model would be practicable to offer an acceptable approximate solution of inelastic seismic response as a result of the peculiarity of brick infilled frame buildings.

2. In cases of building having obvious unsymmetry in mass distribution or stiffness allocation, the shear-torsional model is recommended to take the spaceful action into account and a corresponding computer program GANU has been prepared.

3. When the effect of bending deformation of infilled frame elements becomes not to be despised, a bar-system model should be used and a computer program NER2 has been formulated. In this case, each infilled frame element is treated as a wide column taking shear failure as its control factor and all beams connecting wide columns are considered with rigid zones at

their ends.

In practical engineering, we may choose the most suitable one among the above three, according to the real condition of the building, such as the mechanical behaviour of the brick infilled frame elements, the mass distribution, stiffness allocation of the structure and so on.

AN EXAMPLE OF POST EARTHQUAKE SIMULATION

Fig. 5 show the plan and profile along R-axis of a 7-story brick infilled frame of Tianjin Orthopedics Hospital building located in Tianjin Proper. The foundation is of reinforced concrete mat type and the underlying soil is sandy clay. All infill walls are hollow brick masonry having a thickness of 10cm.

On November 15, 1976, one of the strongest aftershocks with epicenter at Ningho and magnitude 6.9 during the 1976 Tangshan Earthquake occurred. The main damage to the building was the cracking of infill walls (Fig. 6). All strong motion accelerographs set up on the top of the foundation as well as the 2nd, 4th and 6th floor in R-axis frame plan recorded down the accelerograms (Fig. 5).

In accordance with it's acture conditions, a post earthquake simulation to the building was carried out by applying the related formulae in this paper and using the story shear model to analyze the inelastic response. The results were checked by the shear-torsional model.

Fig. 7 is the comparison of the calculated and recorded time history of acceleration responses, which are in conformity with each other on the whole.

Fig. 8 shows the calculated max. response of story shear, surpassing the corresponding crack shear strength, while still less than yielding values.

ACKNOWLEDGEMENT

The authors would like to express their deep thanks to Engineers Xu Xianyi, Gu Dian, Dong Jingcheng and Qin Yong for their help in preparation of this paper.

REFERENCES

1) R. W. Clough, J. Penjien, "Dynamics of Structures", 1975

2) Dai Guoying, "A Method of Earthquake Response Analysis of Structures by using the Shear Model", Report of Building Research, C.A.B.R. 1978.

3) Wei Lian et al., "Elasto-Plastic Earthquake Response Analysis for Multi-Storeyed Structure Taking Account of

Torsion", 7th WCEE 1980

4) Yin Zhigian et al., "Experimental Study of Influence of Brick Infilled Wall on the Bearing Force of Frame under the Horizontal Load" Seismic Engineering Study Report vol. 3, 1977.

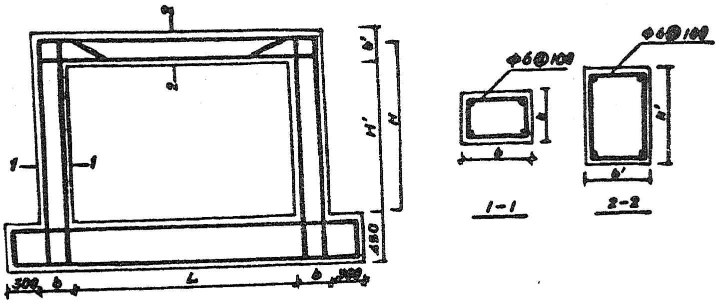


FIG. 1

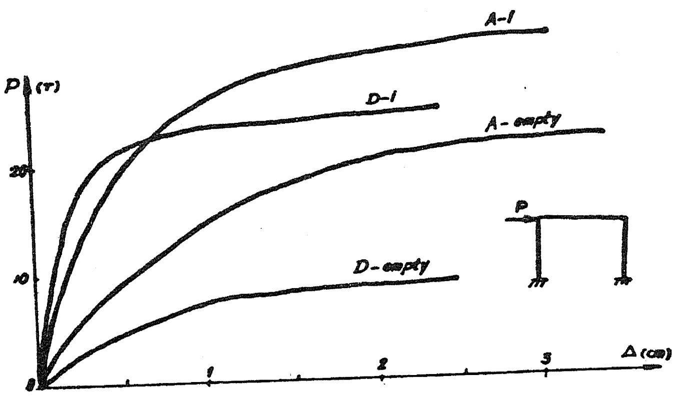


FIG. 2

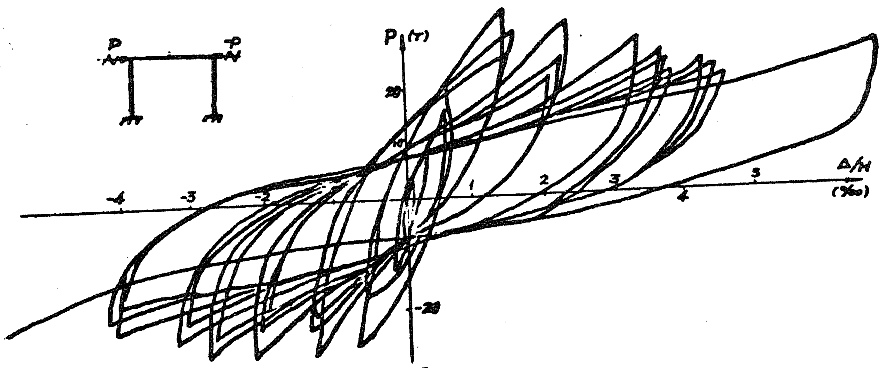


FIG. 3

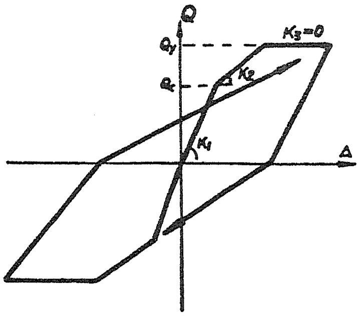


FIG. 4

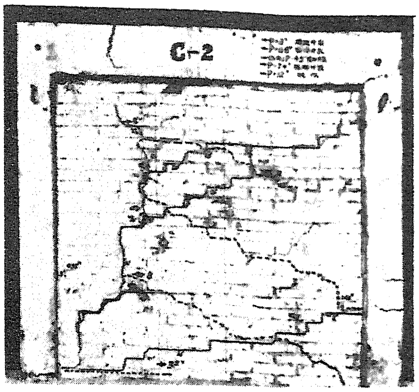
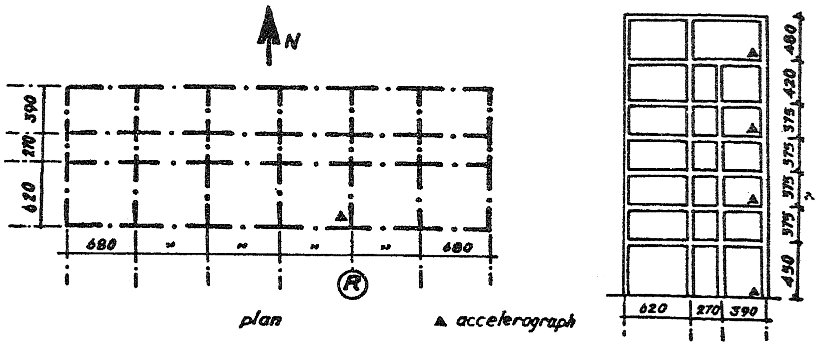


PHOTO 1



plan ▲ accelerograph

FIG. 5 R-axis section

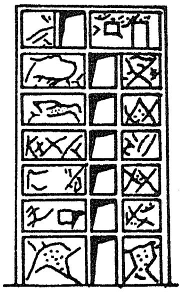


FIG. 6

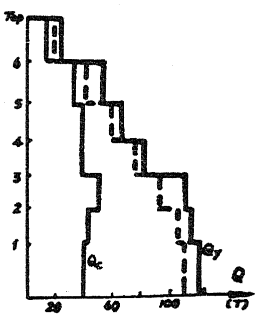


FIG. 8

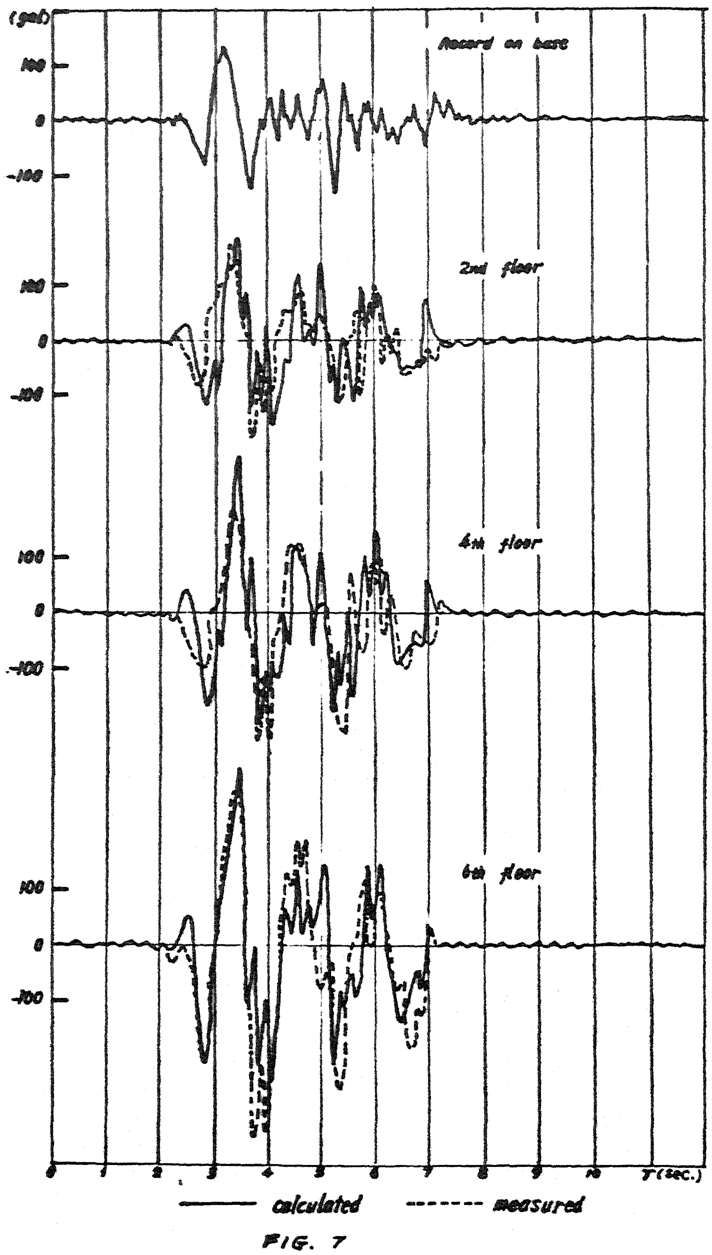

(gal)
Record on base
100
0
-100
2nd floor
100
0
-100
4th floor
100
0
-100
6th floor
100
0
-100
0
1
2
3
4
5
6
7
8
9
10
T (sec.)
calculated
measured

FIG. 7