Paper No. 1255. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

DAMAGE TO 11-STORY SRC CONDOMINIUM BY HANSHIN EARTHQUAKE IN 1995

K. TAKIGUCHI[1], K. KIMURA[2] and S. MIYASHITA[2]

[1] Department of Architecture, Tokyo Institute of Technology,
2-12-1, Oookayama, Meguro-ku, Tokyo 152, Japan
[2] Structural Engineering Department, Tokyu Construction Co., Ltd.
1-16-14, Shibuya, Shibuya-ku, Tokyo 150, Japan

ABSTRACT

An 11-story SRC condominium in Hyogo prefecture was damaged by the earthquake (M=7.2) in January 17, 1995. The investigation of damage to this building was conducted in order to judge the structural safety and find the repair procedure.

The main damage of this building is the tensile fracture of reinforcing bars of the first story column. The tensile fracture of reinforcing bars can not explain by some conventional analyses. The tensile fracture of reinforcing bars may occur because of strain concentration. If a continuous structural wall assume a cantilever, this phenomenon can not explain.

A deforming model assumed in this paper derives strain concentration to reinforcing bars at the bottom of the first story column which is placed at the edge of continuous structural walls. The tensile fracture of reinforcing bars occur when the drift angle reach to 1/100-1/50 radian.

KEYWORDS

Seismic evaluation; SRC structure; tensile fracture of reinforcing bar; theory of plasticity

INTRODUCTION

The seismic evaluation is very important for judging the safety of a damaged building by big earthquake such as HANSHIN earthquake. The safety of a damaged building is judged by various points, width of cracks, residual drift angle and so on. A damage that can not explain by some analyses is embarrassed the inspectors.

The tensile fracture of reinforcing bars can not explain by some conventional analyses. The tensile fracture of reinforcing bars may occur because of strain concentration. If a continuous structural wall assume a cantilever, this phenomenon can not explain.

This paper explains the reason of the tensile fracture taking account of bi-axial horizontal deformation effect. A deforming model assumed in this paper derives strain concentration to reinforcing bars at the bottom of the first story column which is placed at the edge of continuous structural walls.

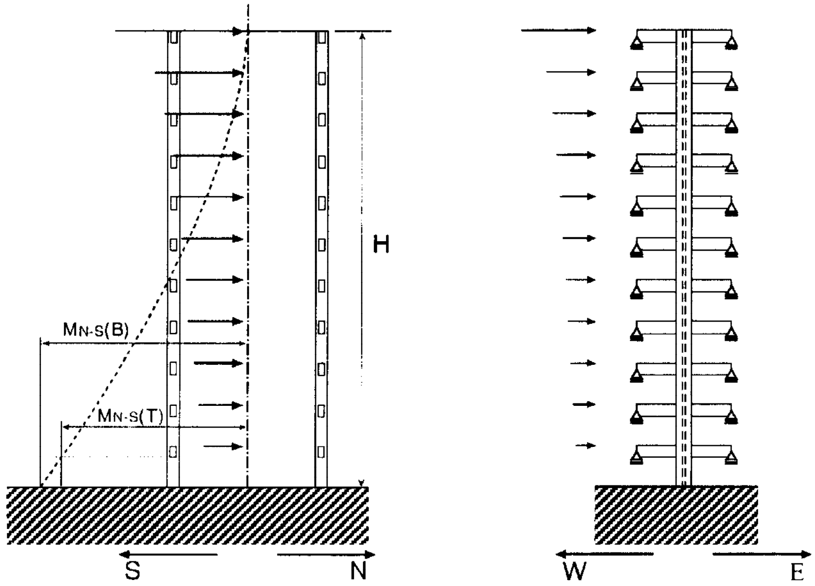

Fig. 4 Modeling of building

Modeling of Column

The column is assumed as shown in Fig. 5. The sectional area is A_S, the distance from the reinforcing bar of compression to the reinforcing bar of tension is D. The west side reinforcing bar is RB_W, and the east side reinforcing bar is RB_E.

Modeling of Deformation

In this paper three states are discussed as shown in Fig. 6, i.e. :

State(i) : N-S direction deformation only.
State(i+1) : after state(i), E-W direction deformation is occurred.
State(i+2) : after state(i+1), opposite E-W direction is occurred.

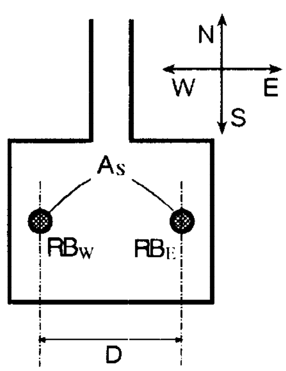

Fig. 5 Modeling of column

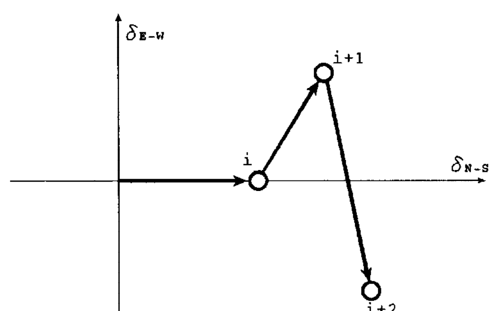

Fig. 6 Modeling of deformation

Assumption of Stress and Strain of Reinforcing Bars (1)

The stress and strain of reinforcing bars is assumed as shown in Fig. 7. The bottom is just before strain hardening at state(i). At state(i+1) RB_W starts strain hardening and RB_E is unloaded. The top is elastic at state(i). At state(i+1) RB_E is yield and RB_W is unloaded.

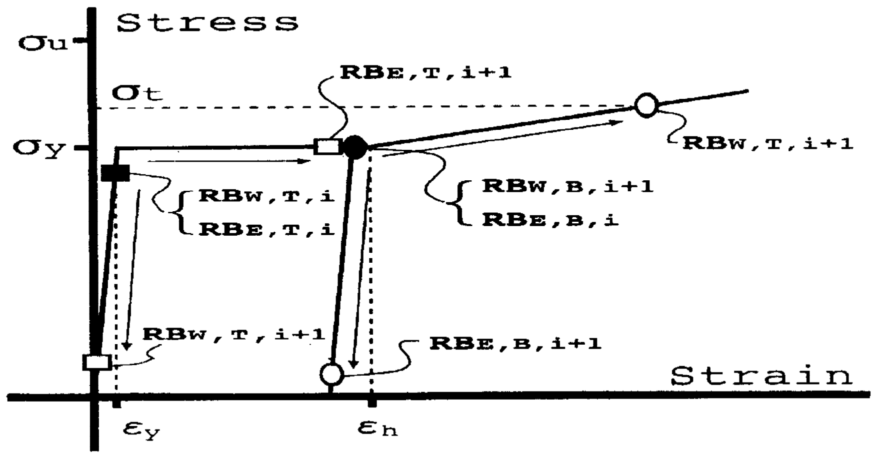

Fig. 7 σ–ε relationship

Bending moment-curvature-axial force-axial deformation relationship of column section

There is an analogy between bending moment-curvature-axial force-axial deformation relationship and the theory of plasticity as shown in Fig. 8.

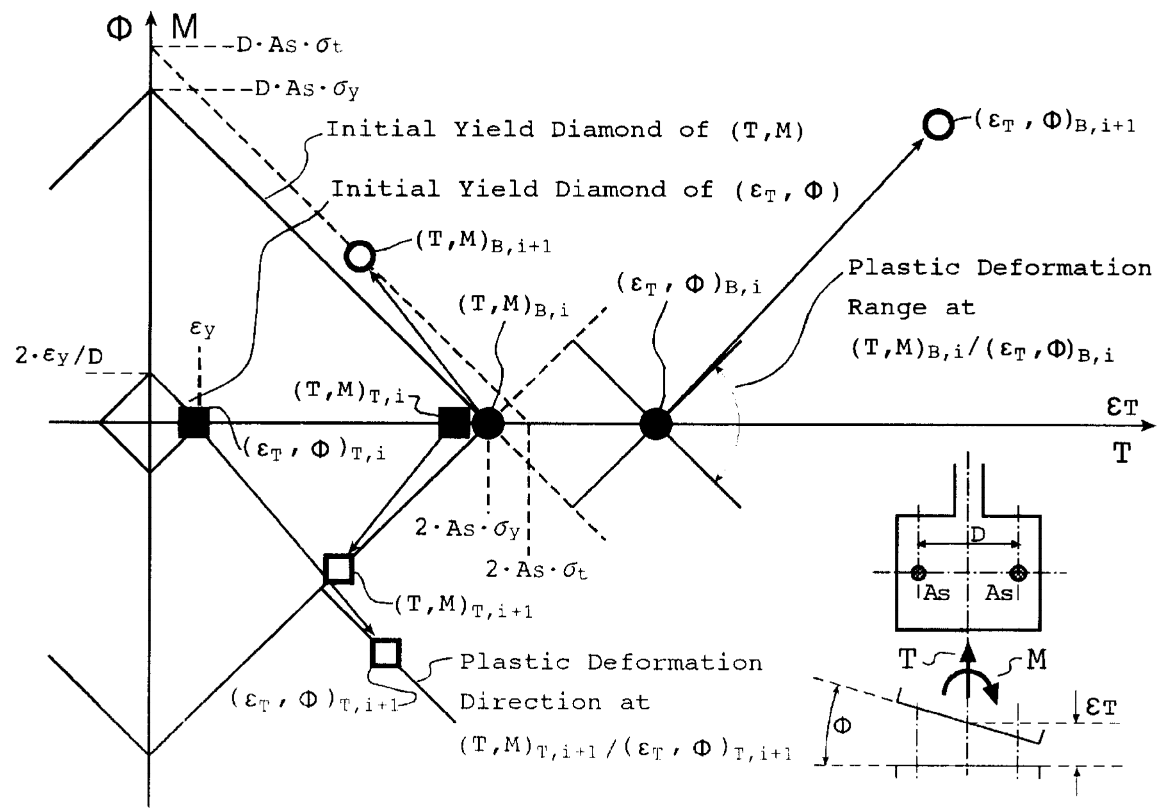

Fig. 8 Analogy of M-ϕ–T–ε_T relationship to the theory of plasticity

Stress Distribution of Reinforcing Bars (1)

The stress distribution of reinforcing bars are assumed Fig. 9(a) from Figs. 7 & 8. The strain distribution of reinforcing bars are shown in Fig. 9(b). And the real distribution is supposed as shown in Fig. 9(c).

The total elongation of reinforcing bars of west side is equal to the total elongation of reinforcing bars of east side without the bending deformation of girders that connects with top and bottom of the column.

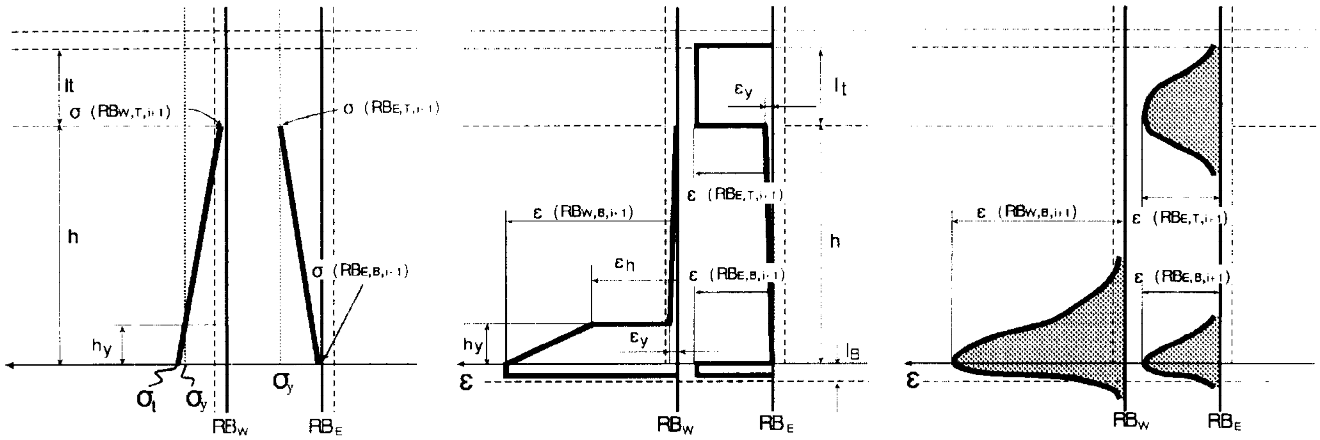

Fig. 9 Stress and Strain distribution of reinforcing bar

Local Bending Moment

If reinforcing bars are yield by tensile force, cracks may be occurred as shown in Fig. 10. In this condition the local bending moment and shearing force of reinforcing bars are occurred as shown in Fig. 10.

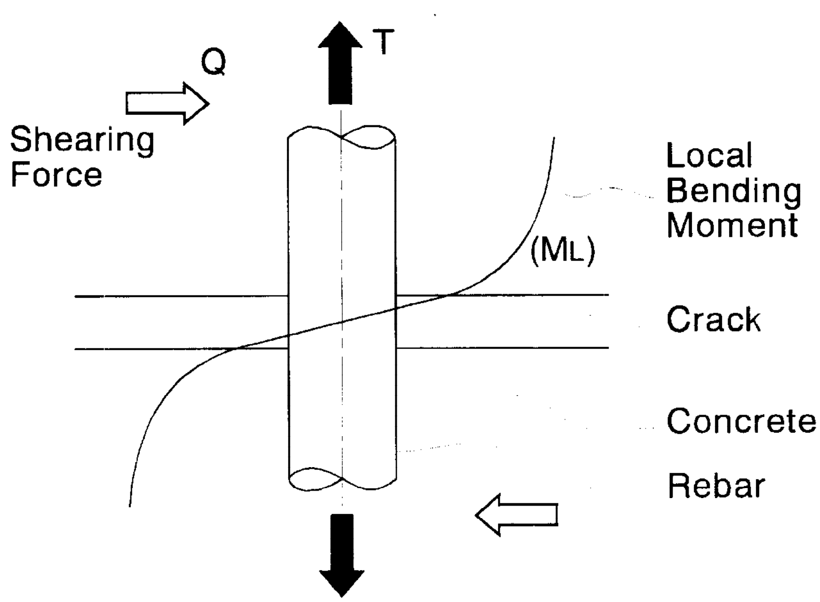

Fig. 10 Local bending moment

T-Q & M-T Relationship

The local bending moment of reinforcing bars is assumed as shown in Fig. 10, T-Q relationship may be expressed as shown in Fig. 11. And also M-T relationship may be expressed as shown in Fig. 12.

Considering these assumption, σ_y of reinforcing bar yielded by tensile force decrease.

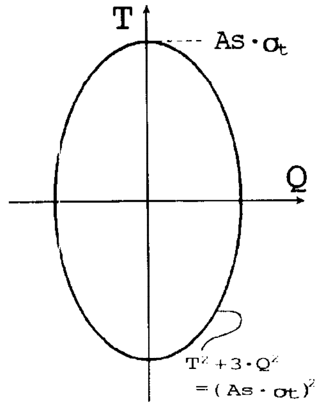

Fig. 11 T-Q relationship

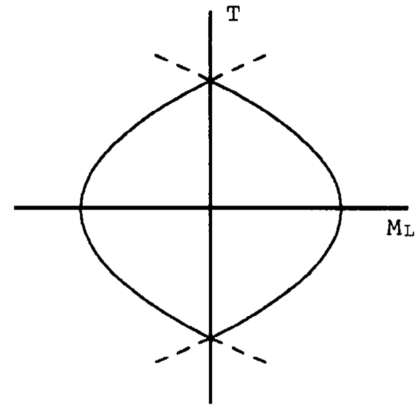

Fig. 12 M-T relationship

Assumption of Stress and Strain of Reinforcing Bars (2)

At state(i+2), the stress and strain of reinforcing bars is assumed as shown in Fig. 13. At the bottom of the column, RB_E starts strain hardening and RB_W is unloaded. At the top RB_W is yield and RB_E is unloaded.

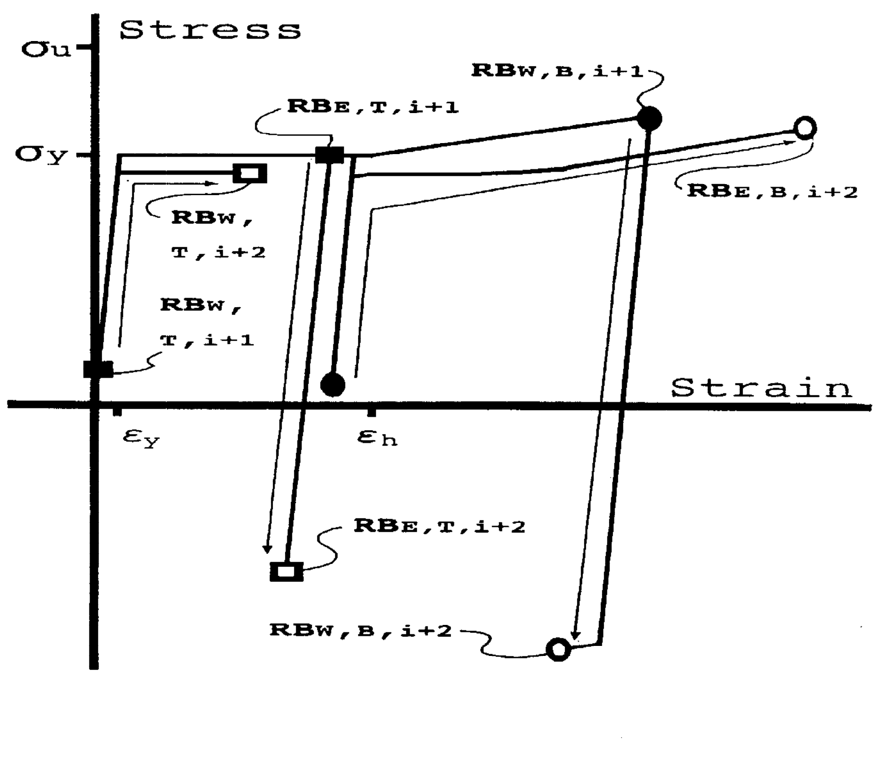

Fig. 13 σ−ε relationship

Strain Distribution of Reinforcing Bars (2)

A continuous structural wall to develop plastic deformation by flexural yielding under the action of bending may be deformed as shown in Fig. 14(right). The strain distribution of reinforcing bars are supposed Fig. 14(left).

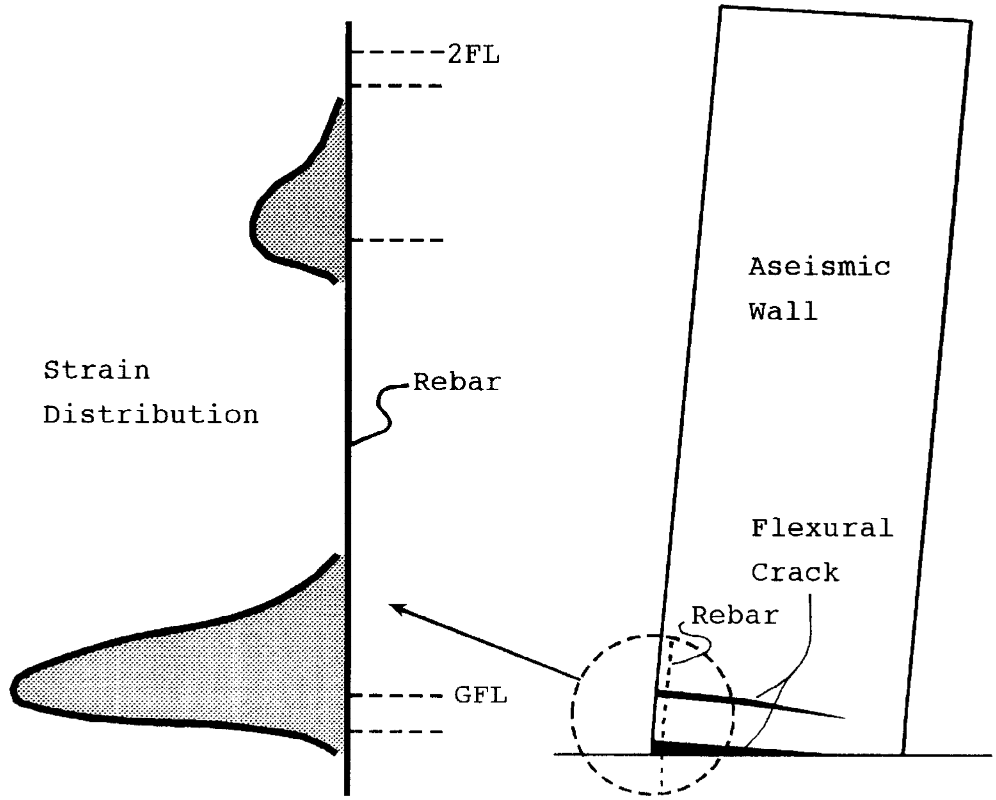

Fig. 14 Strain distribution of reinforcing bar

CONCLUSION

This paper explains the reason of the tensile fracture taking account of bi-axial horizontal deformation effect. This deforming model assumed in this paper derives strain concentration to reinforcing bars at the bottom of the first story column which is placed at the edge of continuous structural walls. Assuming to the strain concentrate region is 30d(d : diameter of reinforcing bar), main reinforcing bar is D25(d=25mm) and the elongation of reinforcing bar is 20%, the tensile fracture of reinforcing bar occur when the drift angle reach to 1/100-1/50 radian.