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EXPERIMENTAL TEST AND ANALYTICAL PREDICTION OF ENVELOPES FOR RC SLITTED SHEAR WALLS

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ABSTRACT

The purpose of this paper is to introduce the test of 34 RC slitted shear walls and to establish an equivalent frame analytical model under static horizontal loads. The analytical model proposed in this paper is considering the slitted wall unit as an ordinary column. In other words, slitted wall together with boundary elements is treated as a multi-bay rigid frame. Once the horizontal load acting to the rigid frame is getting larger and larger, the flexural stiffness, shear stiffness and axial stiffness of each member of the rigid frame will deteriorate gradually until collapse. At final stage, the ultimate capacity of bending moment of each column would increase due to confinement of diagonal compression action.

The predicted P-Δ curves are compared to 34 specimens with reasonable accuracy. The average error of ultimate horizontal load is 6.7%. Finally, one example of office building, strengthened with RC slitted shear walls, is employed to assess the collapse peak ground acceleration by using the frame model for slitted walls. It shows that collapse PGA increases quite a lot after strengthened wih RC slitted shear walls.

KEYWORDS

RC slitted shear walls; column models; equivalent frame model; nonlinear stiffness; P-Δ curves; nonlinear spectrum analysis; strengthening

EXPERIMENTAL STUDY

34 specimens, divided into 3 groups, are tested in this paper. Specimens in Group 1 are one-story slitted walls without boundary columns. Dimension of wall is 100 cm wide, 10 cm thick, 50 cm or 75 cm high; Specimens in Group 2 are one-story slitted walls with boundary columns. Dimension of wall is 70 cm wide, 7 cm thick, 50 cm or 75 cm high. Dimension of boundary column is 15cm×17cm; Specimens in Group 3 are two-story wall with boundary columns. Dimension of each story is exact the same as that of Group 2. Fig. 1 shows the details of Group 2 specimens. Slits of every specimen cut from top of wall down to bottom of wall. f_c' is 20 to 35 MPa; f_y is 400 to 500MPa.

All the specimens are loaded statically and reversed cyclicly in horizontal direction at top beam through 5 high tension bolts with one hydraulic jack pushing on one side and another jack pulling on other side. Lateral deflection of wall is measured by linear potentiometers on both sides. From load-deflection curves, the ductility ratio of slitted shear wall without boundary column is about 10. It is about 18 for slitted shear wall with boundary column. The details of deflections, cracking patterns, failure modes are discussed in (Hong, 1987), (Chen, 1988) and (Chen, 1989).

PREDICTION OF LOAD-DEFLECTION CURVES UNDER MONOTONIC LOADING

Since the behaviours of RC slitted shear walls under horizontal loadings are pretty ductile. So the analytical model for P-Δ envelope prediction is to consider each slitted wall unit as a column. In other words, slitted wall together with boundary elements is treated as a multi-bay rigid frame as shown in Fig. 2. Once slitted shear wall subjects to any loading, stress of each wall unit could be defined clearly through rigid frame analysis. More over, the reinforcement of each wall unit may be designed simply by column formulas.

Now consider a rigid frame, as shown in Fig.2, subjects to static horizontal load gradually at top beam. Nonlinear incremental method is used to modify flexural stiffness, shear stiffness and axial stiffness at every loading step for each member. For flexural stiffness, the effective stiffness used in ACI Code is employed to derive the tangential flexural stiffness. The tangential shear stiffness before or after diagonal cracks is calculated by Equs.(1) or (2) respectively:

$$GA = E_c A_{gt} / 3 \tag{1}$$

$$GA = E_c A_{gt} / 9 \tag{2}$$

The tangential axial stiffness before or after axial tension crack is caculated by Equs. (3) or (4):

$$EA = E_c A_{gt} \tag{3}$$

$$EA = E_c \left[a - b(f_s / f_y) + c(f_s / f_y)^2 \right] A_{st} \tag{4}$$

where E_c is secant modulus of elasticity of concrete, A_{gt} is gross transformed sectional area, A_{st} is total rebar cross-sectional area, f_s and f_y are axial stress and yield strength of rebar; a, b and c are functions of bar diameter, D_b, and caculated by:

$$a = 1.83 + 0.016 D_b \tag{5}$$

$$b = 1.14 + 0.283 D_b \tag{6}$$

$$c = 0.79 + 0.039 D_b \tag{7}$$

The ultimate capacity of bending moment of each wall unit would increase due to confinement of diagonal compressive action from whole set of slitted wall. So the ultimate capacity of bending moment of each slitted wall unit is calculated such that M_u, specified in ACI Code, multiplied by Equ. (8) when slits are infilled with timber sheets.

$$\lambda = 14.44(A / \sum A) - 0.32(H / W) > 1.0 \tag{8}$$

where A is cross-sectional area of one slitted wall unit, $\sum A$ is the sum of total area of all slitted wall units, H/W is the height to width ratio of slitted wall units.

If the bending moment of slitted wall unit reaches λM_u, plastic hinge is introduced to that member end. If shear force of slitted wall unit reaches V_u in ACI Code, shear stiffness reduces to zero. If slitted wall unit is crushed by axial compression or fractured by axial tension, axial stiffness becomes zero.

Fig. 3 is the comparison of predicted envelopes to test results for typical specimens of each group.

STRENGTHENING OF OFFICE BUILDING BY ADDING SLITTED RC SHEAR WALLS

Fig. 4 shows a typical plan of a 10-story office building. The original plan does not have central core. So the vulnerability by nonlinear spectrum analysis tells that the collapse PGA is 0.18g. If this building is strengthened by using 25 cm thick slitted shear walls as central core, the collapse PGA increases to 0.36g. On the other hand, if it is strengthened by using 25 cm thick traditional non-slitted shear walls as central core, the collapse PGA becomes 0.20g. Fig.5 is the vulnerability diagram before and after strengthenings. Where retrofitting 1 is strengthened by slitted RC shear walls and retrofitting 2 is strengthened by traditional non-slitted RC walls. The modification of stiffness in last section is used for nonlinear dynamic analysis to get the results of Fig. 5.

CONCLUSIONS

1. From experimental test, the ductility ratio of slitted shear wall without boundary column is about 10. It is about 18 for slitted shear wall with boundary columns.
2. The equivalent rigid frame model proposed by this paper predicts very well the load-deflection curves for slitted shear walls with/without boundary columns.
3. For high-rise building structure, the collapse peak ground acceleration would increase tremendously, if slitted RC shear walls are used for earthquake resistance.

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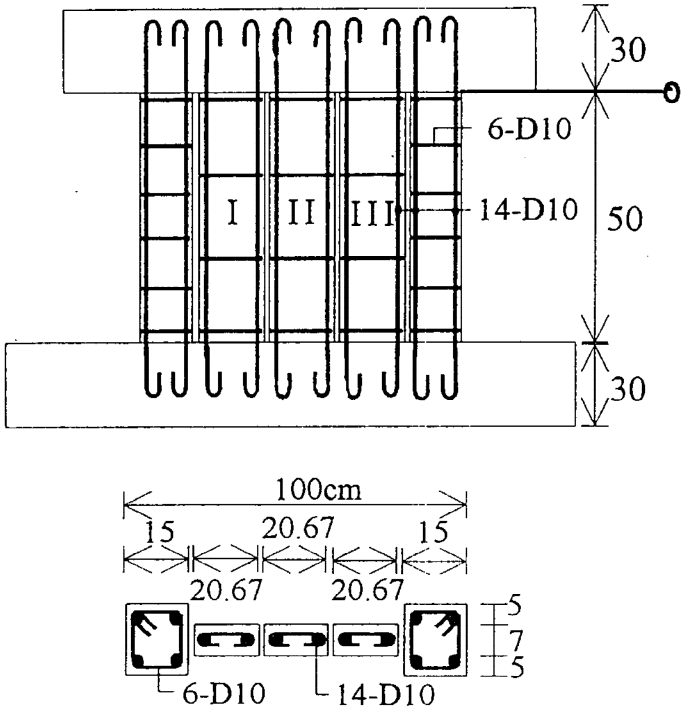


Fig. 1. Dimension and Reinforcement of Group 2 Specimens

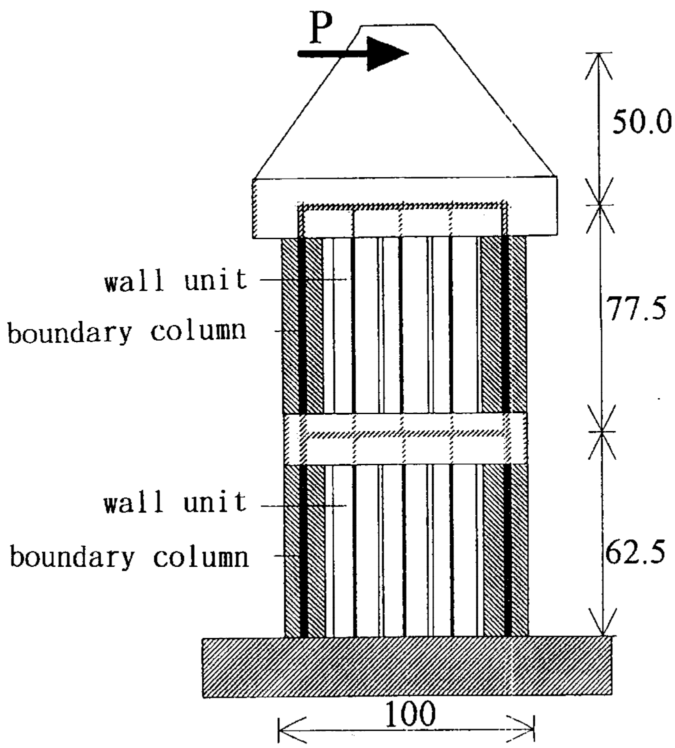
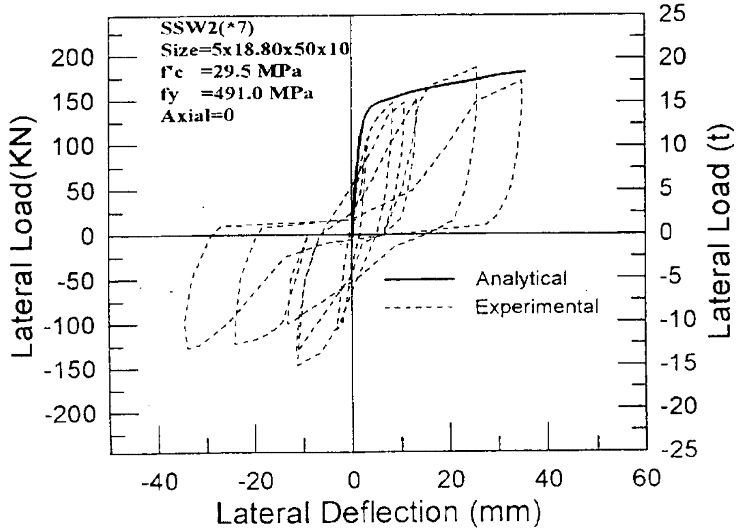
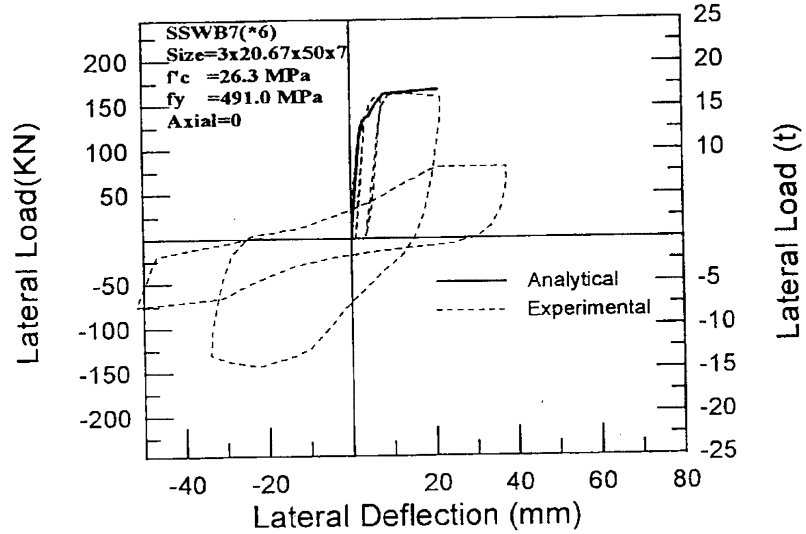
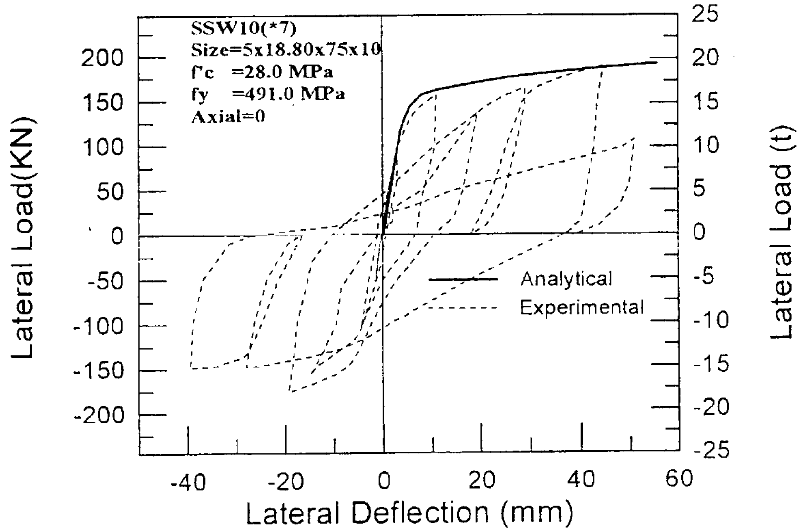
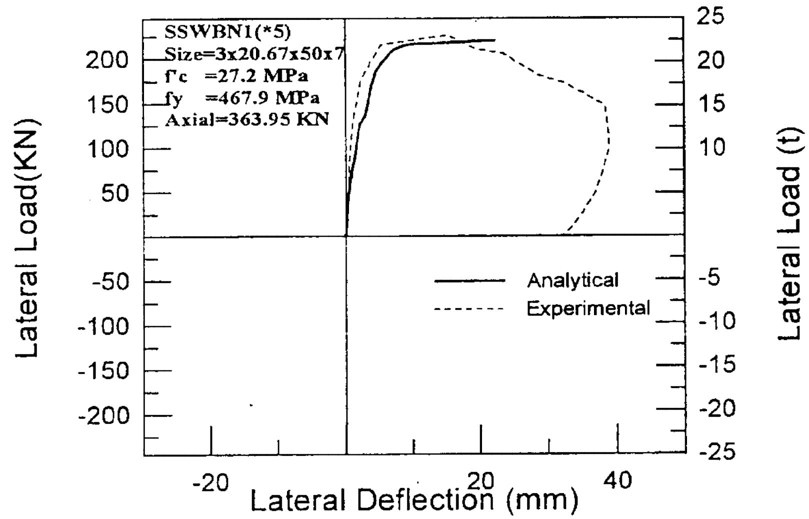


Fig. 2. Equivalent Frame Model for Group 3 Specimens





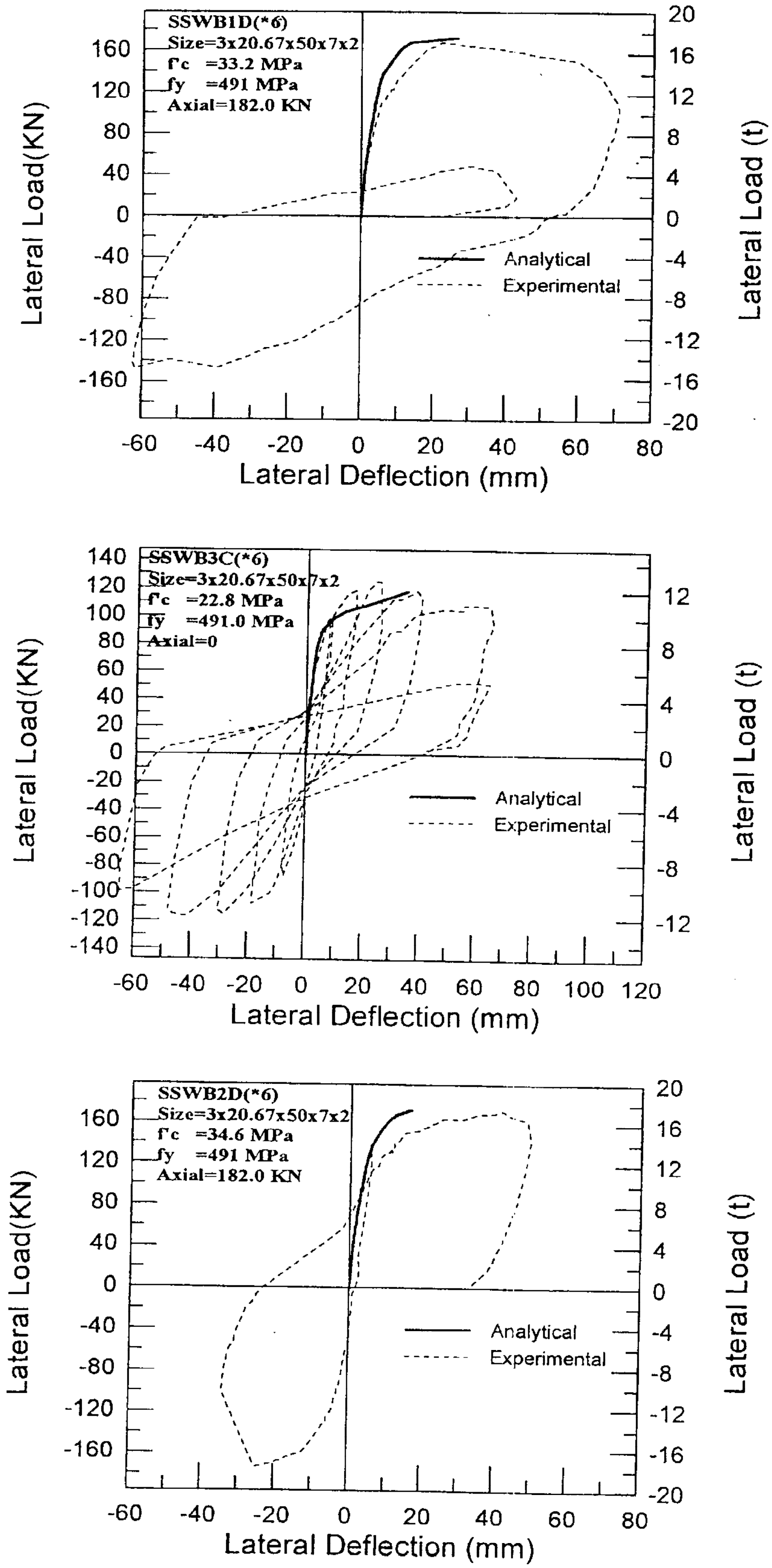




(a) Typical Group 1 Specimens

(b) Typical Group 2 Specimens

Fig. 3. Comparsion of Analytical and Experimental Results



(c) Typical Group 3 Specimens

Fig. 3. Comparison of Analytical and Experimental Results (cont'd)

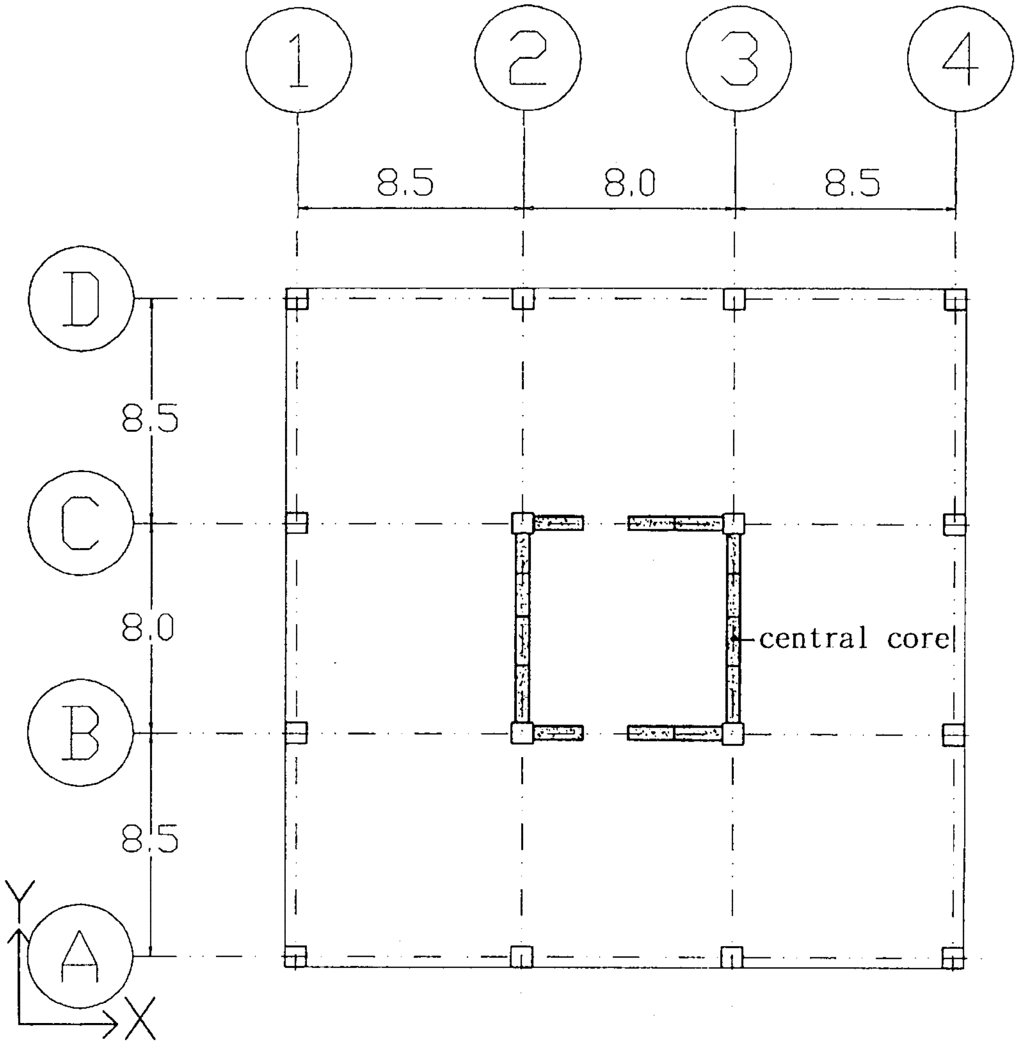


Fig. 4. Plan of Office Building unit:meters

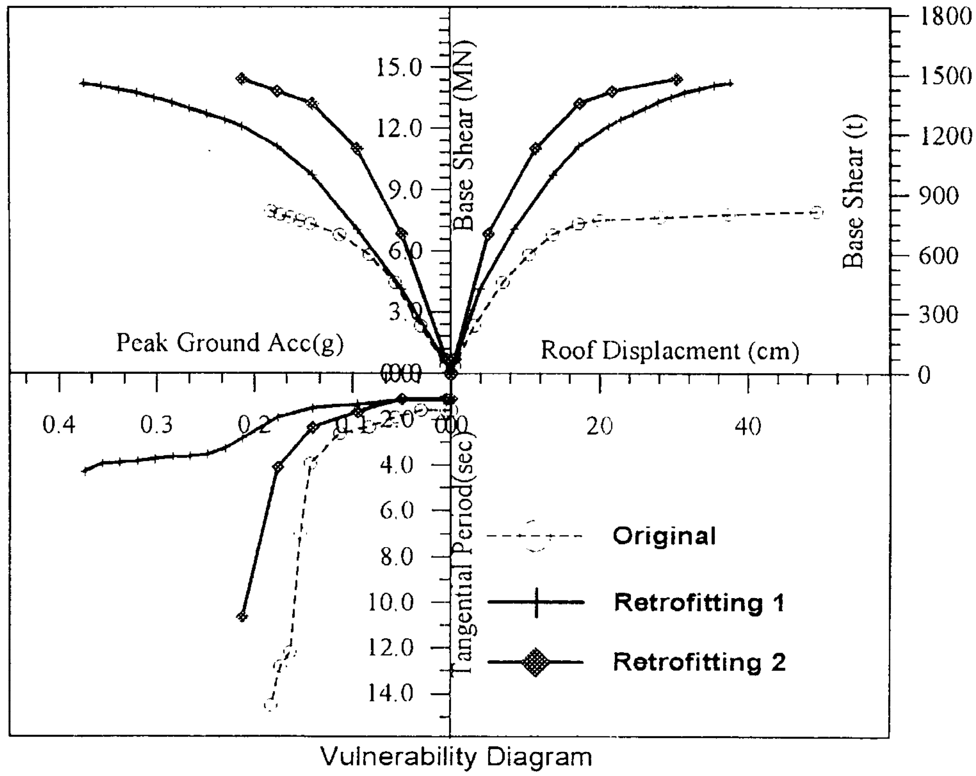


Fig. 5. Vulnerability Diagram under Earthquake