

**EXAMPLE 5-002**

**Nonlinear Seismic Response of Small Scale RC building**

**1. EXAMPLE DESCRIPTION**

Figure 1.a shows a layout of the experiment by Kazutaka et al [Ref. 1], in which a small scale reinforced concrete building is subjected to tri-axial shaking table test with the wave of JMA Kobe NS, EW, UD (1995) earthquake shown in Fig. 1.c. The mesh discretization of the building used in ELS is shown in Fig.1.d. Table 1 shows the dimension and the reinforcement details of all the structural component of the building.

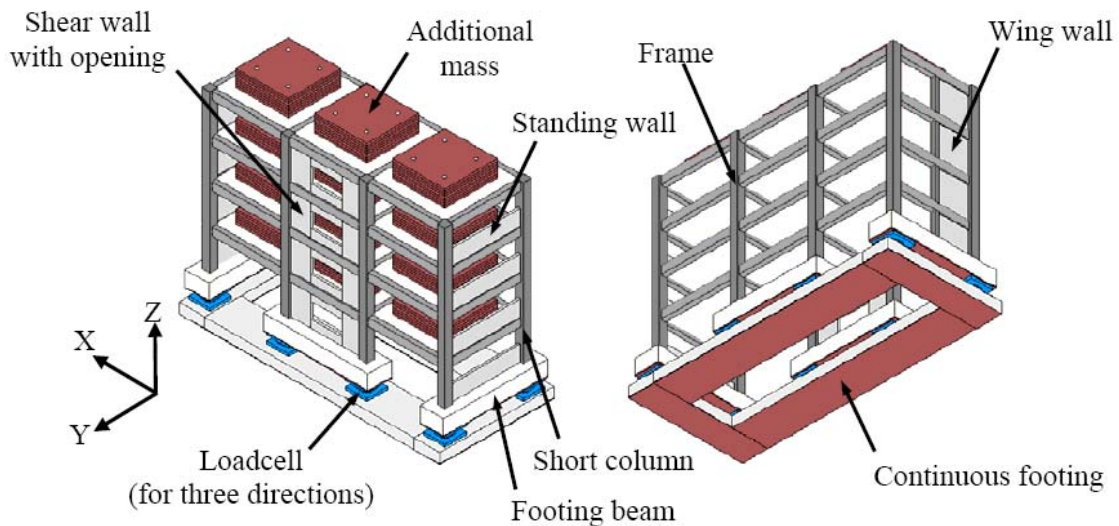
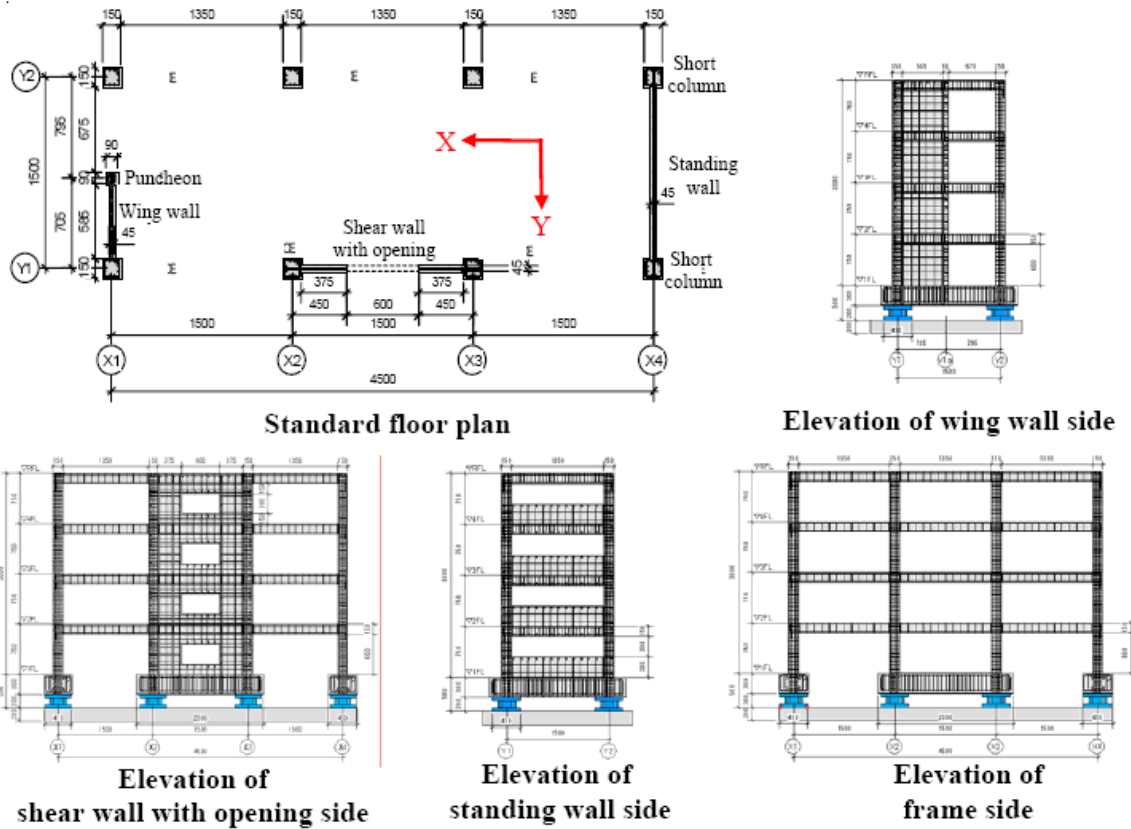


Fig. 1.a Problem layout



Dim. In mm

Fig. 1.b Problem geometry

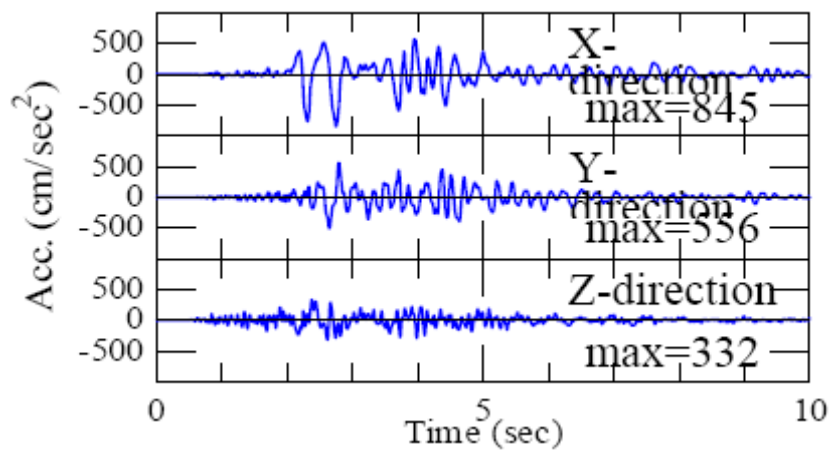


Fig. 1.c Wave used in the experiment

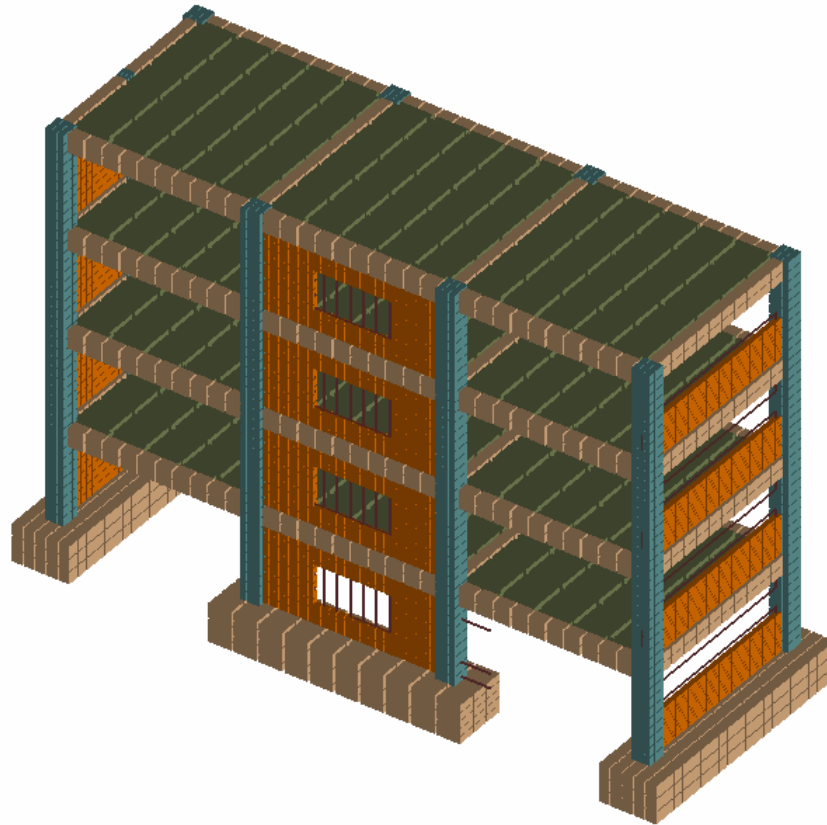


Fig. 1.d ELS mesh

Fig. 1 Experiment Layout and Details of Tested Specimen by Kazutaka et al. [Ref. 1]

**Table 1** Details of the specimens [Ref. 1]

Portion	Section (mm)	Arrangement of bar	
		Main bar, Slab, Wall	Hoop, Stirrup, Remarks
Column	150 x 150	12-D6 (pg=1.71%)	2-D4@60 (pw=0.29%)
Short column	150 x 150	ditto	2-D4@40 (pw=0.44%)
Puncheon	90 x 90	4-D6 (pg=1.58%)	2-D4@60 (pw=0.49%)
Girder (Y1, Y2 St.)	b90 x D150	Top 2-D6 (pt=0.54%) Bottom 2-D6 (pt=0.54%)	2-D4@110 (pw=0.27%)
Girder (X2, X3 St.)	b90 x D150	Top 3-D6 (pt=0.81%) Bottom 2-D6 (pt=0.54%)	ditto
Girder (X1, X4 St.)	b90 x D150	ditto	2-D4@55 (pw=0.53%)
Footing beam	b450 x D300	Top 6-D19 (pt=1.41%) Bottom 6-D19 (pt=1.41%)	4-D10@60 (pw=1.05%) PL9 is set up at the bottom
Slab	t80	D4@80 double	--
Shear wall with opening	t45	D4@110 single (ps=0.27%)	Opening w600 x h300 Reinforcement of opening: 1-D6 (horizontal and vertical)
Standing wall, Wing wall	t45	D4@110 single (ps=0.27%)	Standing wall : h300

## 2. MATERIAL PROPERTIES

The concrete compressive strength is 4.42 ksi (0.0305 kN/mm<sup>2</sup>), the yield stress of steel D4 RFT is 53.8 ksi (0.371 kN/mm<sup>2</sup>) while D6 RFT is 54.2 ksi (0.374 kN/mm<sup>2</sup>).

The applied element method follows a discrete crack approach, in which, the material is represented by a group of springs located at the surfaces of the element. The springs represent the axial and shear behavior of the material. For more details about material constitutive models refer to the ELS® technical manual.

## 3. RESULTS

Figure 2 shows a comparison between the observed experimental cracking pattern of the building and the principal strains obtained by the ELS. The principal strains represent a good, obvious representation of crack localizations. The experimental cracks are generally in a good agreement with the ELS results. Figures 3.a, 3.b show the displacement vs. shear base curve obtained from the analysis while Figs. 3.c, 3.d show the experimental displacement vs. shear base curve.

## 4. CONCLUSIONS

Based on the analytical and experimental results, it can be concluded that the ELS can successfully analyze and predict the nonlinear behavior of reinforced concrete structures under dynamic loading.

## 5. REFERENCES

1. Shira K., Kabeyasawa T., Katsumata H. and Kabeyasawa T. “Tri-axial Shaking Table Test on Reinforced Concrete building with Large Eccentricity” Proceedings of the First NEES/E-Defense Workshop on collapse simulation of reinforced concrete building structures 6-8 July 2005. Berkeley, California.
2. Technical Manual of Extreme Loading for Structures.

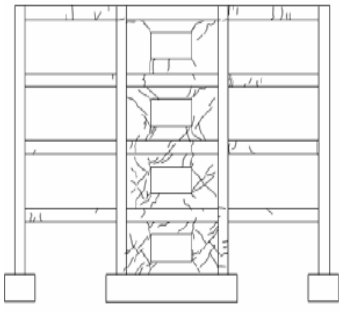
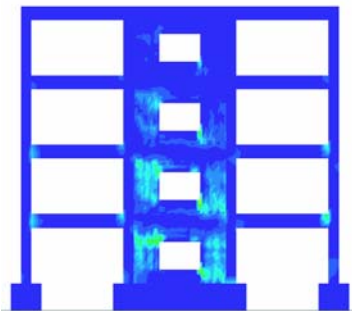
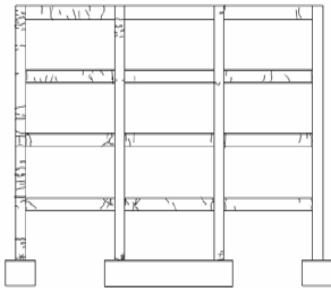
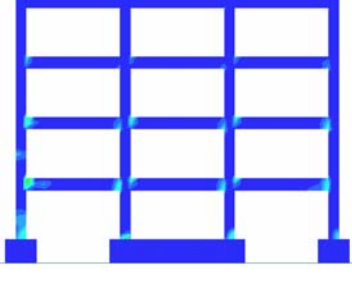
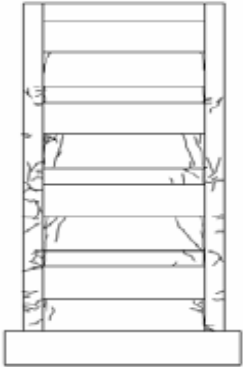
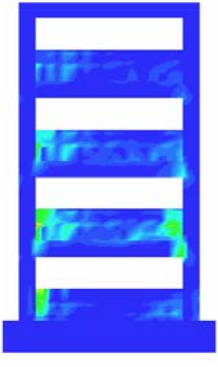
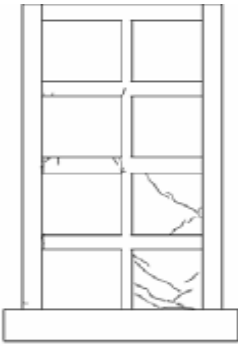
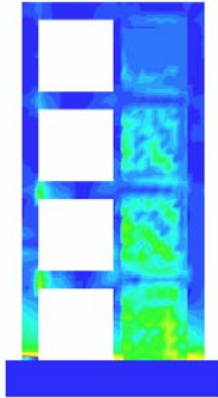
Wall Name	Experiment Results	ELS Results
Shear Wall with opening		
Frame Side		
Standing Wall		
Wing Wall		

Fig. 2 Comparison between the observed experimental cracking pattern of the building and the principal strains obtained by the ELS

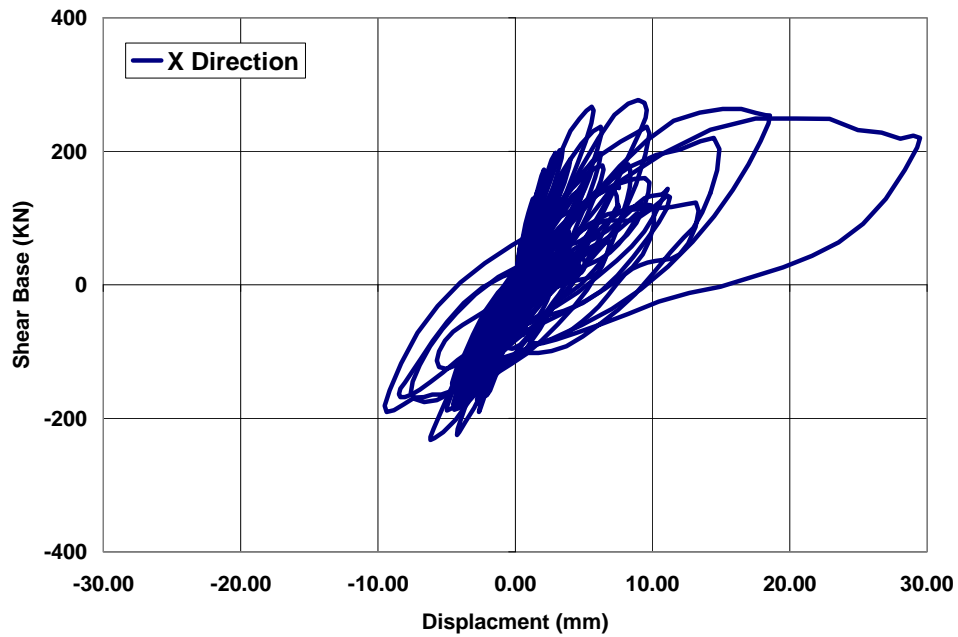


Fig. 3.a ELS displacement vs. Shear base in E-W direction

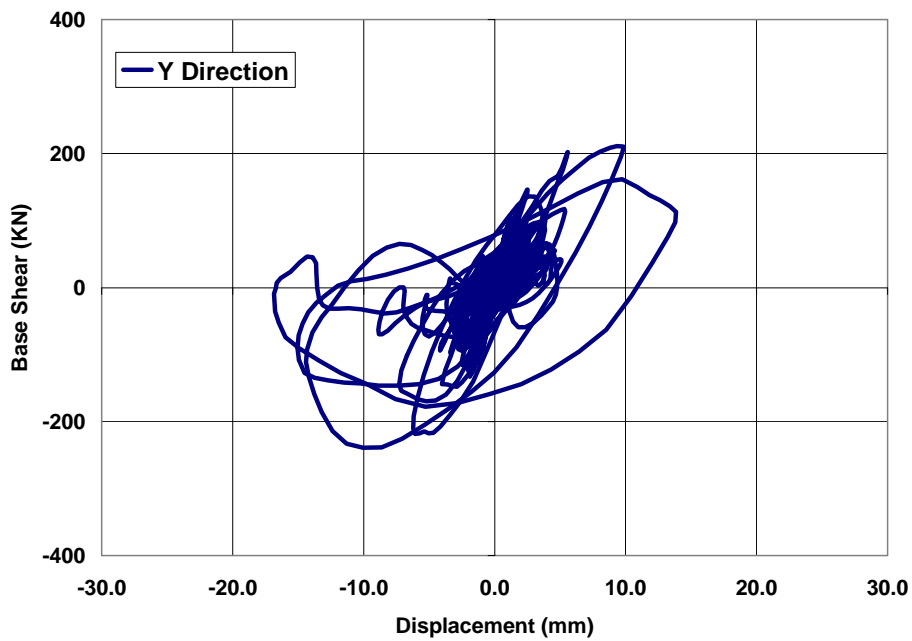


Fig. 3.b ELS displacement vs. Shear base in N-S direction

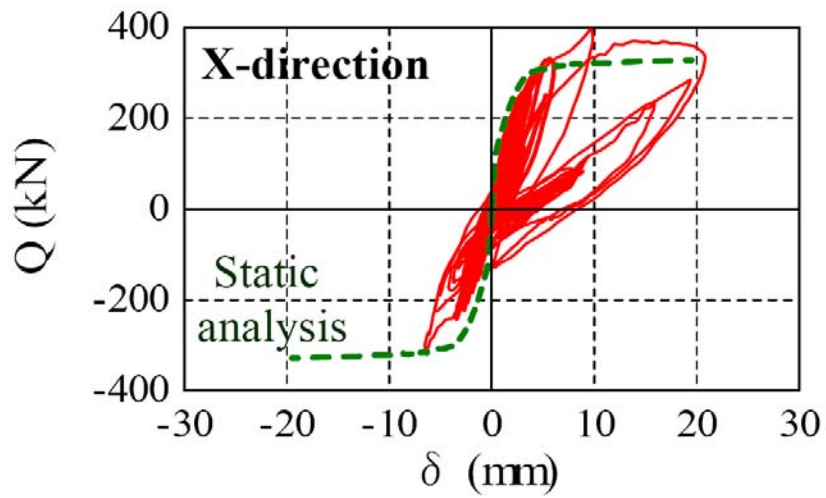


Fig. 3.c Experimental displacement vs. Shear base in E-W direction

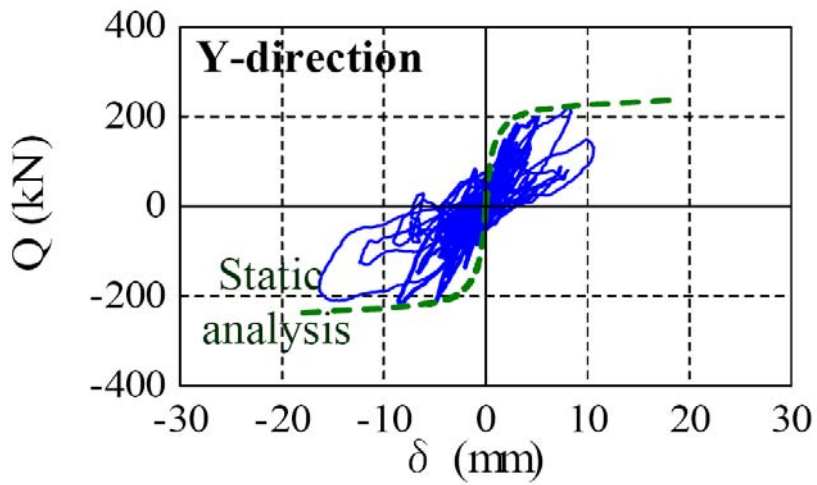


Fig. 3.d Experimental displacement vs. Shear base N-S direction