Dynamic Analysis of a Concrete Shear-Wall

Jaegyun Park¹, Chul-Hun Chung¹, Jang Seok Yi², and Byung-Moo Jin³

¹Professor, Dankook University
²Researcher, Hyundai Institute of Construction Technology Development
³Researcher, Daewoo Engineering & Construction

Keywords: IAEA CRP program, Dynamic analysis, Concrete shear wall, Shell element, Earthquake ground motion

1 ABSTRACT

Many structures built under the earthquake resistant design were severely damaged in Loma Prieta(1989), Northridge(1994), and Kobe(1995) earthquakes. Current design trend is to limit the maximum displacement under the load. To evaluate the effectiveness of the displacement control under the near-field ground motion due to earthquake, IAEA initiated CRP. In this paper, we try to regenerate the test results of the CRP using ABAQUS, a general purpose nonlinear FE program, and improve the previous results. The model of the concrete shear wall uses two dimensional shell element. A modal analysis on this model resulted in the 3 initial modes of the structure, which are close to that of real structure. To describe the response of the concrete structure more precisely, calibrations were made successfully.

2 INTRODUCTION

The Current trend of earthquake resistant design is performance based one which limits the maximum displacement under the load. To evaluate the effectiveness of the displacement control under the near-field ground motion due to earthquake, IAEA initiated the CRP(Co-ordinated Research Program). As a first step, they performed an analysis of a shear wall and compared the result with the shaking table test results(Hyun et al, 2005). In this paper, we use better concrete and rebar model to regenerate the test results using ABAQUS, a general purpose nonlinear FE program, and calibrate the model.

3 TEST SETUP

The original test specimen is explained in IAEA(2004). The 1/3rd scaled model to be studied is composed of two parallel 5-floor R/C walls without opening (Fig. 1) linked by 6 square floors. The shear wall is firmly anchored to the shaking table. The dimensions of the different parts are the following ones:

- Wall :
  Length = 1.70m
  Thickness = 6.00 cm (theoretical)
  Height = 0.90 m (by storey)

- Floor :
  Length = 1.70 m
  Width = 1.70 m
  Thickness = 0.21 m

- Footing:
  Length = 2.10m
  Height = 0.60 m
  Thickness = 0.10 m

The total height of the model is 5.10 m.

The walls are loaded in their own plane. The stiffness and the strength in the perpendicular direction are increased by adding some lateral triangular bracing. This system has reduced the risk of failure which might be induced by some parasite transversal motion or a non-symmetric failure of the structural walls. Lateral bracing is such that the two walls carry all the vertical loads.
The characteristic of concrete and rebar are listed in table 1. The configuration of the rebar is shown in Fig. 2.

Table 1. Material Properties of the Shear Wall

<table>
<thead>
<tr>
<th></th>
<th>Concrete</th>
<th>Steel Rebar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength(MPa)</td>
<td>35</td>
<td>500</td>
</tr>
<tr>
<td>Young’s Modulus(MPa)</td>
<td>28000</td>
<td>200000</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.15</td>
<td>0.3</td>
</tr>
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</table>
4 FINITE ELEMENT MODEL

Due to the symmetry of the specimen and the load direction, all the response exists in a two dimensional plane. This condition enables us to define a two dimensional model (Fig. 3). The shaking table is modeled as a rigid body and supported by three linear springs.

\[ K_r = 400 \text{ MN/m} \]

\[
\begin{array}{c}
\text{AZ0T1} \\
\text{Actuator} \\
\text{AZ0T2}
\end{array}
\]

\[
\begin{array}{c}
3.53 \text{ m} \\
3 \text{ m} \\
0.39 \text{ m} \\
1.02 \text{ m}
\end{array}
\]

\[ K_r, 2K_r, K_r \]

**Figure 3.** Two dimensional model of the Shaking table and Shear wall

Two dimensional shell elements (4 nodes) are used to describe the main concrete structure as illustrated in Fig. 4. Main concrete structure is modeled as a linear elastic-plastic material with several plasticity models (Lee, J. and Fenves, G. L., 1998; Lubliner et al, 1989). This paper presents results using Drucker-Prager (Kang, 2005; Lubliner, 2008) model plasticity.

**Figure 4.** Shell element

**Figure 5.** Finite element rebar distribution

The steel rebar is modeled by the ‘REBAR LAYER’ option of ABAQUS and perform as a linear elastic perfect plastic material. The exact amounts of steel are distributed as shown in Fig. 5 (red color). All the masses (including concrete mass and steel bracing) of shear wall are distributed on each floor as shown in Fig. 6 (red color), which are implemented by mass element of ABAQUS.
Figure 6. Mass element

Shaking table consists of 4 node shell elements with rigid material in Fig. 7. The boundary spring was installed in the vertical direction (Fig. 8) using 2 node truss element. The shaking table is fixed to the ground in the horizontal direction.

Figure 7. Shaking table modelling

Figure 8. Spring modelling

5  ANALYSIS RESULT

In this paper, we include two analysis results. The first one is the elastic modal analysis to detect initial several modes (Table 2). This analysis result is in good agreement with the original test (IAEA, 2004), considering the simplification of the finite element model and no calibration is needed. However, the overall values of the mode frequency are slightly higher than those of the test result.

The first mode is a bending mode with fixed shaking table(Fig. 9a). The second mode is a vertical mode(Fig. 9b) and the third mode is the second bending mode with the rotation of the shaking table(Fig. 9c).
Table 2. First three modes of the shear wall

<table>
<thead>
<tr>
<th></th>
<th>IAEA report(Hz)</th>
<th>This analysis(Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODE 1</td>
<td>7.24</td>
<td>7.7139</td>
</tr>
<tr>
<td>MODE 2</td>
<td>20</td>
<td>24.979</td>
</tr>
<tr>
<td>MODE 3</td>
<td>33</td>
<td>33.194</td>
</tr>
</tbody>
</table>

Figure 9a. First mode  
Figure 9b. Second mode  
Figure 9c. Third mode

Following is the time history analysis. We used the “Nice” input motion, which is an artificial ground motion. The shape of its response spectrum fits the response spectrum applicable to the Nice city, according to the French regulation. It is representative of a far field input motion (Fig. 10). Fig. 11 and Fig. 12 presents top displacement and top acceleration with the original experiment result.
Figure 10. Nice input ground acceleration

Figure 11. Shear wall relative top displacement

Figure 12. Shear wall top acceleration
6 CONCLUSION

In this paper, we modelled a concrete shear wall systematically. Due to the complexity of the material behaviour of concrete after yielding, this kind of analysis always includes many uncertainties. As expected, elastic behaviour of the shear wall is well predicted via mode detection. The time history analysis shows that this model also well predicted the plastic behaviour considering its maximum responses. However, more analyses are necessary to express the effect of concrete damage, which is a crucial part in the modelling of a concrete structure.

REFERENCES


IAEA, 2004, IAEA-NFE Camus Benchmark - experimental results and specifications to the participants.


