# 연결보가 있는 벽식 구조물의 내진성능 평가

## Evaluation of Seismic Performance of Bearing Wall Structure with Coupling Beam


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ABSTRACT

Coupling beams have been used in bearing wall system during last decades. Practically their sectional effects are fully considered in analysis stage to control lateral displacement because they have good contribution to the stiffness of bearing wall system. But the high resultant forces of coupling beam are not fully satisfied in design stage because coupling beams are restricted in sectional size. In this paper the performance of bearing wall system with coupling beam has been evaluated based on improved equivalent linearization procedure of FEMA 440. 15 storied building is selected for analysis. Variables for performance evaluation are natural period, degree of coupling and soil site. To evaluate performance, demand capacity spectrum is calculated based on KBC 2005. As a result, for the most of the cases the life safety limit of chord rotation of coupling beam is less than the performance point of system for soil site $S_{D.}$ That means that the coupling beam can be severly damaged before the system reaches at performance point.

요 약

내력벽시스템에 사용되는 연결보는 횡변위 조절을 위하여 효과적으로 사용되는 요소이나, 단면의 폭과 춤이 시스템에 의하여 제한되므로 연성능력을 향상시키기 위한 철근의 상세처리가 어렵다. 이러한 이유로 지진에 의하여 횡력이 발생할 경우 가장 먼저 연결보에 손상이 발생하게 될 것이므로, 본 연구에서는 연결보가 있는 내력벽 시스템의 성능을 평가하고자 하였다. 이러한 성능평가는 FEMA 400의 수정된 등가 선형의 절차에 의하여 수행되었다. 평가를 위한 모델은 15층이고 연결보의 강성은 변동이 없으며 질량을 변화하여 구조물의 주기를 변화하였다. 요구 스펙트럼 산정은 KBC 2005의 계수를 곱하지 않은 스펙트럼을 사용하였다. 성능 평가 결과로서, 토질 $S_D$에 대하여 대부분의 모델에서 인명안전 수준에서 검토된 연결보의 제한 변위가 성능점 보다 작게 나타났다. 전반적으로 시스템의 주기가 짧아질수록 연결보의 손상도에 의하여 성능점이 감소되는 현상을 나타내었다.



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## 1. Introduction

Performance-based design is a widely used analytical approach nowadays.[1] For both safety and economy considerations, it is reasonable for a building to reach performance points. Reinforced concrete(RC) structural shear walls with coupling beams have been recognized as effective lateral force resisting systems[2].

Practically, full section of coupling beam is considered in analysis stage to control lateral displacement, since they have good contribution to the stiffness of bearing wall structures. But the high resultant forces on the coupling beam can not be fully met in design stage because the sizes of coupling beams are restricted. Also coupling beams have conventional longitudinal reinforcement with nonconforming transverse reinforcement. Hence, coupling beams can be damaged easily in case of lateral displacement.

In this paper, nonlinear static procedure is used to analyze a 15-story shear wall building with coupling beams. The main objective is to check the performance conditions of models under different parameters, such as the axial load ratio of walls and degree of coupling (DOC) of the system. Performance evaluations[3]are executed based on improved equivalent linearization procedure of FEMA 440 as a modification to the Capacity-Spectrum Method(CSM) of ATC-40.

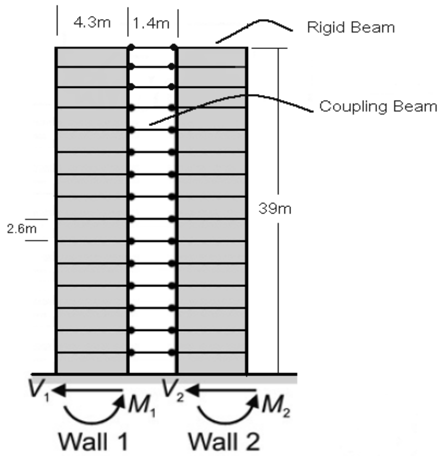


Fig.1 Geometry of Building

Table 1. Model description and performance points of model for Soil Site Sc and Sd

| Type | Reinforce-ment Ratio | Mass (tonf) | Natural Period (sec) | Sd(m) | |
|---|---|---|---|---|---|
| | | | | for Sc | for Sd |
| A30-0 | 0.20% | 87 | 1.77 | 0.100 | 0.145 |
| | 0.85% | 87 | 1.77 | 0.082 | 0.156 |
| A30-2 | 0.20% | 127 | 1.19 | 0.066 | 0.107 |
| | 0.85% | 127 | 1.19 | 0.066 | 0.097 |
| A30-4 | 0.20% | 87 | 0.98 | 0.056 | 0.079 |
| | 0.85% | 87 | 0.98 | 0.061 | 0.080 |
| A30-5 | 0.20% | 57.4 | 0.8 | 0.044 | 0.060 |
| | 0.85% | 57.4 | 0.8 | 0.043 | 0.061 |

## 2. Building Models

As shown in Fig. 1, the analytical model is of 15 stories, with walls located at two sides, linked by coupling beams. Thickness of walls is 0.2m and length is 4.3m. Strength of concrete and reinforcement is fck=20MPa and fy=400MPa, respectively.

Five cases of models are considered with different axial load ratios but nearly the same DOC of 0.634. Detailed differences of five models are shown in Table 1. Model A30-0 is a case that the ends of coupling beams are hinges, while other models have no hinges. By varying mass, the natural period is changed from 08 to 1.77 sec.

Different values of vertical reinforcement ratio of shear wall is considered in this study, as also stated in Table 1, which are 0.2% and 0.85%.

Beams are all of the same cross section dimensions, with the width 0.2m and height 0.4m, and spacing of closed stirrups over the entire length of coupling beams is 250mm. According to FEMA 356[(4)], for a coupling beam with closed stirrups spacing greater than d/3, it is treated as conventional longitudinal reinforcement with noncomforming transverse reinforcement. In this study, all the models are of nonconforming cases of transverse reinforcement, as 250mm > d/3=133.3mm.

## 3. Analysis

For numerical modeling, beam elements are used to simulate the behavior of walls. Rigid beams are used to connect the walls and coupling beams, as shown in Fig. 1. RUAUMOKO program is used for the nonlinear static procedures.

Specific ductilities of elements are required, for both walls and beams. In this research, the calculation of ductility is referred to Table 6-18 and 6-19 of FEMA-356. In these two tables, for cases under different values of axial load ratios and shear ratios, plastic hinge rotation and performance levels are defined, in which plastic hinge rotation is used to calculate the ductilities of elements.

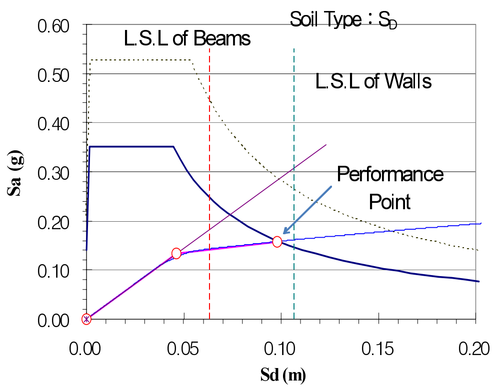


Fig2. Performance point of A30C5

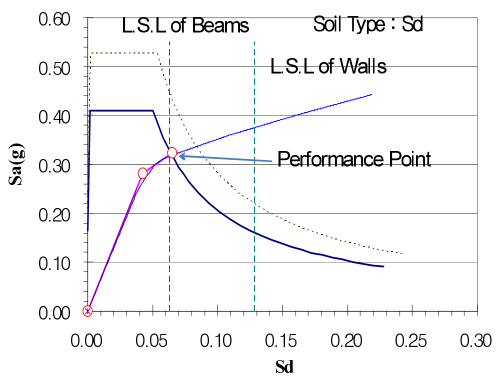


Fig3. Performance point of A30C5

## 4. Performance Evaluation

Performance evaluations[(5)] are executed based on improved equivalent linearization procedure as a modification to the Capacity-Spectrum Method(CSM) of ATC-40. Direct iteration procedure is done to converge directly on a performance point. The demand spectrum curve is estimated by reducing the standard elastic 5% damped design spectrum of KCI 2005 by the spectral reduction method. The capacity curve could be obtained through the pushover analysis as in chapter 3.

The ADRS demanded spectra generated for various values of effective damping are modified to intersect the capacity spectrum. Intersection points are performance points which are compared to the allowable Life-Safety drift limit of walls and coupling beams. If the drift limit is less than performance point value, the drift capacity should be reduced to Life Safety limit.

According to FEMA 356, Life Safety (LS) limit and Collapse Prevention (CP) limit are used to check if performance points are reached. For flexural controlled wall element, the LS and CP acceptable plastic hinge rotations are 0.002 and 0.003 radians, respectively, as primary elements.

For shear controlled coupling beam elements, the LS and CP acceptable chord rotations are 0.007 and 0.012 radians, respectively, as secondary elements.

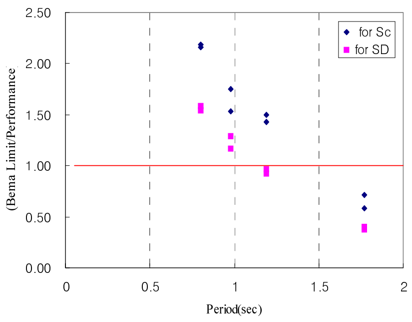


Fig4. Performance Condition of LS

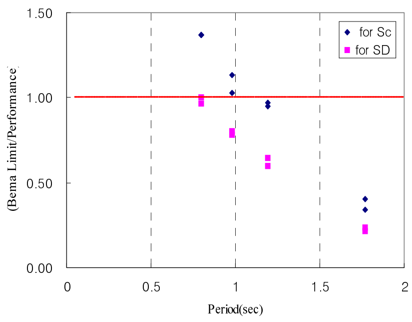


Fig5. Performance Condition of CP

## 5. Conclusion

In Table 1, the value of performance are listed. The limit of spectral displacement corresponding to beam chord rotation is calculated and divided by the performance value for each model in table 1 and plotted for periods as in Fig. 4 and 5. Fig. 4 is the case that the beam limit is calculated for LS level. Except for period 1.77, the performance capacity of all models is limited by limit of beam rotation. That means the coupling beams are damaged severely before reaching the performance point.

Also in Fig. 5, the case that the beam limit is calculated for CP level is described. Except period 0.88 and 0.98, the performance capacity of all models is not limited by limitation of beam rotation. From these figures, as period of bearing wall system with coupling beam is shorter, the performance is limited because of the damage of coupling beams.

## 감사의 글

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