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Assessment of Earthquake Behavior of Reinforced Concrete Buildings with Slab Discontinuity

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Abstract

The most important principle of the earthquake-resistant design of reinforced concrete structures is that the structural elements must carry both vertical loads and horizontal loads as a whole. For this reason, it is required that the structural elements carry their own weight with sufficient safety and the loads arose from external forces must be transferred safely to the load carrying vertical elements. However, discontinuity of the slabs disturbs the integrity of the structures and causes problems in transferring earthquake loads to the structural elements. In this study, the effect of slab discontinuity in plan on seismic behaviors of multi - storey reinforced concrete structures was investigated by using incremental linear dynamic analysis method. To investigate this irregularity situation, one regular and three irregular multi-storey reinforced concrete building models were selected. Dynamic envelopes of the structures were obtained from the analysis results and compared with each other. Thus, it was observed that the irregular structures subjected to more shear force than the regular structure.

Keywords: Reinforced concrete building, Slab discontinity, Incremental linear dynamic analysis

Döşeme Süreksizliğine Sahip Betonarme Binaların Deprem Davranışlarının Değerlendirilmesi

Özet

Betonarme yapıların depreme dayanıklı tasarımının en önemli ilkesi yapıyı oluşturan taşıyıcı elemanların hem düşey yükleri hem de yatay yükleri bütün bir eleman olarak taşımasıdır. Bu nedenle yapısal elemanlardan kendi ağırlıklarını yeterli güvenlikle taşıması, dış kuvvetlerden gelen yükleri taşıyıcı elemanlara güvenli bir şekilde aktarması istenmektedir. Ancak yapıların bütünlüğünü bozan döşeme süreksizlikleri, deprem yüklerinin taşıyıcı elemanlara aktarılmasında sorunlara neden olmaktadır. Bu çalışmada planda döşeme süreksizliğinin sahip çok katlı betonarme yapıların deprem davranışına etkisi artımsal dinamik analiz yöntemiyle incelenmiştir. Bu düzensizlik durumunun incelenmesi için biri düzenli diğerleri düzensiz olmak üzere toplam altı adet çok katlı betonarme yapı modeli seçilmiştir. Analiz sonuçlarından yapıların dinamik itme zarfları elde edilmiştir. Yapılan değerlendirme sonucunda döşeme süreksizliğine sahip yapıların düzenli yapıya göre daha fazla kesme kuvvetine maruz kaldığı görülmüştür.

Anahtar Kelimeler: Betonarme yapı, Döşeme süreksizliği, Artımsal lineer dinamik analiz

1. Introduction

The earthquake effect is a natural catastrophe that has caused massive devastation on people and the environment. But the main reason of the losses in the earthquakes is that the structures not provided the desired earthquake behavior. While designing the building systems, it is aimed that the buildings resist the earthquake forces at least must be provide life safety level. To provide this performance level, the structure has symmetrical and regular load carrying system. Regular structures; both in practice and in dimensioning, provide simple the calculation and forces are calculated accurately. For this reason, regular construction is the most practical choice for a good design.

Lateral forces are transmitted to the vertical load carrying elements by slabs. It is assumed that the slab behaviors as a rigid diaphragm during the design of structure. But the large openings in the slab invalids rigid diaphragm assumption [1-4]. So, Turkish Seismic Code (TSC-2007) [5] requires some requirements about this irregularity. These requirements are shown in Fig.1. According to code, In any floor

a) The case where the total area of the openings including those of stairs and elevator shafts exceeds 1/3 of the gross floor area,

b) The case where local floor openings which make the safe transfer of seismic loads difficult to vertical structural elements,

c) The cases of abrupt reductions in the in-plane stiffness and strength of floors.

$$A_b = A_{b1} + A_{b2}$$

$$\frac{A_b}{A} > \frac{1}{3}$$

where

A_b shows sum of the openings and A shows gross floor area, respectively.

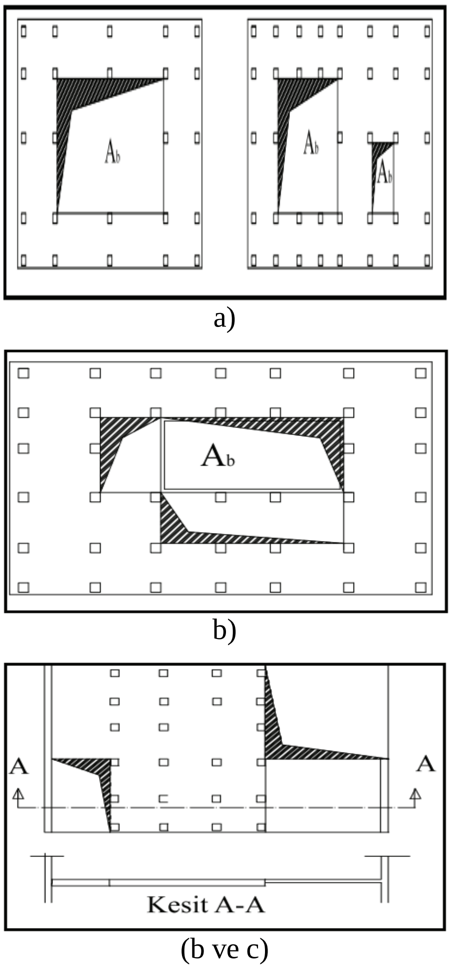


Figure 1. Slab discontinuity situations defined in TSC

To investigate this irregularity situation, one regular and three irregular multi-storey reinforced concrete building models were selected. Incremental linear dynamic analyses were performed and dynamic envelopes of the structures were obtained from the analysis results. In dynamic analysis, elastic diaphragm assumption was made.

2. Material and Methods

Numerical study

A. Selected Building Models

For dynamic analyses three 3D irregular and a regular building models were selected. These models have five stories and height of stories are 3.50 m. The dimensions for columns were selected as 50x50 cm, and dimensions for beams were selected as 30x60 cm. Slab thickness was selected as 13 cm. It was assumed that, the building importance coefficient is 1.0 and, concrete class is C25 and reinforcement steel class is S420. Selected models and rates of slab openings are illustrated in Figs.2-5. In this models, first and end bays are 500 cm and the middle bays are 450 cm in x direction. For y direction first and end bays are 600 cm, the other bays are 500 cm. The dynamic analyses are performed by SAP2000 structural analysis program [6]

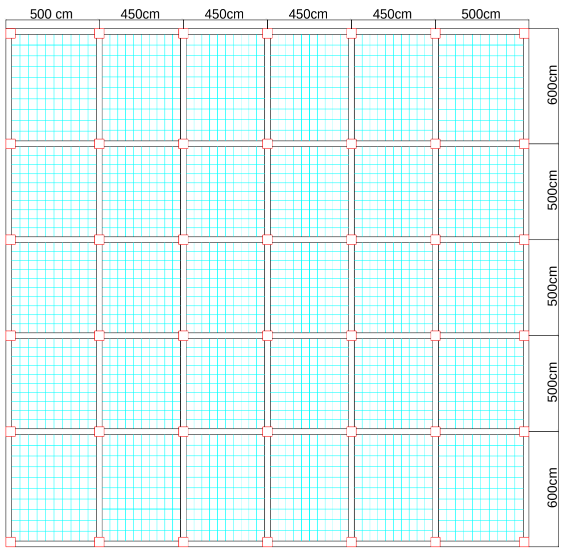


Figure 2. Regular model

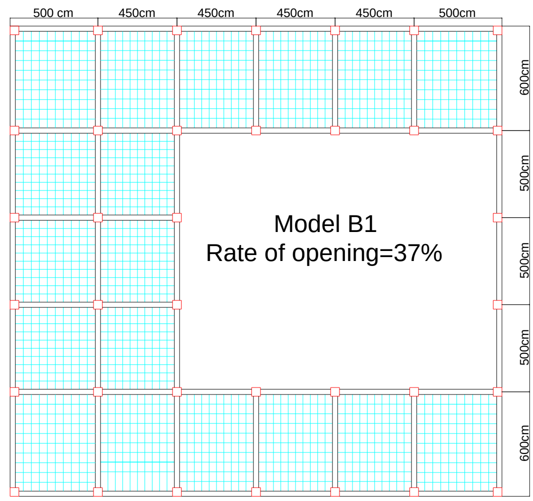


Figure 3. B1 irregular model

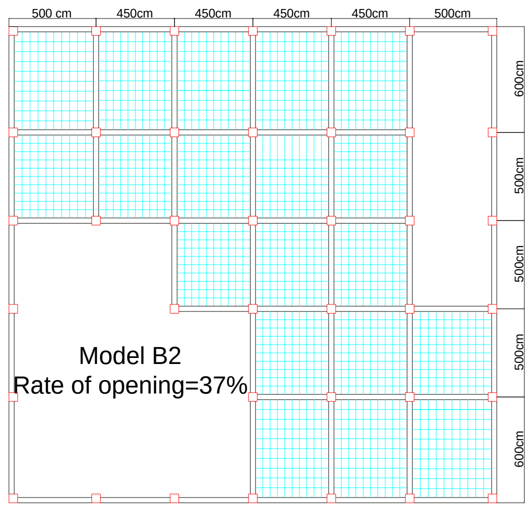


Figure 4. B2 irregular model

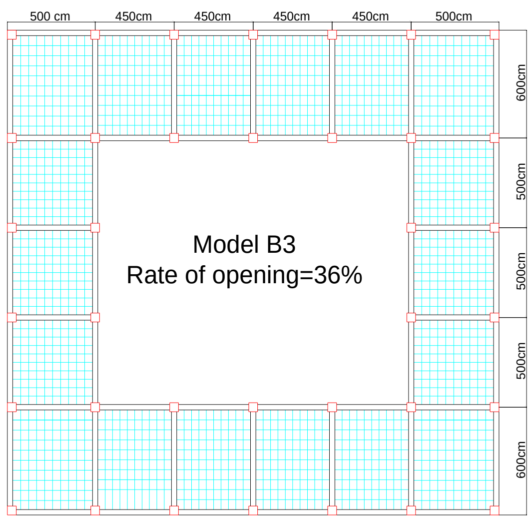


Figure 5. B 3 irregular model

B. Earthquake Parameters and Local Site Conditions

Table 1 shows selected earthquake accelerations properties used in dynamic analysis. The seismic records have been selected from the PEER Strong Motion Database [7] and scaled in order to be compatible with the design spectrum according to seismic zones and local site conditions in TSC. Soil classes (from Z1 to Z4) are characterized in term of periods T_A and T_B. The design spectrums are given according to local site classes in *Fig.* 6.

Table 1. Selected earthquake acceleration records for dynamic analysis

Eartquakes	Kocaeli	Loma Prieta	İmperial Valley
Station	Sakarya	Corralitos	El Centro Array
Direction	North-South	East-West	East-West
Date	August 17, 1999	October 18, 1989	May 19, 1940
Magnitude	7.4	6.9	7.0
PGA(g)	0.376	0.644	0.313

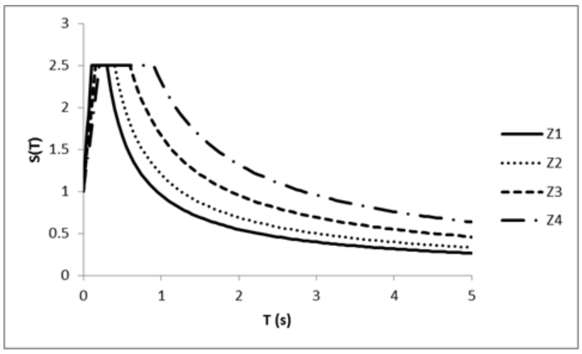
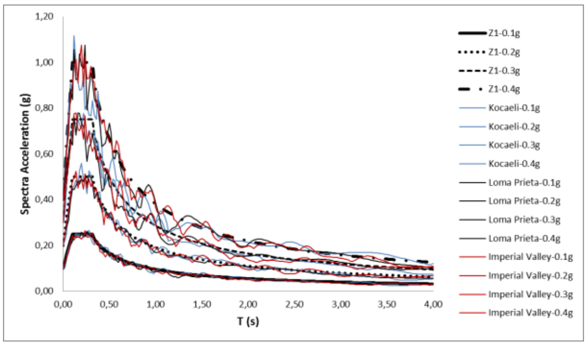
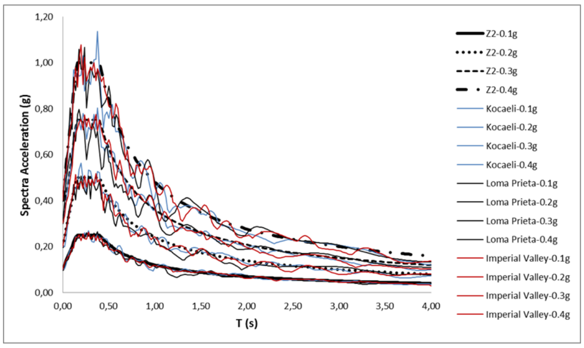


Figure 6. Recommended elastic response spectra for ground types Z1 to Z4 (for 5% damping)

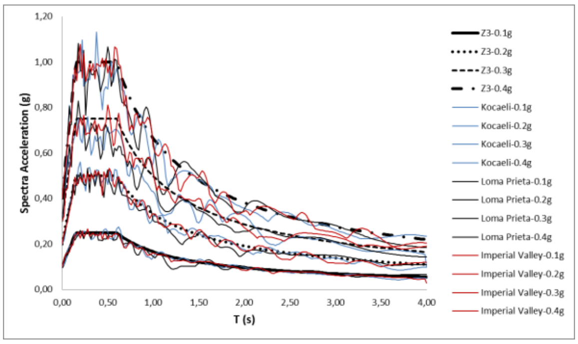
Selected earthquake records were scaled in frequency content in order to be compatible with the target design spectrum of four effective ground accelerations and different soil classes (Fig. 7a-d). The records were scaled using SeismoArtif and SeismoSignal programs.



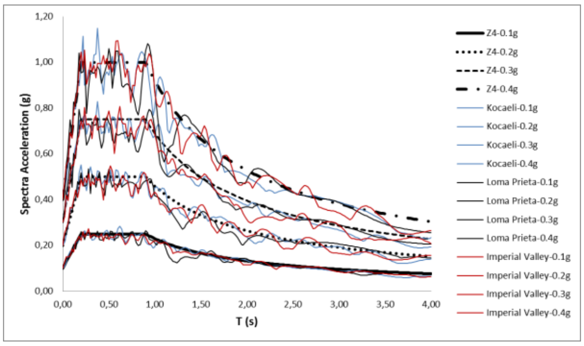
a) Response spectra of the earthquake acceleration records scaled according to the elastic design spectrum for Z1 soil class and effective ground accelerations



b) Response spectra of the earthquake acceleration records scaled according to the elastic design spectrum for Z2 soil class and effective ground accelerations



c) Response spectra of the earthquake acceleration records scaled according to the elastic design spectrum for Z3 soil class and effective ground accelerations



d) Response spectra of the earthquake acceleration records scaled according to the elastic design spectrum for Z4 soil class and effective ground accelerations

Figure 7. Response spectra of the earthquake acceleration records scaled according to the elastic design spectrum for four soil classes and effective ground accelerations defined in TSC

3. Results

Maximum responses of the incremental dynamic time history analyses are given in Figs. 8-10 for the x direction and Figs. 11-13 for the y direction. Dynamic envelopes are obtained according to these responses. Each irregular models are compared with regular building. According to these figures, the correlation coefficient values, are exceed 0.90 for x direction. Also, it is seen that dynamic envelopes of each irregular building models exceed the dynamic envelope of regular building. This situation is a evidence of the irregularity causes more shear forces.

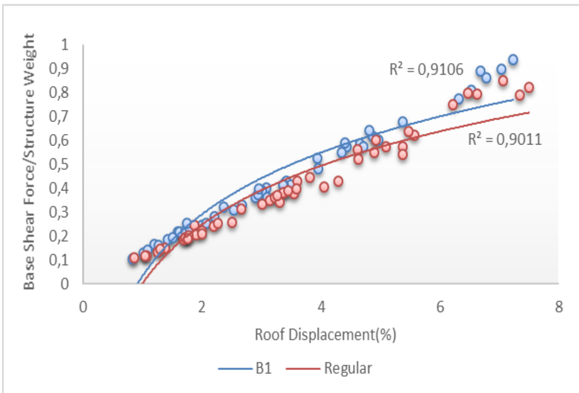


Figure 8. Comparision of dynamic envelopes of B1 irregular model and Regular model for x direction

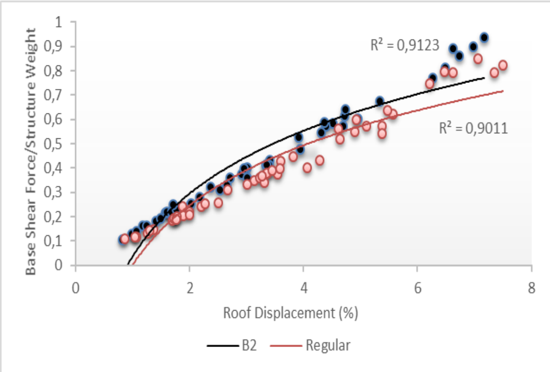


Figure 9. Comparision of dynamic envelopes of B2 irregular model and Regular model for x direction

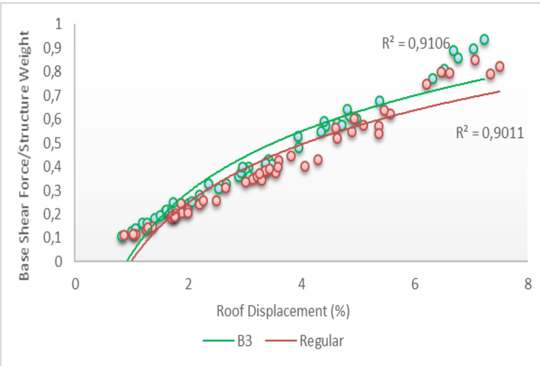


Figure 10. Comparision of dynamic envelopes of B3 irregular model and Regular model for x direction

According to Figs.11-13, the correlation coefficient values are approximately 0.90 for regular building and for the other coefficient exceed the 0.90 for y direction. Seismic actions obtained from the scaled earthquakes follow the same trend and shape to that of the dynamic envelopes, similar to that in the x direction.

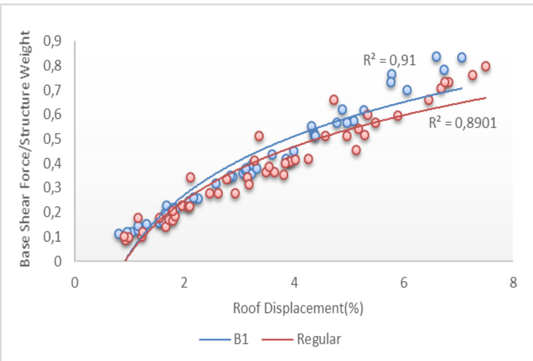


Figure 11. Comparision of dynamic envelopes of B1 irregular model and Regular model for y direction

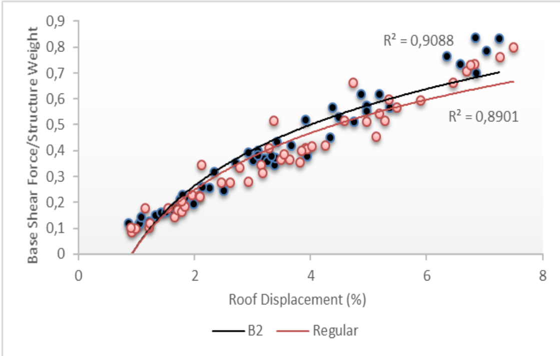


Figure 12. Comparision of dynamic envelopes of B2 irregular model and Regular model for y direction

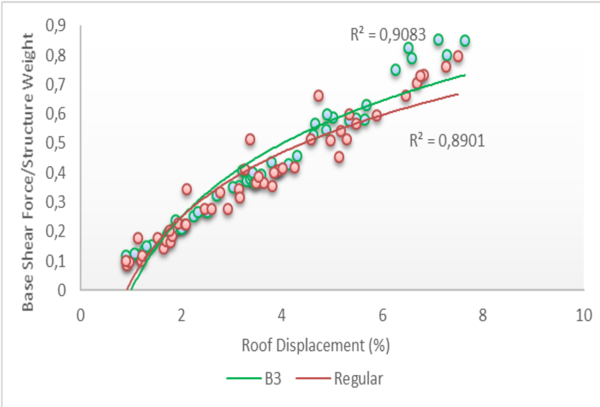


Figure 13. Comparision of dynamic envelopes of B3 irregular model and Regular model for y direction

4. Discussion

In this paper, the effect of slab discontinuity in plan on seismic behaviors of multi-storey reinforced concrete structures was investigated by using incremental dynamic analysis method. To investigate this irregularity situation, one regular and three irregular multi-storey reinforced concrete building models were selected. Dynamic envelopes of the structures were obtained from the analysis results.

According to analysis results, dynamic envelopes obtained from each irregular building models exceed the dynamic envelope of regular building for x and y directions This situation shows that this type of irregularity causes more shear forces. So, it is should be abstain from the application of this irregularity.

5. References

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