

Evaluation of the effect of shear wall with and without opening on the ductility of RC structures

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ABSTRACT

The ductility of a structure is an important factor that should be taken under consideration in the design against lateral loads like an earthquake. This paper presents the effect of the shear wall on the ductility of the structure and the effects of the presence of opening in it on the ductility. Eighteen 2D moment-resisting frames (MRFs), with the shear wall (SW) and SW with opening structural models, were created and designed. The pushover analyses using ETABS 19 software were performed on the designed models to calculate the ductility of the structural models. The obtained results show that the shear wall in the models increases the ductility of the structures significantly, while the presence of an opening decreases it slightly. Besides, the increase in the number of storeys increases the ductility of MRF models but decreases the ones with SW. Oppositely; the increase in span length reduced the ductility of MRF models and increases the ductility of the models with SW.

1. INTRODUCTION

Lateral loads like the earthquake that happens suddenly are critical and dangerous to the buildings therefore the behaviour of the structure during an earthquake must be investigated thoughtfully considering a lot of aspects and parameters. The ductility of the structure is one of the most important aspects that must be focused on during the design. Where the collapse mechanism of a brittle structure is very dangerous and result in a high number of casualties. on the other hand, ductile buildings go through long deformation before collabs. This deformation increases the structural capacity and it is very important to alarm the residences and give them a chance to escape. Regarding that, a lot of specified details and factors can be applied in design to increase its ductility as the special moment-resisting frame (SMRF) which can include the span length, storey height, P-Delta effect and steel reinforcements. Pérez et al. (2015) in their paper studied some of these factors and concluded that “the ductility is strongly influenced by the length of the span”. Hashemi et al. (2018) in their paper gave a full analysis of the ductility factor for bubble deck system with different parameters including the number of storeys and span length. Kang et al. (2009) in their paper made a wide study about ductility factor with a lot of

parameters including soil profiles, failure mechanisms, seismic zones, number of storeys. Sarhan and Raslan (2020) stated that the ductility of the structure is directly related to the occurrence of plastic hinges in the structure.

The nonlinear static analysis (pushover) is a useful analysis that can predict the failure mechanism of the structure, and the nonlinear behaviour of under letteral loads. Also, detect the location and occurrence of any plastic hinges in advance by gradually pushing the structural system until its complete collapse. Pushover analysis estimates the capacity of the structure and produces the pushover curve that can be used to calculate the ductility of the structure.

$$R\mu = \frac{\Delta u}{\Delta y} \quad (1)$$

where:

$R\mu$: The ductility of a structure,

Δu : Failure displacement,

Δy : Yield displacement.

Fig. 1 The ductility factor R_{μ} is defined according to Committee Euro-International Du Beton (1996) and ASCE 7-16 (2017) as the ratio between failure displacements Δu to yield displacements Δy .

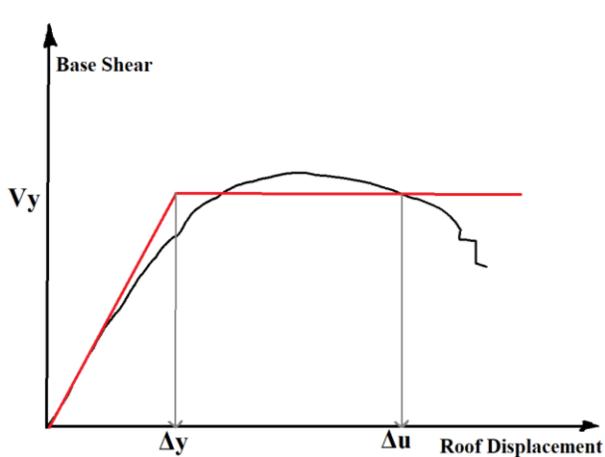


Fig. 1. Base shear vs roof displacement pushover curve

Response reduction factor R is an important factor influenced by the ductility factor of the structure, and it “incorporate indeterminacy and ductility capacity of lateral bearing systems” (Baradaran et al., 2019). Besides, “The response modification factor R plays a vital role in the non-linear response of a structure” (Nishanth, 2015). However, this factor was fixed for each type of structure in the building codes as this paper takes the R -value of the models from the American code ASCE 7-16.

The basic structural systems can be classified into the moment-resisting frame (MRF), Shear wall (SW) system and dule system (SW-MRF) which composed of both shear wall and moment frame where “Coupling two resisting systems allows overcoming structural deficiencies of single resisting systems and takes advantage of synergy besides being versatile and allow architectural flexibility” (Zerbin et al., 2020). Also, a special moment-resisting frame (SMRF) is a frame that was especially detailed to have a high ductility therefore it was used in the models to ensure ductile behaviour. Those specified structural details can include the sizes of columns and beams which plays a very important role in the ductility of structure, where it is one of the SMRF requirements in many building codes to have weak beams and strong columns (ACI 318-19, 2019). In order to let the plastic hinges forms in the beams while the columns remain intact because the columns failures will result in brittle collapse. Tawfik et al. (2013) verified that having equal beam-column dimensions will results in the formation of plastic hinges in the column, and having a stiff column result in forming plastic hinges in the beams. However, in this paper for research purposes, the sizes of beams and columns are fixed for all models to ensure that it will not influence the value of ductility. Bazan and Fernandez-Davila (2020) concluded that the ductility was

significantly influenced by concrete strength and steel reinforcement radio. Also, Nishanth et al. (2017) stated that the ductility value of SMRF changes significantly with the fundamental period and zone factor. The presence of shear wall of the models will have a significant effect on R_{μ} value and plays a big role in lateral load resistance as Foroughi et al. (2020) concluded that the axial load on the shear wall is an important parameter and that the transverse reinforcement diameter directly proportional to the optimum moment bearing capacity and the R_{μ} value of the cross-section. According to Kim et al. (2021) in the seismic design of the shear wall, a boundary confinement reinforcement is required to increase the ductility and to prevent brittle failure by increasing the deformation capacity. Also, Allahyari et al. (2011) state that “confinement has an important role in the ductile behaviour of structures”.

2. METHODOLOGY

2.1. Modelling and analysis

In this study G+5, G+9, G+13 RC structural models have been created and designed as residential buildings according to ACI 318R-19 code. A different combination of storey numbers, span length (5 m and 6 m), shear wall and shear walls with 1 m² opening were considered. The modelling and the pushover analysis of the structural models were done in ETABS V19 software. Fig. 2 shows one of the models.

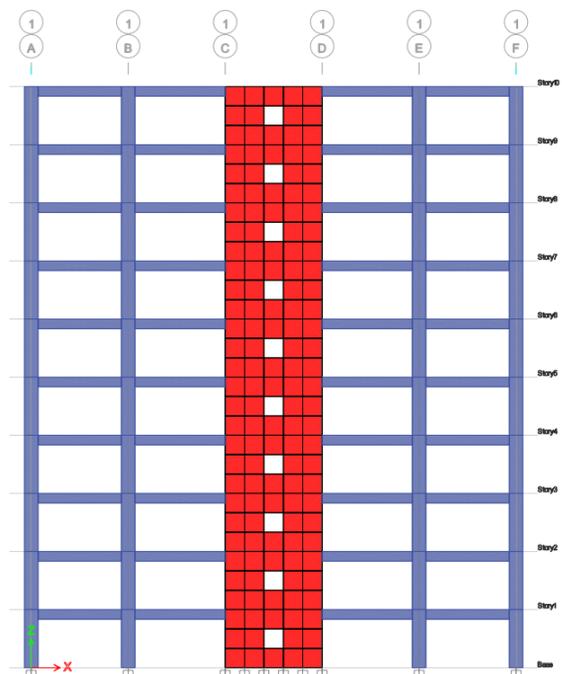


Fig. 2. Elevation of 10S-5SL-SW with opening model

2.2. Models' characteristics

Table 1 illustrates the models' characteristics.

Table 2. Models' characteristics

Number of models	18
Storey high	3 m
Live load	20 kN/m
Dead load	20 kN/m
Acceleration S1	0.4
Acceleration Ss	1
Site class	D

2.3. Materials' properties

Table 2 demonstrates the materials' properties.

Table 2. Materials' properties

Concrete strength	30 MPa
Longitudinal steel yield strength	420 MPa
Confinement steel yield strength	275 MPa

3. RESULTS AND DISCUSSIONS

3.1. Number of storeys

The effect of the number of storeys on the ductility varies between our model's types as SMRF ductility value increased with the increase of the number of storeys. On the other hand, models with SW and SW with opening ductility value decreased as the number of storeys increases. Fig. 3 shows the relation between the ductility value and the number of stories for all models.

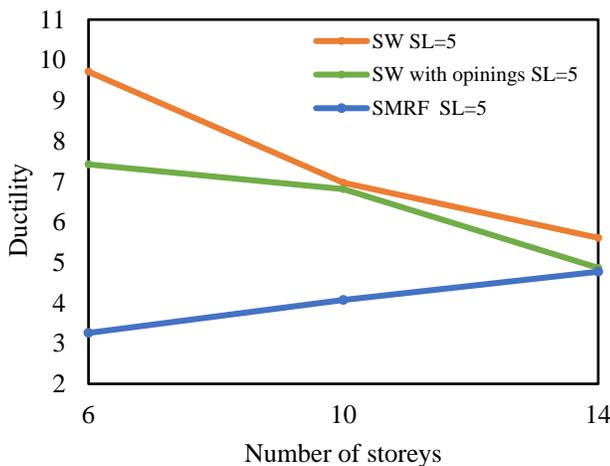


Fig. 3. The effects of the number of storeys on the ductility

3.2. Span length

The span length is a very important factor that affects the value of ductility of the structure. In this study, the results show that the SMRF ductility value decreased when the span length of the beams increased from 5 m to 6 m. On the other hand, the models with SW and SW with an opening. The value of the ductility factor increased with the increase of the span length. Fig. 4 shows the changes in the ductility value of all the models with respect to span length.

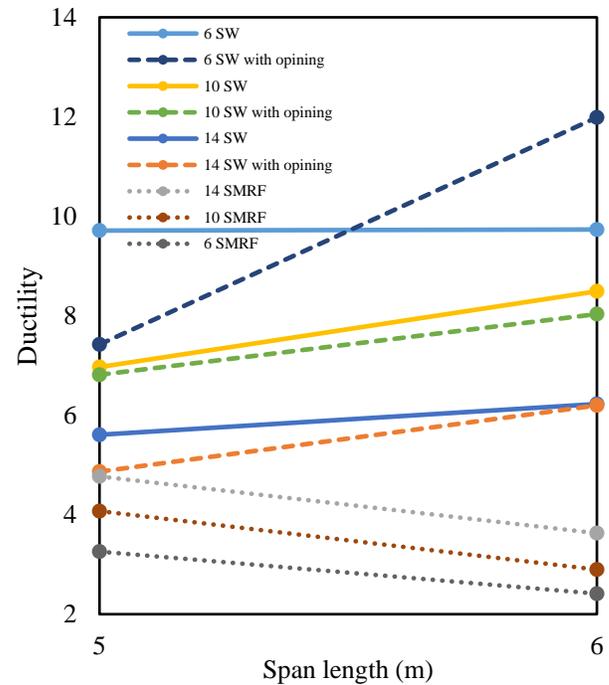


Fig. 4. The effect of span length on the ductility

3.3. Effect of SW and SW with an opening on the value of ductility

Adding a shear wall to the structural system increased its ductility significantly as almost all of the structural models with the shear wall had a very higher ductility value compare with other models as shown in Fig. 5. The presence of an opening in the shear wall is very common in every structure as a window for instance. Therefore, it is important to study the effects on our structures and how affect their ductility. The results of this study as shown in Fig. 5 the presence of an opening in SW decreased the ductility of most of the models slightly, but the ductility value remains more than the SMRF models.

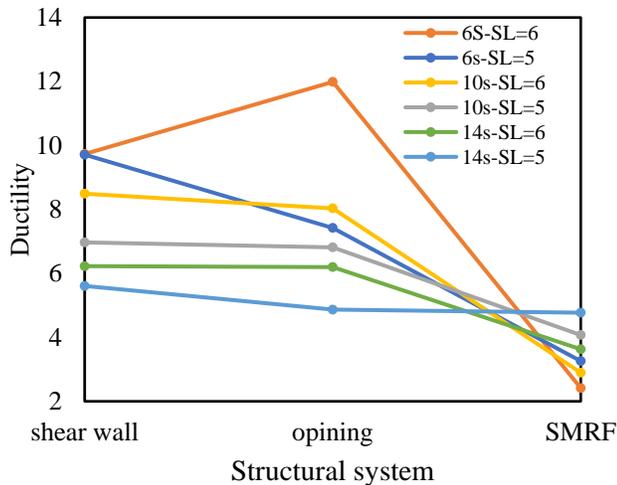


Fig. 5. The value of ductility of models with SMRF, SW and WS with opening

4. CONCLUSIONS

The main purpose of this study is to evaluate the value of ductility factor in RC building with and without shear walls using shear walls with and without opening. Also, additional parameters were included like the number of stories and span length to take under consideration a large number of influencing variables on the value of ductility. All the eighteen 2D models were created and designed in ETABS 19 software. The results of this study can be summarized under the following points.

- The ductility of the structure increases with the increase of the number of storeys for SMRF buildings,
- The ductility of the structure decreases with the increase of the number of storeys for SW buildings and SW with an opening,
- The ductility of the structure increases with this increase of the span length for SW buildings and SW this opening,
- The ductility of the structure decreases with this increase of the span length for SMRF buildings,
- The ductility of the structure increases when adding shear walls to the structural system,
- The presence of opening in the shear wall slightly decrease the ductility of the structure.

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