Influence of Slenderness Ratio on the Ductility of Reinforced Concrete Portal Structures

Kahil Amar, Nekmouche Aghiles, Titouche Billal, Hamizi Mohand, Hannachi Naceur Eddine

***Abstract*—**The ductility is an important parameter in the nonlinear behavior of portal structures reinforced concrete. It may be explained by the ability of the structure to deform in the plastic range, or the geometric characteristics in the map may influence the overall ductility. Our study is based on the influence of geometric slenderness (Lx / Ly) on the overall ductility of these structures, a study is made on a structure has 05 floors with varying the column section of 900 cm², 1600 cm² and 1225 cm². A slight variation in global ductility is noticed as (Lx/Ly) varies; however, column sections can control satisfactorily the plastic behavior of buildings.

***Keywords*—**Ductility, nonlinear behavior, pushover analysis, geometric slenderness, structural behavior.

I. Introduction

THE recent earthquakes have all shown the vulnerability of reinforced concrete structures. This vulnerability has been assessed on existing reinforced concrete portal structures buildings before the introduction of seismic regulations.

The vulnerability of portal structures in reinforced concrete can be increased by several parameters, primarily related to the problems of soil implantation, poor design problems in resistant structural elements [7], and configuration problems in plane (architectural design).

Our study focuses on the influence of the plan configuration of structures in reinforced concrete portico on the overall ductility, this variety of building (often encountered in highly-seismic regions). They generally have a mild behavior toward earthquakes

The work we present in this study, addresses the issue of modeling self-stable reinforced concrete structures [3], determining the capacity curves through the pushover method for different structural models, distinguished by their dimensions in plane.

The structures considered for the study, are regular structures in plane, which are 15.30 m (05 floors) high. The bracing is ensured by self-stable portals in reinforced concrete. The floors are made of slabs (16+4cm) (Fig. 1). The cross-section of the main and secondary beams is (30 cm x 35 cm), while the columns' is (30cm x30cm) for V_30, (35 cm x35 cm) for the V_35 variant and (40 cm x40 cm) for V_40, Table I illustrates the various structures, taken into account in the study.

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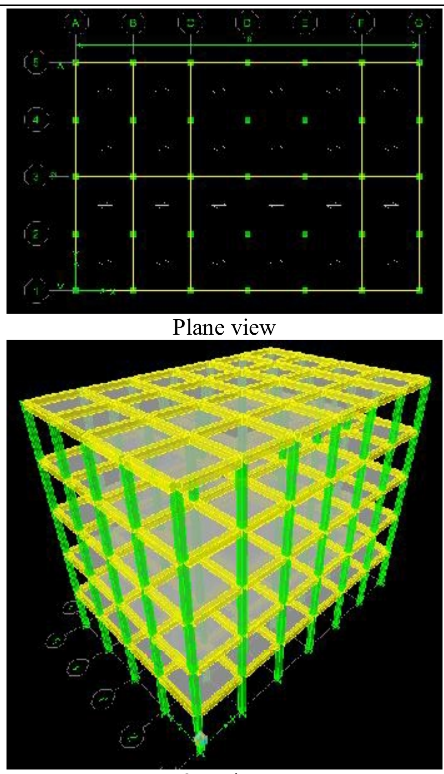
TABLE I
PLANE DIMENSION OF THE STUDIED VARIANTS

Variants	Longitudinal direction Ly (m)	Transversal direction Lx (m)	Variants	Longitudinal direction Ly (m)	Transversal direction Lx (m)
V30_1			V30_5		
V35_1	27.00		V35_5	15.00	
V40_1			V40_5		
V30_2			V30_6		
V35_2	24.00		V35_6	12.00	12.00
V40_2		12.00	V40_6		
V30_3			V30_7		
V35_3	21.00		V35_7	09.00	
V40_3			V40_7		
V30_4					
V35_4	18.00				
V40_4					



Plane view

3D View

Fig. 1 Example of a structure studied

II. Capacity Curve

The capacity curve of a structure is a graphical representation (Fig. 2), which connects the shear force at its base to the displacement at its top [5], transformed into spectral coordinates [2], [6], it is obtained by a non-linear static analysis, said “Pushover analysis” [7], [8]. The principle of this analysis consists of the application of a lateral load that is increased in an incremental manner (progressive) to collapse.

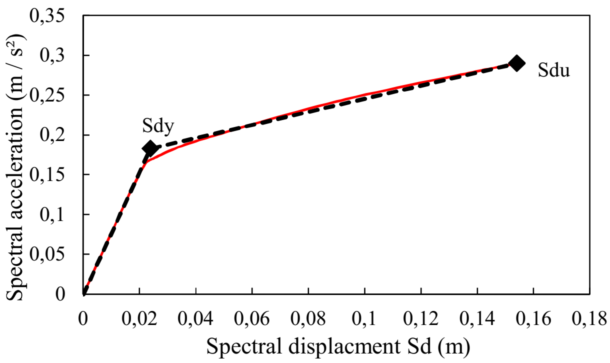


Fig. 2 Capacity curve in spectral coordinates

III. Basic Notions on Ductility

The deformability of a structure is the ability of a material, a structural element, or the entire structure to deform before the collapse [1]. By contrast, ductility is the ability of the structure to deform plastically without excessive loss of strength, but with a significant deterioration in rigidity, and is manifested by the formation of plastic hinges. There are four ways to quantify ductility, in displacement, in rotation, in bending, and in deformation [2].

IV. Displacement Ductility

The displacement ductility is defined as the ratio of the ultimate lateral displacement by the elastic lateral displacement [2], [4].

$$\mu\Delta = Sdu/Sdy$$

V. Geometric Slenderness

Geometric slenderness in plane of a structure is defined by the ratio (Lx/Ly), the span lengths are kept constant (3.00 m) [9].

VI. Results and Interpretations

We present the evolution of the overall ductility according to geometric slenderness for three structural models studied (V_30, V_35 and V_40)1st Case: V_30 Model (Columns with 30x30 cm² Gross-Section)

The variation step "Lx" / "Ly" has been set at (0.25) in the transverse direction with an initial value of 0.75 which gives us a value of 4.12 ductility. And, when this ratio is increased to 1.00, the variation in ductility (μ) is not really significant; however, the adoption of a ratio of 1.25 enables to obtain a significant difference (0.31) compared to the initial slenderness (0.75) or (7% increase). Beyond $\frac{Lx}{Ly} = 1.25$, a drop in the ductility is noted until a slenderness ratio of 1.75 for which a ductility coefficient 4.27 is obtained, then, it follows an ascending slope until reaching a value of 4.54 for a slenderness ratio of 2.25. Longitudinal direction

TABLE II
Geometric Slenderness of Variant

Variant	Slenderness ratio $\frac{Lx}{Ly}$	Variant	Slenderness ratio $\frac{Lx}{Ly}$
V30_1		V30_5	
V35_1	2.25	V35_5	1.25
V40_1		V40_5	
V30_2		V30_6	
V35_2	2.00	V35_6	1.00
V40_2		V40_6	
V30_3		V30_7	
V35_3	1.75	V35_7	0.75
V40_3		V40_7	
V30_4			
V35_4	1.50		
V40_4			

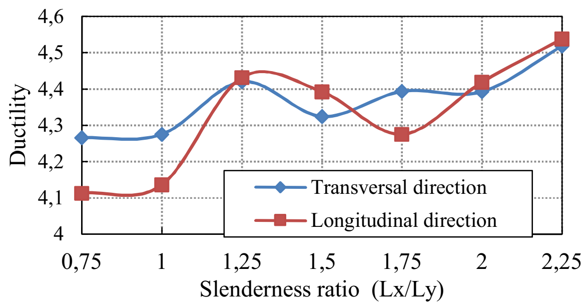


Fig. 3 Global ductility variation versus the slenderness ratio $\frac{Lx}{Ly}$ in both directions for the V_30 structural model

A-1st Case: V_30 Model (Columns with 30x30 cm² Gross-Section)

In the longitudinal direction, the same profile is represented for the transversal direction, with different ductility values ($\frac{Lx}{Ly}$ = 0.75 to 1.00) in the range of μ = 4.27.

For a slenderness of 1.25, overall ductility is 4.42 representing a variation of 3% in this direction with a deterioration of the curve from $\frac{Lx}{Ly}$ = 1.25 to 1.50, beyond this point, the curve shows an ascending behavior yet with a small variation up to a ductility of μ = 4.53 for $\frac{Lx}{Ly}$ = 2.25. Globally, both directions have shown a peak at a slenderness ratio of 1.25, while the best ductility has been recorded for $\frac{Lx}{Ly}$ = 2.25.

Fig. 4 shows the change in ductility versus $\frac{Lx}{Ly}$ for column gross-sections of (35x35) cm^2, the ratio 1.25 gives a peak in the longitudinal direction, while in transversal direction, ductility does not vary considerably.

B-2nd Case: V_35 Model (Columns with 35x35 cm² Gross-Section)

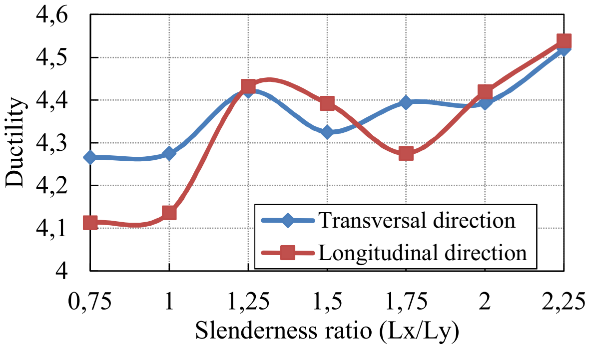


Fig. 4 Global ductility variation versus the slenderness ratio $\frac{Lx}{Ly}$ in both directions for the V_35 structural model

C-3rd Case: V_40 Model (Columns with 40x40 cm² Gross-Section)

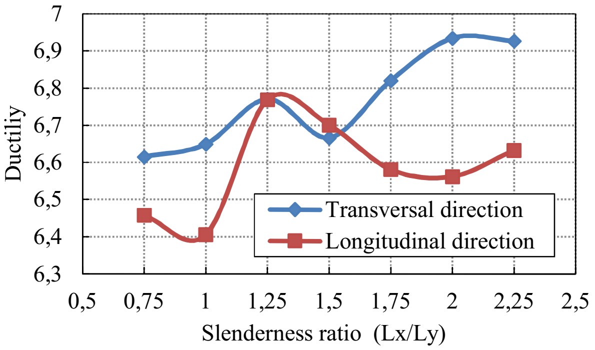


Fig. 5 Global ductility variation versus the slenderness ratio $\frac{Lx}{Ly}$ in both directions for the V_40structural model.

Fig. 3 shows the results of V_40 model (40x40cm² cross-section), as we can see, the best ductility value is given by (Lx/Ly=2.00) in transversal, by cons for a slenderness of (Lx/Ly=1.25) a better behavior is noticed for both directions.

VII. Influence of the Columns Geometric Dimensions on the Global Ductility

A. Transversal Direction

Fig. 6 clearly shows the variation in the overall ductility in the transverse direction for the three structural models studied. Improved ductility of 27% is observed during crossing V_30 has V_35, between 20% and V_35 V_40 and augmentation 47% V_30 has V_40. These percentages are calculated for the same geometric slenderness (Lx/Ly=1.25).

In the longitudinal direction (Fig. 7), we note that ductility increases, in deed, a percentage increase of 31% is noted for the 35x35 cm² columns compared to the 30x30 cm² ones, 16% between the 35x35 columns and the 40x40 ones, and a percentage of 46% between the 40x40 columns and the 30x30 ones.

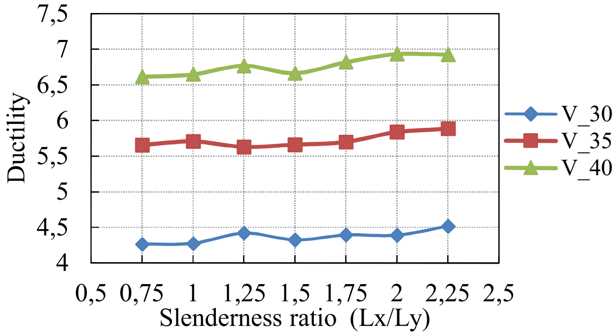


Fig. 6 Global ductility variation versus the slenderness ratio $\frac{Lx}{Ly}$ for the different models V_30, V_35 and V_40 in the transversal direction

B. Longitudinal Direction

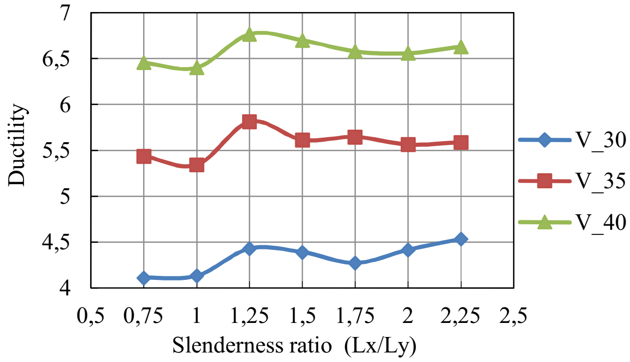


Fig. 7 Global ductility variation versus the slenderness ratio $\frac{Lx}{Ly}$ for the different models V_30, V_35 and V_40 in the longitudinal direction

VIII. Conclusion

The study that we presented in this paper addresses the issue of modeling self-stable structures in reinforced concrete in order to determine the capacity curves, this, through the pushover method for different structural models distinguished by their size in plans.

Through this study, in which we investigated the behavior structure with 05 floors and seven variants differentiated by their ductility, showed that:

– Ductility is not proportional to slenderness.
– The best gain percentage is 7% when going from (Lx/Ly=0.75 to 1.25) in both directions.
– The change in column sections has allowed us to notice that the going from a (30x30 cm²) cross-section to a (cross-section 35x35cm²) one actually increased ductility by 27%, and when we went from (cross-section 35x35cm² to 40x40cm²) the percentage was 20% in both the considered directions. The increase of the column sections improves the behavior of a structure in terms of ductility adequately.

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