The influence of the diameter of the longitudinal reinforcement of RC walls to their displacements against lateral instability

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Abstract. The possibility of failure because of lateral instability is limited significantly with the proper choice of an adequate thickness, which is specified by (most) modern seismic codes as a percentage of the height of the bottom storey. The current work investigates one parameter that may be affecting the stability of structural walls. This parameter is the diameter of the longitudinal reinforcement of the boundary edges of load-bearing walls. It contains an experimental research that tries to investigate the influence of the diameter of longitudinal reinforcement to the displacements of test specimens. It has to be noted that in order to examine experimentally the influence of the diameter of longitudinal reinforcement, test specimens of scale 1:3 simulating the boundary edges of structural walls were used. These specimens were reinforced with the same or almost the same longitudinal reinforcement ratios (2.68% - 2.79%) but had a different number of reinforcement bars of varying diameter. The diameters of bars which were used were equal to 8mm and 10mm. The specimens which were compared to each other contained (apart from bars of different diameter) a different number of bars and consequently a different way of placement of these bars at the wall end sections.

Keywords: R/C walls, lateral instability, diameter, longitudinal reinforcement.

1 INTRODUCTION

One important aspect of seismic design of buildings with a dual reinforced concrete structural system is the lateral stability of structural walls (Fig. 1), when they face this danger mainly due to flexural overstrain. The deep excursion in the yield region of the boundary parts of bearing walls increases dramatically their flexibility and since at the same time they are liable, because of the earthquake vibration, to a reversing axial loading (tension – compression), their lateral stability is at stake.

In the past few years, a concern is observed internationally regarding the seismic mechanical behavior of reinforced concrete walls, especially against their transverse instability under extreme seismic loads. This increasing concern is connected directly to the types of damage that are observed in reinforced concrete structures. It is observed that the relevant bibliography does not refer and does not include as damage the out-of-plane buckling of walls. Indeed, for the case of bending type of damage of walls, crash of the compression zone is referred as a result for the compression zone for this specific type of damage. However, it is known that bending type of failure can be manifested as buckling of compression zone and not necessarily with its crash, a fact that leads to the so-called failure of transverse buckling. It becomes explicit that failure due to transverse instability is difficult to be observed in actual structures after the event of seismic excitation, even if it is certain that it exists as phenomenon. Consequently, it is concluded that the phenomenon of transverse buckling at the compression edges of walls in the plastic hinge region (base of wall) is a no warning (and consequently very dangerous) phenomenon since it leads to total collapse of the structures and in particular without leaving proofs that the total collapse and failure emanated from this specific phenomenon. Moreover, this is also one of the reasons that relevant code provisions exist in several modern international codes, as is e.g. EC8 (Eurocode 8, 2004), New Zealand Concrete Code (NZS 3101: 2006). Consequently, because of the big importance of transverse instability and the role that plays in the seismic behavior and safety of constructions, a sedulous study is required about the mechanism of occurrence of this phenomenon and the factors that lead to its growth.

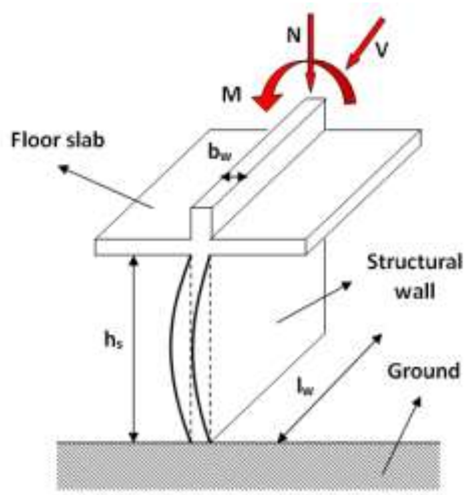


Fig. 1. Out-of-plane buckling of structural wall.

2 EXPERIMENTAL RESEARCH

2.1 Aim of experimental investigation

The main objective of the experimental investigation was to determine the influence of the diameter of longitudinal reinforcement bars of the end areas of a wall to their displacements due to lateral buckling.

2.2 Test specimen characteristics

The test specimens were made using the scale 1:3 as construction scale. The dimensions of the specimens are equal to 7.5x15x90 cm. The reinforcement of the first specimen consists of 6 bars of 8 mm diameter and the reinforcement of the second specimen consists of 4 bars of 10 mm diameter. Thus, the longitudinal reinforcement ratio of the first specimen is equal to 2.68% and the longitudinal reinforcement ratio of the second specimen is equal to 2.79%. It can be noticed that the two specimens have almost the same longitudinal reinforcement ratio. The difference is small and can be easily considered as negligible. The total number of specimens is equal to 2. First, each specimen was stressed under uniaxial tensile loading to a specific and default elongation degree equal to 30‰ and then was stressed under concentric compressive loading. Degree of elongation 30‰ was chosen because it has been observed in actual structures (Chai and Elayer, 1999). Differentiation of specimens lies in varying diameters of the longitudinal bars of each specimen. The characteristics of the specimens are shown collectively in Table 1, while Fig. 2 shows the cross section and a front view of specimens both for tensile and compressive loading.

Table 1. Test specimens' characteristics.

N/A	Description of specimens	Dimensions (cm)	Longitudinal reinforcement	Transverse reinforcement	Longitudinal reinforcement ratio (%)	Concrete cube resistance at 28 days (MPa)	Degree of elongation (‰)
1	Y-6Ø8-268-30-1	15x7.5x90	6Ø8	Ø4.2/3.3cm	2.68	22.22	30.00
2	Y-4Ø10-279-30-2	15x7.5x90	4Ø10	Ø4.2/3.3cm	2.79	22.22	30.00

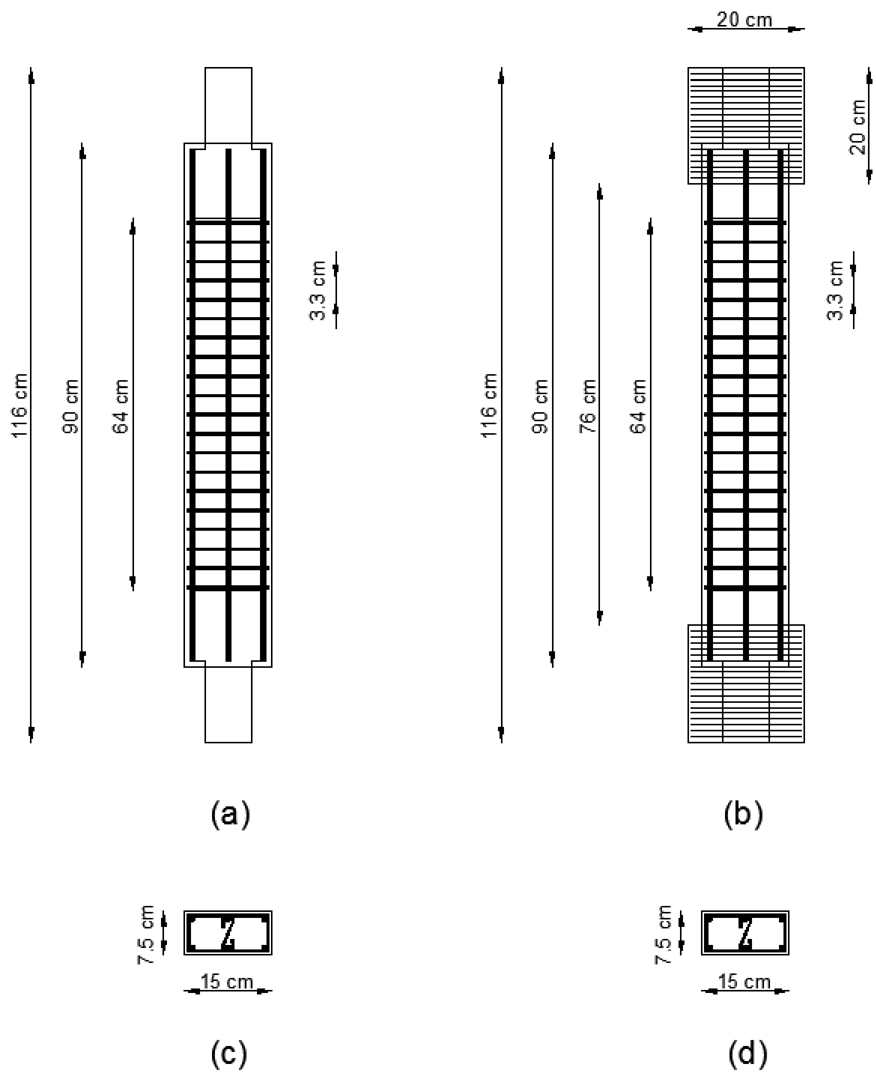
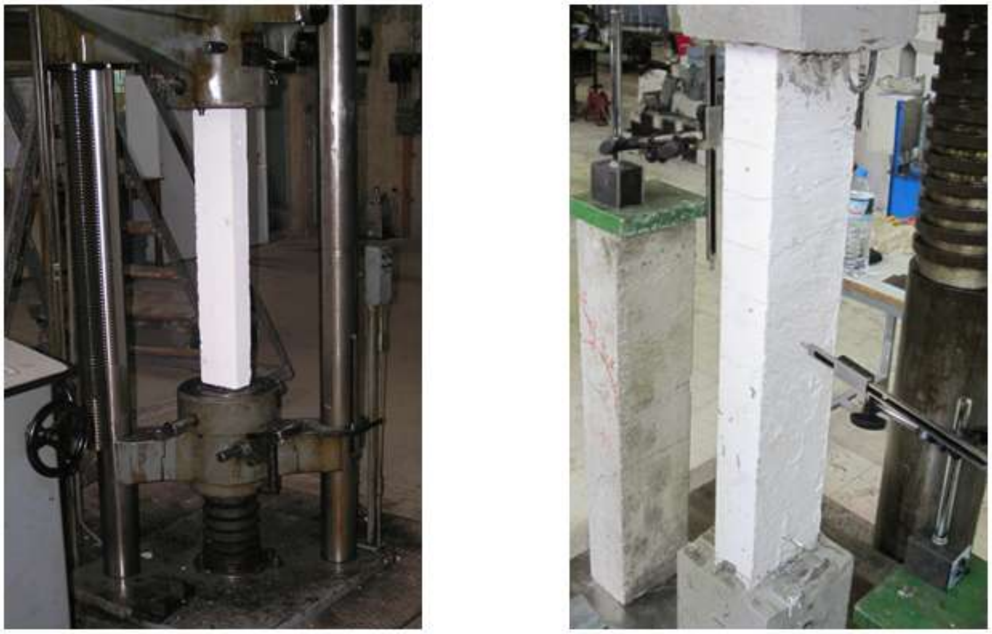


Fig. 2. Column specimen Y-6Ø8-268-30-1: (a) Front view in tension, (b) Front view

in compression, (c) Cross section, (d) Cross section.
(Reinforcement differs for each specimen. Example shows typical longitudinal reinforcing bars 6Ø8.



(a) (b)

Fig. 3. Test setup for application of: (a) Tensile loading, (b) Compressive loading.

2.1 Loading of specimens

The experimental setups used in order to impose to the specimens in the first semi cycle of loading a uniaxial tensile load and in the second semi cycle of loading a concentric compressive load are shown in Fig. 3.

3 EXPERIMENTAL RESULTS

Fig. 4 refers to the uniaxial tensile test and shows the variation of elongation of the specimens in relation to the applied tensile load. It becomes evident, from a simple observation of the diagram that the real degrees of elongation differ somewhat from the nominal degree of elongation (30‰). However, in all cases, the differences are minor and negligible. Fig. 5 refers to the concentric compression test and shows the change of transverse displacement relative to the applied compressive load this time, while Fig. 6 depicts the residual transverse displacement in relation to the normalized specimen height. Finally, Fig. 7 shows the various failure modes of all specimens after the completion of the compression loading.

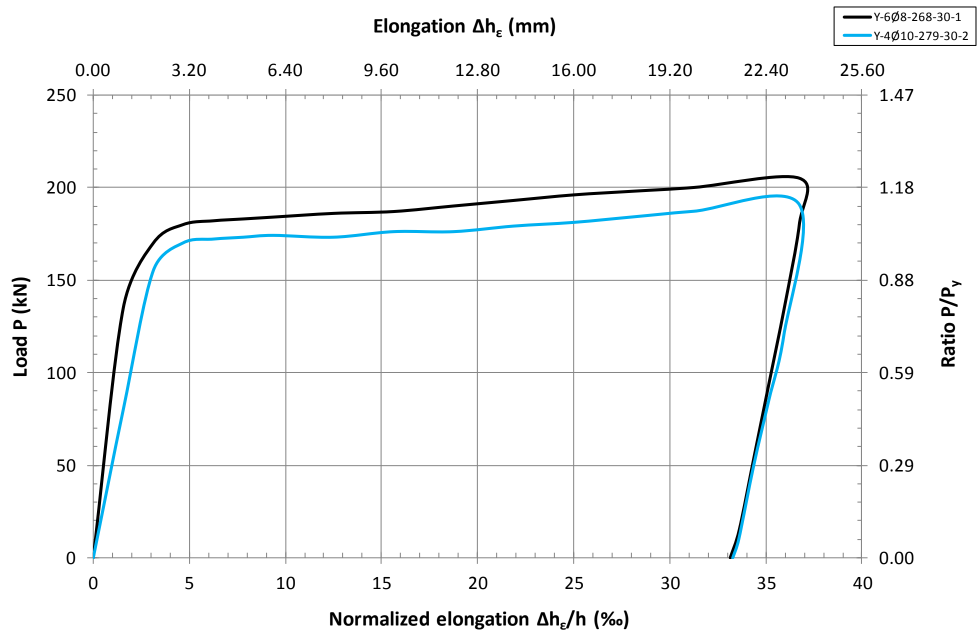


Fig. 4. Diagram of tensile load [P(kN), P/P_y] - elongation [$\Delta h_\varepsilon/h$(‰), Δh_ε(mm)].

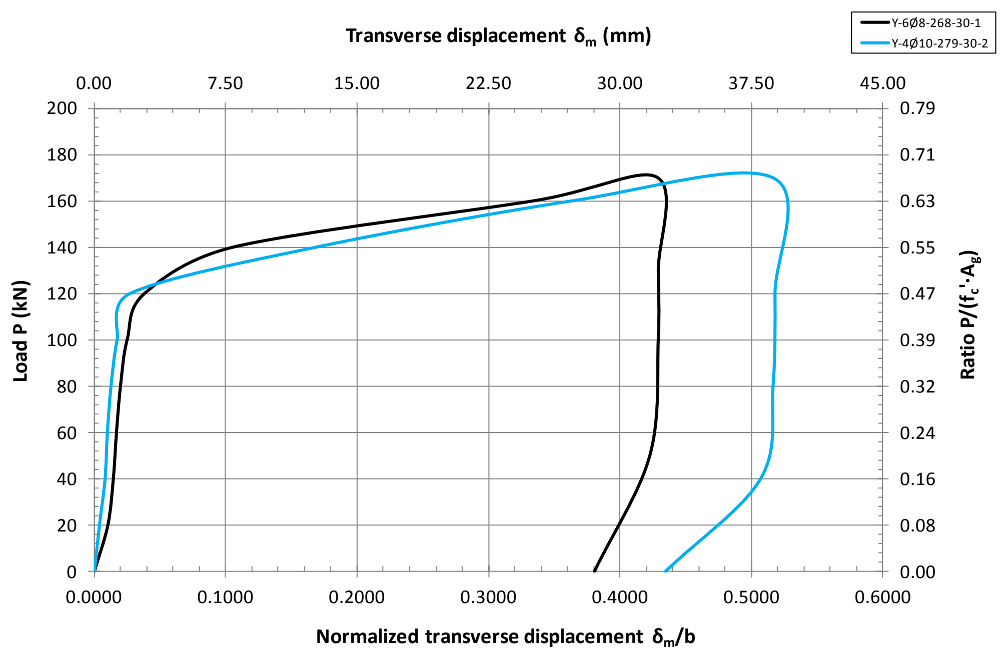


Fig. 5. Diagram of compressive load [P(kN), $P/(f_c'\cdot A_g)$] – transverse displacement at the midheight of test specimens [δ_m/b, δ_m(mm)].

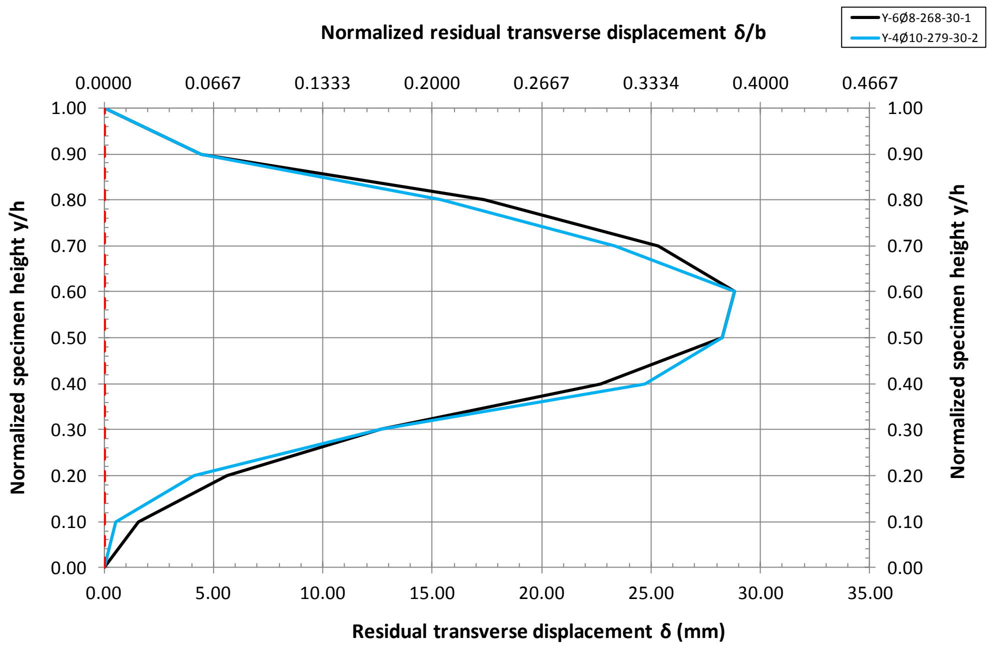


Fig. 6. Diagram of normalized specimen height [z/h] – residual transverse displacement [δ(mm), δ/b].

(a) (b)

Fig. 7. Failure modes of specimens after the experiment of compression: (a) Y-6Ø8-268-30-1, (b) Y-4Ø10-279-30-2.

4 ANALYSIS OF RESULTS

The observations from the conduct of the experimental investigation are as follows:

1. First, it is observed that the change of the longitudinal reinforcement diameter does not change the failure mode of the specimens. Thus, for both diameters failure takes place due to buckling.
2. It becomes readily apparent that there is no substantial variation of the maximum failure load by varying the diameter of longitudinal reinforcement.
3. The evaluation of maximum residual transverse displacements and failure transverse displacements (transverse displacements corresponding to the maximum failure load) indicates that these types of displacements have similar values for the two specimens compared. However, this is true for these types of diameters, it might not be the same for other types of diameters.

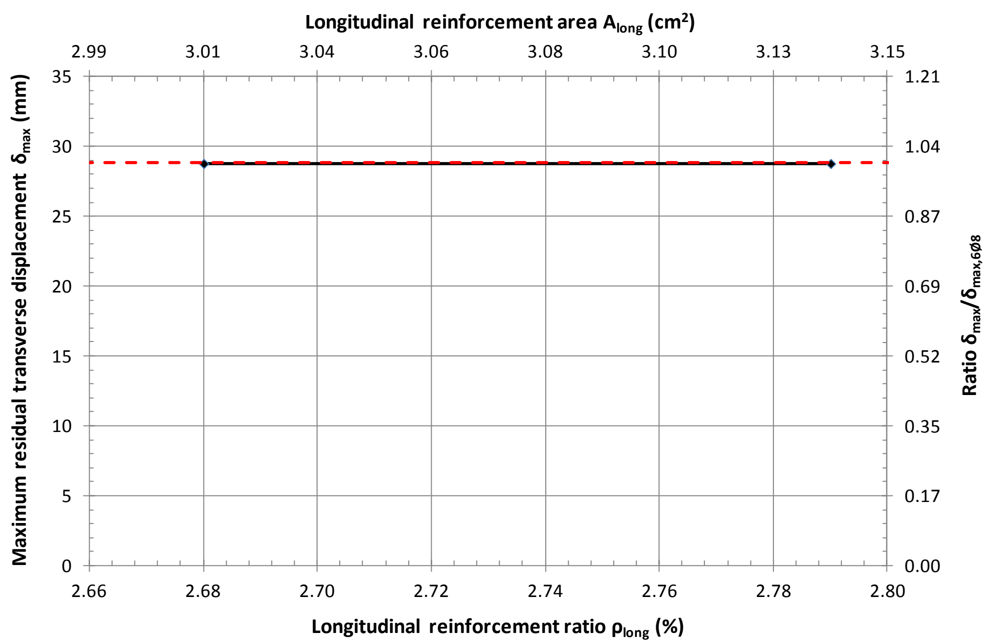


Fig. 8. Diagram of maximum residual transverse displacement [δ_{max}(mm), $\delta_{max}/\delta_{max,1.79‰}$] – longitudinal reinforcement ratio and longitudinal reinforcement area [ρ_{long}(‰), A_{long}(cm^2)].

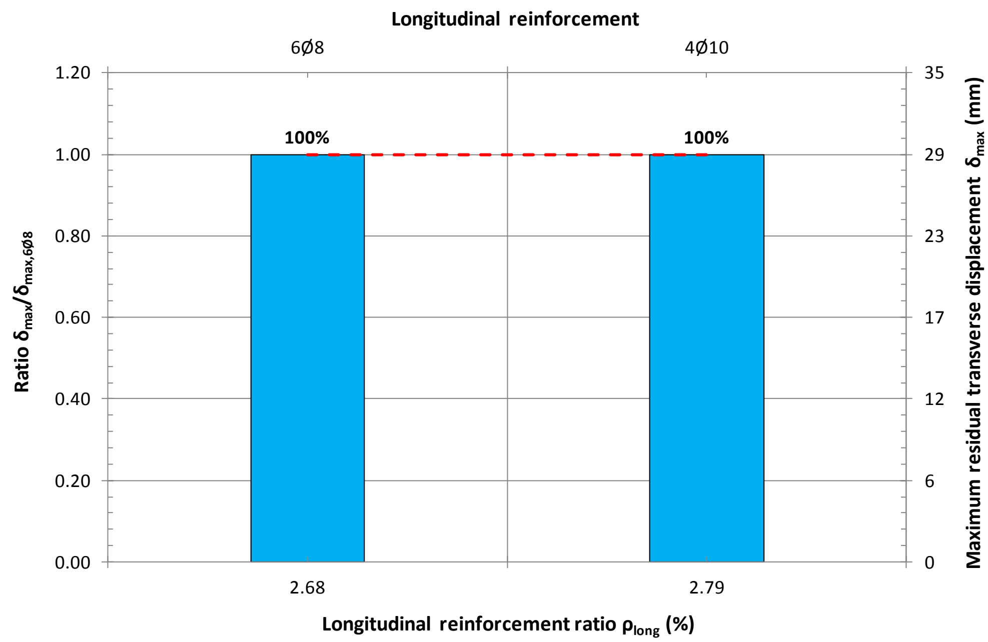


Fig. 9. Column diagram of maximum residual transverse displacement [$\delta_{max}/\delta_{max,1.79‰}$, δ_{max}(mm)] – longitudinal reinforcement ratio and type of longitudinal reinforcement [ρ_{long}(‰)].

5 CONCLUSIONS

Analysis and evaluation of experimental results lead to the following conclusions:

1. Longitudinal reinforcement diameter does not affect failure mode of specimens and cannot prevent out-of-plane buckling.
2. Longitudinal reinforcement diameter seems not to affects maximum failure load of test specimens. More tests on this matter have to be conducted before a final conclusion can be derived.
3. As far as transverse displacements (maximum residual transverse displacements and failure transverse displacements) are concerned, it seems that they are not affected by the variation of longitudinal reinforcement diameters. More experiments need to be conducted on this matter however before a final conclusion I reached.

References

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