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The influence of the degree of elongation to the displacements of seismic walls with maximum code-prescribed reinforcement ratio

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Abstract. It is expected that walls which were designed either with increased ductility requirements according to the Greek Concrete Code 2000 or were designed to be in a high ductility category according to EC8: 2004, NZS 3101: 2006 and other modern international codes, present extensive tensile deformations, especially in the plastic hinge region of their base. Depending on the geometric characteristics and the level of ductility design of walls, large tensile deformations are expected. These tensile deformations can cause their lateral instability depending on their size. Large width cracks, which are created as result of deep entry in the plastic region, are required to close, so that the in-plane flexural mode of wall can be completely developed at the reversal of loading sign. It is obvious that there should be a sufficient wall thickness, so that it is ensured that the compressive force can be developed in the compression zone of the wall cross-section without the event of out-of-plane buckling. A critical situation arises when at the reversal of the sign of moment, the cracks that emanate from tension (at the previous semi-cycle of loading) cannot close and thus, traverse buckling takes place, which leads the wall end section to lateral instability. The current work investigates one of the most basic parameters affecting the stability of structural walls, which is (apart from the wall thickness) the degree of tensile strain of the longitudinal reinforcement of the boundary edges of load-bearing walls. The present work is experimental. It has to be noted that in order to examine experimentally the influence of tensile strain, 5 test specimens of scale 1:3 simulating the boundary edges of structural walls were used. These specimens were reinforced with the maximum code-prescribed longitudinal reinforcement ratio (4.02%) and they all had the same reinforcement ratio. The degree of elongation which was applied was different for each specimen and it took values equal to 0‰, 10‰, 20‰, 30‰ and 50‰. The present article tries to investigate the influence of the degree of tensile strain to the displacements and the modes of failure of test specimens.

Keywords: R/C walls, displacements, tensile strain, reinforcement ratio.

1 INTRODUCTION

Extensive tensile deformations are expected to take place at RC structural walls designed to be in a high ductility category according to modern international codes such as EC8 (2004) and NZS 3101 (2006) or designed with increased ductility requirements according to Ε.Κ.Ω.Σ. 2000 (Greek Concrete Code, 2000). According to Chai and Elayer (1999), tensile deformations until 30‰ are expected at the walls of the bottom storey height depending on their geometric characteristics and the level of ductility design of the walls. These tensile deformations, depending on their size, can cause out-of-plane buckling of walls. Prominent researchers, like Paulay (1986), propose the use of flanges or enlarged boundary elements in the extreme regions of walls providing protection to the bending compression regions against transverse instability. Moreover, these elements are easier to be confined. New Zealand

Concrete Code (NZS 3101, 2006) and other modern international codes propose the construction of such elements. The present work on the phenomenon of out-of-plane buckling constitutes a small part of an extensive research program that took place at the Laboratory of Reinforced Concrete and Masonry Structures of the School of Engineering of Aristotle University of Thessaloniki.

2 EXPERIMENTAL RESEARCH

2.1 Test specimen characteristics

The test specimens were constructed using the scale 1:3 as a scale of construction. The dimensions of specimens are equal to 7.5x15x90 cm. The reinforcement of specimens consists of 4 bars of 12 mm diameter. The total number of specimens is equal to 5. Each specimen was submitted first in tensile loading of uniaxial type up to a preselected degree of elongation and then was strained under concentric compressive loading. Different degrees of elongation were imposed on each one of the specimens. Fig. 1 presents their front view both for tensile and compressive loading, while all specimen characteristics are brought together in Table 1.

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-4Ø12-402-0-1	15x7.5x90	4Ø12	Ø4.2/3.3cm	4.02	34.96	0.00
2	Y-4Ø12-402-10-2	15x7.5x90	4Ø12	Ø4.2/3.3cm	4.02	34.96	10.00
3	Y-4Ø12-402-20-3	15x7.5x90	4Ø12	Ø4.2/3.3cm	4.02	34.96	20.00
4	Y-4Ø12-402-30-4	15x7.5x90	4Ø12	Ø4.2/3.3cm	4.02	34.96	30.00
5	Y-4Ø12-402-50-5	15x7.5x90	4Ø12	Ø4.2/3.3cm	4.02	34.96	50.00

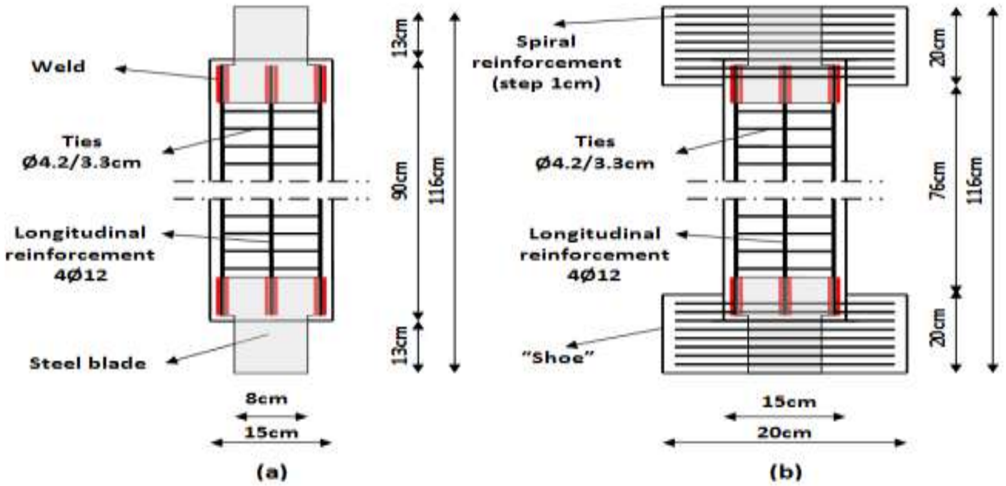

Fig. 1. Sketch of front view of specimens for: (a) tension, (b) compression.

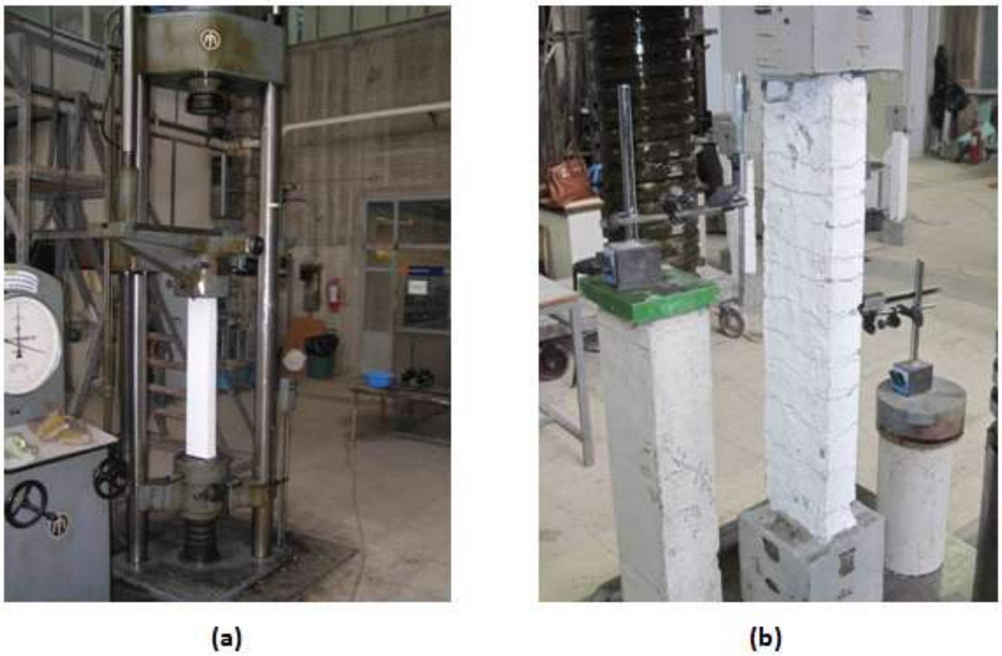
(a) (b)

Fig. 2. 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 a uniaxial tensile load (first semi cycle) and a concentric compressive load (second semi cycle) are shown in Fig. 2.

3 EXPERIMENTAL RESULTS

Fig. 3 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 degrees of elongation (10‰, 20‰, 30‰ and 50‰). However, in all cases, the differences are minor and negligible. Fig. 4 refers to the concentric compression test and shows the change of transverse displacement relative to the applied compressive load this time, while Fig. 5 depicts the residual transverse displacement in relation to the normalized specimen height. Finally, Fig. 6 shows the various failure modes of all specimens after the completion of the compressive loading.

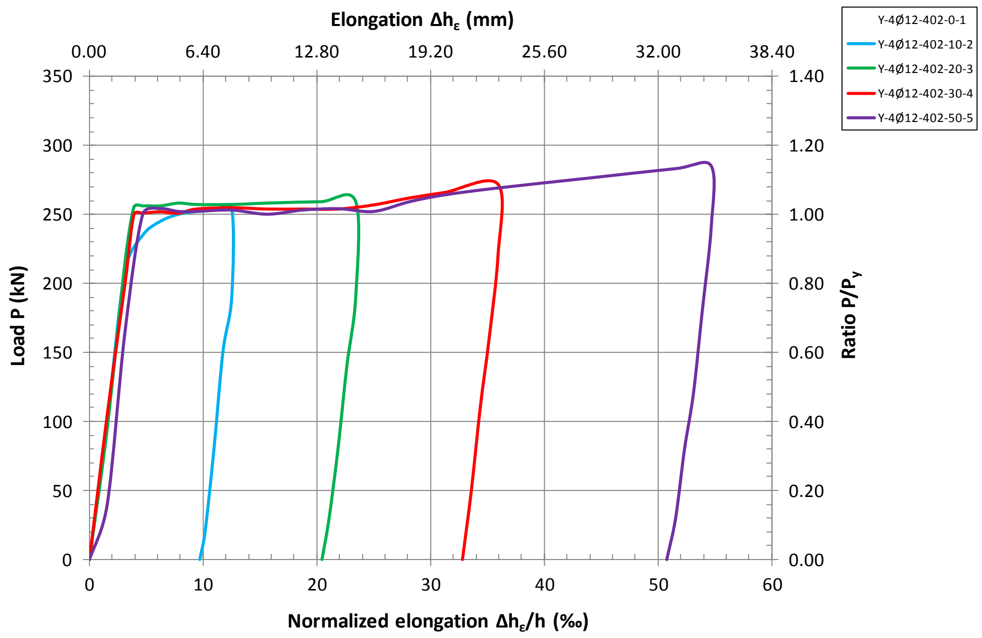

Fig. 3. Diagram of tensile load [P(kN), P/P$_y$] – elongation [Δh_ε/h(‰), Δh_ε(mm)].

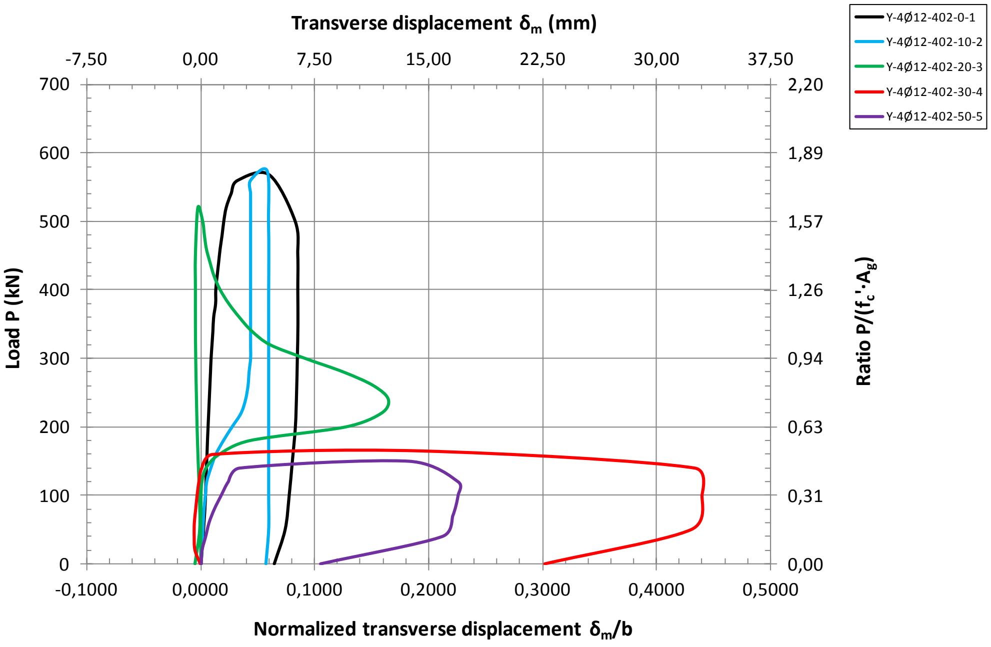

Fig. 4. Diagram of compressive load [P(kN), P/(f_c'·A_g)] – transverse displacement at the midheight of test specimens [δ_m/b, δ_m(mm)].

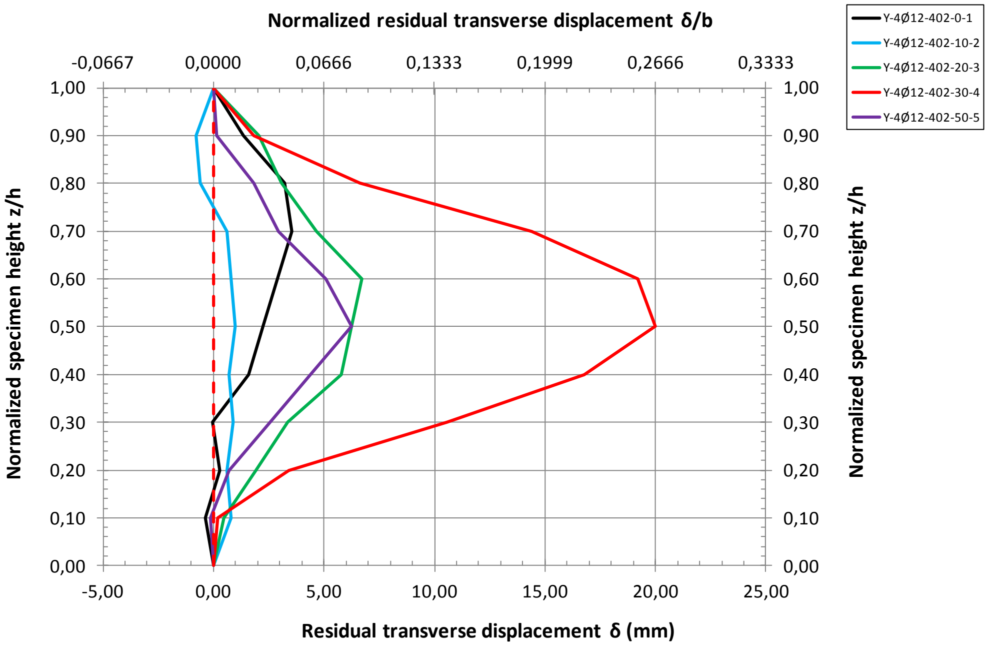

Fig. 5. Diagram of normalized specimen height [z/h] – residual transverse displacement [δ(mm), δ/b].

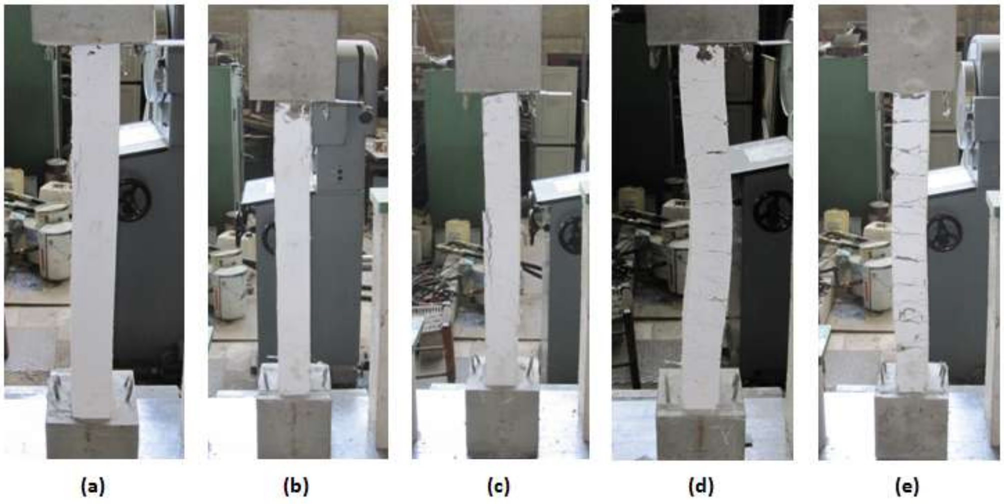

Fig. 6. Failure modes of specimens after the experiment of compression: (a) Y-4Ø12-402-0-1, (b) Y-4Ø12-402-10-2, (c) Y-4Ø12-402-20-3, (d) Y-4Ø12-402-30-4, (e) Y-4Ø12-402-50-5.

4 ANALYSIS OF RESULTS

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

1. The evaluation of maximum residual transverse displacements and failure transverse displacements (transverse displacements corresponding to the maximum failure load) indicates that there is a tendency for these types of displacements to be increased by increasing the degree of elongation. However, this is only a tendency and it is not true for all degrees of elongation (Figs. 7, 8).

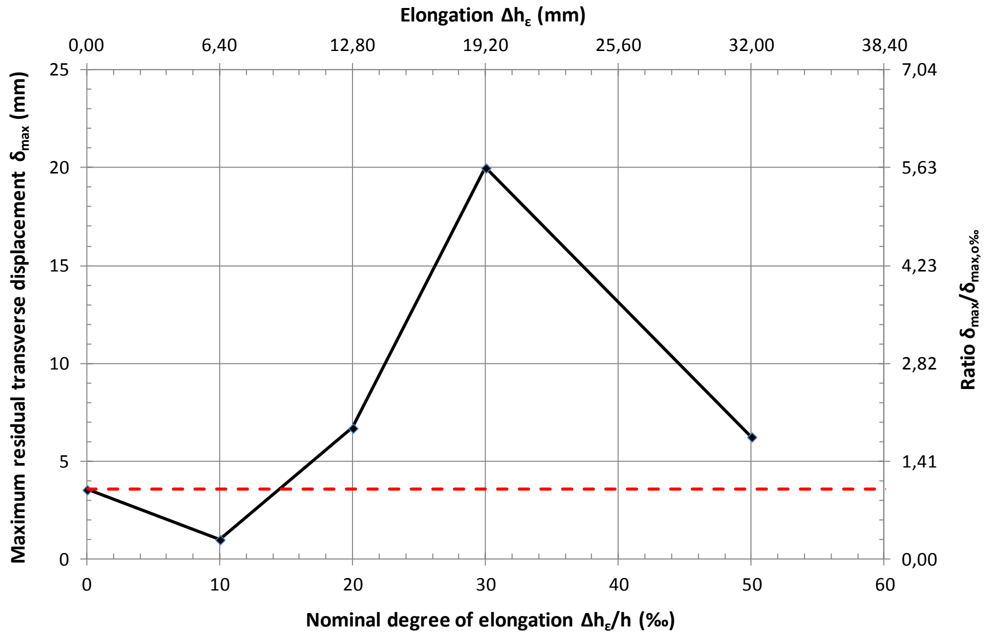

Fig. 7. Diagram of maximum residual transverse displacement [δ_{max}(mm), $\delta_{max}/\delta_{max,0‰}$] – elongation [$\Delta h_\varepsilon/h$(‰), Δh_ε(mm)].

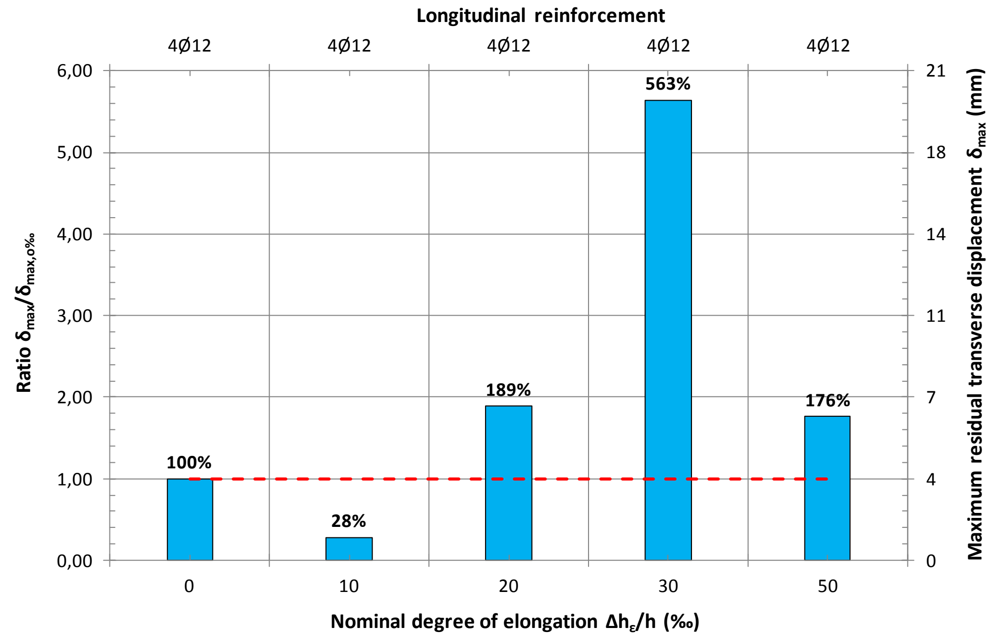

Fig. 8. Column diagram of maximum residual transverse displacement [$\delta_{max}/\delta_{max,0‰}$, δ_{max}(mm)] – elongation and type of longitudinal reinforcement [$\Delta h_{\varepsilon}/h$(‰)].

5 CONCLUSIONS

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

1. As far as transverse displacements (maximum residual transverse displacements and failure transverse displacements) are concerned, it seems that there is not a clear relation between degree of elongation and transverse displacements. So, no clear conclusion has been derived on this matter apart from a general tendency for the transverse displacements to be increased with an increase of degree of elongation.

References

(2004). EN 1998-1, Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings. European Committee for Standardization: Brussels, Belgium.

(2006). Ε.Κ.Ω.Σ. 2000: Greek Concrete Code. Ο.Α.Σ.Π. / Σ.Π.Μ.Ε.: Athens, Greece.

(2006). NZS 3101, Concrete structures standard: Part 1 – The design of concrete structures. Standards New Zealand, Wellington, New Zealand.

Chai Y. H., Elayer DT. (1999) Lateral stability of reinforced concrete columns under axial reversed cyclic tension and compression. *ACI Structural Journal*, 96(5), 780-789.

Paulay T. (1986). The design of ductile reinforced concrete structural walls for earthquake resistance. *Earthquake Spectra*, 2(4), 783-823.