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Low Reinforced Shear Walls: Displacements and Failure Modes Due to Lateral Buckling

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Abstract-The past few years, it has become 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 and can even lead to general collapse of structures. 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. The present work is experimental and consists of 5 test specimens of scale 1:3 simulating the boundary edges of structural walls. These specimens were reinforced with the same low longitudinal reinforcement ratio (1.79%). The degree of elongation applied was different for each specimen. The present paper tries to investigate the influence of the degree of elongation to the displacements and the modes of failure of test specimens.

Keywords- *lateral instability, tensile strain, low reinforcement ratio*

I. INTRODUCTION

The formation of the structural system of buildings using a number of sufficient structural walls is usually considered a good practice by consulting designers. Experience has shown that buildings with a large number of structural walls have demonstrated exceptional behaviour against seismic action, even for walls detailed and reinforced according to older perceptions (Wallace and Moehle, 1992) [1]. Structural walls designed to be in a high ductility category according to modern international codes such as EC8 (2004) [2], NZS 3101 (2006) [3], CSA (2004) [4] and UBC (1997) [5] or designed with increased ductility requirements according to Ε.Κ.Ω.Σ. 2000 (Greek Concrete Code, 2000) [6], are expected to present extensive tensile deformations, especially in the plastic hinge region of their base. Prominent researchers like Paulay and Priestley (1993) [7] have proved that out-of-plane buckling of RC walls depends basically on the size of tensile deformations imposed during the first semi-cycle of seismic loading. Other researchers have conducted research on the out-of-plane buckling of RC structural walls (Penelis et al., 1995, 1996, Paulay and Priestley, 1993, Chai and Kunnath, 2005, Paulay, 1986, Chai and Elayer, 1999) [8, 9, 7, 10, 11, 12]. The present work on the phenomenon of transverse 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. Results for test specimens reinforced with various different longitudinal reinforcement ratios have been presented in previous publications (Chrysanidis et al., 2008, 2009, 2013, 2014) [13-17].

II. EXPERIMENTAL RESEARCH

A. *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 8 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. The differentiation of specimens lies in varying degrees of elongation imposed on each one of them. Fig. 1 presents specimens' front view both for tensile and compressive loading. Specimen characteristics are brought together in Table 1.

TABLE I. 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-4Ø8-179-0-1	15x7.5x90	4Ø8	Ø4.2/3.3cm	1.79	24.89	0.00
2	Y-4Ø8-179-10-2	15x7.5x90	4Ø8	Ø4.2/3.3cm	1.79	24.89	10.00
3	Y-4Ø8-179-20-3	15x7.5x90	4Ø8	Ø4.2/3.3cm	1.79	24.89	20.00
4	Y-4Ø8-179-30-4	15x7.5x90	4Ø8	Ø4.2/3.3cm	1.79	23.33	30.00
5	Y-4Ø8-179-50-5	15x7.5x90	4Ø8	Ø4.2/3.3cm	1.79	24.89	50.00

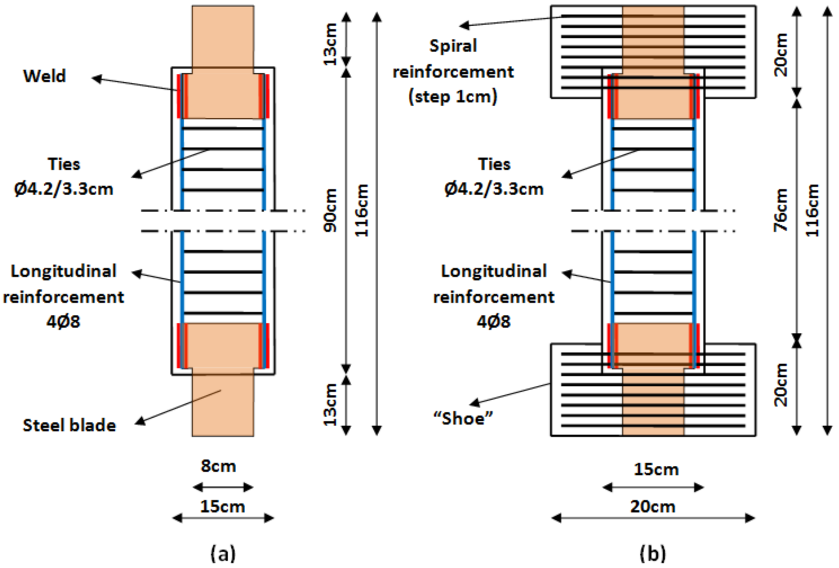

Figure 1. Sketch of front view of specimens for: (a) tension, (b) compression.

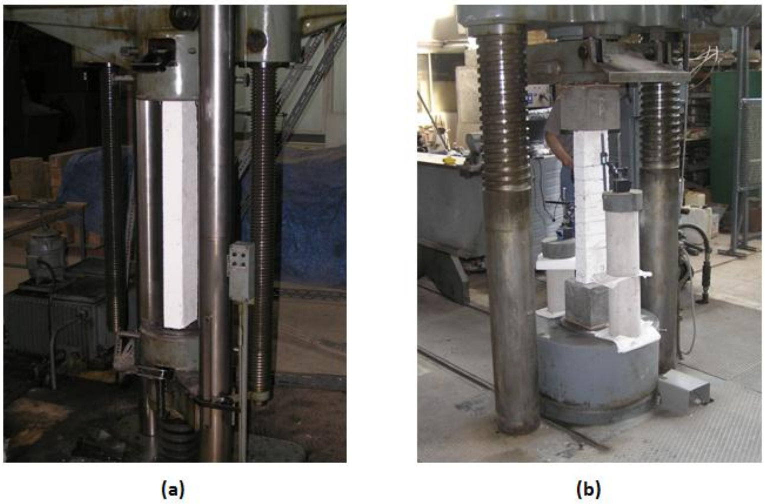

Figure 2. Test setup for application of: (a) Tensile loading, (b) Compressive loading.

B. *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.

III. 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. 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.

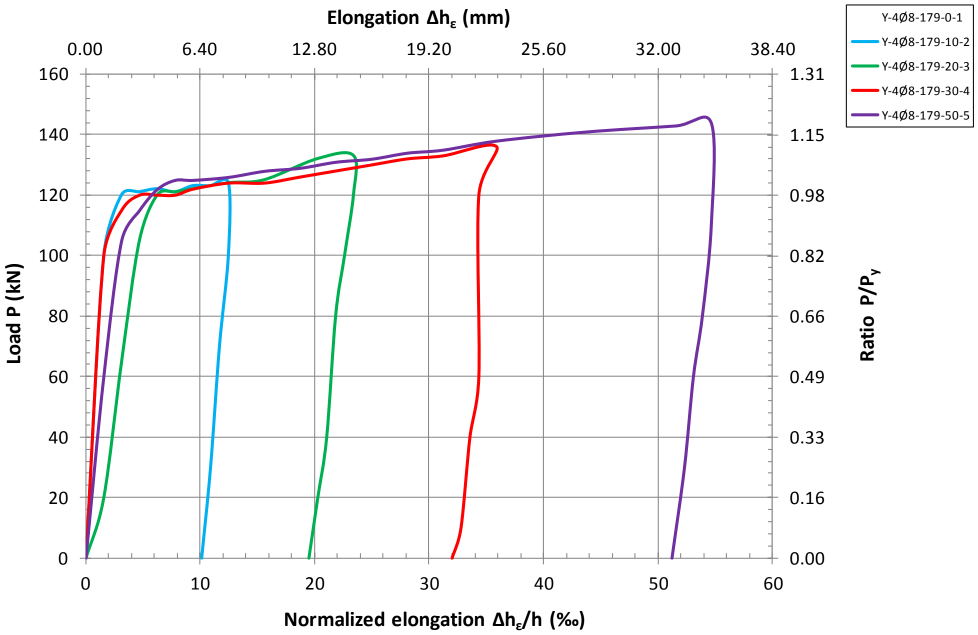

Figure 3. Diagram of tensile load [P(kN), P/P$_y$] – elongation [Δh$_ε$/h(‰), Δh$_ε$(mm)].

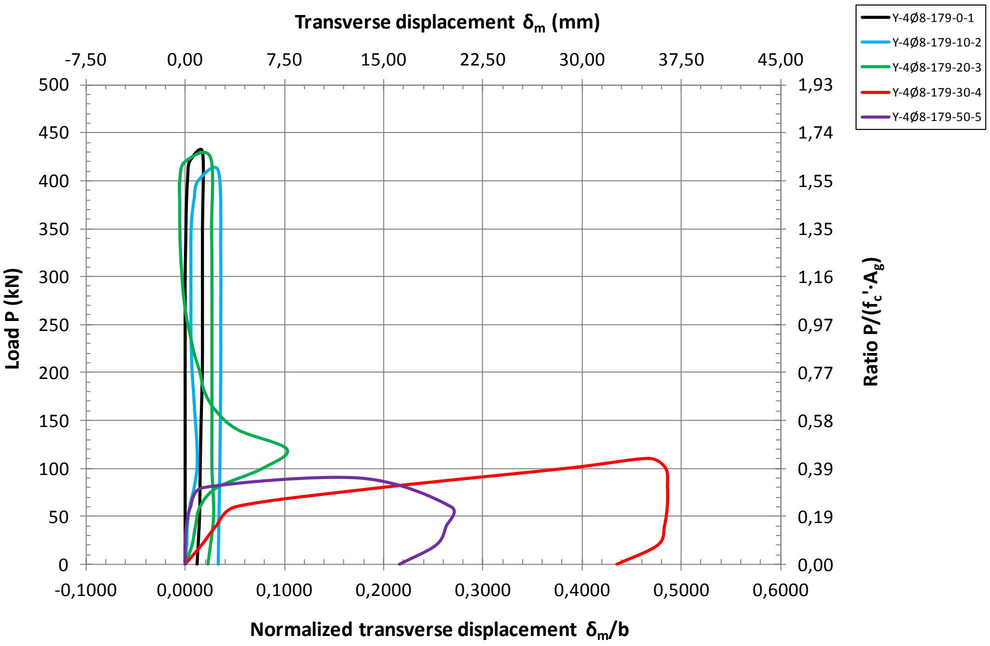

Figure 4. Diagram of compressive load [P(kN), P/(f$_c$'·A$_g$)] – transverse displacement at the midheight of test specimens [δ$_m$/b, δ$_m$(mm)].

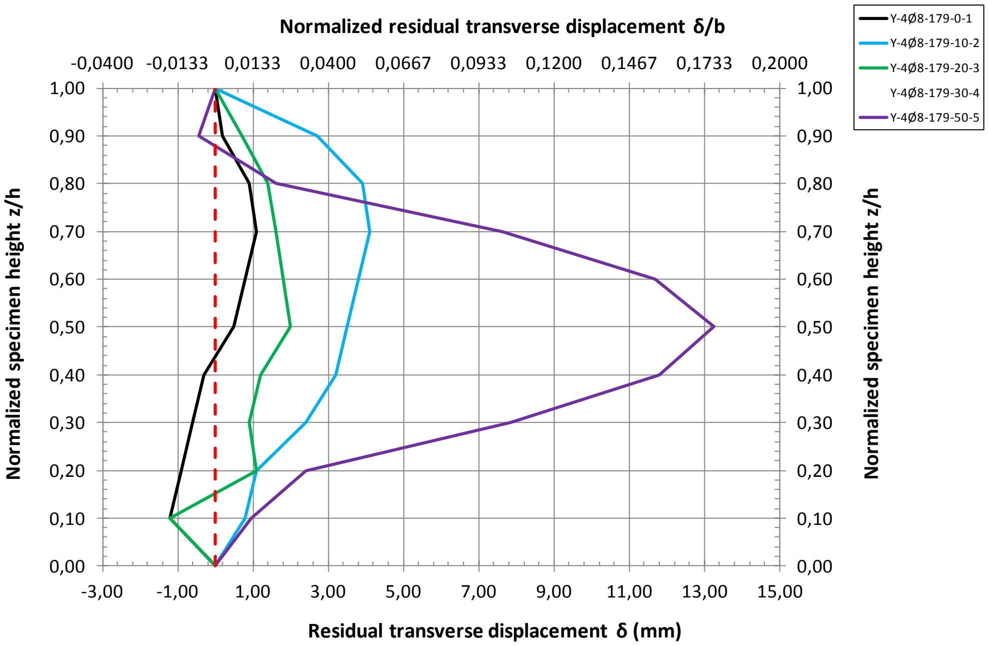

Figure 5. Diagram of normalized specimen height [z/h] – residual transverse displacement [δ(mm), δ/b].

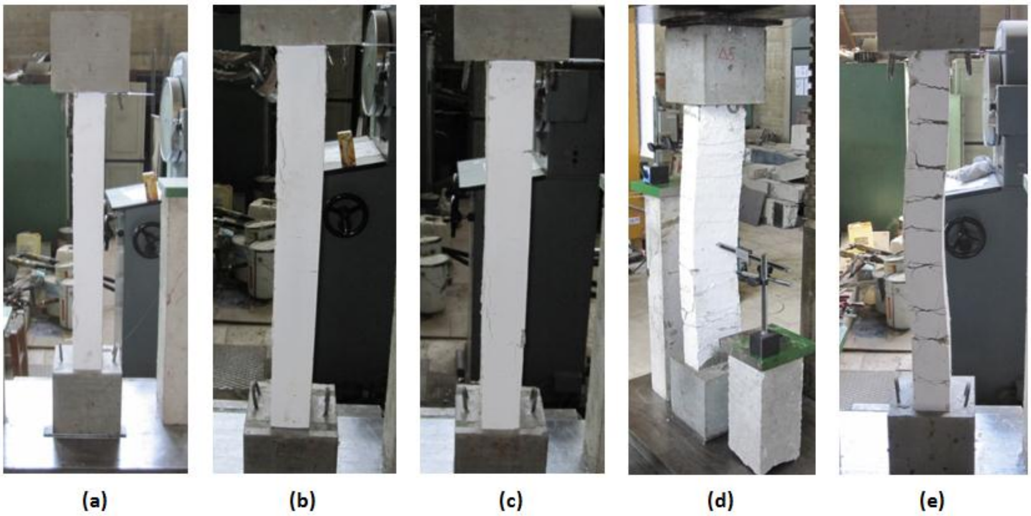

Figure 6. Failure modes of specimens after the experiment of compression: (a) Y-4Ø8-179-0-1, (b) Y-4Ø8-179-10-2, (c) Y-4Ø8-179-20-3, (d) Y-4Ø8-179-30-4, (e) Y-4Ø8-179-50-5.

IV. 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).

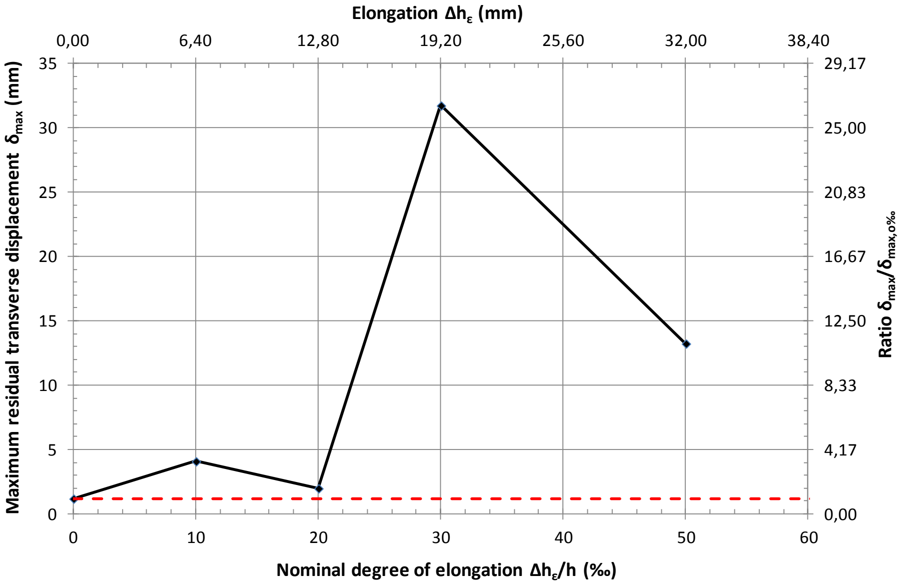

Figure 7. Diagram of maximum residual transverse displacement [δ_{max}(mm), $\delta_{max}/\delta_{max,0‰}$] – elongation [$\Delta h_\varepsilon/h$(‰), Δh_ε(mm)].

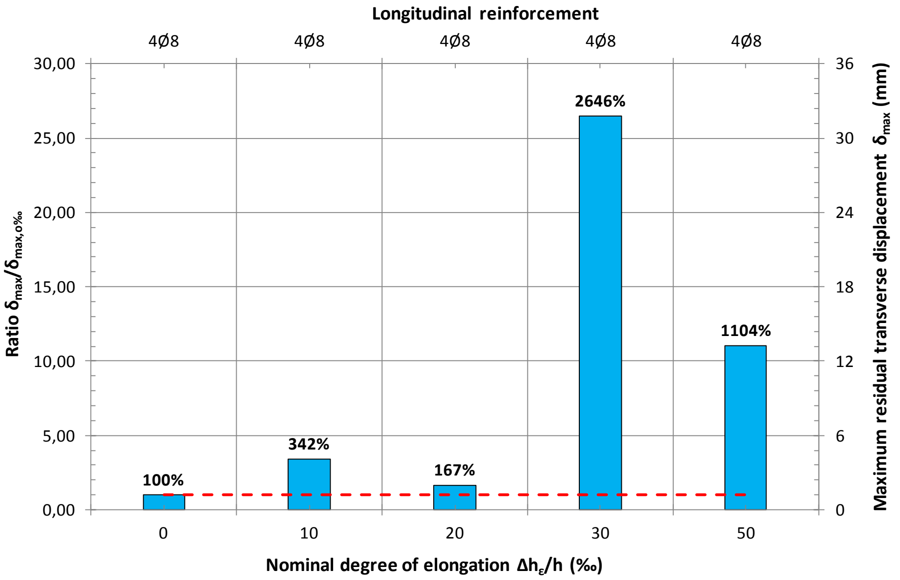

Figure 8. Column diagram of maximum residual transverse displacement [$\delta_{max}/\delta_{max,0‰}$, δmax(mm)] – elongation and type of longitudinal reinforcement [$\Delta h_\varepsilon/h$(‰)].

V. CONCLUSIONS

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

1. 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.

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