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Research Article

Investigation of nonlinear behavior of high ductility reinforced concrete shear walls

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ABSTRACT

In this study, the nonlinear behavior of ductile reinforced concrete (RC) shear walls having different parameters was analytically investigated. The purpose of this study is to determine the effect of axial load, longitudinal reinforcement ratio and transverse reinforcement ratios on the moment-curvature and lateral force-lateral peak displacement relationships of RC shear walls. RC shear walls that have various parameters were designed by taking into account the regulation of the Turkish Building Earthquake Code (TBEC, 2018). By considering the nonlinear behavior of the materials, behaviors of the RC shear walls were examined within the framework of the moment-curvature relation. The moment-curvature relations of RC shear walls with different parameters were obtained with the Mander model which takes into consideration the lateral confined concrete strength for different parameters. The effects of the analyzed parameters on the nonlinear behavior of the RC shear walls were evaluated in terms of curvature ductility, moment capacity, peak displacement, the angular displacement and displacement ductility values. It was seen that changes in the transverse reinforcement, longitudinal reinforcement, and axial load levels had important influence on the moment-curvature and lateral force-lateral peak displacement behavior of the RC shear walls.

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1. Introduction

Predicting the deformation capacity of RC shear walls is very important for a comprehensive performance-based seismic evaluation of existing or new buildings [1]. In order to achieve a more accurate simulation of the real structural behavior, designers need the accurate moment-curvature relationship for RC members and stress-strain relationships for unconfined and confined concrete [2]. To be able to understand if a structural design, realized regarding a specific seismic code or not, achieves the main aim of the seismic design, displacement ductility can be utilized [3].

RC shear walls are used effectively in earthquake-resistant building design or strengthening of existing structures in terms of the earthquake. In the seismic design performed displacement-based and for the performance assessment of structural members, sectional deformation quantities, such as ductility and curvature, have great importance. Nonlinear analysis are tools where the deformation response of structural elements is predicted according to the displacement-based procedures [4-5]. In this study, a parametric study was conducted in order to determine the effects of axial load levels (N/N_{max}), longitudinal reinforcement ratio, transverse reinforcement diameter and transverse reinforcement spacing on RC shear wall behavior. Many modeling approaches and analysis programs represent the nonlinear behavior of RC shear walls with different approaches. The behaviors of RC shear walls were examined over moment-curvature and lateral load-lateral peak displacement relations considering the nonlinear behavior of the materials. For this analytical study, a rectangular cross-sectional RC shear walls were designed. The rules are given in TS500 [6] and TBEC [7] are taken into consideration in the design of RC shear walls (Figure 2 and Table 1). The effects of different longitudinal reinforcement ratios, different axial load levels, transverse reinforcement diameters, and spacing on the nonlinear behavior of RC shear walls were investigated.

Inelastic behavior of the sections were obtained with the

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aid of the moment-curvature relationship based on the actual material behavior. The effects of axial load level, transverse reinforcement, longitudinal reinforcement, and special seismic crossties on the moment-curvature behaviors for the RC shear wall models were investigated and interpreted in detail. Lateral force-lateral peak displacement relationships were obtained and interpreted with the aid of the moment-curvature relationships of the RC shear walls.

2. Nonlinear Displacement in Reinforced Concrete Shear Walls

A significant part of the seismic design of concrete wall buildings is to ensure that the flexural displacement capacity of the shear walls is bigger than the flexural displacement demand [8]. The flexural displacement characteristic of a cantilever shear wall is normally the sum of the yield and the plastic displacement [9]. To determine the seismic response of RC structural walls, the plastic hinge method is still utilized broadly in seismic designs performed displacement-based and in the performance evaluation processes [10].

In the moment-curvature relationship, the RC shear wall peak displacement value up to the yield curvature can be calculated by Equation (1). The lumped plastic rotation (θ_p), along the plastic hinge length (L_p) is then computed using Equation (2). Where φ_u refers to the maximum curvature and φ_y refers to the yield curvature, as shown in Figure 1.

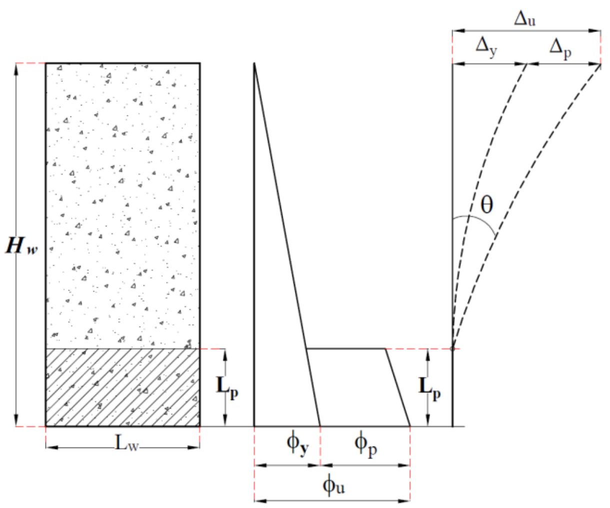

Figure 1. Theoretical model of elastic and plastic displacements in cantilever RC shear wall

In the plastic hinge analysis, the total peak displacement of the RC shear wall before the collapse (Δ_u) is obtained by summing its yield displacement (Δ_y) and plastic displacement (Δ_p) components (Equation (4)). H_w is the total height in the RC shear walls. After the calculation of both displacements, displacement ductility is determined as $\mu_\Delta = \Delta_u/\Delta_y$. The angular displacement of the RC shear wall before the collapse (θ_u) can be calculated by Equation (5).

$$\Delta_y = \frac{\varphi_y \times H_w^2}{3} \tag{1}$$

$$\theta_p = \varphi_p L_p = (\varphi_u - \varphi_y) L_p \tag{2}$$

$$\Delta_p = (\varphi_u - \varphi_y) \times L_p \times (H_w - 0.50 L_p) \tag{3}$$

$$\Delta_u = \Delta_y + \Delta_p \tag{4}$$

$$\theta_u = \frac{\varphi_y \times H_w}{2} + (\varphi_u - \varphi_y) \times L_p \tag{5}$$

To be able to determine the plastic hinge length (L_p), different equations have been suggested. For obtaining a safe displacement capacity from the curvature capacity, plastic hinge length may be considered as half of the shear wall length [8]. According to [7-8, 10-12], the length of the plastic deformation region called as plastic hinge length (L_p) is taken as the half of the section length in the active direction ($L_p = 0.50h$). The most significant parameter that affects the plastic hinge length is the dimensions of the reinforced concrete shear walls. The increases in plastic hinge length significantly affect the displacement and displacement ductility values of reinforced concrete shear walls [13].

3. Materials and Method

In this study, the nonlinear behavior of the rectangular cross-sectional high ductile RC shear walls were analytically investigated by changing the axial load levels, transverse reinforcement diameter, longitudinal reinforcement ratios, and transverse reinforcement spacing. For this analytical study, a rectangular cross-sectional concrete shear wall with 300mm×3000mm dimensions were designed. In TBEC [7] the ratio of the length of the long edge ($l_w = 3000mm$) of the RC shear walls to the thickness ($b_w = 300mm$) in the plan has been determined to be greater than six ($l_w > 6b_w$). As the ratio of the total height ($H_w = 10000mm$) in the RC shear walls to the plan length ($l_w = 3000mm$) is chosen to be greater than two ($H_w/l_w > 2$), the shear walls confined boundary elements are formed at both ends of the walls. Confined boundary region dimensions (l_u) of RC shear walls are chosen as 300mm×600mm.

The reinforcement diameters and reinforcement ratio used in the shear wall cross-sections were determined by considering the limitations given by TBEC [7]. According to TBEC [7], total cross-section area of each of the longitudinal and transverse web reinforcement on both faces of the structural wall shall not be less than 0.0025 of the cross-section area of the shear wall web remaining in between the shear wall boundary regions. The ratio of the total longitudinal reinforcement area at each wall boundary region to the gross wall cross-section area shall not be less than 0.002 along with the critical shear wall height. The longitudinal and transverse web reinforcement spacing of the RC shear walls were designed according to TBEC [7]. Longitudinal web reinforcement and longitudinal reinforcements in boundary regions limitations were checked for the designed RC shear wall according to the TBEC [7]. Checked of the longitudinal reinforcement limitations in web and boundary regions for the designed RC shear wall are given Table 2. For all models, as concrete grade, C30 was selected, and as reinforcement, B420C was used. The stress-strain curves presented in TBEC [7] were utilized for the reinforcement behavior model. In the analytical study for RC shear walls, the material parameters given in Table 3 for reinforcement and concrete are used. For concrete classes, concrete elasticity modulus (E_c) are calculated according to the concrete compressive strengths (f_{ck}) given in TS500 [6], ($E_c = 3250\sqrt{f_{ck}} + 14000\ MPa$).

$$\frac{A_s}{(l_w - 2l_u) \times b_w} \geq 0.0025 \leftrightarrow \frac{A_s}{(3000 - 2 \times 600) \times 300} \geq 0.0025 \leftrightarrow A_s \geq 1350mm^2 \quad (6)$$

$$\frac{A_s}{l_w \times b_w} \geq 0.002 \leftrightarrow \frac{A_s}{3000 \times 300} \geq 0.002 \leftrightarrow A_s \geq 1800mm^2 \quad (7)$$

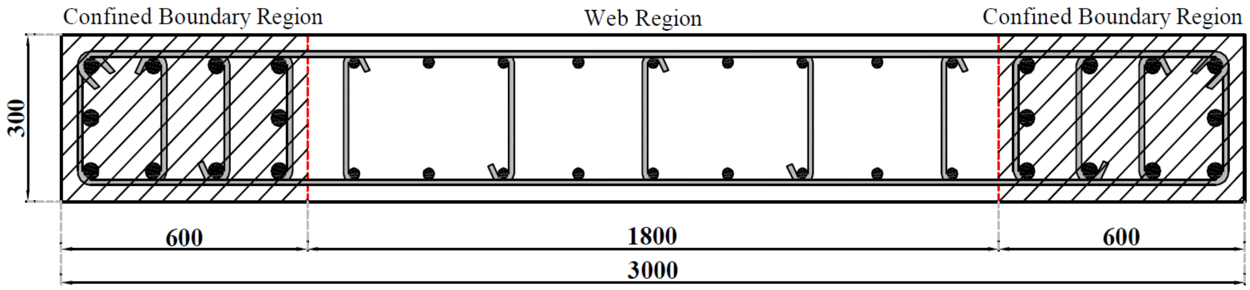

Figure 2. The sectional geometry and reinforcement appearance of RC shear walls

Table 1. Details for the designed RC shear wall cross-sections

No	Longitudinal reinforcement on confined boundary region	Transverse reinforcement on confined boundary region	Longitudinal reinforcement on shear wall web region	Transverse reinforcement on shear walls
P1	10Φ16mm	Φ8/150mm	18Φ12mm	Φ8/150mm
P2	10Φ16mm	Φ8/100mm	18Φ12mm	Φ8/100mm
P3	10Φ16mm	Φ8/50mm	18Φ12mm	Φ8/50mm
P4	10Φ16mm	Φ10/100mm	18Φ12mm	Φ10/100mm
P5	10Φ16mm	Φ12/100mm	18Φ12mm	Φ12/100mm
P6	10Φ16mm	Φ14/100mm	18Φ12mm	Φ14/100mm
P7	10Φ18mm	Φ12/100mm	18Φ12mm	Φ12/100mm
P8	10Φ20mm	Φ12/100mm	18Φ12mm	Φ12/100mm
P9	10Φ20mm	Φ12/100mm	18Φ14mm	Φ12/100mm
P10	10Φ20mm	Φ12/100mm	18Φ16mm	Φ12/100mm

Table 2. Longitudinal reinforcement limitations in web and boundary regions for the designed shear wall [7]

Longitudinal web reinforcement limitation			
Selected Reinforcement	18Φ12mm	18Φ14mm	18Φ16mm
$\frac{A_s}{(L_w - 2l_u) \times b_w} \geq 0.0025$	$0.0038 \geq 0.0025$	$0.0051 \geq 0.0025$	$0.0067 \geq 0.0025$
Longitudinal reinforcements in boundary region limitation			
Selected Reinforcement	10Φ16mm	10Φ18mm	10Φ20mm
$\frac{A_s}{L_w \times b_w} \geq 0.002$	$0.0022 \geq 0.002$	$0.0028 \geq 0.002$	$0.0035 \geq 0.002$

Table 3. Material parameters for concrete and reinforcement [7]

Standard Strength	Parameters	Values
Concrete: C30	Strain at maximum stress of unconfined concrete (ε_{co})	0.002
	Ultimate compression strain of concrete (ε_{cu})	0.0035
	Characteristic standard value of concrete compressive strength (f_{ck})	30MPa
Reinforcement: B420C	Yield strain of reinforcement (ε_{sy})	0.0021
	Strain hardening value of reinforcing steel (ε_{sp})	0.008
	Strain in reinforcing steel at ultimate strength (ε_{su})	0.080
	Characteristic yield strength of reinforcement (f_{yk})	420MPa
	Ultimate strength of reinforcement (f_{su})	550MPa

The relationships of moment-curvature were determined and shown as graphically by applying SAP2000 Software that takes into account nonlinear behaviors of materials [14]. The designed cross-section models of the reinforced shear wall were thought as consisting of three components. These components were confined concrete, cover concrete, and reinforcement steel. The material models of SAP2000 [14] are determined by taking into account the Mander unconfined concrete model for cover concrete, and the Mander confined concrete model [15] for core concrete. To be able to identify the moment-curvature relations of RC members, a concrete model suggested by the Mander model [15] that was broadly utilized, commonly accepted, and mandatory in TBEC [7] was utilized. In terms of reinforcement modeling, material parameters for reinforcement presented in TBEC [7] was utilized.

The influences of the analyzed parameters on the nonlinear behaviors of the RC shear walls were evaluated in terms of curvature ductility (μ_φ) and the moment capacity, yield displacement, plastic displacement, total peak displacement, the angular displacement of the shear wall (θ_u) and displacement ductility (μ_Δ) values. The moment-curvature and lateral force-lateral peak displacement curves were drawn for RC shear walls with different parameters and were interpreted by comparing the curves. The curvature ductility factor (μ_φ) is obtained by the ratio of curvature determined at the ultimate limit state and the curvature determined at the first yield ($\mu_\varphi = \varphi_u/\varphi_y$).

The combined effect of seismic and vertical loads (N_{dm}) and cross-section area of the shear wall should meet the condition of $A_c \geq N_{dm}/0.35f_{ck}$ [7]. The moment-curvature, displacement and displacement ductility values were obtained for 0.15, 0.25, and 0.35 of axial load ratio for the RC shear wall sections. To be able to examine the influence of the axial load on the cross-section behaviors, the shear wall models were examined for three different axial forces: $N_1 = 4050kN$, $N_2 = 6750kN$ and $N_3 = 9450kN$.

It has been observed in previous studies that the moment-curvature behaviors of the reinforced concrete columns are affected significantly by changes occurring in axial load, transverse reinforcement diameter, longitudinal reinforcement diameter, and transverse reinforcement spacing [16].

Yield displacement, plastic displacement and total displacement values of the elements were calculated for different axial load levels according to the calculated by plastic hinge length in RC shear wall sections. Elastic and plastic displacements are taken into consideration in the total displacement relations of RC shear walls. In calculating the total displacement of the RC shear walls, the yield and maximum curvature values were obtained from the moment-curvature relations which take into account the section height, plastic hinge length and nonlinear behavior are taken into consideration.

4. Research Findings and Discussion

The limits of the damage regions were calculated based on the moment-curvature relations of RC shear walls according to various parameters. Curvature and moment values were obtained for the yield curvature and curvature values before the collapse condition in RC shear wall sections. The curvature ductility of the RC shear wall sections were calculated according to the yield curvature and ultimate curvature values. Depending on the curvature values which were obtained from the curvature-moment relations, the peak displacement in the case of yield and pre-collapse, angular displacement of the shear walls and the peak displacement ductility values were obtained. The effects of the analyzed parameters on the nonlinear behaviors of the RC shear walls were evaluated in terms of curvature ductility and the moment capacity, yield displacement, plastic displacement, total peak displacement, the angular displacement of the shear wall, and displacement ductility values. The results of the investigations carried out on the moment-curvature relations are presented in tables and the failure types and behaviors of the RC shear wall sections are analyzed.

Yield curvature and maximum curvature values of the curvature-moment relations of the sections were obtained for the calculation of the total displacement values of the RC shear walls. According to different axial load levels, the displacement ductility of the shear walls was calculated by obtaining yield, plastic and total displacement values of RC shear walls.

Comparison of the moment-curvature and lateral force-lateral peak displacement relationships of P1, P2 and P3 shear walls for different axial load levels are given in Figure 3. For constant axial load levels of P1, P2 and P3, moment-curvature relationships for different transverse reinforcement spacing are given in Figure 4. Moment-curvature and lateral force-lateral peak displacement relationships of P4, P5 and P6 for different axial load levels are given in Figure 5. For constant axial load levels of P4, P5 and P6, moment-curvature relationships for different transverse reinforcement diameters are given in Figure 6. Comparison of the moment -curvature and lateral force-lateral peak displacement relationships of P7 and P8 for various axial load levels are given in Figure 7. For constant axial load levels, moment-curvature relationships for different longitudinal reinforcement diameters at the confined boundary region of P7 and P8 are given in Figure 8. Moment-curvature and lateral force-lateral peak displacement relationships of P9 and P10 for various axial load levels are given in Figure 9 comparatively. For constant axial load levels, comparison of the curvature-moment relations for various longitudinal reinforcement diameters at the web region of P9 and P10 are shown in Figure 10.

Values of curvature and moment were obtained for the yield curvature and curvature values before the collapse condition for various axial load levels in RC shear wall sections with different transverse reinforcement spacing. The μ_{φ}, Δ_y, Δ_u, θ_u and μ_{Δ} values of the P1, P2 and P3 shear wall sections for different transverse reinforcement spacing are presented in Table 4.

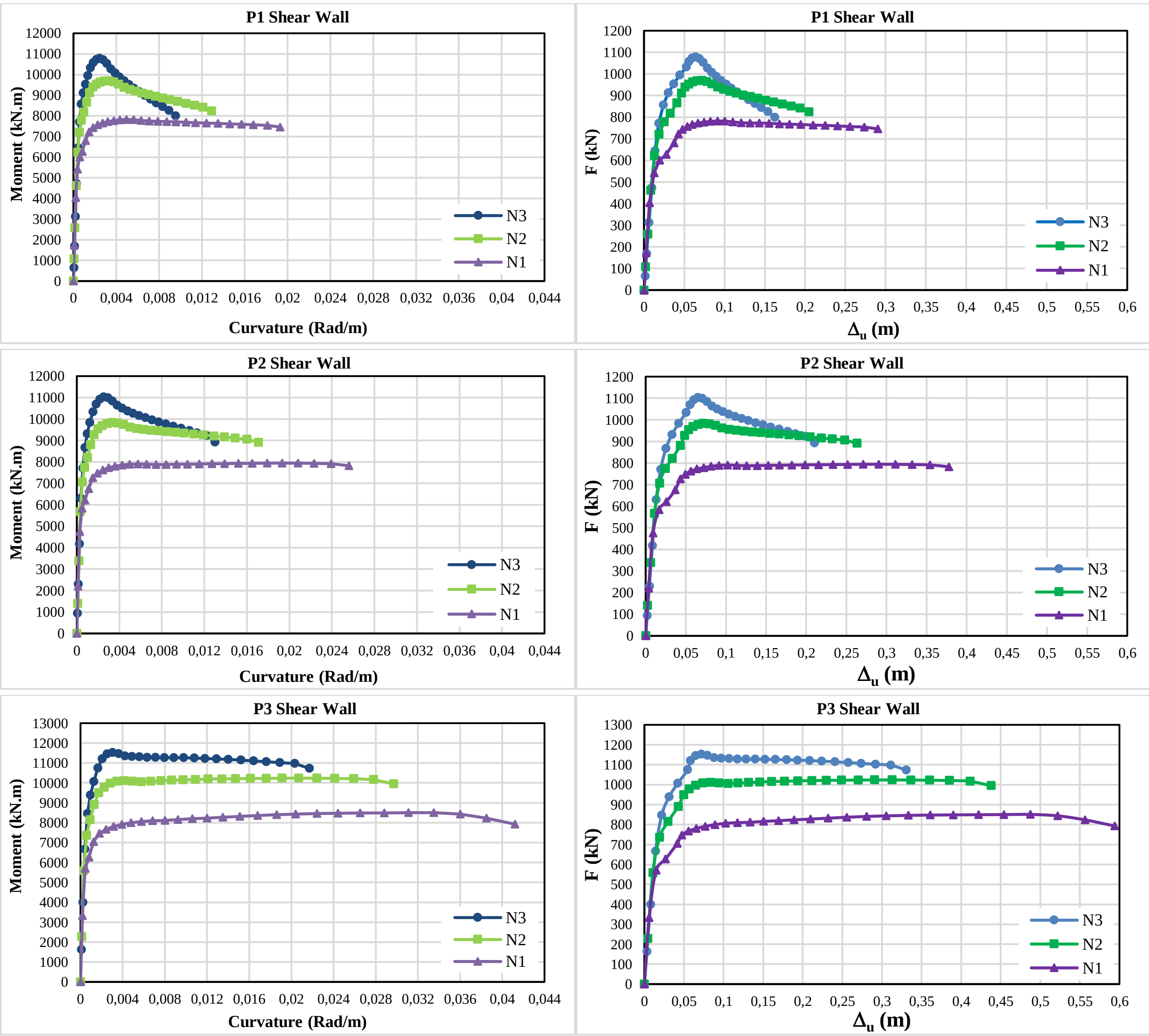

Figure 3. Moment-curvature and lateral force-lateral peak displacement relationships for different axial load levels

In RC shear walls (P4, P5 and P6) with different transverse reinforcement diameters, moment and curvature values were obtained for the yield curvature and curvature values before the collapse condition for different axial load levels. According to the yield curvature and curvature values before the collapse, μ_φ, Δ_y, Δ_u, θ_u and μ_Δ values of P4, P5 and P6 shear wall sections are presented in Table (5).

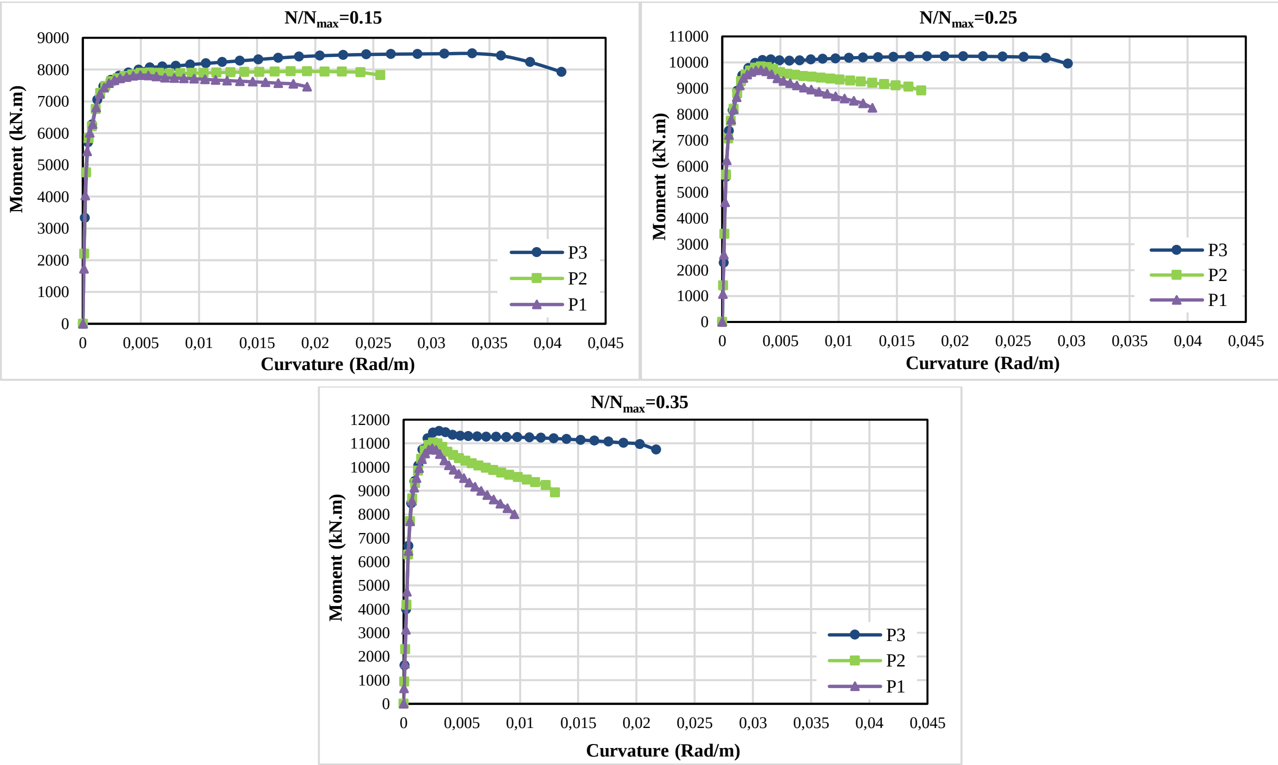

Figure 4. For different transverse reinforcement spacing, moment-curvature relations

Table 4. Analysis results of P1, P2 and P3 for different transverse reinforcement spacing

No	N/N_{max}	M_y (kN.m)	φ_y (Rad/m)	M_u (kN.m)	φ_u (Rad/m)	μ_φ	$\Delta_y(m)$	$\Delta_u(m)$	θ_u (Rad)	μ_Δ
P1	0.15	6847	0.0012	7523	0.0193	16.78	0.038	0.290	0.033	7.57
	0.25	8841	0.0013	9404	0.0129	9.70	0.044	0.205	0.024	4.62
	0.35	10290	0.0016	10490	0.0095	6.14	0.052	0.162	0.020	3.14
P2	0.15	6867	0.0012	7941	0.0256	22.26	0.038	0.378	0.042	9.85
	0.25	8871	0.0013	9837	0.0171	12.86	0.044	0.263	0.030	5.94
	0.35	10379	0.0015	11028	0.0130	8.44	0.051	0.210	0.025	4.10
P3	0.15	6895	0.0012	8506	0.0412	35.83	0.038	0.594	0.066	15.50
	0.25	8964	0.0013	10236	0.0297	22.50	0.044	0.438	0.049	9.95
	0.35	10546	0.0015	11519	0.0217	14.28	0.051	0.331	0.038	6.53

Table 5. Analysis results of P4, P5 and P6 shear wall sections for different transverse reinforcement diameters

No	N/N_{max}	M_y (kN.m)	φ_y (Rad/m)	M_u (kN.m)	φ_u (Rad/m)	μ_φ	$\Delta_y(m)$	$\Delta_u(m)$	θ_u (Rad)	μ_Δ
P4	0.15	6835	0.0012	8187	0.0360	31.30	0.038	0.522	0.058	13.61
	0.25	8896	0.0013	9946	0.0242	18.20	0.044	0.362	0.041	8.16
	0.35	10449	0.0015	11223	0.0173	11.23	0.051	0.270	0.031	5.26
P5	0.15	6897	0.0012	8471	0.0403	33.00	0.038	0.597	0.066	15.57
	0.25	8971	0.0013	10169	0.0327	24.59	0.044	0.480	0.054	10.82
	0.35	10531	0.0015	11487	0.0243	15.88	0.051	0.367	0.042	7.19
P6	0.15	6926	0.0012	8672	0.0406	35.30	0.038	0.657	0.072	17.64
	0.25	9043	0.0013	10610	0.0426	29.27	0.044	0.550	0.061	14.02
	0.35	10671	0.0015	11756	0.0299	19.80	0.050	0.444	0.050	8.83

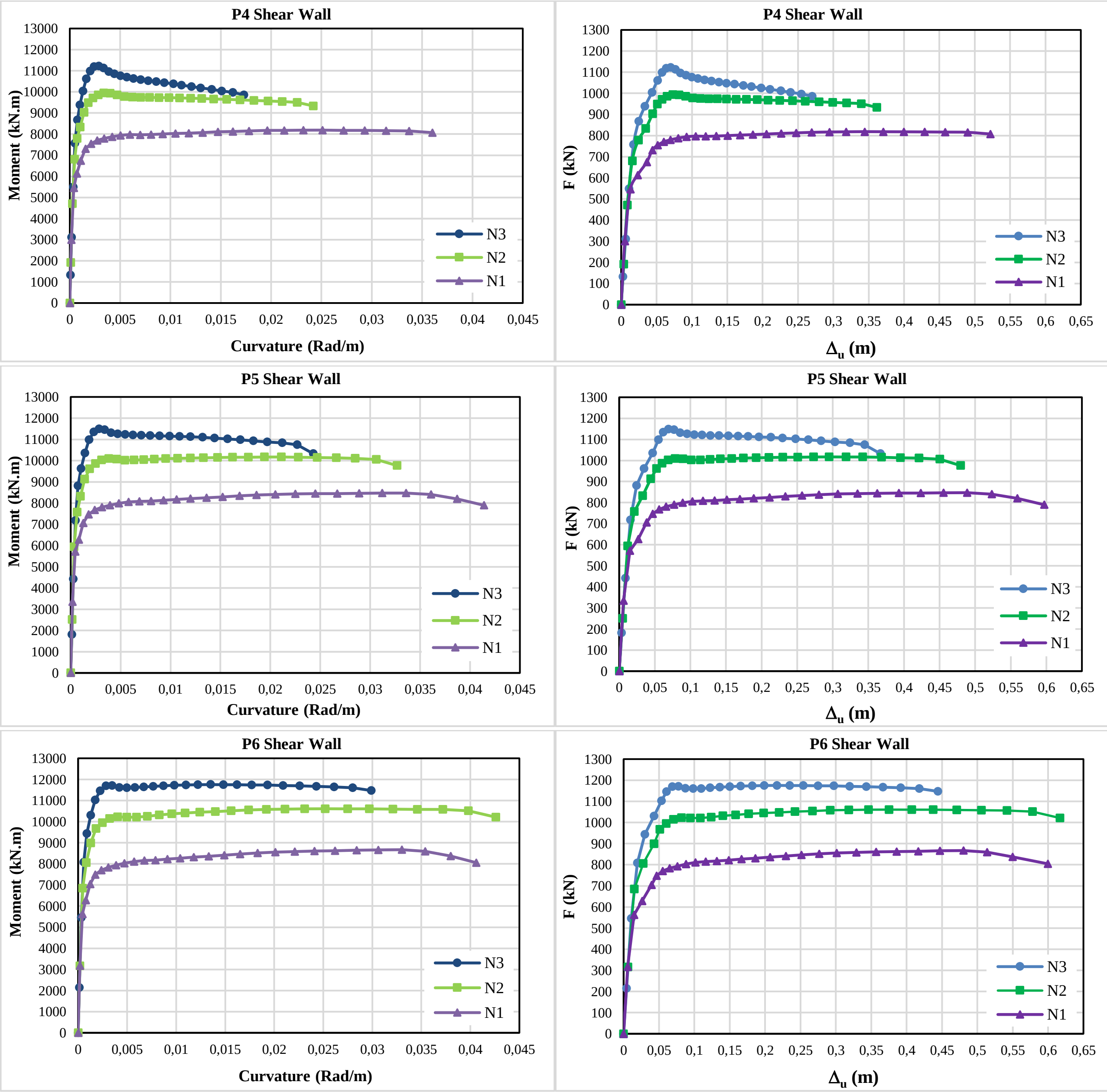

Figure 5. Moment-curvature and lateral force-lateral peak displacement relationships for different axial load levels

Moment and curvature values were obtained for the yield curvature and curvature values before the collapse condition of P7 and P8 with different longitudinal reinforcement diameters at the confined boundary region for different axial load levels. According to the yield curvature and curvature values before the collapse condition, μ_φ, Δ_y, Δ_u, θ_u and μ_Δ values of the P7 and P8 shear wall sections are presented in Table 6.

Table 6. Analysis results of P7 and P8 shear walls for different longitudinal reinforcement diameters at the confined boundary region

No	N/N_{max}	M_y (kN. m)	φ_y (Rad/m)	M_u (kN. m)	φ_u (Rad/m)	μ_φ	$\Delta_y(m)$	$\Delta_u(m)$	θ_u (Rad)	μ_Δ
P7	0.15	7328	0.0012	9144	0.0414	35.69	0.039	0.597	0.066	15.44
	0.25	9403	0.0013	10798	0.0327	24.59	0.044	0.480	0.054	10.82
	0.35	10972	0.0015	12011	0.0243	15.88	0.051	0.367	0.042	7.19
P8	0.15	7811	0.0012	9891	0.0413	35.3	0.039	0.596	0.066	15.28
	0.25	9896	0.0013	11503	0.0323	24.29	0.044	0.474	0.053	10.69
	0.35	11464	0.0015	12595	0.0243	15.88	0.051	0.367	0.042	7.19

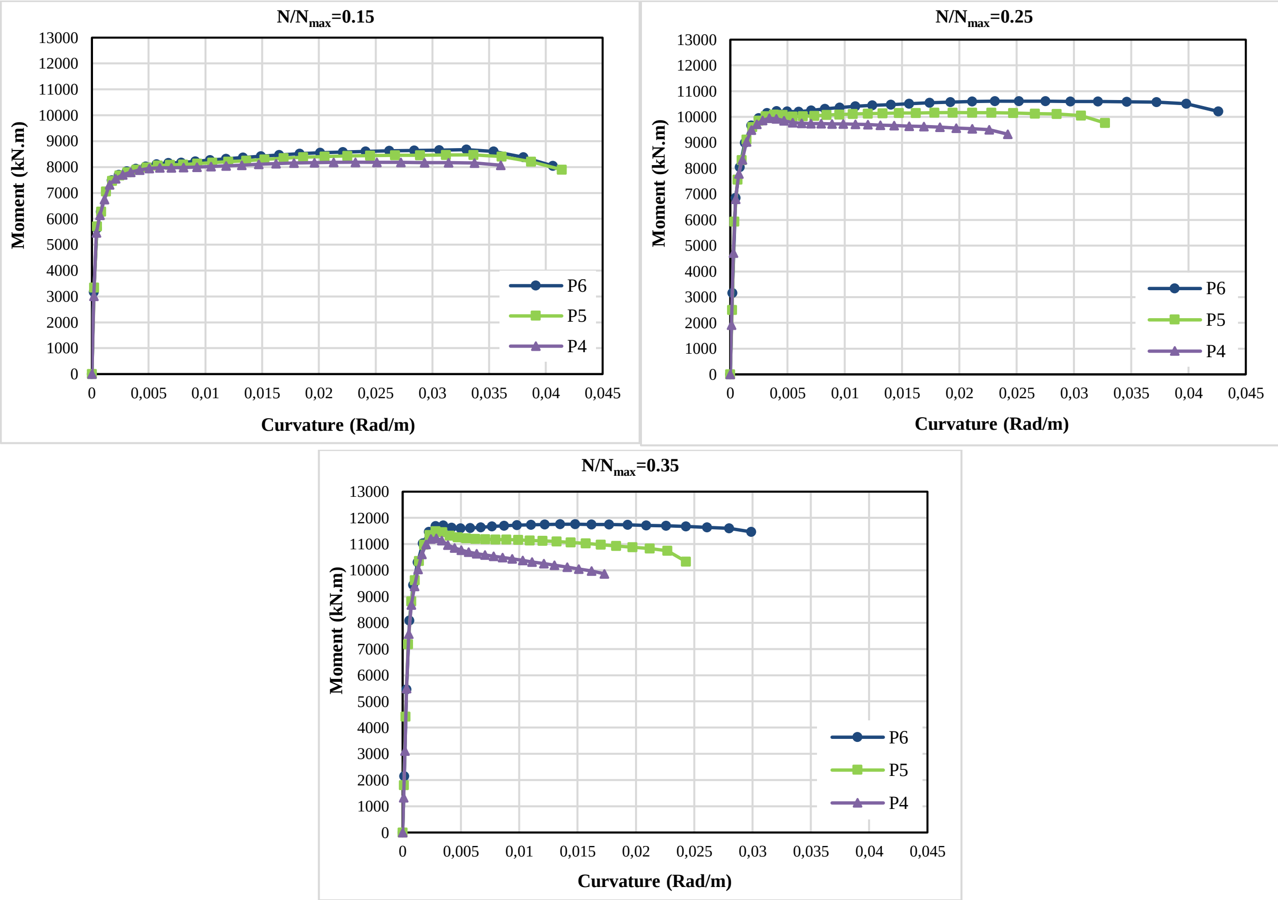

Figure 6. Moment-curvature relationships of P4, P5 and P6 for different transverse reinforcement diameters

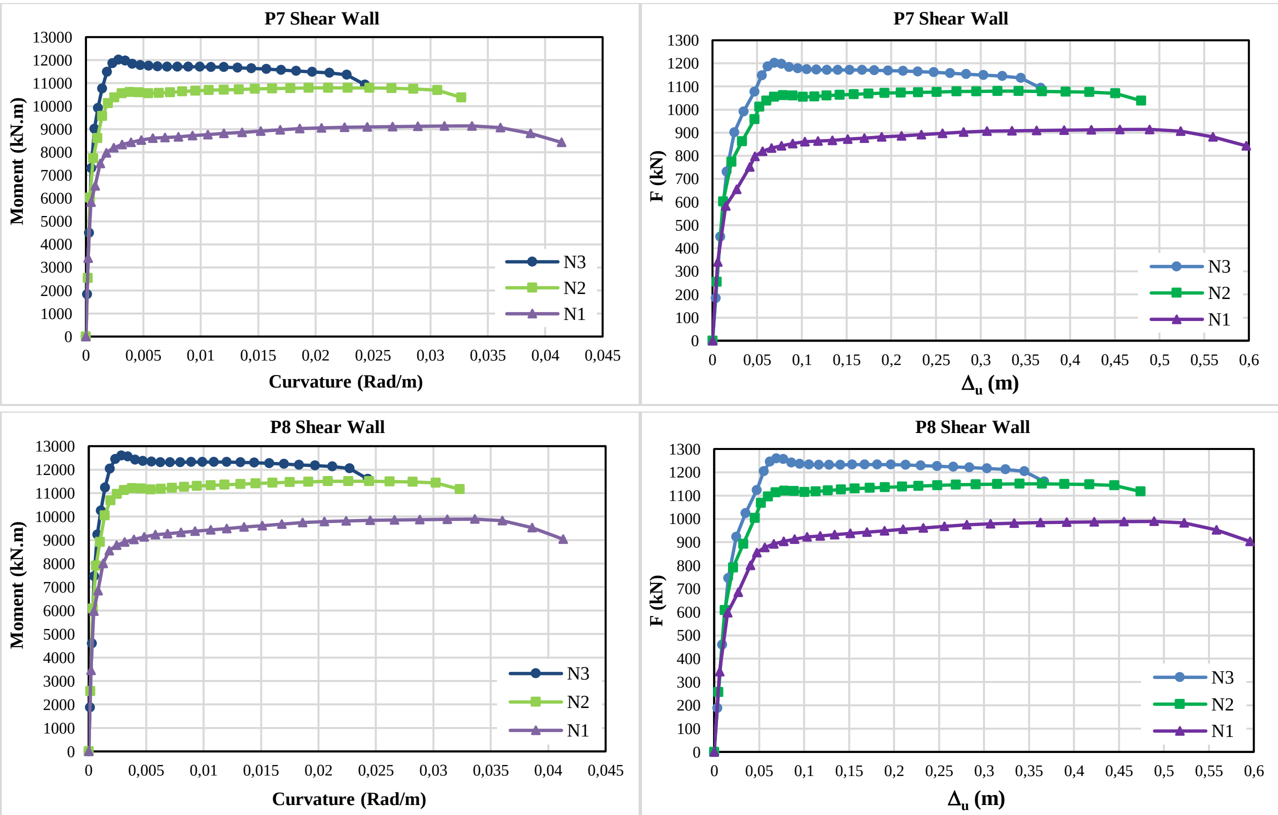

Figure 7. Moment-curvature and lateral force-lateral peak displacement relationships for different axial load levels

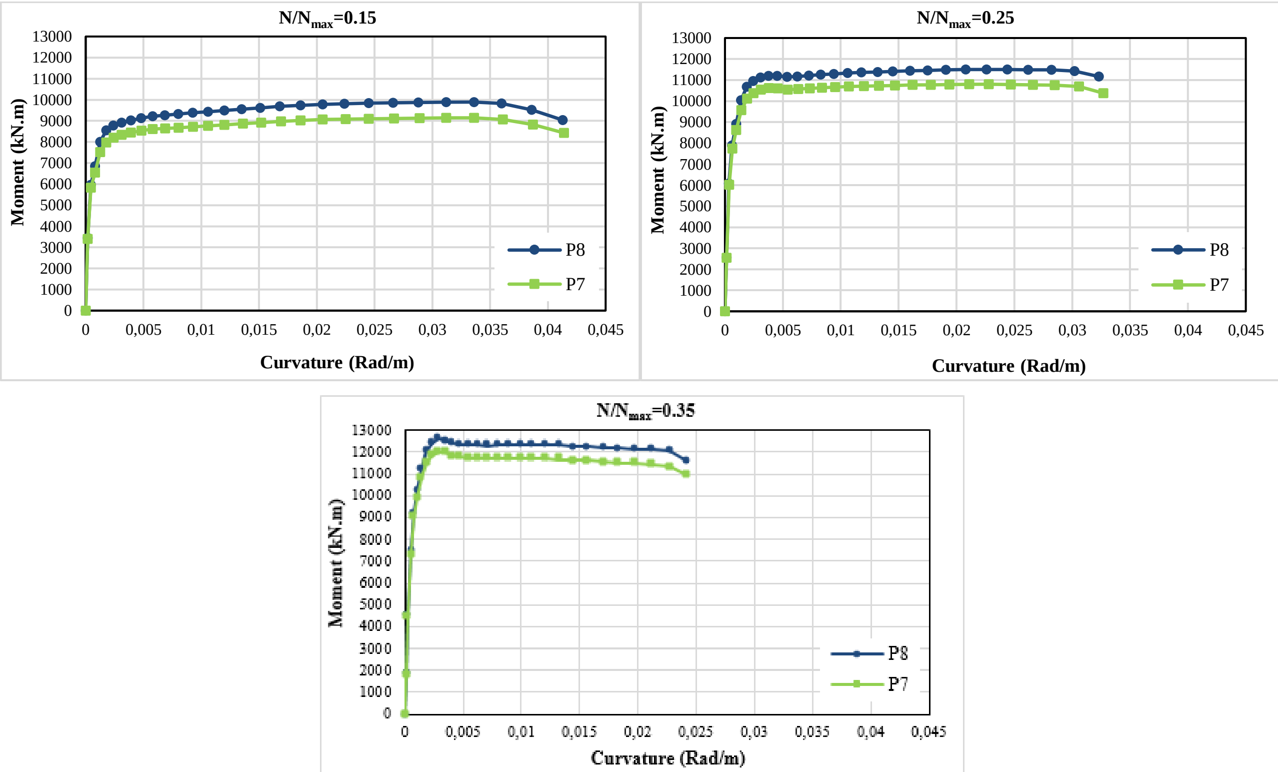

Figure 8. Moment-curvature relations with various longitudinal reinforcement diameters at the confined boundary region for P7 and P8 shear wall sections

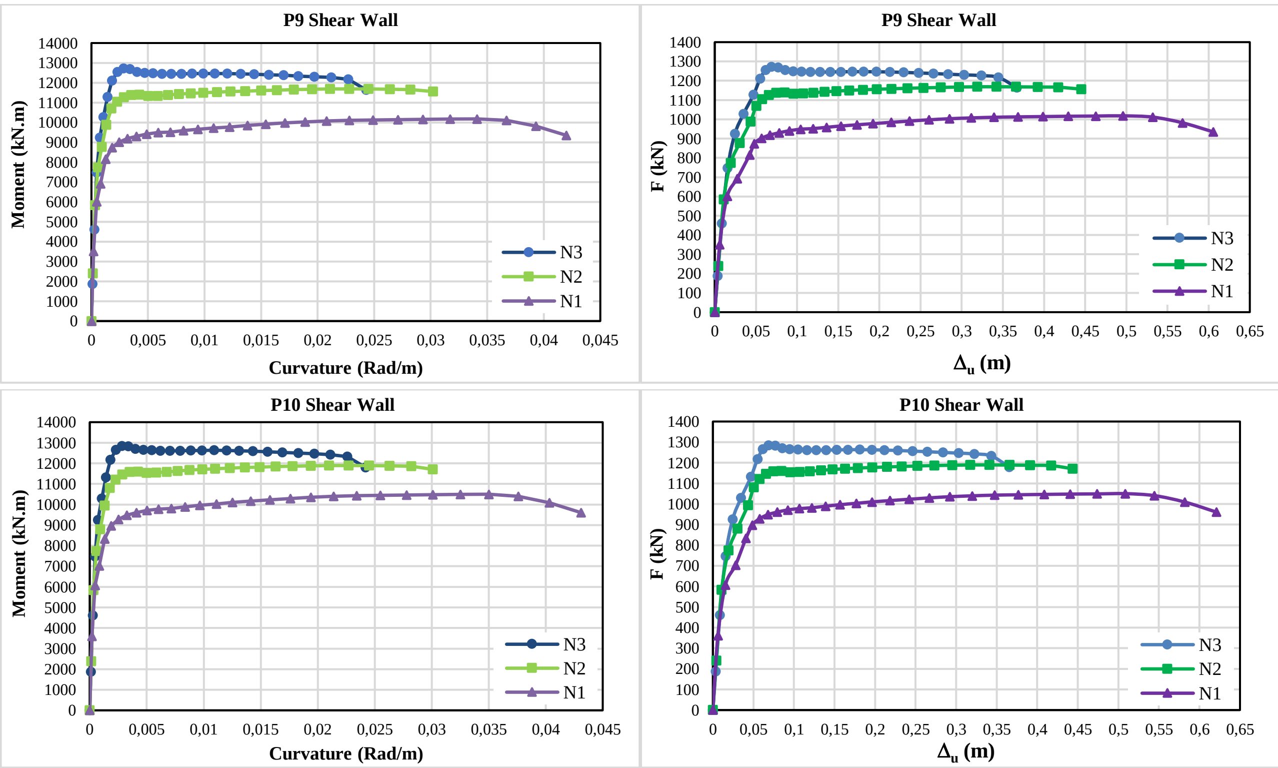

Figure 9. Moment-curvature and lateral force-lateral peak displacement relationships for different axial load levels

Moment and curvature values were obtained for the yield curvature and curvature values before the collapse condition of P9 and P10 shear wall sections with different longitudinal reinforcement diameters at the web region for different axial load levels. According to the yield curvature and curvature values before the collapse condition, μ_{φ}, Δ_y, Δ_u, θ_u and μ_{Δ} values of the P9 and P10 shear wall sections are presented in Table (7). Effects of various parameters on the ultimate moment, total displacement, curvature ductility, displacement ductility and angular displacement before the collapse for different axial load levels of the shear walls are given in Figures (11, 12, 13,14 and 15) respectively.

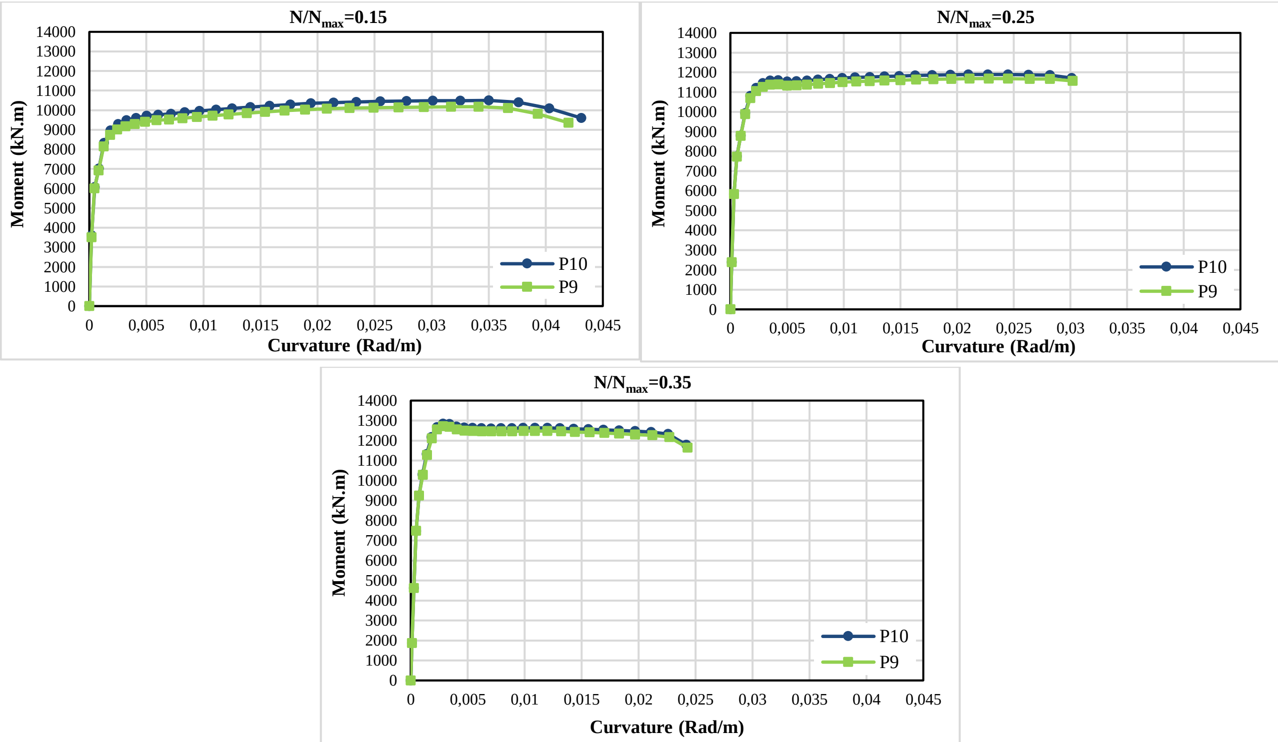

Figure 10. Moment-curvature relations for different longitudinal reinforcement diameters at the web region of P9 and P10 shear wall sections

Table 7. Analysis results of P9 and P10 shear wall for different longitudinal reinforcement diameters at the web region

No	N/N_{max}	M_y (kN.m)	φ_y (Rad/m)	M_u (kN.m)	φ_u (Rad/m)	μ_φ	$\Delta_y(m)$	$\Delta_u(m)$	θ_u (Rad)	μ_Δ
P9	0.15	7899	0.0012	10180	0.042	35.9	0.039	0.606	0.067	15.53
	0.25	9955	0.0013	11688	0.0302	22.55	0.045	0.445	0.050	9.97
	0.35	11514	0.0015	12715	0.0243	15.88	0.051	0.367	0.042	7.19
P10	0.15	7986	0.0012	10500	0.0431	36.84	0.039	0.621	0.069	15.92
	0.25	10026	0.0013	11892	0.0301	22.46	0.045	0.444	0.050	9.93
	0.35	11570	0.0015	12848	0.0242	15.82	0.051	0.366	0.042	7.17

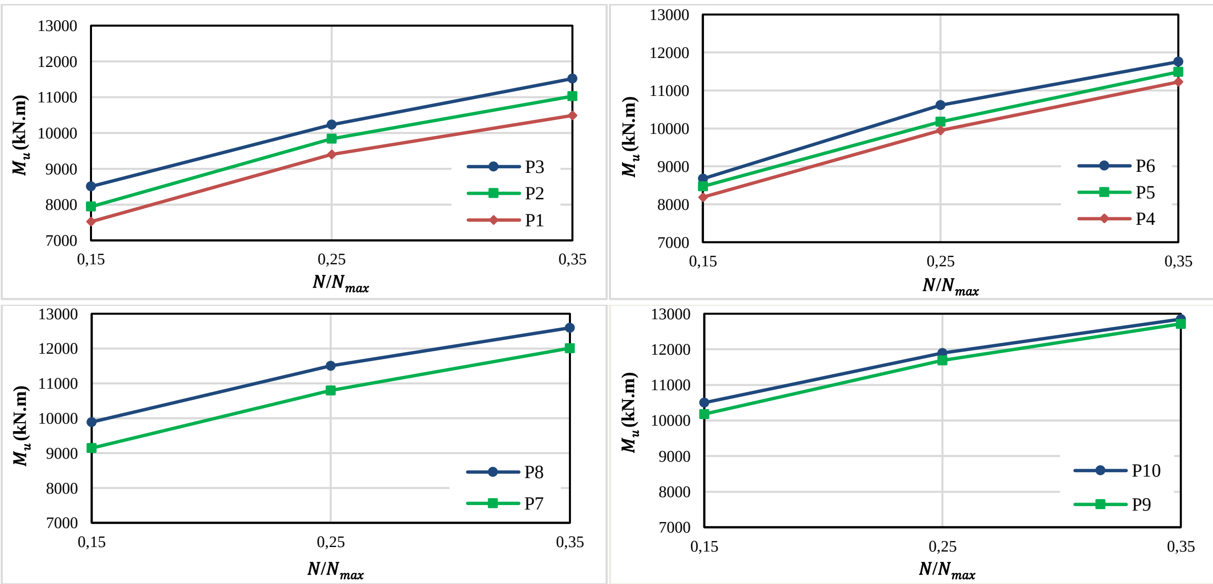

Figure 11. Effects of different parameters on the ultimate moment for various axial load levels

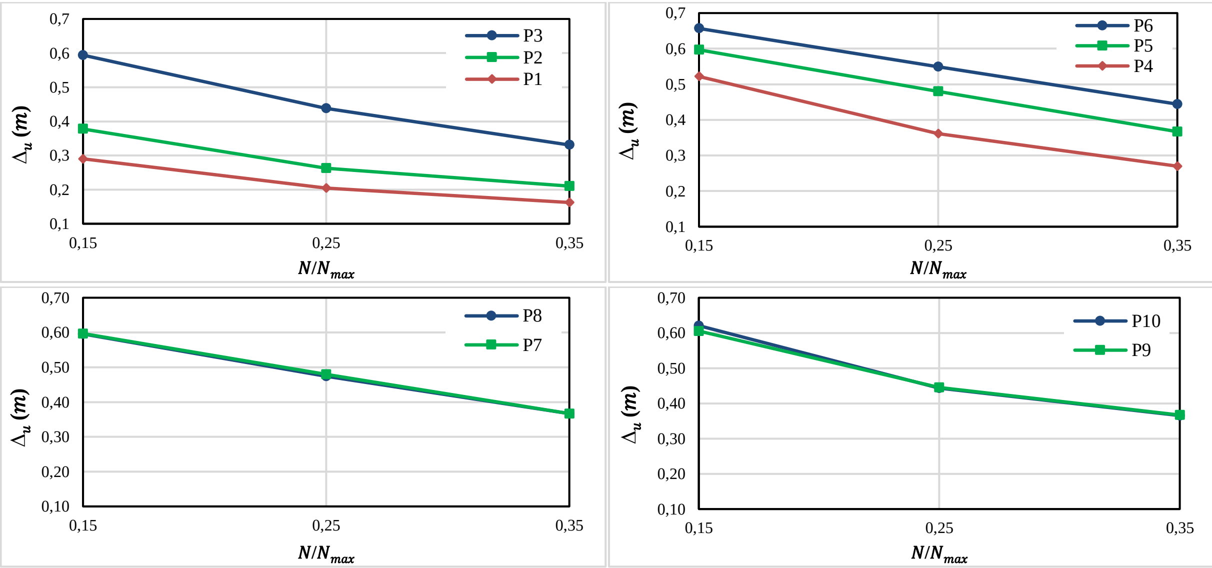

Figure 12. Effects of different parameters on the total displacement for various axial load levels

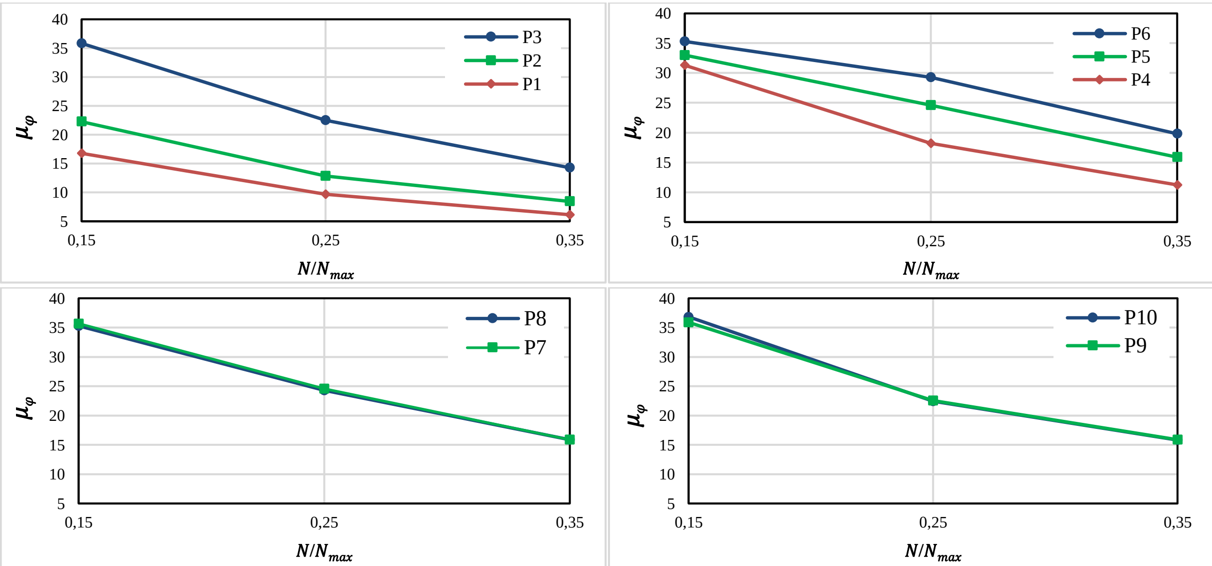

Figure 13. Influence of various parameters on the curvature ductility for different axial load levels

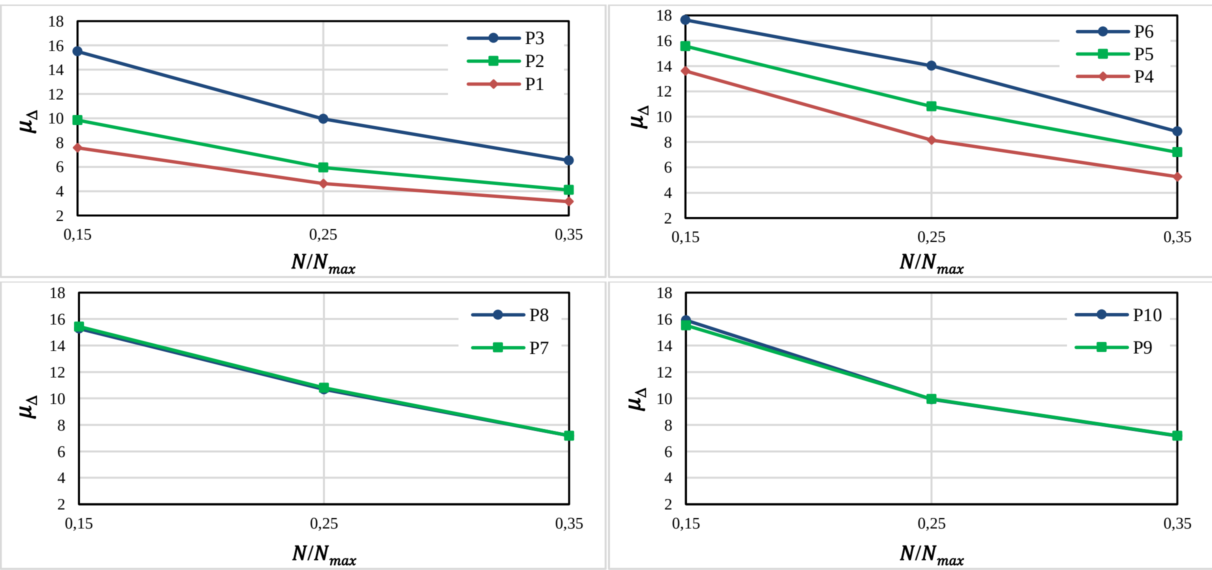

Figure 14. Influence of different parameters on the displacement ductility for different axial load levels

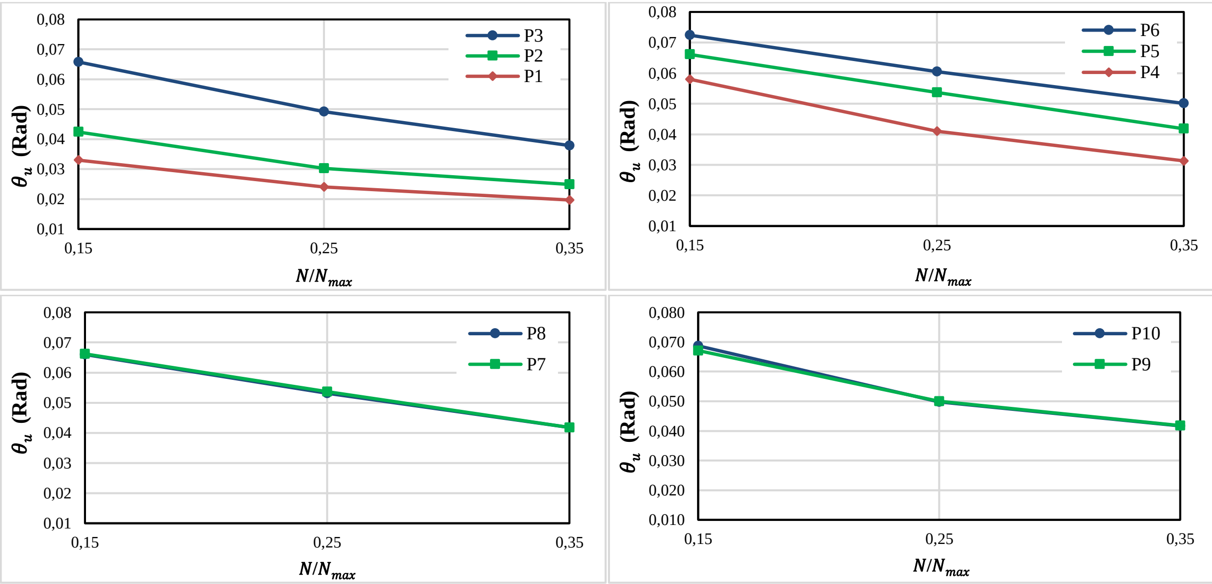

Figure 15. Effects of different parameters on the angular displacement before the collapse for different axial load levels

The results of the investigations conducted on the moment-curvature and lateral load-lateral peak displacement analysis of RC shear walls are given above. Based on the results of the analyses, it can be said that as the axial load values increase, yield, curvature, and ultimate moment values also increase. On the other hand, values of the curvature ductility and ultimate curvature decrease as the axial load values increase for the constant transverse reinforcement ratios. Curvature ductility values of the RC shear walls for constant transverse reinforcement and longitudinal reinforcement ratios decrease with increasing axial load ratio. It is observed that there are important decreases in ductility capacities of the shear walls as a result of increase in axial force. Looking at the moment-curvature graphs, it is seen that for fixed axial loads, the curvature ductility decreases as the transverse reinforcement spacing increases. It is observed that the curvature ductility increases significantly as the transverse reinforcement spacing decreases. There is a positive relationship between the transverse reinforcement diameters and the ductility of the cross-section and the maximum moment bearing capacity. In other words, as the former increases, the later ones also increase. Similarly, as the transverse reinforcement diameters increase, values of the ultimate curvature, moment, and curvature ductility values also increase; however, values of yield curvature and moment keep to be almost constant. While keeping the other parameters constant, an increase in the longitudinal reinforcement diameter leads to increase in values of yield moment, ultimate moment, yield curvature, and ultimate curvature; but, values of the curvature ductility decrease. Yield and ultimate moment capacities increase with the increment of longitudinal reinforcing ratio at the confined boundary and web region of the RC shear walls. There are differences in the yield curvature, ultimate curvature, yield displacement, plastic displacement, total peak displacement and displacement ductility values calculated according to different axial load levels. Yield displacement value increases however, plastic displacement, total peak displacement and displacement ductility values decrease with increasing axial load levels. Total peak displacement and displacement ductility values increase as the transverse reinforcement diameter of the shear wall increases. Total peak displacement and displacement ductility values decrease with the increase of the transverse reinforcement spacing of the shear wall. Total peak displacement and displacement ductility values almost constant with the increase of the longitudinal reinforcement ratio at the confined boundary and web region of the shear wall. Since the yield curvature value of the sections does not change, the peak-displacement value of the sections remains constant in the case of yield and however, the peak-displacement and angular displacement values are decreases before the collapse.

5. Conclusions

The results of this study show that changes in the longitudinal, and transverse reinforcements and axial load levels significantly affect the moment-curvature and lateral force-lateral peak displacement behaviors of the RC shear walls. In terms of affecting section ductility, axial load can be shown as one of the important parameters. According to the results, the ratio of transverse reinforcement affects the cross-section behaviors of RC shear walls. As the transverse reinforcement diameter increases, the optimum moment bearing capacity and the ductility of the cross-section also increase. As the transverse reinforcement ratio increases, the ductile behavior is ensured more because of the increment of curvature ductility on RC shear walls. The value of displacement ductility decreases with increasing yield displacement values and decreasing of total peak displacement values. Since the curvature values of the sections are constant in the yield state, the total peak-displacement values remain constant in the yield state and the angular displacement values of the peak displacement and sections before the collapse increase. As the axial load level increases, the total peak-displacement and angular displacement values of the sections decrease. There is not much change in the angular displacement values of the sections with the increase in the longitudinal reinforcement diameters at the confined boundary and web region of shear walls.

Declaration

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