SEISMIC PERFORMANCE EVALUATION OF DUAL REINFORCED CONCRETE SYSTEMS DESIGN ACCORDING TO TURKISH SEISMIC CODE, 2007

by

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ABSTRACT

SEISMIC PERFORMANCE EVALUATION OF DUAL REINFORCED CONCRETE SYSTEMS DESIGN ACCORDING TO TURKISH SEISMIC CODE, 2007

The aim of this study is to investigate the dual reinforced concrete frame systems of mixed ductility level which are described in Turkish Seismic Code, 2007, (TSC '07) by using Nonlinear Static Analysis (Pushover Analysis) for evaluating the seismic performance of these reinforced concrete buildings. For this purpose, a sample reinforced concrete structure is used according to Turkish Seismic Code, 2007, (2.5.4.1(c)), to evaluate the performance where the ratio of the sum of base shear developed at the bases of solid structural walls under seismic loads to the total base shear developed for the entire building is between the values 0.4 and 2/3 ($0.4<\alpha_S<2/3$). The sample structure has six storey with one-way ribbed slab system having two shearwalls in both x- and y-direction of high ductility level and it is also symmetrical to both x- and y-axes.

In the Nonlinear Static Analysis, modal load pattern procedure is used. The fundamental first mode is taken into account while evaluating the performance of the sample structure. Pushover Analysis including the capacity spectrum method (CSM) demonstrates how the building will behave when subjected to major earthquakes where it is assumed that the elastic capacity of the structure will be exceeded.

By performing the Pushover Analysis, interstorey drift ratios, hinge rotations and curvatures are obtained. The strain values of hinges were calculated by using the curvatures and these strain values are compared with the limit strain values described in TSC '07 (7.6.9).

Life safety (LS) structural performance level is chosen as a target for the model structure subjected to a design earthquake that may be exceeded within a period of 50 years with 10% probability. Comparing these values, the structure performance is evaluated and the results are shown in the tables.

ÖZET

SÜNEKLİK DÜZEYİ BAKIMINDAN KARMA TAŞIYICI BETONARME SİSTEMLERİN 2007 DEPREM YÖNETMELİĞİ'NE GÖRE PERFORMANS DEĞERLENDİRMESİ

Bu çalışmada, Türkiye Deprem Yönetmeliği'nde (2007) tanımlanan süneklilik düzeyi bakımından karma taşıyıcı sistemlerin lineer olmayan statik analiz yöntemi ile incelenerek performans değerlendirilmesi amaçlanmıştır.

Bu amaçla, Deprem Yönetmeliği'nde (2007) (2.5.4.1(c)) tanımlanan ve perdelerin tabanında deprem yüklerinden meydana gelen kesme kuvvetlerinin toplamının, binanın tümü için tabanda meydana gelen kesme kuvvetine oranı (α_S) 0.4 ve 2/3 değerleri arasında kalacak şekilde örnek bir betonarme bina dizayn edilmiştir. Seçilen bina 6 katlı dişli döşeme sistemli ve her iki yönde ikişer tane olmak üzere toplam dört adet perdeli çerçeveli bir sistemdir. Ayrıca bina x ve y eksenlerine göre simetrik olarak tasarlanmıştır.

Lineer olmayan analiz yönteminde, modal yükleme şekli kullanılmıştır. Birinci (dikkate alınan doğrultudaki hakim) mod şekli dikkate alınarak bina performans değerlendirmesi yapılmıştır. Kapasite spektrum metodunu içeren itme analizi, şiddetli depremlere maruz kalan binaların elastik kapasitelerini aştıktan sonra nasıl davranacaklarını gösteren bir metotdur.

Bu itme analizi sonucunda, rölatif kat ötelemeleri, plastik mafsal dönmeleri ve şekil değiştirme değerleri elde edilmiştir. Hesaplanan bu değerler, 2007 Deprem Yönetmeliği'ndeki (7.6.9) limit değerlerle karşılaştırılarak binanın performans değerlendirilmesi yapılmış ve sonuçlar tablolar halinde sunulmuştur.

Seçilen örnek bina için, 50 yıllık bir süre içinde aşılma olasılığı %10 olarak tanımlanan tasarım depremi etkisi altında can güvenliği (LS) performans seviyesi hedeflenmiştir.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS / ABBREVIATIONS

f_{ck}	Characteristic compressive cylinder strength of concrete
f_{cd}	Design compressive strength of concrete
f_{yk}	Characteristic yield strength of longitudinal reinforcement
f_{yd}	Design yield strength of longitudinal reinforcement
α_s	Ratio of the sum of base shear at the bases of structural walls of high ductility level to the base shear of the entire building
T_1	First natural vibration period of building [sec]
m_i	i^{th} storey mass of building ($m_i = w_i / g$)
d_{fi}	Displacement calculated at i^{th} storey of building under fictitious loads F_{fi}
F_{fi}	Fictitious load acting at i^{th} storey in the determination of fundamental natural vibration period
V_t	In the Equivalent Seismic Load Method, total equivalent seismic load acting on the building (base shear) in the earthquake direction considered
ΔF_N	Additional equivalent seismic load acting on the N^{th} storey (top) of building
w_i	Weight of i^{th} storey of building by considering Live Load Participation Factor
F_i	Design seismic load acting at i^{th} storey in Equivalent Seismic Load Method
H_i	Height of i^{th} storey of building measured from the top foundation level (In buildings with rigid peripheral basement walls, height of i^{th} storey of building measured from the top of ground floor level) [m]
W	Total weight of building calculated by considering Live Load Participation Factor
g_i	Total dead load at i^{th} storey of building
n	Live Load Participation Factor
q_i	Total live load at i^{th} storey of building
g	Acceleration of gravity (9.81 m/s^2)
S(T)	Spectrum Coefficient
T	Building natural vibration period [sec]
T_A ,T_B	Spectrum Characteristic Periods [sec]
A_o	Effective Ground Acceleration Coefficient
I	Building Importance Factor

η_{bi}	Torsional Irregularity Factor defined at i^{th} storey of building
H_N	Total height of building measured from the top foundation level (In buildings with rigid peripheral basement walls, total height of building measured from the top of the ground floor level) [m]
R	Structural Behaviour Factor
$R_{NÇ}$	Structural Behaviour Factor defined in Table 2.5 (TSC '07) for the case where entire seismic loads are carried by frames of nominal ductility level
R_{YP}	Structural Behaviour Factor defined in Table 2.5 (TSC '07) for the case where entire seismic loads are carried by walls of high ductility level
$R_a(T)$	Seismic Load Reduction Factor
A(T)	Spectral Acceleration Coefficient
N	Total number of stories of building from the foundation level (In buildings with rigid peripheral basement walls, total number of stories from the ground floor level)
$(EI)_e$	Effective flexural stiffness of the cracked section
$(EI)_0$	Flexural stiffness of the non-cracked section
N_D	Axial force at columns and walls under vertical loads
A_c	Gross section area of column or wall
f_{cm}	Available strength of concrete according to Section 7.2 (TSC '07)
f_{ym}	Available yield strength of reinforcement according to Section 7.2 (TSC '07)
ε_c	Maximum strain value of concrete
ε_s	Maximum strain value of reinforcement
θ_p	Plastic rotation demand
Φ_p	Plastic curvature demand
Φ_t	Total curvature demand
MN (ML)	Minimum damage limit
GV (SL)	Safety limit
GC (FL)	Failure limit

1. INTRODUCTION : STRUCTURAL ANALYSIS AND DESIGN OF A 6-STOREY REINFORCED CONCRETE WALL-FRAME SYSTEM COMPRISED OF INFILLED JOIST SLAB SYSTEM USING EQUIVALENT SEISMIC LOAD METHOD

1.1. Structural Analysis

Building Requirements :		
Number of stories	:	6
Storey height	:	3.0 m.
Total height of building, [H]	:	18.0 m.
Floor area	:	22 m. x 18 m. = 396 m^2
Propose of occupancy	:	Residential building
Material Properties :		
Concrete	:	C25 (f_{ck} = 25 MPa) (f_{cd} = 16.67 MPa)
Steel	:	S420 (f_{yk} = 420 MPa) (f_{yd} = 365.22 MPa)
Modulus of elasticity of concrete, [E_c]	:	30250 MPa
Modulus of elasticity of steel, [E_s]	:	200000 MPa
Safety ratio for concrete	:	1.50
Safety ratio for steeel	:	1.15
Seismic Load Parameters :		
Seismic zone	:	1
Effective ground acceleration coefficient, [A_0]	:	0.4
Building importance factor, [I]	:	1.0
Local site class	:	Z2
Spectrum characteristic periods	:	T_A = 0.15 s., T_B = 0.40 s.
Structural behaviour factor, [R]	:	5.65
Live load participation factor, [n]	:	0.3

Self and Live Load Definition :

Weight per unit volume of concrete	:	25.0 kN/m^3
Outer wall loads (13cm+mortar)	:	6.625 kN/m^2
Covering	:	1.50 kN/m^2
Live load at roof	:	1.0 kN/m^2
Live load at usual stories	:	2.0 kN/m^2

The 6-storey wall-frame system with one-way ribbed slab system having the above mentioned properties will be analysed under vertical and lateral earthquake loads using the equivalent seismic load method.

The structural frame system composed of beams and columns of nominal ductility level is mixed with structural walls of high ductility level so that it can be applicable in the first and second seismic zone. In this analysis, the mixed structural system is chosen so that the ratio of the sum of base shear developed at the bases of structural walls to the total base shear developed for the entire building in each earthquake direction, α_S, is between the values 0.40 and 2/3 ($0.4 < \alpha_S < 2/3$).

The structural behaviour factor, R, will be calculated after the ratio α_S is obtained. In this structure, the column and beam dimensions are selected same at each story. The general formwork plan and section of the structure is drawn in Figure 1.1, 1.2.

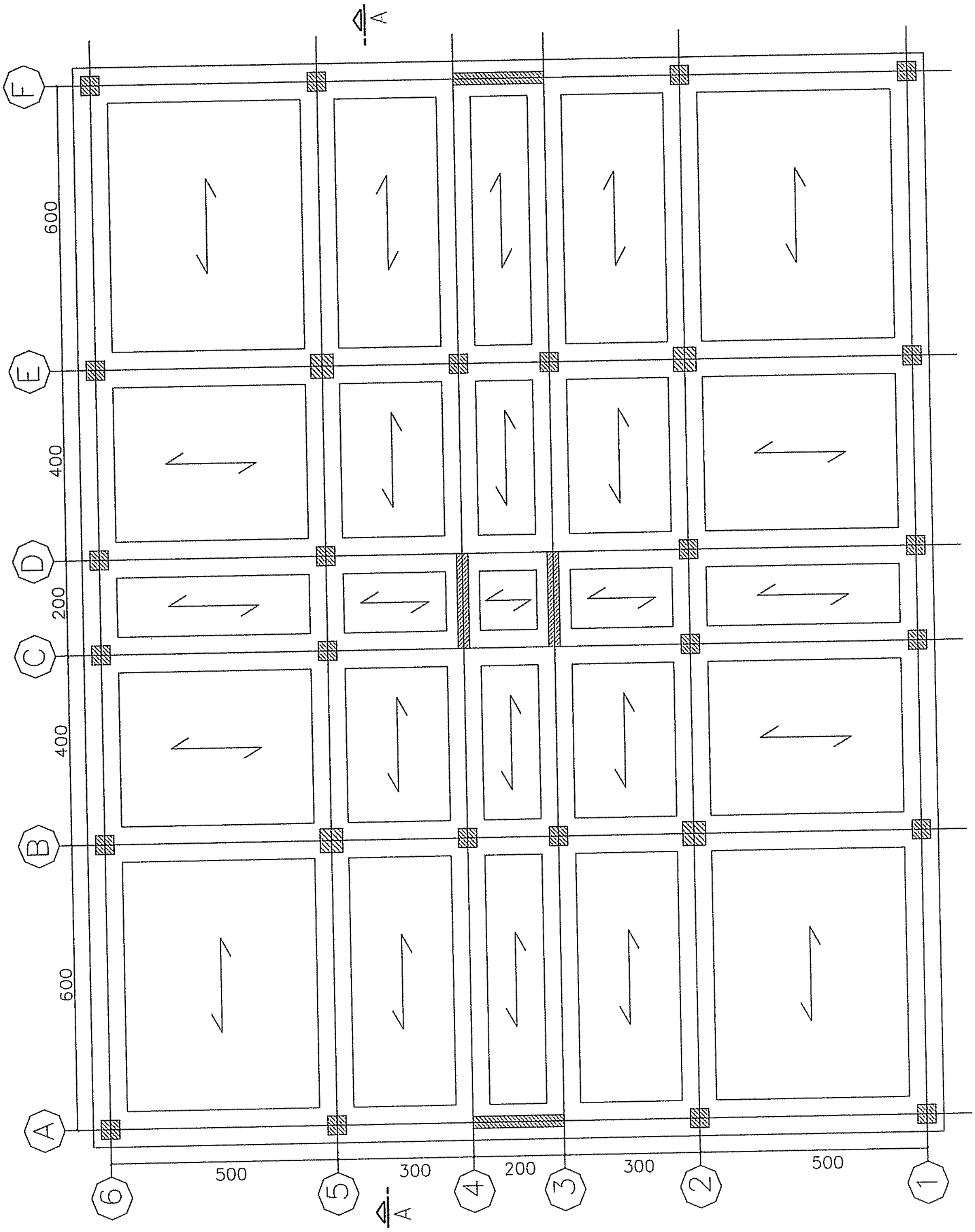


Figure 1.1. Floor plan of six-storey R.C. wall-frame system with the same story height.

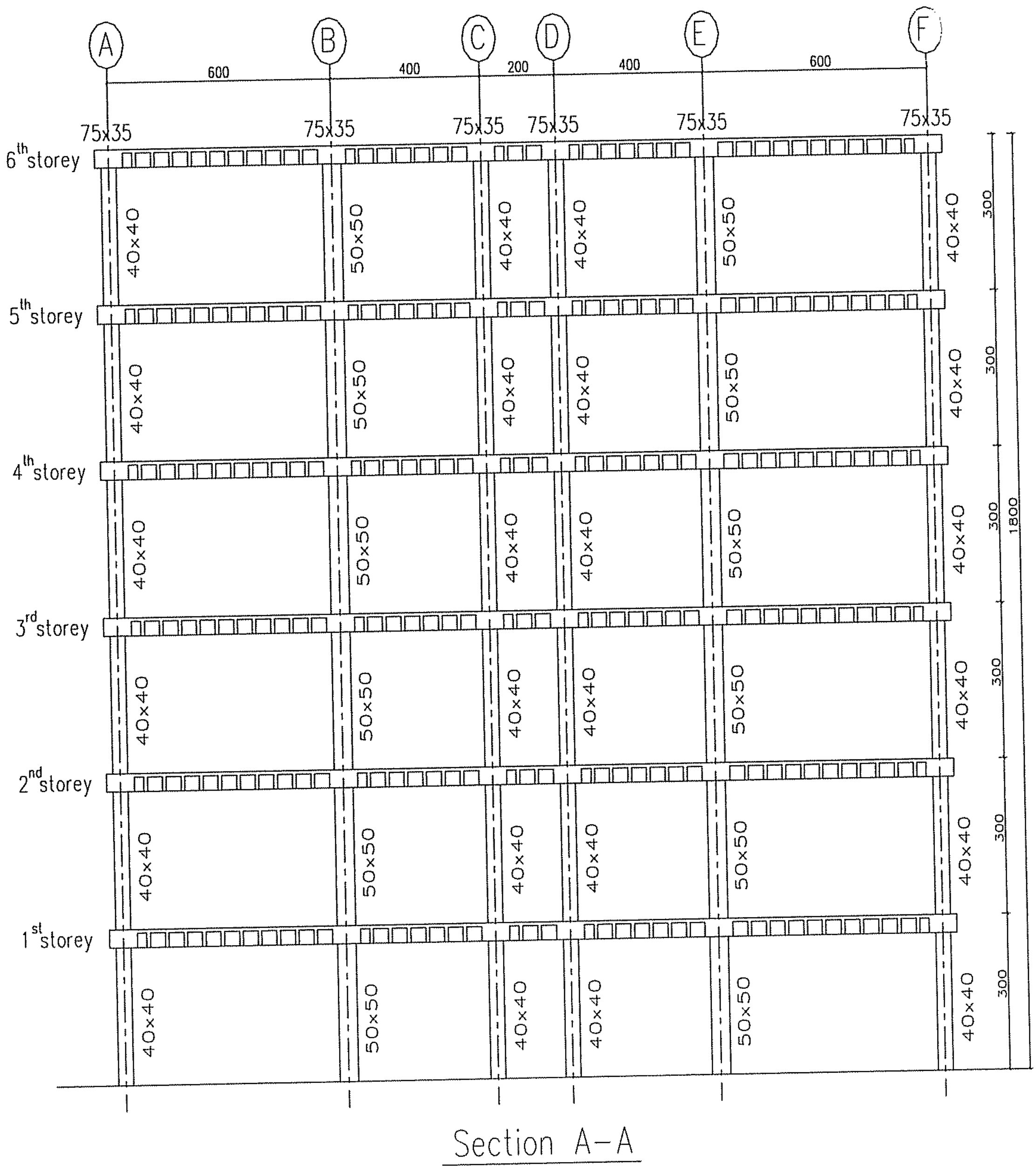


Figure 1.2. Section A-A of six-storey R.C. wall-frame system with the same story height.

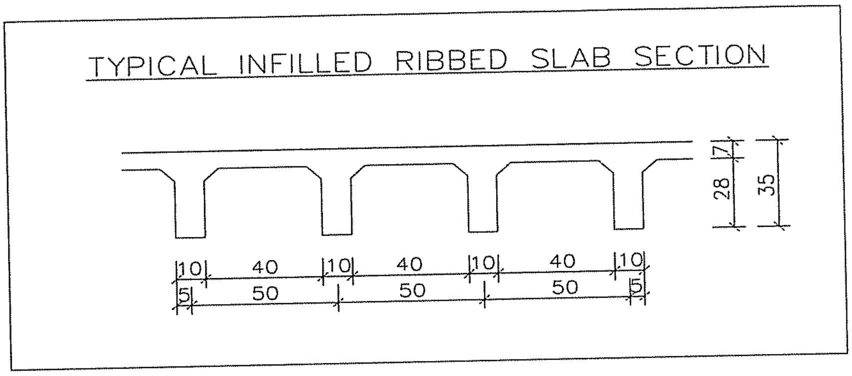


Figure 1.3. Typical infilled ribbed slab section

The dimensions of the structural member sections (column, beam, wall, slab) are selected as shown in Table 1.1.

Table 1.1. Dimensions of the structural members.

Frame Element Type	**Dimension (cm)**
Column	40x40 / 50x50
Main Beam	75x35
Secondary Beam	10x35
Wall	25x200
Slab Thickness	7

Load definition of the infilled joist slab system :

Self-weight of slab	(0.07m.)	: 0.07x25	= 1.75 kN/m^2
Self-weight of ribs	(0.10x0.35)	: 2x0.10x0.28x25	= 1.40 kN/m^2
Self-weight of infill		:	= 1.60 kN/m^2
Covering		:	= 1.50 kN/m^2

Dead load	:	g= 6.25 kN/m^2
Live load at usual stories	:	q= 2.00 kN/m^2
Live load at roof	:	q= 1.00 kN/m^2

The loads acting on the slab are defined below in Table 1.2.

Table 1.2. Dead and live loads acting on the slab.

Storey	Dead Load (kN/m^2)	Live Load (kN/m^2)
Roof	6.25	1.0
Usual Storey	6.25	2.0

It is also considered 6.625 kN/m^2 as infill wall load on the outer beams at each storey excluding at the roof.

Additional infill wall load (13cm brick+mortar) : 2.5 kN/m^2 x 2.65m = 6.625 kN/m^2

The dead load consists of self weight of the frame elements, covering load of the slab system and loads of infill wall on the outer beams. Dead and live loads acting on the beams at usual stories and at the roof are shown in Figure 1.4, 1.5, 1.6, 1.7.

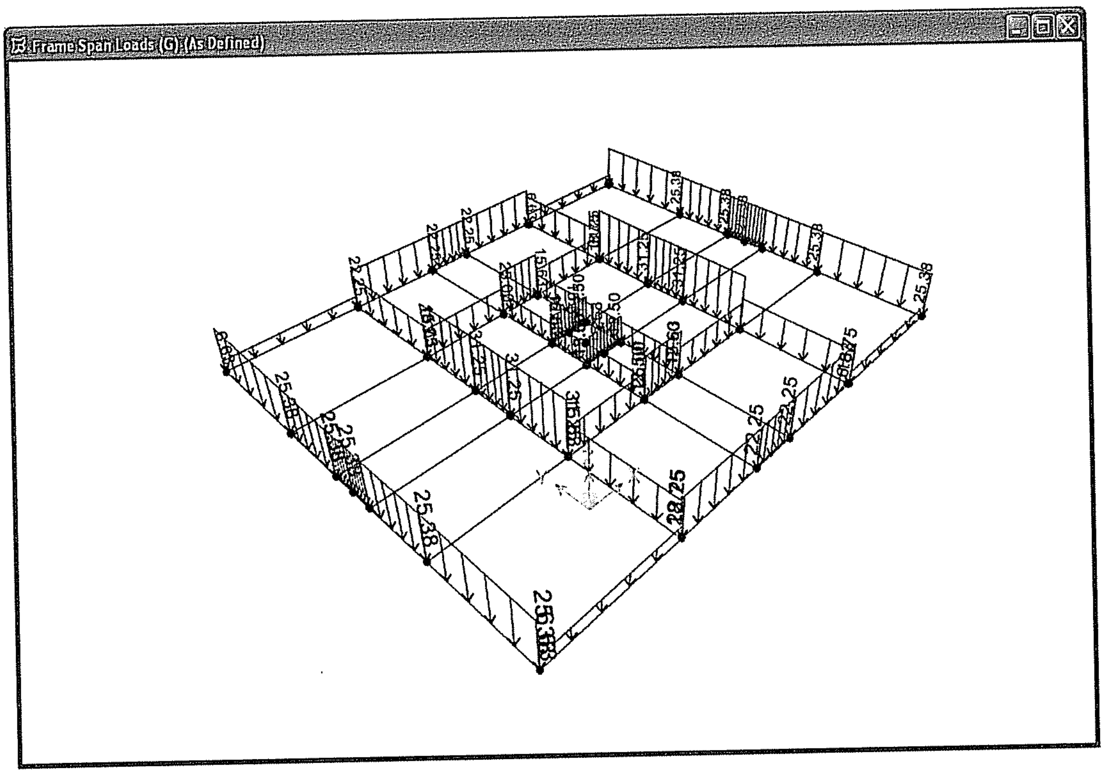


Figure 1.4. Dead load acting on the beams at usual stories.

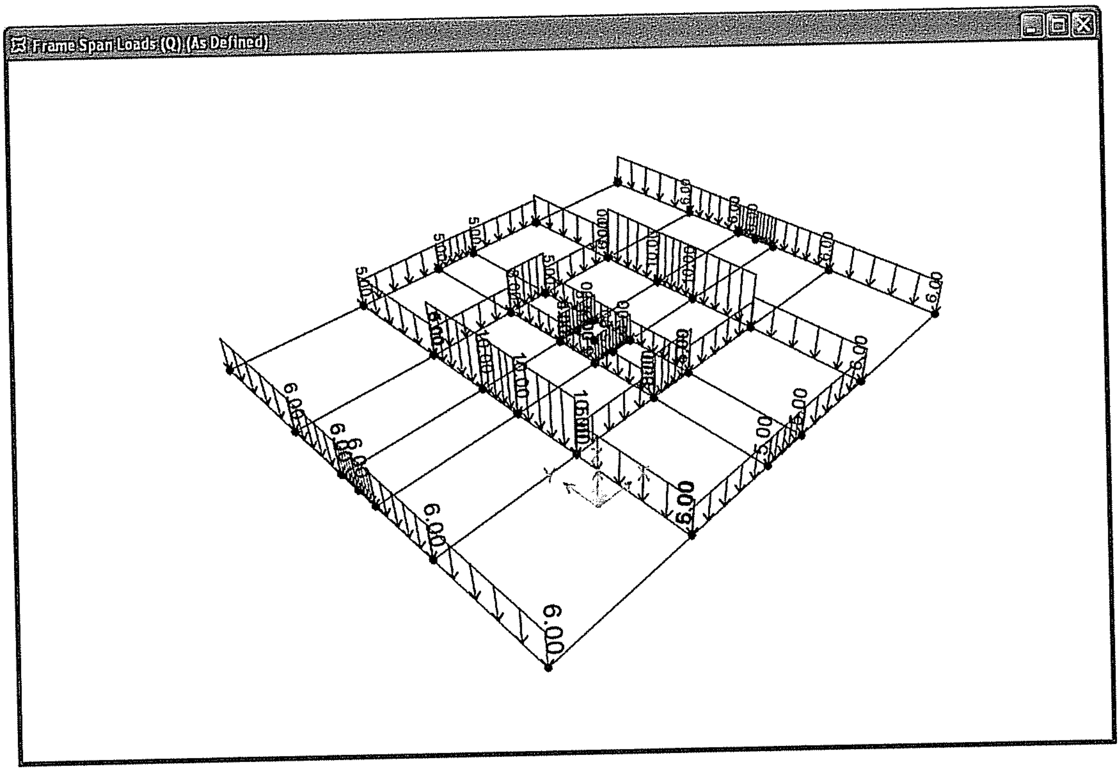


Figure 1.5. Live load acting on the beams at usual stories.

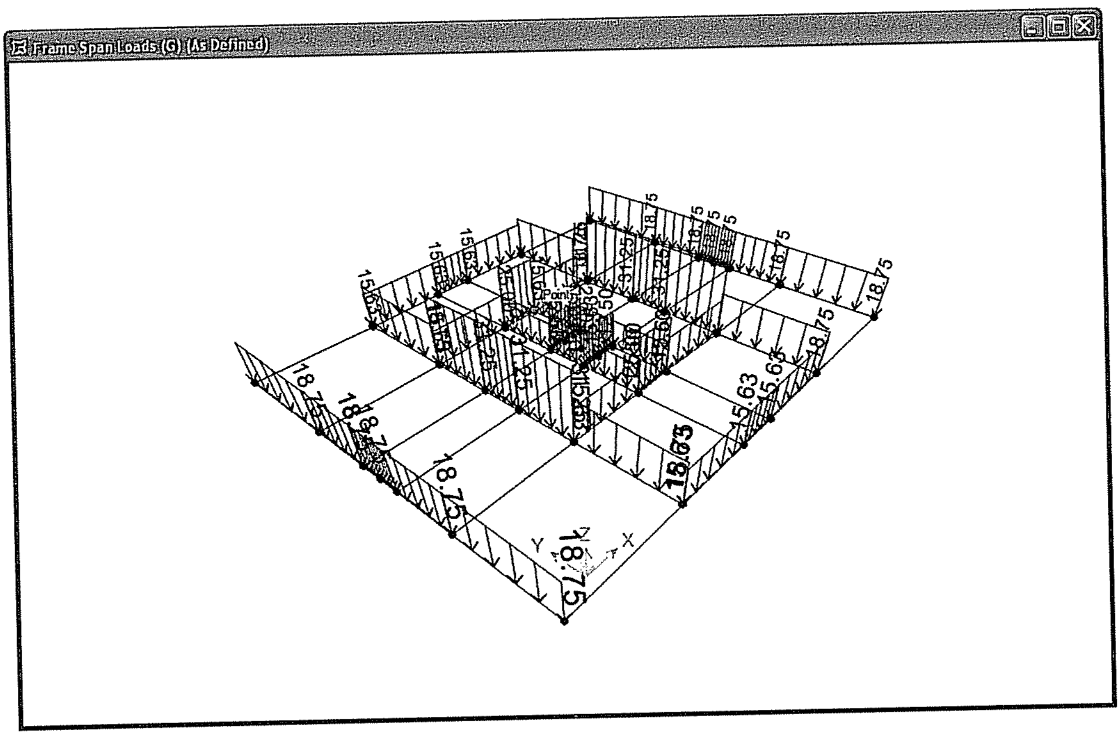


Figure 1.6. Dead load acting on the beams at the roof.

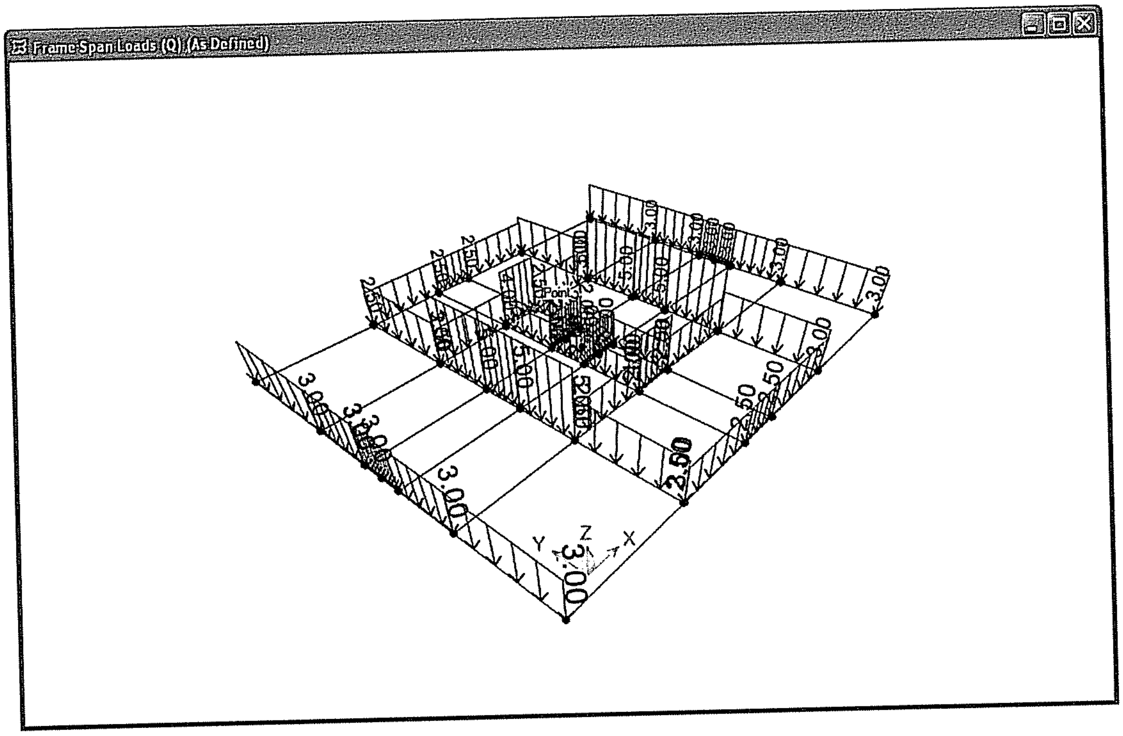


Figure 1.7. Live load acting on the beams at the roof.

1.1.1. Determination of First Natural Vibration Period of Building

The first natural vibration period of the building to which Equivalent Seismic Load Method is applied is calculated by the below mentioned expression which is described in Turkish Seismic Code, 2007, Eq.(2.11).

$$T_1 = 2\,\pi\,[\sum_{i=1}^{N} (m_i\, d_{fi}^{\,2}) \,/\, \sum_{i=1}^{N} (F_{fi}\, d_{fi})]^{1/2} \tag{1.1}$$

In order to calculate the first natural vibration period of the building in both direction, the fictitious load, F_{fi}, is applied to i^{th} storey which is obtained from the equation below by substituting unit value 100.000 kN in place of $(V_t - \Delta F_N)$.

$$F_i = (V_t - \Delta F_N) \frac{w_i H_i}{\sum_{j=1}^{N} (w_j H_j)} \qquad (1.2)$$

The values used in Eq.(1.2) are given in Table 1.3. The live load participation factor, n , is taken as 0.3 according to Turkish Seismic Code, 2007 (Table 2.7).

$$W = \sum_{i=1}^{N} w_i \qquad w_i = g_i + nq_i \qquad m_i = W_i / g \qquad g = 9.81 \text{ m/s}^2$$

Table 1.3. The storey weights and masses which will be used by determining the equivalent seismic load.

STOREY	STOREY HEIGHT	DEAD LOAD	LIVE LOAD	STOREY WEIGHT	LUMPED MASS
	(m)	G (kN)	Q (kN)	W (kN)	m (s^2kN/m)
6	18	4306.50	396.00	4425.3	451.101
5	15	5093.00	792.00	5330.6	543.384
4	12	5093.00	792.00	5330.6	543.384
3	9	5093.00	792.00	5330.6	543.384
2	6	5093.00	792.00	5330.6	543.384
1	3	5093.00	792.00	5330.6	543.384
			ΣW =	31078.3	

The below equation Eq.(1.3) is used by calculating the natural period of the building. The obtained results are given in Table 1.4, 1.5.

$$T_1 = 2\pi \left[\sum_{i=1}^{N} (m_i d_{fi}^2) / \sum_{i=1}^{N} (F_{fi} d_{fi}) \right]^{1/2} \qquad (1.3)$$

$T_{1x} = 2\pi\,[\,819.337 / 56529.945]^{1/2} = 0.756$ sec.

$T_{1y} = 2\pi\,[\,714.287 / 52781.138]^{1/2} = 0.731$ sec.

Table 1.4. Unit loading (100.000 kN) applied to the structure to calculate the natural period in x-direction.

STOREY	F_{fi} (kN)	d_{fi} (m)	w (kN)	m_i	$m_i * d_{fi}^2$	$F_{fi} * d_{fi}$
6	24928.740	0.764139	4425.3	451.101	263.402	19049.022
5	25023.753	0.681197	5330.6	543.384	252.146	17046.106
4	20019.003	0.564162	5330.6	543.384	172.948	11293.961
3	15014.252	0.414797	5330.6	543.384	93.493	6227.867
2	10009.501	0.246807	5330.6	543.384	33.100	2470.415
1	5004.751	0.088431	5330.6	543.384	4.249	442.575

100.000 kN

Σ =	819.337	56529.945

T_{1x} = 0.756 sn.

Table 1.5. Unit loading (100.000 kN) applied to the structure to calculate the natural period in y-direction.

STOREY	F_{fi} (kN)	d_{fi} (m)	w (kN)	m_i	$m_i * d_{fi}^2$	$F_{fi} * d_{fi}$
6	24928.740	0.710347	4425.3	451.101	227.622	17708.055
5	25023.753	0.635168	5330.6	543.384	219.222	15894.287
4	20019.003	0.527827	5330.6	543.384	151.388	10566.570
3	15014.252	0.389777	5330.6	543.384	82.554	5852.210
2	10009.501	0.233444	5330.6	543.384	29.612	2336.658
1	5004.751	0.084591	5330.6	543.384	3.888	423.357

100.000 kN

Σ =	714.287	52781.138

T_{1y} = 0.731 sec.

1.1.2. Determination of Spectral Acceleration

The Spectrum Coefficient, S(T), is determined by the equation below, depending on the local site conditions and the building natural period, T.

$$S(T) = 2.5\ (T_B / T\ )^{0.8} \qquad (T > T_B) \qquad (1.4)$$

$$S(T_{1x}) = 2.5\ (0.4 / 0.756\ )^{0.8} = 1.5023$$

$$S(T_{1y}) = 2.5\ (0.4 / 0.731\ )^{0.8} = 1.5433$$

$$A(T_{1x}) = A_0.I.S(T_{1x}) = 0.4*1.0*1.5023 = 0.6009$$

$$A(T_{1y}) = A_0.I.S(T_{1y}) = 0.4*1.0*1.5433 = 0.6173$$

As the structure satisfies the condition $\eta_{bi} \leq 2.0$ (torsional irregularity factor) and total height of building H_N=18m ≤ 25m. is, Equivalent Seismic Load Method is applicable for this building.

1.1.3. Determination of Total Equivalent Seismic Load

To determine the total equivalent seismic load, the structural behaviour factor, R, shall be primarily calculated. The structure is modelled so that the ratio of the sum of the shear forces developed at the bases of the structural walls under seismic loads to the base shear of the entire building in each earthquake direction is in the range $0.40 < \alpha_s < 2/3$.

The base shear developed at the bases of the structural walls in the x-direction is 810.50 kN and that in the y-direction 917.53 kN. The base shear for the entire building developed in x-direction is 2947.27 kN and in y-direction 3141.05 kN.

$\alpha_s = 2*810.50 / 2947.27 = 0.55$ in x-direction

$\alpha_s = 2*917.53 / 3141.05 = 0.58$ in y-direction

The structural behaviour factor, R, obtained from the equation below is applied to the entire structural system in both earthquake direction.

$$R = R_{NÇ} + 1.5\ \alpha_s\ (R_{YP}-R_{NÇ}) \qquad (0.40 < \alpha_s < 2/3) \qquad (1.5)$$

$$R = 4 + 1.5*0.55*(6-4) = 5.65$$

Total Equivalent Seismic Load, V_t, acting on the entire building in the earthquake direction considered is determined by the equation below :

$$V_t = W\ A(T_1) / R_a(T_1) \geq 0.10\ A_o I\ W \qquad (1.6)$$

$$V_{tx} = 31078.3*0.6009 / 5.65 = 3305.30 \text{ kN}$$

$$V_{ty} = 31078.3*0.6173 / 5.65 = 3395.51 \text{ kN}$$

$$V_t \geq 0.10\ A_o I\ W = 0.10*0.4*1.0*31078.3 = 1243.13 \text{ kN.}$$

$$V_{tx} = 3305.30 \text{ kN} > 1243.13 \text{ kN} \qquad V_{ty} = 3395.51 \text{ kN} > 1243.13 \text{ kN}$$

Additional equivalent seismic load, ΔF_N, which is acting on the top of the structure, is determined by Eq.(1.7).

$$\Delta F_N = 0.0075.N.V_t \qquad (1.7)$$

$$\Delta F_{Nx} = 0.0075.N.V_{tx} = 0.0075*6*3305.30 = 148.74 \text{ kN.} \quad \text{(in x-direction)}$$

$$\Delta F_{Ny} = 0.0075.N.V_{ty} = 0.0075*6*3395.51 = 152.80 \text{ kN.} \quad \text{(in y-direction)}$$

Excluding ΔF_N, remaining part of the total equivalent seismic load (base shear) is distributed to stories of the building in accordance with Eq.(2.9) in TSC '07.

As the floor behaves as rigid horizontal diaphragm, the distributed seismic loads are applied in the form of concentrated loads to the floor mass centre as well as to shifted mass center to account for the additional eccentricity effects. The shifted mass centres are obtained by shifting the actual mass center by +5% and -5% times the floor length in the perpendicular direction to the earthquake direction considered.

Calculated storey loads and the torsional moments obtained by multiplying the eccentricity with the story load are summarised in Table 1.6, 1.7.

Table 1.6. Equivalent seismic loads and torsional moments acting at each storey in x-direction.

STOREY	h_i (m)	H_i (m)	w (kN)	w*H_i	F_x	e_y	M_z
6	3.00	18.00	4425.30	79655.40	935.69	0.90	842.122
5	3.00	15.00	5330.60	79959.00	789.94	0.90	710.948
4	3.00	12.00	5330.60	63967.20	631.95	0.90	568.758
3	3.00	9.00	5330.60	47975.40	473.97	0.90	426.569
2	3.00	6.00	5330.60	31983.60	315.98	0.90	284.379
1	3.00	3.00	5330.60	15991.80	157.99	0.90	142.190
		ΣW =	31078.30	319532.40	3305.52		

Table 1.7. Equivalent seismic loads and torsional moments acting at each storey in y-direction.

STOREY	h_i (m)	H_i (m)	w (kN)	w*H_i	F_y	e_x	M_z
6	3.00	18.00	4425.30	79655.40	961.20	1.10	1057.325
5	3.00	15.00	5330.60	79959.00	811.48	1.10	892.630
4	3.00	12.00	5330.60	63967.20	649.19	1.10	714.104
3	3.00	9.00	5330.60	47975.40	486.89	1.10	535.578
2	3.00	6.00	5330.60	31983.60	324.59	1.10	357.052
1	3.00	3.00	5330.60	15991.80	162.30	1.10	178.526
		ΣW =	31078.30	319532.40	3395.65		

1.1.4. Load Combinations used for the Design of the Structure

The load combinations used for the design of the building are given in Table 1.8.

G : Dead load

Q : Live load

EX : Earthquake load in x-direction

EY : Earthquake load in y-direction

Table 1.8. Load combinations used for the design of the building.

Load Combination		G	Q	EX+	NEX-	EY+	NEY-
Nr.	Expression						
1	G+Q	1.4	1.6				
2	$0.9G+EX^+$	0.9		1			
3	$0.9G-EX^+$	0.9		-1			
4	$0.9G+NEX^-$	0.9			1		
5	$0.9G-NEX^-$	0.9			-1		
6	$0.9G+EY^+$	0.9				1	
7	$0.9G-EY^+$	0.9				-1	
8	$0.9G+NEY^-$	0.9					1
9	$0.9G-NEY^-$	0.9					-1
10	$G+Q+EX^+$	1	1	1			
11	$G+Q-EX^+$	1	1	-1			
12	$G+Q+NEX^-$	1	1		1		
13	$G+Q-NEX^-$	1	1		-1		
14	$G+Q+EY^+$	1	1			1	
15	$G+Q-EY^+$	1	1			-1	
16	$G+Q+NEY^-$	1	1				1
17	$G+Q-NEY^-$	1	1				-1

1.2. Concrete Frame Design

The reinforcement details of beams, columns and shear walls according to Turkish Seismic Code, 2007 (Part 3), are given in Appendix A.

X-Y Plane and 3D-View of the sample wall-frame system prepared by the computer programme SAP 2000 are shown in Figure 1.8, 1.9.

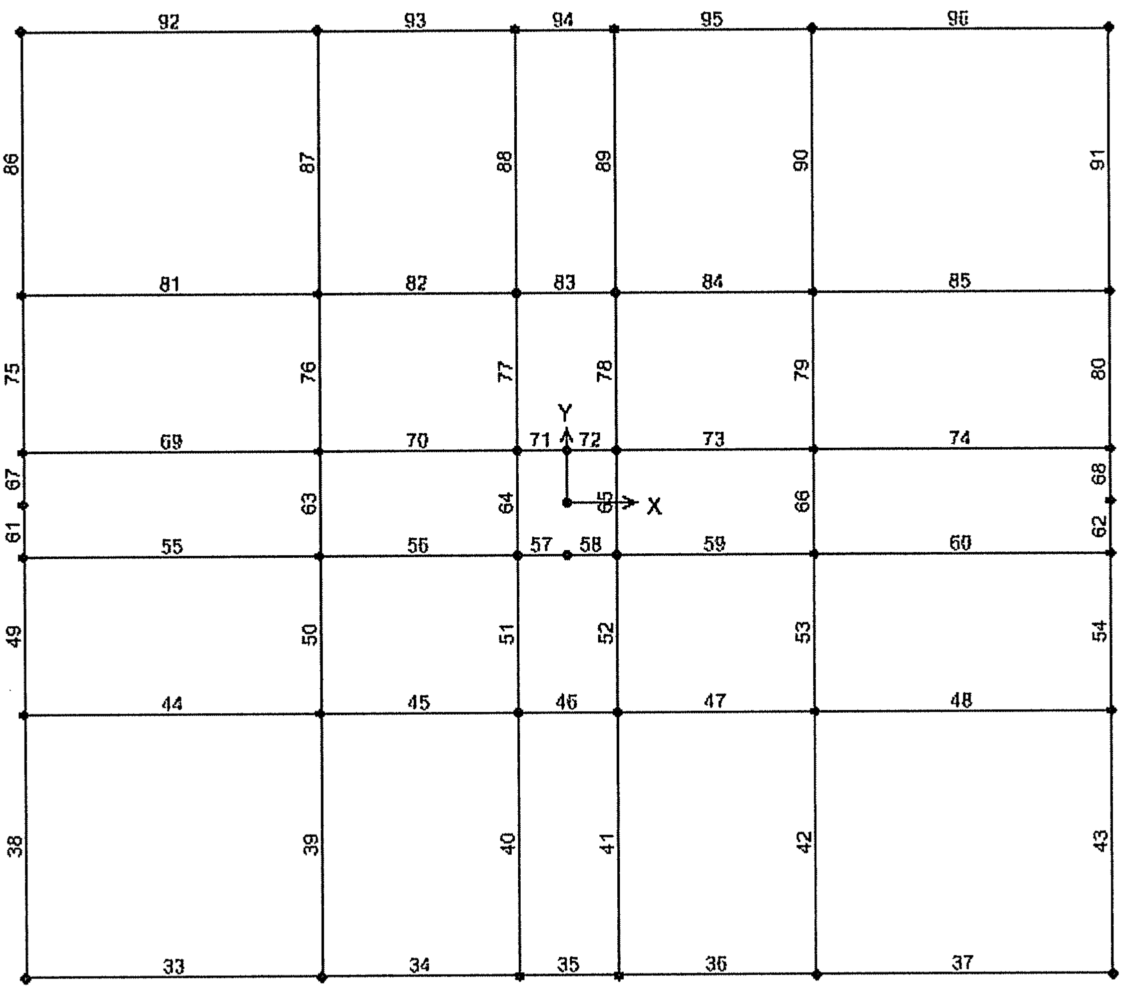


Figure 1.8. X-Y Plane of the wall-frame system prepared by the computer programme SAP 2000

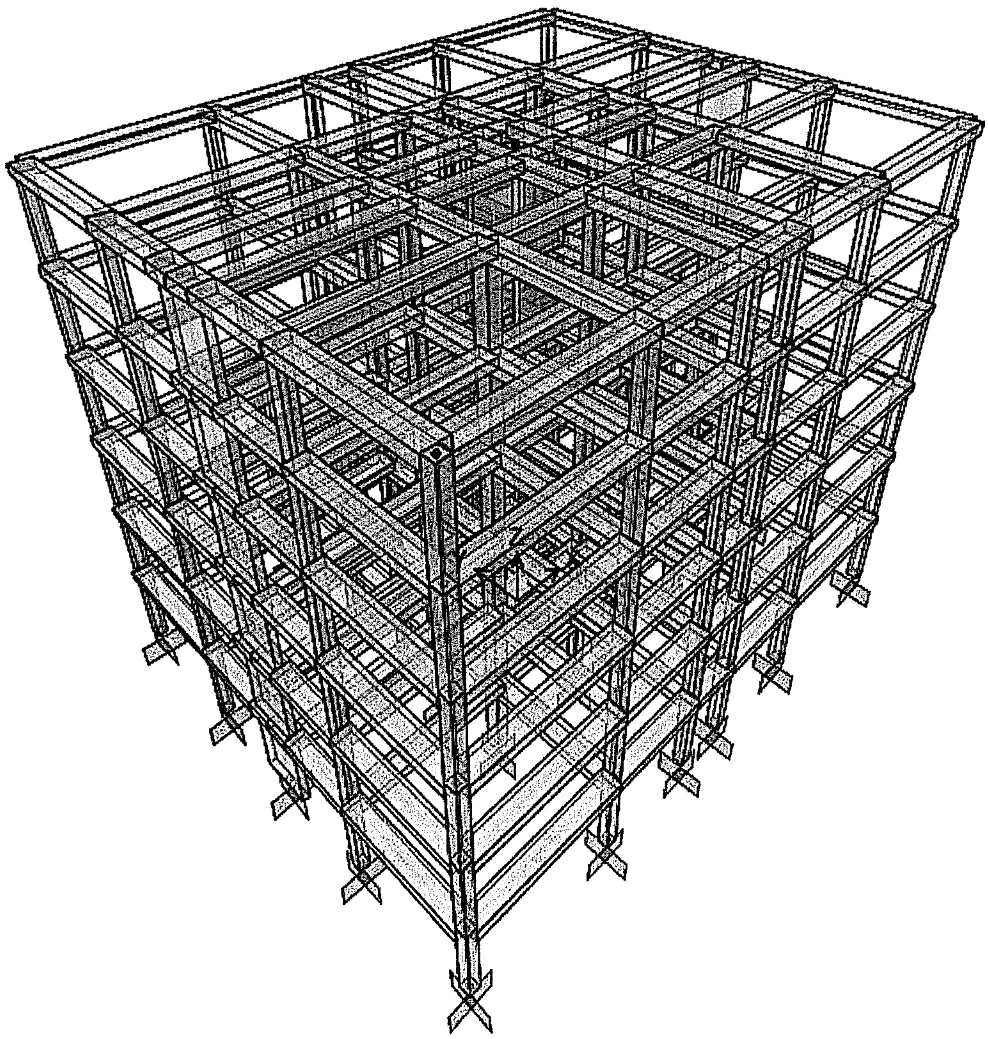


Figure 1.9. 3D-View of the wall-frame system prepared by the computer programme SAP 2000

2. NONLINEAR STATIC PUSHOVER ANALYSIS PROCEDURE FOR EVALUATING THE PERFORMANCE OF THE SAMPLE BUILDING

2.1. Introduction

Although an elastic analysis gives a good indication of the elastic capacity of structures and indicates where the first yielding will occur, it cannot predict failure mechanisms and account for redistribution of forces during progressive yielding (ATC40, 1996).

Nonlinear static pushover analysis is a specialized procedure used in performance-based design for seismic loading in order to demonstrate how buildings really work by identifying modes of failure and the potential for progressive collapse. It will be helpful to understand how structures will behave when subjected major earthquakes, where it is assumed that the elastic capacity of the structure will be exceeded.

The probability of exceedance of the design earthquake within a period of 50 years is 10%. Life Safety (LS) structural performance level is chosen as a target for this sample building.

To evaluate the performance of this building, nonlinear static pushover analysis is used which includes the capacity spectrum method (CSM) that uses the intersection of the capacity (pushover) curve and a reduced response spectrum to estimate maximum displacement.

To obtain the pushover curves of the structure, SAP 2000 Structural Analysis Programme is used. In pushover analysis of the structure, plastic hinge hypothesis is taken into consideration. In that hypothesis, plastic deformations are considered to gather at critical sections called plastic hinge and other parts of system behave linear elastic.

2.2. Idealizing of Nonlinear Response of the Frame Elements and Creating of the Computer Model

2.2.1. Definition of Effective Flexural Stiffness Concerning the Cracked Section of Frame Elements

According to Turkish Seismic Code 2007, (7.4.13), the effective flexural stiffness concerning the cracked section of the structural members will be used in the pushover analysis.

A nonlinear static analysis will be performed using the flexural stiffness of the uncracked sections by considering the vertical loads compatible with storey lumped masses (1.0G+0.3Q). The axial loads obtained from this analysis will be used for calculating the effective flexural stiffness values of columns and walls.

For beams : $(EI)_e = 0.40\ (EI)_0$ (2.1a)

For columns and structural walls : $N_D / (A_c f_{cm}) \leq 0.10$ ..... : $(EI)_e = 0.40\ (EI)_0$ (2.1b)

$N_D / (A_c f_{cm}) \geq 0.40$ ..... : $(EI)_e = 0.80\ (EI)_0$ (2.1c)

The effective stiffness values for $N_D / (A_c f_{cm})$ in the range 0.10-0.40 are calculated with the linear interpolation method. These values are given in Table 2.1a, 2.1b, 2.1c.

Table 2.1a. The effective flexural stiffness values concerning the cracked section of the structural elements at Axis 1

Storey	Load Case	Case Type	P KN	A_c (m^2)	$N_d/(A_c{*}f_{cm})$	$(EI)_e$
1st Storey Columns at **Axis 1**						
1	G+0.3Q	NonStatic	-774.864	0.16	0.194	0.525 $(EI)_o$
2	G+0.3Q	NonStatic	-1002.925	0.16	0.251	0.601 $(EI)_o$
3	G+0.3Q	NonStatic	-712.83	0.16	0.178	0.504 $(EI)_o$
4	G+0.3Q	NonStatic	-712.83	0.16	0.178	0.504 $(EI)_o$
5	G+0.3Q	NonStatic	-1002.925	0.16	0.251	0.601 $(EI)_o$
6	G+0.3Q	NonStatic	-774.864	0.16	0.194	0.525 $(EI)_o$
2nd Storey Columns at **Axis 1**						
97	G+0.3Q	NonStatic	-642.013	0.16	0.161	0.481 $(EI)_o$
98	G+0.3Q	NonStatic	-824.864	0.16	0.206	0.542 $(EI)_o$
99	G+0.3Q	NonStatic	-594.467	0.16	0.149	0.465 $(EI)_o$
100	G+0.3Q	NonStatic	-594.467	0.16	0.149	0.465 $(EI)_o$
101	G+0.3Q	NonStatic	-824.864	0.16	0.206	0.542 $(EI)_o$
102	G+0.3Q	NonStatic	-642.013	0.16	0.161	0.481 $(EI)_o$
3rd Storey Columns at **Axis 1**						
193	G+0.3Q	NonStatic	-506.944	0.16	0.127	0.436 $(EI)_o$
194	G+0.3Q	NonStatic	-649.541	0.16	0.162	0.483 $(EI)_o$
195	G+0.3Q	NonStatic	-473.397	0.16	0.118	0.424 $(EI)_o$
196	G+0.3Q	NonStatic	-473.397	0.16	0.118	0.424 $(EI)_o$
197	G+0.3Q	NonStatic	-649.541	0.16	0.162	0.483 $(EI)_o$
198	G+0.3Q	NonStatic	-506.944	0.16	0.127	0.436 $(EI)_o$
4th Storey Columns at **Axis 1**						
289	G+0.3Q	NonStatic	-371.073	0.16	0.093	0.400 $(EI)_o$
290	G+0.3Q	NonStatic	-476.147	0.16	0.119	0.425 $(EI)_o$
291	G+0.3Q	NonStatic	-350.773	0.16	0.088	0.400 $(EI)_o$
292	G+0.3Q	NonStatic	-350.773	0.16	0.088	0.400 $(EI)_o$
293	G+0.3Q	NonStatic	-476.147	0.16	0.119	0.425 $(EI)_o$
294	G+0.3Q	NonStatic	-371.073	0.16	0.093	0.400 $(EI)_o$
5th Storey Columns at **Axis 1**						
385	G+0.3Q	NonStatic	-234.547	0.16	0.059	0.400 $(EI)_o$
386	G+0.3Q	NonStatic	-304.177	0.16	0.076	0.400 $(EI)_o$
387	G+0.3Q	NonStatic	-226.992	0.16	0.057	0.400 $(EI)_o$
388	G+0.3Q	NonStatic	-226.992	0.16	0.057	0.400 $(EI)_o$
389	G+0.3Q	NonStatic	-304.177	0.16	0.076	0.400 $(EI)_o$
390	G+0.3Q	NonStatic	-234.547	0.16	0.059	0.400 $(EI)_o$
6th Storey Columns at **Axis 1**						
481	G+0.3Q	NonStatic	-97.18	0.16	0.024	0.400 $(EI)_o$
482	G+0.3Q	NonStatic	-132.742	0.16	0.033	0.400 $(EI)_o$
483	G+0.3Q	NonStatic	-102.261	0.16	0.026	0.400 $(EI)_o$
484	G+0.3Q	NonStatic	-102.261	0.16	0.026	0.400 $(EI)_o$
485	G+0.3Q	NonStatic	-132.742	0.16	0.033	0.400 $(EI)_o$
486	G+0.3Q	NonStatic	-97.18	0.16	0.024	0.400 $(EI)_o$

Table 2.1b. The effective flexural stiffness values concerning the cracked section of the structural elements at Axis 2

Storey	**Load Case**	**Case Type**	**P** KN	A_c (m^2)	$N_d/(A_c*f_{cm})$	$(EI)_e$
1st Storey Columns at **Axis 2**						
7	G+0.3Q	NonStatic	-897.612	0.16	0.224	0.566 $(EI)_o$
8	G+0.3Q	NonStatic	-1335.142	0.25	0.214	0.551 $(EI)_o$
9	G+0.3Q	NonStatic	-784.494	0.16	0.196	0.528 $(EI)_o$
10	G+0.3Q	NonStatic	-784.493	0.16	0.196	0.528 $(EI)_o$
11	G+0.3Q	NonStatic	-1335.141	0.25	0.214	0.551 $(EI)_o$
12	G+0.3Q	NonStatic	-897.612	0.16	0.224	0.566 $(EI)_o$
2nd Storey Columns at **Axis 2**						
103	G+0.3Q	NonStatic	-730.931	0.16	0.183	0.510 $(EI)_o$
104	G+0.3Q	NonStatic	-1110.387	0.25	0.178	0.504 $(EI)_o$
105	G+0.3Q	NonStatic	-647.006	0.16	0.162	0.482 $(EI)_o$
106	G+0.3Q	NonStatic	-647.005	0.16	0.162	0.482 $(EI)_o$
107	G+0.3Q	NonStatic	-1110.387	0.25	0.178	0.504 $(EI)_o$
108	G+0.3Q	NonStatic	-730.931	0.16	0.183	0.510 $(EI)_o$
3rd Storey Columns at **Axis 2**						
199	G+0.3Q	NonStatic	-572.399	0.16	0.143	0.457 $(EI)_o$
200	G+0.3Q	NonStatic	-887.547	0.25	0.142	0.456 $(EI)_o$
201	G+0.3Q	NonStatic	-513.323	0.16	0.128	0.438 $(EI)_o$
202	G+0.3Q	NonStatic	-513.322	0.16	0.128	0.438 $(EI)_o$
203	G+0.3Q	NonStatic	-887.546	0.25	0.142	0.456 $(EI)_o$
204	G+0.3Q	NonStatic	-572.399	0.16	0.143	0.457 $(EI)_o$
4th Storey Columns at **Axis 2**						
295	G+0.3Q	NonStatic	-418.667	0.16	0.105	0.406 $(EI)_o$
296	G+0.3Q	NonStatic	-664.922	0.25	0.106	0.409 $(EI)_o$
297	G+0.3Q	NonStatic	-382.301	0.16	0.096	0.400 $(EI)_o$
298	G+0.3Q	NonStatic	-382.3	0.16	0.096	0.400 $(EI)_o$
299	G+0.3Q	NonStatic	-664.922	0.25	0.106	0.409 $(EI)_o$
300	G+0.3Q	NonStatic	-418.667	0.16	0.105	0.406 $(EI)_o$
5th Storey Columns at **Axis 2**						
391	G+0.3Q	NonStatic	-268.382	0.16	0.067	0.400 $(EI)_o$
392	G+0.3Q	NonStatic	-442.593	0.25	0.071	0.400 $(EI)_o$
393	G+0.3Q	NonStatic	-253.149	0.16	0.063	0.400 $(EI)_o$
394	G+0.3Q	NonStatic	-253.149	0.16	0.063	0.400 $(EI)_o$
395	G+0.3Q	NonStatic	-442.592	0.25	0.071	0.400 $(EI)_o$
396	G+0.3Q	NonStatic	-268.382	0.16	0.067	0.400 $(EI)_o$
6th Storey Columns at **Axis 2**						
487	G+0.3Q	NonStatic	-121.203	0.16	0.030	0.400 $(EI)_o$
488	G+0.3Q	NonStatic	-221.962	0.25	0.036	0.400 $(EI)_o$
489	G+0.3Q	NonStatic	-125.811	0.16	0.031	0.400 $(EI)_o$
490	G+0.3Q	NonStatic	-125.811	0.16	0.031	0.400 $(EI)_o$
491	G+0.3Q	NonStatic	-221.962	0.25	0.036	0.400 $(EI)_o$
492	G+0.3Q	NonStatic	-121.203	0.16	0.030	0.400 $(EI)_o$

Table 2.1c. The effective flexural stiffness values concerning the cracked section of the structural elements at Axis 3 and Axis A

Storey	**Load Case**	**Case Type**	**P** KN	**A_c** (m^2)	**$N_d/(A_c*f_{cm})$**	**$(EI)_e$**
1st Storey Columns at **Axis 3**						
13	G+0.3Q	NonStatic	-818.194	0.16	0.205	0.539 $(EI)_o$
SW14	G+0.3Q	NonStatic	-1370.984	0.50	0.110	0.413 $(EI)_o$
15	G+0.3Q	NonStatic	-818.192	0.16	0.205	0.539 $(EI)_o$
2nd Storey Columns at **Axis 3**						
109	G+0.3Q	NonStatic	-676.406	0.16	0.169	0.492 $(EI)_o$
SW110	G+0.3Q	NonStatic	-1160.446	0.50	0.093	0.400 $(EI)_o$
111	G+0.3Q	NonStatic	-676.405	0.16	0.169	0.492 $(EI)_o$
3rd Storey Columns at **Axis 3**						
205	G+0.3Q	NonStatic	-537.029	0.16	0.134	0.446 $(EI)_o$
SW206	G+0.3Q	NonStatic	-939.399	0.50	0.075	0.400 $(EI)_o$
207	G+0.3Q	NonStatic	-537.028	0.16	0.134	0.446 $(EI)_o$
4th Storey Columns at **Axis 3**						
301	G+0.3Q	NonStatic	-399.802	0.16	0.100	0.400 $(EI)_o$
SW302	G+0.3Q	NonStatic	-709.106	0.50	0.057	0.400 $(EI)_o$
303	G+0.3Q	NonStatic	-399.801	0.16	0.100	0.400 $(EI)_o$
5th Storey Columns at **Axis 3**						
397	G+0.3Q	NonStatic	-264.093	0.16	0.066	0.400 $(EI)_o$
SW398	G+0.3Q	NonStatic	-472.195	0.50	0.038	0.400 $(EI)_o$
399	G+0.3Q	NonStatic	-264.092	0.16	0.066	0.400 $(EI)_o$
6th Storey Columns at **Axis 3**						
493	G+0.3Q	NonStatic	-129.023	0.16	0.032	0.400 $(EI)_o$
SW494	G+0.3Q	NonStatic	-229.447	0.50	0.018	0.400 $(EI)_o$
495	G+0.3Q	NonStatic	-129.023	0.16	0.032	0.400 $(EI)_o$

Shear Wall at **Axis A**						
SW16	G+0.3Q	NonStatic	-1487.004	0.50	0.119	0.425 $(EI)_o$
SW112	G+0.3Q	NonStatic	-1256.238	0.50	0.100	0.401 $(EI)_o$
SW208	G+0.3Q	NonStatic	-1009.987	0.50	0.081	0.400 $(EI)_o$
SW304	G+0.3Q	NonStatic	-754.182	0.50	0.060	0.400 $(EI)_o$
SW400	G+0.3Q	NonStatic	-491.515	0.50	0.039	0.400 $(EI)_o$
SW496	G+0.3Q	NonStatic	-222.677	0.50	0.018	0.400 $(EI)_o$

2.2.2. Definition of Plastic Hinges at Beams, Columns and Shear Walls

2.2.2.1. Material Strength and Maximum Strain Values for Calculation of Plastic Hinge Moment. The material strength and the maximum strain values according to Turkish Seismic Code 2007 (7.4.11) are used for the definition of the interaction curves of plastic hinges at the member ends.

For concrete : $f_{cm} = 25$ MPa, $\varepsilon_c = 0.003$

For steel : $f_{ym} = 420$ MPa, $\varepsilon_s = 0.010$

2.2.2.2. Definition of Plastic Hinges at Beams. The plastic moment (M_{pa}) values are calculated by using the computer program XSTRACT (Cross Section Analysis Program) to define the internal forces-plastic deformation correlation. According to Turkish Seismic Code 2007 (7.6.4.5(a)), the strain hardening is not taken into account.

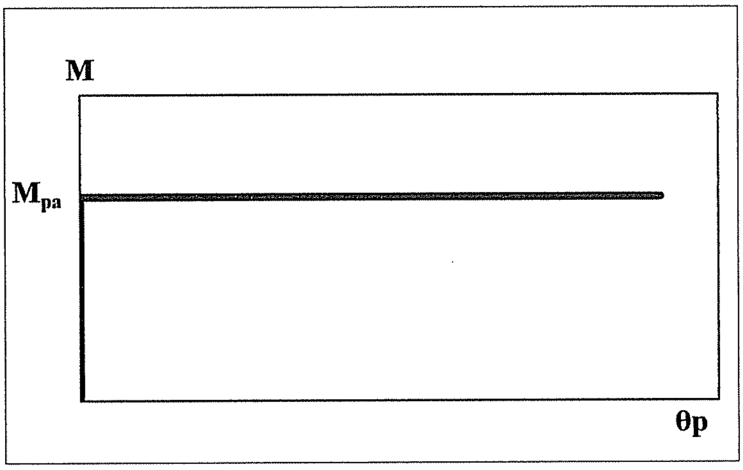


Figure 2.1. The internal force-plastic rotation correlation with no-strain hardening

2.2.2.3. Definition of Plastic Hinges at Columns and at Shear Walls. For columns, the P-M interaction analysis is performed for the bending moments about axes 0°, 45° and 90°. For shear walls, the P-M interaction analysis is performed for the bending moments about axes 0°, 22.5°, 45°, 67.5°and 90°. The diagrams obtained from the P-M interaction curves are entered in the computer programme SAP 2000.

As the nonlinear response in SAP 2000 programme can only be defined at frame elements, the structural walls are modelled as columns having the same size and rigid beams.

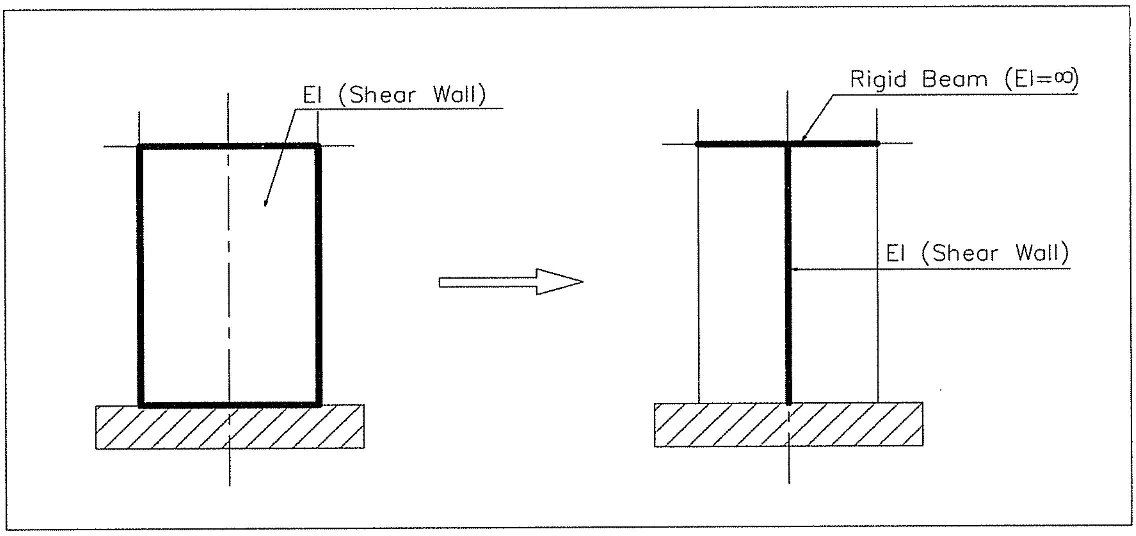


Figure 2.2. Modelling of shear wall as identical column

2.3. Nonlinear Static Pushover Analysis by Using the Incremental Equivalent Seismic Load Procedure

2.3.1. Nonlinear Static Analysis using the Vertical Loads

Using the effective flexural stiffness of the cracked section, the nonlinear static pushover analysis is primarily performed by taking into account the vertical loads (1.0G + 0.3Q) which are also compatible with masses at each storey according to Turkish Seismic Code 2007 (7.6.3(b)). These results are used as the initial conditions of the nonlinear static pushover analysis.

2.3.2. Pushover Analysis Using the Incremental Equivalent Seismic Load Method

<u>2.3.2.1. Applicability of the Incremental Equivalent Seismic Load Method.</u> As defined in Turkish Code 2007 (7.6.5.2), this analysis method can be used by buildings up to about 8

stories. And the torsional irregularity factor must also be smaller than 1.4 by neglecting the effects of ±5% additional eccentricities ($\eta_{bi} < 1.4$). As the analysed building is symmetrical to both axes x and y, the torsional irregularity factor is equal to 1 ($\eta_{bi} = 1.0$) and this procedure can be applied to this sample structure.

The sum of participating effective masses calculated for the first mode in earthquake direction considered shall in no case be less than 70% of the total building mass.

Table 2.2. The effective mass ratios in x- and y-direction

	Period	**Effective mass ratio**			
Mode	**(sec.)**	**in x-direction**	**in y-direction**	**Checking**	
1	1.12089	0.78116	-	>	0.7
2	1.07721	-	0.78417	>	0.7

As the effective mass ratio in both direction is greater than 0.7, as shown in Table 2.2, this method can be used by this analysis.

2.3.2.2. Pushover Analysis. Based on the assumption that the applied lateral load distribution will be constant independently on the changing deflected shape TSC '07 (7.6.5.3), lateral forces are applied in proportion to the product of storey masses and first mode shape of the elastic model of the structure.

The capacity curves are plotted by using the lateral loads acting in x- and y-direction proportional to the fundamental mode of vibration.

Table 2.3. Displacement and base force values of the capacity curve in x-direction

PUSHOVER CURVE IN X-DIRECTION (LOAD CASE : PO_EX)		
Step	**Displacement u_{xN1}(m)**	**Base Force V_{x1}(kN)**
0	0.0000	0.0000
1	0.0147	841.3546
2	0.0356	1876.1063
3	0.0562	2782.8276
4	0.0778	3578.7065
5	0.0897	3870.4961
6	0.0986	4016.7625
7	0.1000	4033.0085
8	0.1154	4152.9731
9	0.1177	4159.7705
10	0.1387	4205.3276
11	0.1517	4225.4922
12	0.1564	4230.5044
13	0.1651	4237.3828
14	0.1717	4240.5117
15	0.1735	4241.2646
16	0.1777	4242.2842
17	0.1801	4242.5288
18	0.1860	4242.9888
19	0.1990	4243.7451
20	0.2000	4243.3882

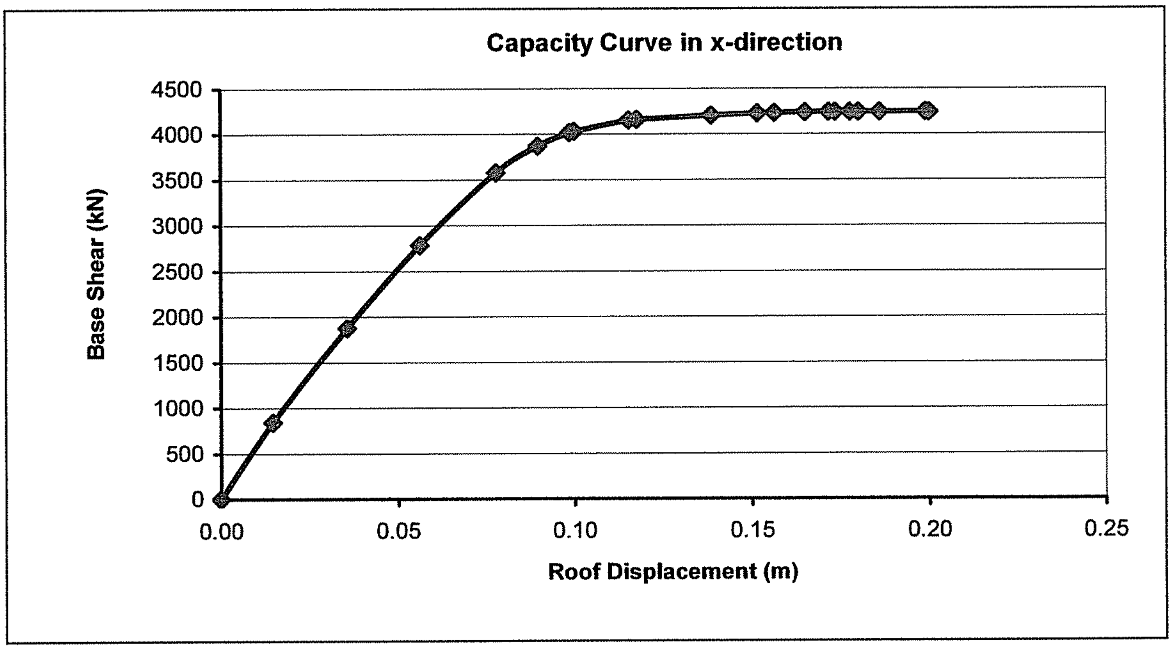


Figure 2.3. Capacity curve in x-direction

Table 2.4. Displacement and base force values of the capacity curve in y-direction

PUSHOVER CURVE IN Y-DIRECTION (LOAD CASE : PO_EY)

Step	Displacement u_{yN1} (m)	Base Force V_{y1} (kN)
0	0.0000	0.0000
1	0.0133	829.5320
2	0.0350	1982.9017
3	0.0593	3070.1262
4	0.0801	3896.0281
5	0.0983	4380.2246
6	0.0994	4399.0801
7	0.1161	4595.6602
8	0.1185	4614.3389
9	0.1254	4654.4438
10	0.1295	4670.0093
11	0.1491	4720.6221
12	0.1498	4720.9448
13	0.1543	4721.3857
14	0.1644	4721.2026
15	0.1679	4720.7412
16	0.1804	4718.6685
17	0.1908	4715.3579
18	0.1968	4712.3120
19	0.2000	4710.5225

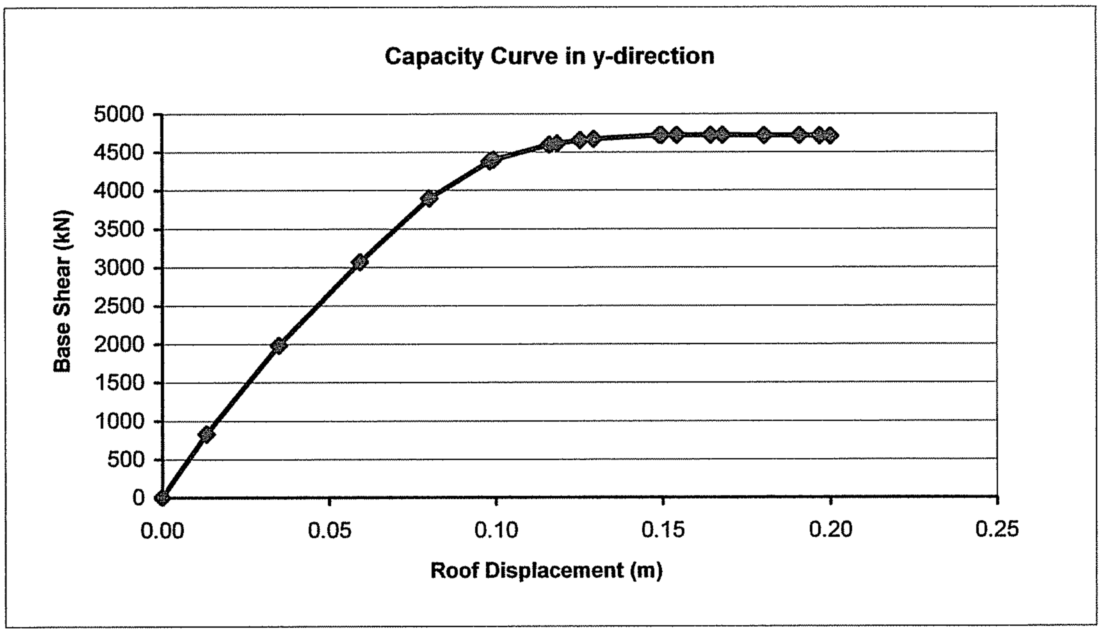


Figure 2.4. Capacity curve in y-direction

2.3.2.3. Conversion of the Capacity Curve to the Capacity Spectrum. To use the capacity spectrum method, it is necessary to convert the capacity curve, which is in terms of base shear and roof displacement to what is called a capacity spectrum which is a representation of the capacity curve in ADRS (S_a versus S_d) format.

The capacity curves in both x and y directions are converted by using the equations below Eq.(2.2), (2.3).

(a) Spectral acceleration for the first natural mode at i[th] step will be obtained by using the below equation, where M_{x1} the efective mass at the first natural mode in x-direction for elastic response:

$$a_1^{(i)} = \frac{V_{x1}^{(i)}}{M_{x1}} \tag{2.2}$$

(b) Spectral displacement for the first natural mode at ith step will be obtained by using the below equation :

$$d_1^{(i)} = \frac{u_{xN1}^{(i)}}{\Phi_{xN1}\,\Gamma_{x1}} \tag{2.3}$$

Γ_{x1} : modal participating factor for the first natural mode.

Φ_{xN1} : amplitude of the first natural mode at the roof.

By using these above equations, the spectral accelerations and displacements are calculated for both x- and y-direction, which are the coordinates of the capacity spectrum in ADRS format.

For x-direction:

Table 2.5. Capacity spectrum values in x-direction

PUSHOVER CAPACITY SPECTRUM IN X-DIRECTION (LC : PO_EX)

Step	Displacement $u_{xN1}^{(i)}$ (m)	Base Force $V_{x1}^{(i)}$(kN)	M_{x1}	Φ_{xN1}	Γ_{x1}	$d_1^{(i)}$ (m)	$a_1^{(i)}$ (m/s^2)
0	0.0000	0.0000	2474.731	0.026717	49.7469	0	0
1	0.0147	841.3546	2474.731	0.026717	49.7469	0.01106	0.33998
2	0.0356	1876.1063	2474.731	0.026717	49.7469	0.02679	0.75811
3	0.0562	2782.8276	2474.731	0.026717	49.7469	0.04228	1.1245
4	0.0778	3578.7065	2474.731	0.026717	49.7469	0.05854	1.4461
5	0.0897	3870.4961	2474.731	0.026717	49.7469	0.06749	1.56401
6	0.0986	4016.7625	2474.731	0.026717	49.7469	0.07419	1.62311
7	0.1000	4033.0085	2474.731	0.026717	49.7469	0.07524	1.62968
8	0.1154	4152.9731	2474.731	0.026717	49.7469	0.08683	1.67815
9	0.1177	4159.7705	2474.731	0.026717	49.7469	0.08856	1.6809
10	0.1387	4205.3276	2474.731	0.026717	49.7469	0.10436	1.69931
11	0.1517	4225.4922	2474.731	0.026717	49.7469	0.11414	1.70745
12	0.1564	4230.5044	2474.731	0.026717	49.7469	0.11767	1.70948
13	0.1651	4237.3828	2474.731	0.026717	49.7469	0.12422	1.71226
14	0.1717	4240.5117	2474.731	0.026717	49.7469	0.12919	1.71352
15	0.1735	4241.2646	2474.731	0.026717	49.7469	0.13054	1.71383
16	0.1777	4242.2842	2474.731	0.026717	49.7469	0.1337	1.71424
17	0.1801	4242.5288	2474.731	0.026717	49.7469	0.13551	1.71434
18	0.1860	4242.9888	2474.731	0.026717	49.7469	0.13995	1.71453
19	0.1990	4243.7451	2474.731	0.026717	49.7469	0.14973	1.71483
20	0.2000	4243.3882	2474.731	0.026717	49.7469	0.15048	1.71469

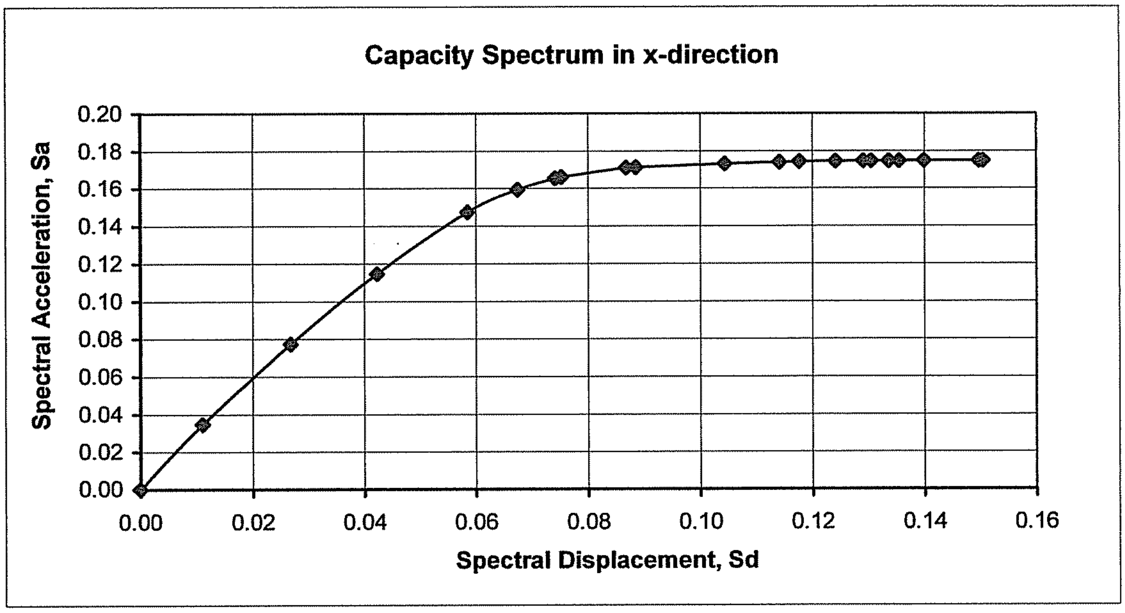


Figure 2.5. Capacity spectrum curve in x-direction

For y-direction:

Table 2.6. Capacity spectrum values in y-direction

PUSHOVER CAPACITY SPECTRUM IN Y-DIRECTION (LC : PO_EY)

Step	Displacement $u_{yN1}^{(i)}$ (m)	Base Force $V_{y1}^{(i)}$(kN)	M_{y1}	Φ_{yN1}	Γ_{y1}	$d_1^{(i)}$ (m)	$a_1^{(i)}$ (m/s^2)
0	0.0000	0.0000	2484.267	0.026589	49.8428	0	0
1	0.0133	829.5320	2484.267	0.026589	49.8428	0.01004	0.33391
2	0.0350	1982.9017	2484.267	0.026589	49.8428	0.02641	0.79818
3	0.0593	3070.1262	2484.267	0.026589	49.8428	0.04475	1.23583
4	0.0801	3896.0281	2484.267	0.026589	49.8428	0.06044	1.56828
5	0.0983	4380.2246	2484.267	0.026589	49.8428	0.07417	1.76319
6	0.0994	4399.0801	2484.267	0.026589	49.8428	0.075	1.77078
7	0.1161	4595.6602	2484.267	0.026589	49.8428	0.0876	1.84991
8	0.1185	4614.3389	2484.267	0.026589	49.8428	0.08942	1.85742
9	0.1254	4654.4438	2484.267	0.026589	49.8428	0.09462	1.87357
10	0.1295	4670.0093	2484.267	0.026589	49.8428	0.09772	1.87983
11	0.1491	4720.6221	2484.267	0.026589	49.8428	0.11251	1.90021
12	0.1498	4720.9448	2484.267	0.026589	49.8428	0.11303	1.90034
13	0.1543	4721.3857	2484.267	0.026589	49.8428	0.11643	1.90051
14	0.1644	4721.2026	2484.267	0.026589	49.8428	0.12405	1.90044
15	0.1679	4720.7412	2484.267	0.026589	49.8428	0.12669	1.90026
16	0.1804	4718.6685	2484.267	0.026589	49.8428	0.13612	1.89942
17	0.1908	4715.3579	2484.267	0.026589	49.8428	0.14397	1.89809
18	0.1968	4712.3120	2484.267	0.026589	49.8428	0.1485	1.89686
19	0.2000	4710.5225	2484.267	0.026589	49.8428	0.15091	1.89614

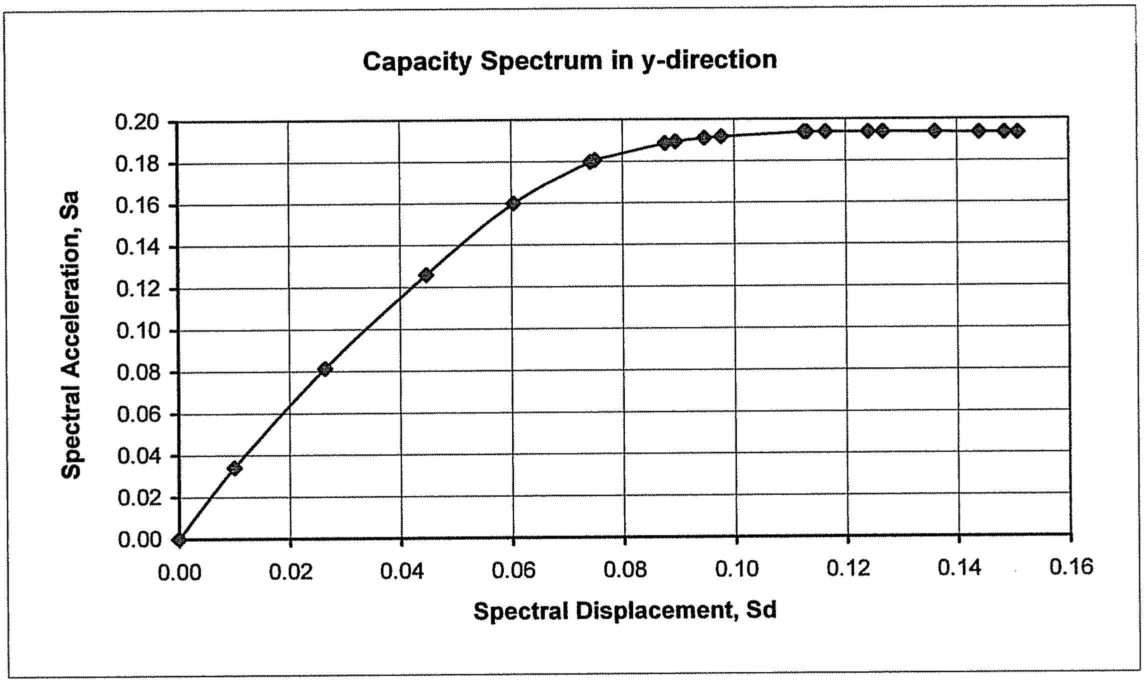


Figure 2.6. Capacity spectrum curve in y-direction

2.3.2.4. Calculation of the Spectral Displacement Demand. The capacity spectrum obtained from the push-over analysis and the elastic response spectrum is needed to estimate the inelastic spectral displacement.

For x-direction :

$$d_1^{(p)} = S_{di1} \tag{2.4}$$

$$S_{di1} = C_{R1} \, S_{de1} \tag{2.5}$$

$$S_{de1} = \frac{S_{ae1}}{(\omega_1^{(1)})^2} \tag{2.6}$$

$(\omega_1^{(1)})^2 = 30.7389$, $S_{ae1} = 4.2643$ m/s^2 $S_{de1} = 0.139$ m.

$T_1^{(1)} = 1.133$ sec. $> T_B = 0.4$ sec $C_{R1} = 1$

$S_{di1} = 1*0.139 = 0.139$ m.

$d_1^{(p)} = S_{di1} = 0.139$ m.

$u_{xN1}^{(p)} = \Phi_{xN1} \, \Gamma_{x1} \, d_1^{(p)}$

$u_{xN1}^{(p)} = 0.026717*49.7469*0.139 = 0.184$ m.

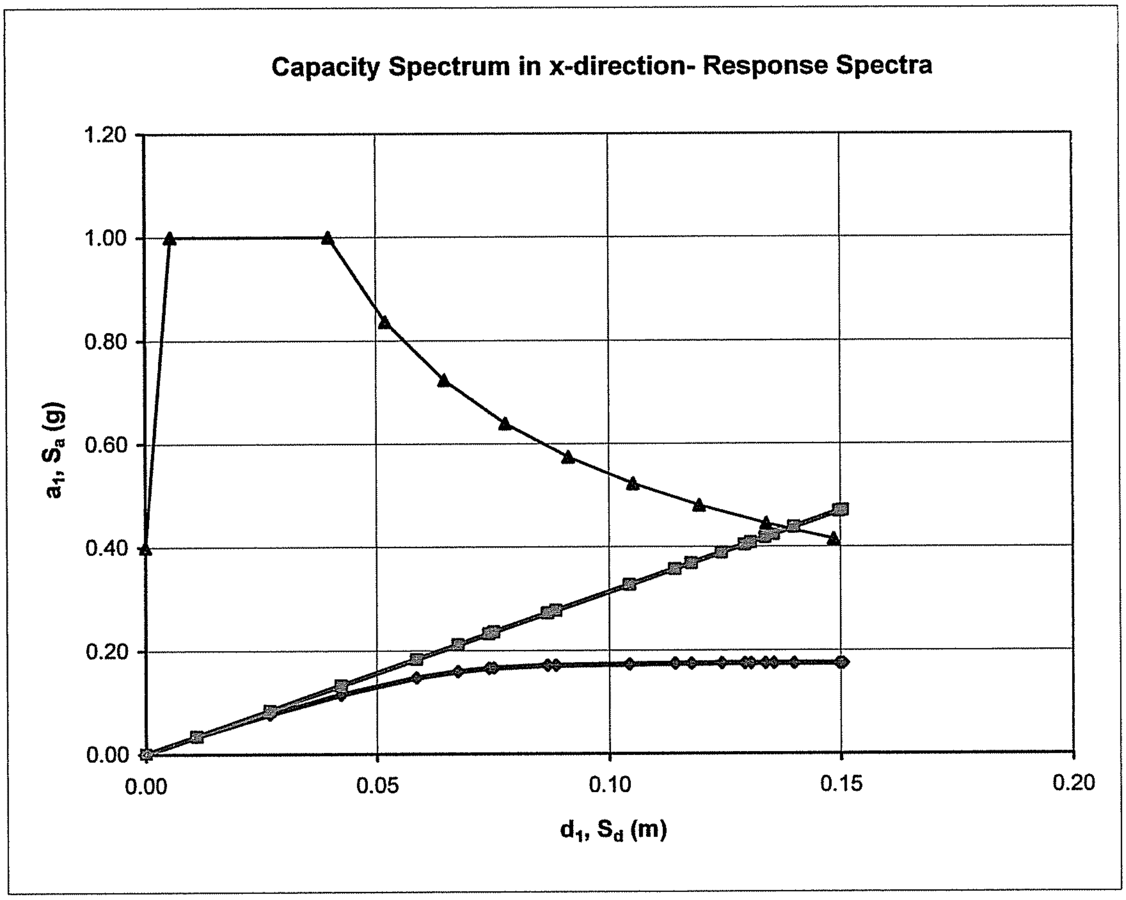


Figure 2.7. Capacity spectrum curve in x-direction – Response Spectra

For y-direction :

Using the equations Eq.(2.4), (2.5), (2.6), the displacement demand for y-direction is calculated as shown below.

$(\omega_1^{(1)})^2 = 33.2726$, $S_{ae1} = 4.4016\ m/s^2$ $S_{de1} = 0.132$ m.

$T_1^{(1)} = 1.0893$ sec. $> T_B = 0.4$ sec $C_{R1} = 1$

$S_{di1} = 1*0.132 = 0.132$ m.

$d_1^{(p)} = S_{di1} = 0.132$ m.

$u_{yN1}^{(p)} = \Phi_{yN1}\ \Gamma_{y1}\ d_1^{(p)}$

$u_{yN1}^{(p)} = 0.026589*49.8428*0.132 = 0.175$ m.

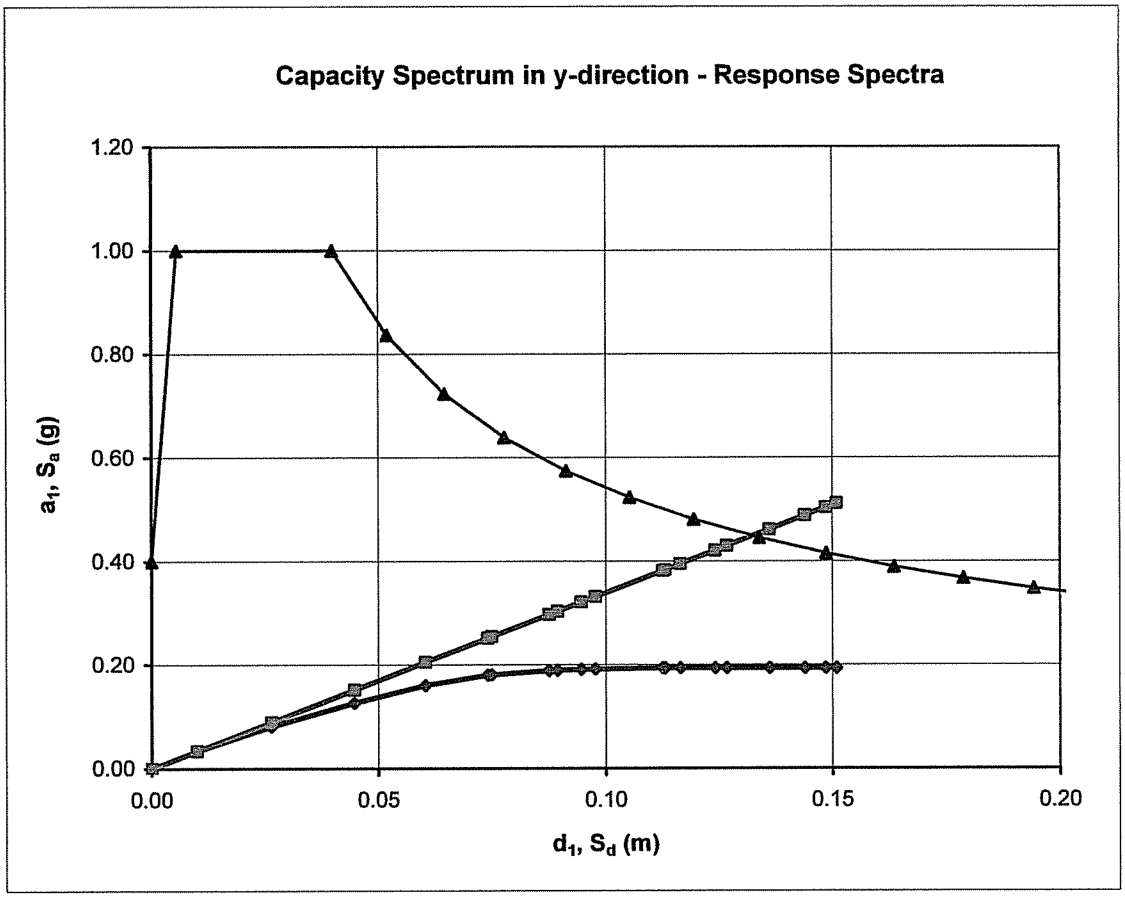
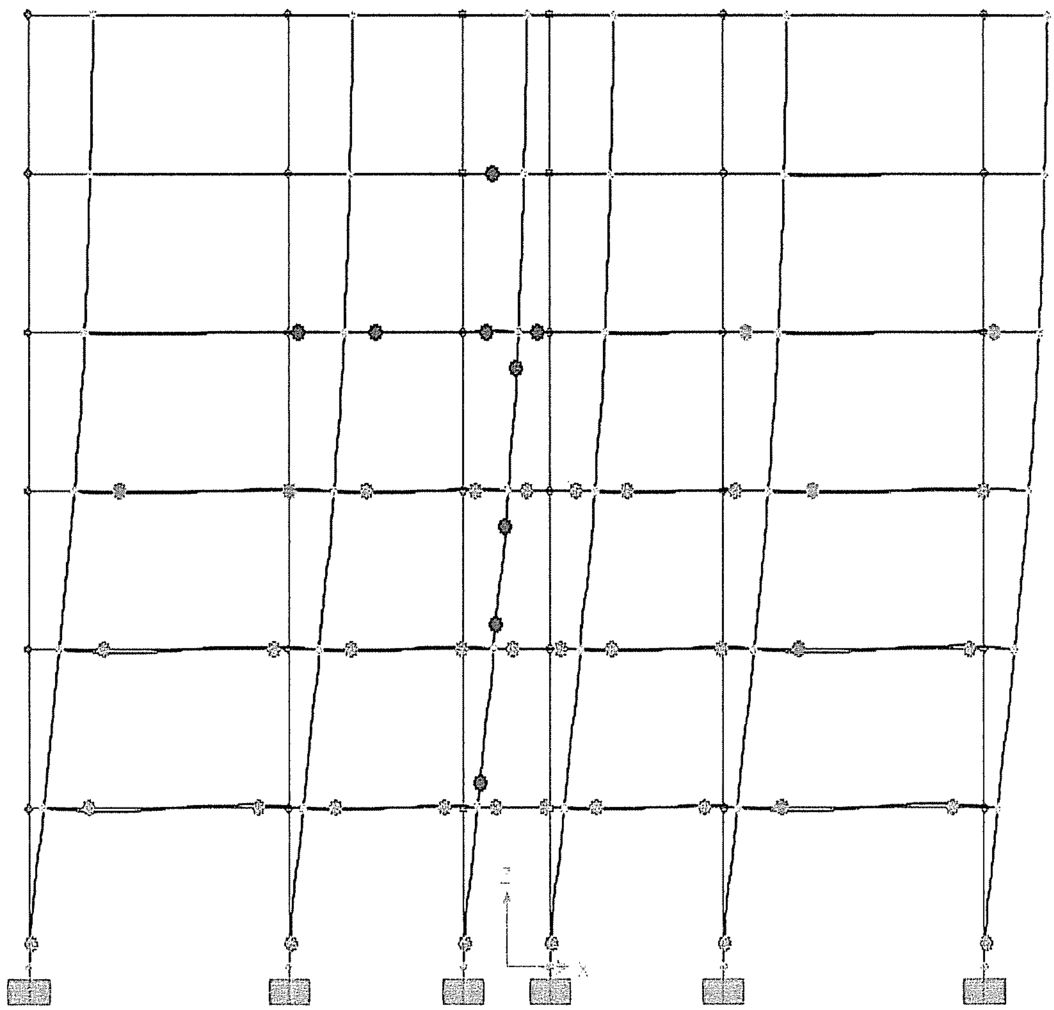


Figure 2.8. Capacity spectrum curve in y-direction – Response Spectra

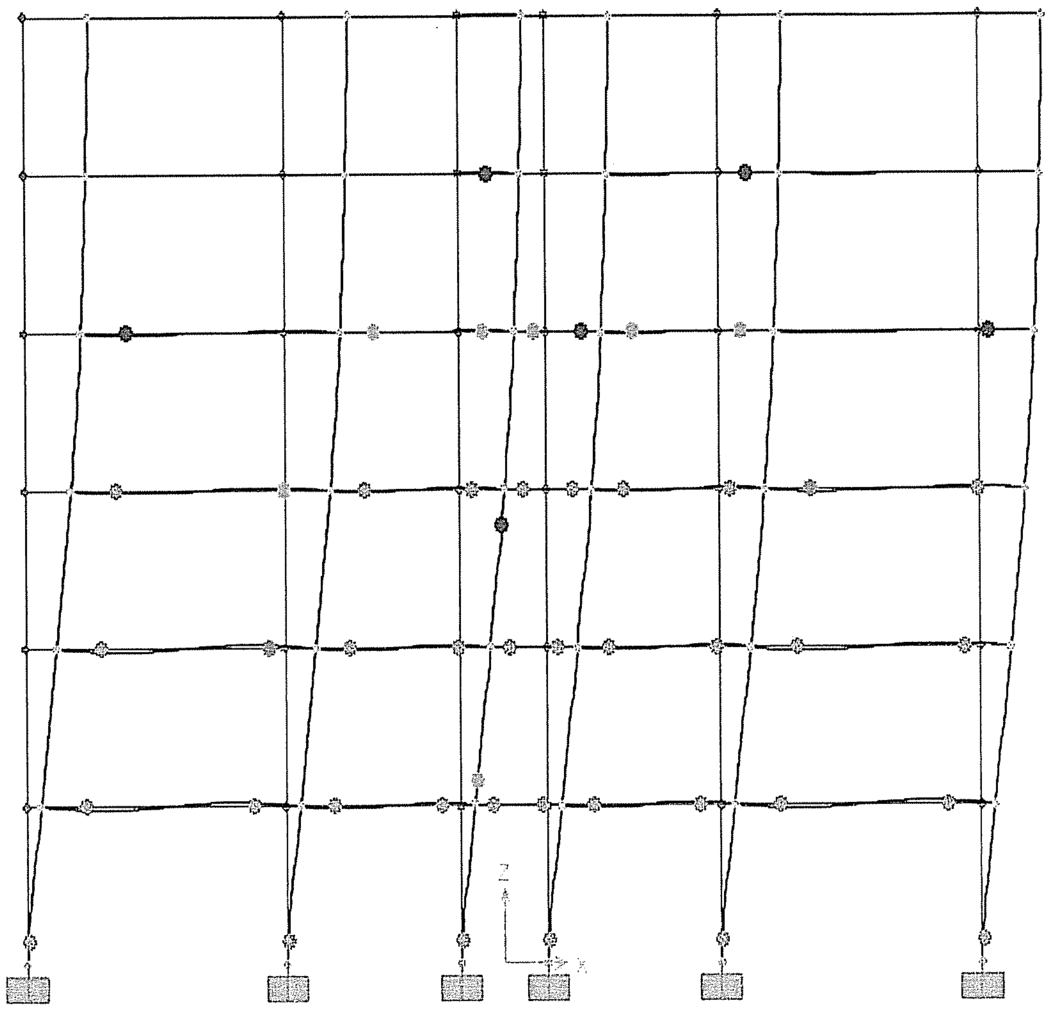
The roof displacement demands are obtained for x-direction 0.184m and for y-direction 0.175 m. The push-over analysis will be repeated to obtain all demand values.

The plastic hinges are shown in the Figure 2.9a, 2.9b, 2.9c, where the roof displacement demand is obtained in the x-direction. The plastic hinges are shown in the Figure 2.10a, 2.10b, 2.10c, where the roof displacement demand is obtained in the y-direction.



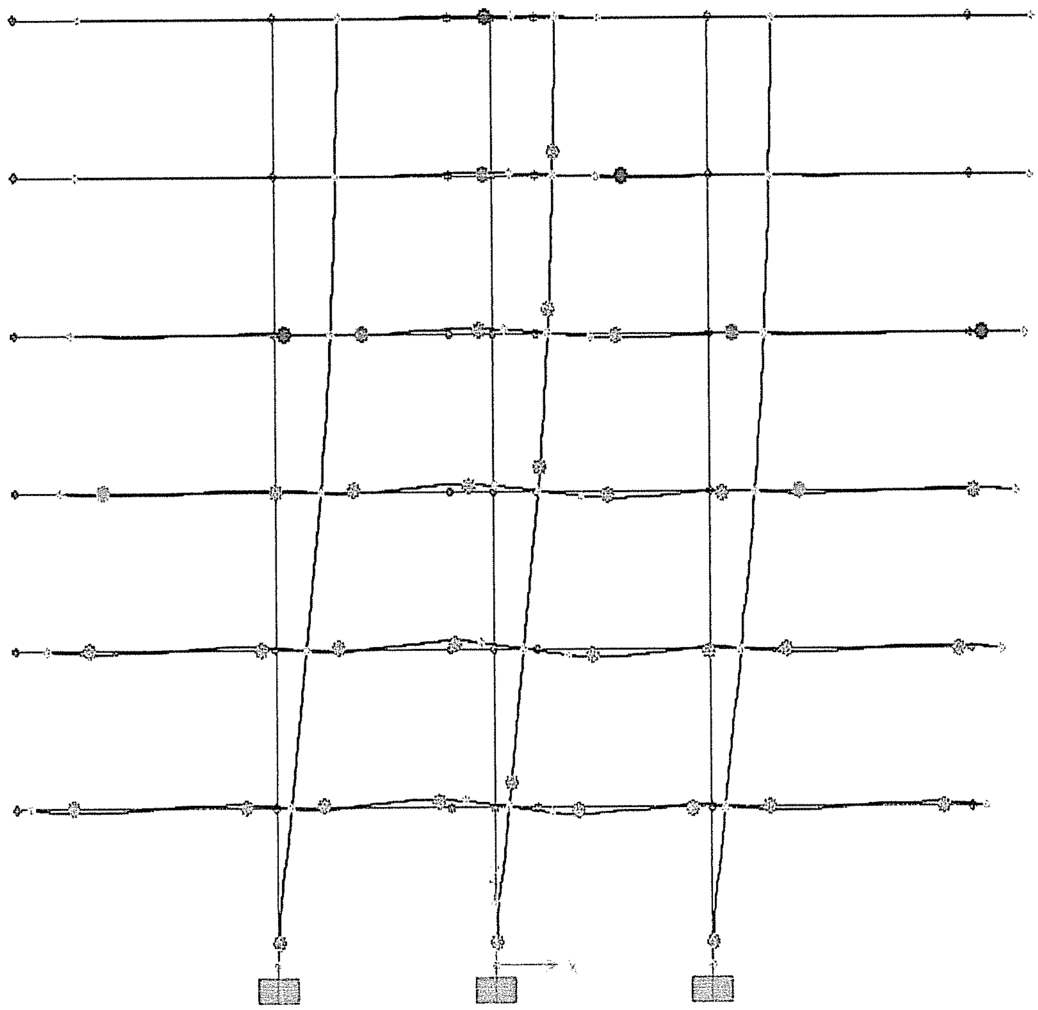
AXIS 1

Figure 2.9a. The plastic hinges obtained at Axis 1



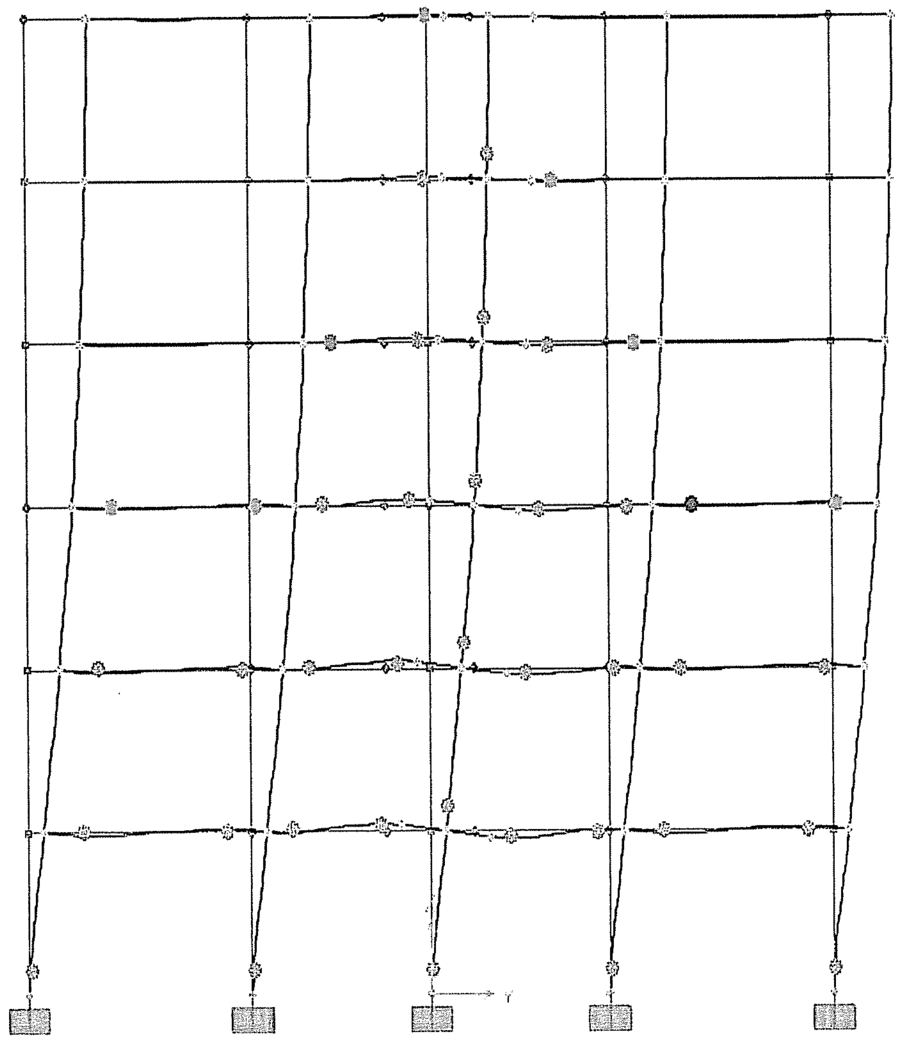
AXIS 2

Figure 2.9b. The plastic hinges obtained at Axis 2



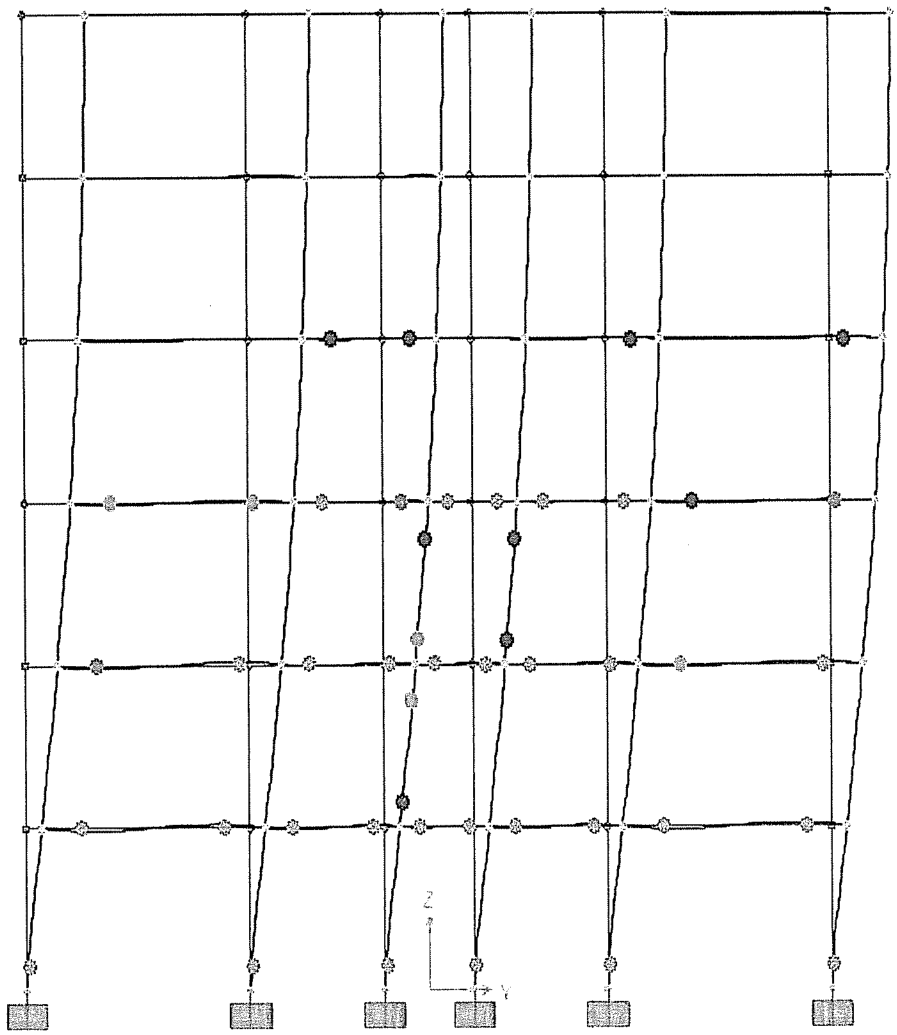
AXIS 3

Figure 2.9c. The plastic hinges obtained at Axis 3



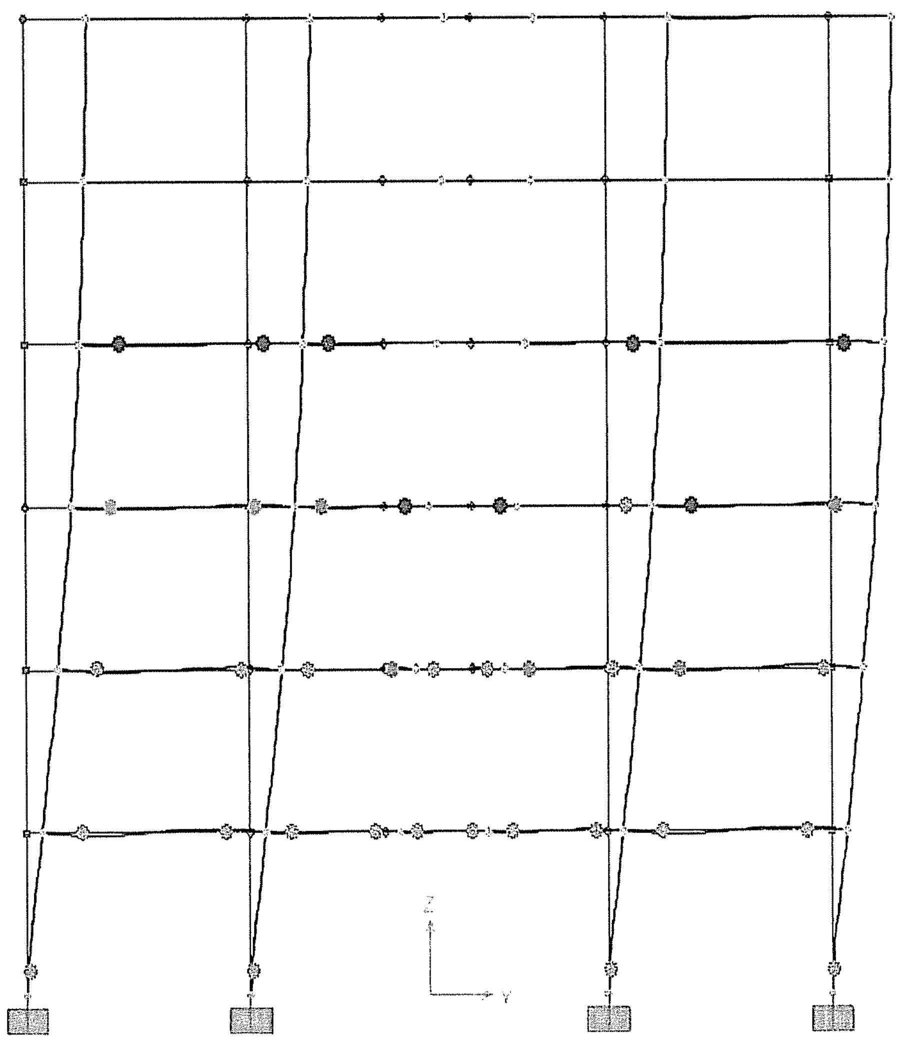
AXIS A

Figure 2.10a. The plastic hinges obtained at Axis A



AXIS B

Figure 2.10b. The plastic hinges obtained at Axis B



AXIS C

Figure 2.10c. The plastic hinges obtained at Axis C

Table 2.7a. Plastic curvature demand at beams in x-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

LEFT END

Storey	Direction	Axis	Beam	Section	θp	Lp	ϕp	ϕy	ϕt					
1^{st} storey	x-direction	Axis 1	B33	33_1	0.00767	0.175	0.043829	0.009733	0.053562	⇒	εc=	1.653E-03	εs=	1.405E-02
			B34	33_2	0.009843	0.175	0.056246	0.009720	0.065966	⇒	εc=	2.076E-03	εs=	1.725E-02
			B35	33_2	0.011166	0.175	0.063806	0.009720	0.073526	⇒	εc=	2.327E-03	εs=	1.922E-02
			B36	33_2	0.009164	0.175	0.052366	0.009720	0.062086	⇒	εc=	1.947E-03	εs=	1.624E-02
			B37	33_2	0.006744	0.175	0.038537	0.009720	0.048257	⇒	εc=	1.525E-03	εs=	1.261E-02
		Axis 2	B44	417_1	0.010769	0.175	0.061537	0.009725	0.071262	⇒	εc=	2.115E-03	εs=	1.877E-02
			B45	226_1	0.011259	0.175	0.064337	0.009736	0.074073	⇒	εc=	2.323E-03	εs=	1.938E-02
			B46	322_1	0.010748	0.175	0.061417	0.009726	0.071143	⇒	εc=	2.182E-03	εs=	1.867E-02
			B47	322_1	0.010881	0.175	0.062177	0.009726	0.071903	⇒	εc=	2.207E-03	εs=	1.887E-02
			B48	226_1	0.008925	0.175	0.051000	0.009736	0.060736	⇒	εc=	1.881E-03	εs=	1.591E-02
		Axis 3	B55	417_1	0.008887	0.175	0.050783	0.009725	0.060508	⇒	εc=	1.795E-03	εs=	1.594E-02
			B56	417_1	0.013681	0.175	0.078177	0.009725	0.087902	⇒	εc=	2.709E-03	εs=	2.305E-02
			B59	417_1	0.014254	0.175	0.081451	0.009725	0.091176	⇒	εc=	2.830E-03	εs=	2.389E-02
			B60	417_1	0.007674	0.175	0.043851	0.009725	0.053576	⇒	εc=	1.598E-03	εs=	1.410E-02
					θp	Lp	ϕp	ϕy	ϕt					
2^{nd} storey	x-direction	Axis 1	B129	33_2	0.008555	0.175	0.048886	0.009720	0.058606	⇒	εc=	1.832E-03	εs=	1.534E-02
			B130	130_1	0.010298	0.175	0.058846	0.009727	0.068573	⇒	εc=	2.180E-03	εs=	1.792E-02
			B131	130_1	0.011403	0.175	0.065160	0.009727	0.074887	⇒	εc=	2.394E-03	εs=	1.955E-02
			B132	130_1	0.009155	0.175	0.052314	0.009727	0.062041	⇒	εc=	1.961E-03	εs=	1.622E-02
			B133	130_1	0.005953	0.175	0.034017	0.009727	0.043744	⇒	εc=	1.404E-03	εs=	1.141E-02
		Axis 2	B140	33_1	0.010692	0.175	0.061097	0.009733	0.070830	⇒	εc=	2.217E-03	εs=	1.853E-02
			B141	141_1	0.011866	0.175	0.067806	0.009665	0.077471	⇒	εc=	2.522E-03	εs=	2.018E-02
			B142	226_1	0.011436	0.175	0.065349	0.009736	0.075085	⇒	εc=	2.361E-03	εs=	1.964E-02
			B143	226_1	0.01098	0.175	0.062743	0.009736	0.072479	⇒	εc=	2.270E-03	εs=	1.896E-02
			B144	141_1	0.008754	0.175	0.050023	0.009665	0.059688	⇒	εc=	1.895E-03	εs=	1.560E-02
		Axis 3	B151	417_1	0.007268	0.175	0.041531	0.009725	0.051256	⇒	εc=	1.540E-03	εs=	1.348E-02
			B152	417_1	0.014047	0.175	0.080269	0.009725	0.089994	⇒	εc=	2.786E-03	εs=	2.359E-02
			B155	417_1	0.015754	0.175	0.090023	0.009725	0.099748	⇒	εc=	3.179E-03	εs=	2.959E-02
			B156	417_1	0.007489	0.175	0.042794	0.009725	0.052519	⇒	εc=	1.571E-03	εs=	1.382E-02
					θp	Lp	ϕp	ϕy	ϕt					
3^{rd} storey	x-direction	Axis 1	B225	33_2	0.005211	0.175	0.029777	0.009720	0.039497	⇒	εc=	1.279E-03	εs=	1.029E-02
			B226	226_1	0.006891	0.175	0.039377	0.009736	0.049113	⇒	εc=	1.532E-03	εs=	1.286E-02
			B227	227_1	0.007052	0.175	0.040297	0.009726	0.050023	⇒	εc=	1.578E-03	εs=	1.308E-02
			B228	227_1	0.005434	0.175	0.031051	0.009726	0.040777	⇒	εc=	1.313E-03	εs=	1.063E-02
			B229	226_1	0.00246	0.175	0.014057	0.009736	0.023793	⇒	εc=	8.840E-04	εs=	6.088E-03
		Axis 2	B236	417_1	0.00755	0.175	0.043143	0.009725	0.052868	⇒	εc=	1.580E-03	εs=	1.391E-02
			B237	141_1	0.008221	0.175	0.046977	0.009665	0.056642	⇒	εc=	1.791E-03	εs=	1.481E-02
			B238	238_1	0.007686	0.175	0.043920	0.009744	0.053664	⇒	εc=	1.670E-03	εs=	1.406E-02
			B239	238_1	0.007839	0.175	0.044794	0.009744	0.054538	⇒	εc=	1.694E-03	εs=	1.429E-02
			B240	141_1	0.005189	0.175	0.029651	0.009665	0.039316	⇒	εc=	1.292E-03	εs=	1.023E-02
		Axis 3	B247	417_1	0.004263	0.175	0.024360	0.009725	0.034085	⇒	εc=	1.116E-03	εs=	8.872E-03
			B248	417_1	0.010286	0.175	0.058777	0.009725	0.068502	⇒	εc=	2.033E-03	εs=	1.804E-02
			B251	417_1	0.013293	0.175	0.075960	0.009725	0.085685	⇒	εc=	2.627E-03	εs=	2.248E-02
			B252	417_1	0.004051	0.175	0.023149	0.009725	0.032874	⇒	εc=	1.088E-03	εs=	8.560E-03

Table 2.7b. Plastic curvature demand at beams in x-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

RIGHT END

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
1st storey	x-direction	**Axis 1**	B33	33_2	0.012440	0.175	0.071086	0.009975	0.081061	⇒	εc=	2.959E-03	εs=	2.071E-02
			B34	33_2	0.011418	0.175	0.065246	0.009975	0.075221	⇒	εc=	2.730E-03	εs=	1.923E-02
			B35	33_2	0.012985	0.175	0.074200	0.009975	0.084175	⇒	εc=	3.082E-03	εs=	2.150E-02
			B36	33_2	0.013249	0.175	0.075709	0.009975	0.085684	⇒	εc=	3.141E-03	εs=	2.188E-02
			B37	33_1	0.013753	0.175	0.078589	0.009915	0.088504	⇒	εc=	3.001E-03	εs=	2.293E-02
		Axis 2	B44	226_1	0.008797	0.175	0.050269	0.010070	0.060339	⇒	εc=	2.250E-03	εs=	1.542E-02
			B45	322_1	0.010055	0.175	0.057457	0.009892	0.067349	⇒	εc=	2.287E-03	εs=	1.744E-02
			B46	322_1	0.011980	0.175	0.068457	0.009892	0.078349	⇒	εc=	2.688E-03	εs=	2.027E-02
			B47	226_1	0.011614	0.175	0.066366	0.010070	0.076436	⇒	εc=	2.857E-03	εs=	1.953E-02
			B48	417_1	0.012171	0.175	0.069549	0.009733	0.079282	⇒	εc=	2.396E-03	εs=	2.083E-02
		Axis 3	B55	417_1	0.010800	0.175	0.061714	0.009733	0.071447	⇒	εc=	2.132E-03	εs=	1.880E-02
			B56	417_1	0.015874	0.175	0.090709	0.009733	0.100442	⇒	εc=	3.185E-03	εs=	2.623E-02
			B59	417_1	0.014045	0.175	0.080257	0.009733	0.089990	⇒	εc=	2.776E-03	εs=	2.358E-02
			B60	417_1	0.011660	0.175	0.066629	0.009733	0.07636157	⇒	εc=	2.293E-03	εs=	2.008E-02
					θp	Lp	φp	φy	φt					
2nd storey	x-direction	**Axis 1**	B129	130_1	0.008542	0.175	0.048811	0.010140	0.058951	⇒	εc=	2.241E-03	εs=	1.503E-02
			B130	130_1	0.009586	0.175	0.054777	0.010140	0.064917	⇒	εc=	2.468E-03	εs=	1.655E-02
			B131	130_1	0.010362	0.175	0.059211	0.010140	0.069351	⇒	εc=	2.637E-03	εs=	1.767E-02
			B132	130_1	0.010089	0.175	0.057651	0.010140	0.067791	⇒	εc=	2.578E-03	εs=	1.728E-02
			B133	33_2	0.013043	0.175	0.074531	0.009975	0.084506	⇒	εc=	3.095E-03	εs=	2.158E-02
		Axis 2	B140	141_1	0.006914	0.175	0.039509	0.010270	0.049779	⇒	εc=	2.033E-03	εs=	1.255E-02
			B141	226_1	0.010411	0.175	0.059491	0.010070	0.069561	⇒	εc=	2.597E-03	εs=	1.778E-02
			B142	226_1	0.010558	0.175	0.060331	0.010070	0.070401	⇒	εc=	2.628E-03	εs=	1.799E-02
			B143	141_1	0.010373	0.175	0.059274	0.010270	0.069544	⇒	εc=	2.775E-03	εs=	1.759E-02
			B144	33_1	0.011113	0.175	0.063503	0.009915	0.073418	⇒	εc=	2.402E-03	εs=	1.915E-02
		Axis 3	B151	417_1	0.010603	0.175	0.060589	0.009733	0.070322	⇒	εc=	2.098E-03	εs=	1.850E-02
			B152	417_1	0.017690	0.175	0.101086	0.009733	0.110819	⇒	εc=	3.609E-03	εs=	2.883E-02
			B155	417_1	0.014008	0.175	0.080046	0.009733	0.089779	⇒	εc=	2.768E-03	εs=	2.353E-02
			B156	417_1	0.010113	0.175	0.057789	0.009733	0.06752157	⇒	εc=	2.012E-03	εs=	1.777E-02
					θp	Lp	φp	φy	φt					
3rd storey	x-direction	**Axis 1**	B225	226_1	0.005395	0.175	0.030829	0.010070	0.040899	⇒	εc=	1.584E-03	εs=	1.040E-02
			B226	227_1	0.005819	0.175	0.033251	0.010110	0.043361	⇒	εc=	1.728E-03	εs=	1.097E-02
			B227	227_1	0.005988	0.175	0.034217	0.010110	0.044327	⇒	εc=	1.762E-03	εs=	1.122E-02
			B228	226_1	0.006756	0.175	0.038606	0.010070	0.048676	⇒	εc=	1.844E-03	εs=	1.241E-02
			B229	33_2	0.009894	0.175	0.056537	0.009975	0.066512	⇒	εc=	2.403E-03	εs=	1.702E-02
		Axis 2	B236	141_1	0.003468	0.175	0.019817	0.010270	0.030087	⇒	εc=	1.368E-03	εs=	7.445E-03
			B237	238_1	0.007829	0.175	0.044737	0.010020	0.054757	⇒	εc=	1.969E-03	εs=	1.412E-02
			B238	238_1	0.007020	0.175	0.040114	0.010020	0.050134	⇒	εc=	1.822E-03	εs=	1.290E-02
			B239	141_1	0.006829	0.175	0.039023	0.010270	0.049293	⇒	εc=	2.016E-03	εs=	1.242E-02
			B240	417_1	0.008083	0.175	0.046189	0.009733	0.055922	⇒	εc=	1.655E-03	εs=	1.472E-02
		Axis 3	B247	417_1	0.007251	0.175	0.041434	0.009733	0.051167	⇒	εc=	1.533E-03	εs=	1.345E-02
			B248	417_1	0.015257	0.175	0.087183	0.009733	0.096916	⇒	εc=	3.041E-03	εs=	2.534E-02
			B251	417_1	0.010110	0.175	0.057771	0.009733	0.067504	⇒	εc=	2.011E-03	εs=	1.776E-02
			B252	417_1	0.007271	0.175	0.041549	0.009733	0.05128157	⇒	εc=	1.536E-03	εs=	1.348E-02

Table 2.7c. Plastic curvature demand at beams in x-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

LEFT END

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
4th storey	x-direction	**Axis 1**	B321	33_1										
			B322	322_1	0.000698	0.175	0.003989	0.009726	0.013715	⇒	εc=	6.439E-04	εs=	3.376E-03
			B323	226_1										
			B324	226_1										
			B325	322_1										
		Axis 2	B332	417_1	0.000759	0.175	0.004337	0.009725	0.014062	⇒	εc=	6.578E-04	εs=	3.463E-03
			B333	226_1	0.002066	0.175	0.011806	0.009736	0.021542	⇒	εc=	8.302E-04	εs=	5.482E-03
			B334	322_1	0.001059	0.175	0.006051	0.009726	0.015777	⇒	εc=	6.902E-04	εs=	3.932E-03
			B335	322_1	0.001684	0.175	0.009623	0.009726	0.019349	⇒	εc=	7.764E-04	εs=	4.892E-03
			B336	226_1										
		Axis 3	B343	417_1										
			B344	417_1	0.003511	0.175	0.020063	0.009725	0.029788	⇒	εc=	1.018E-03	εs=	7.710E-03
			B347	417_1	0.007298	0.175	0.041703	0.009725	0.051428	⇒	εc=	1.544E-03	εs=	1.353E-02
			B348	417_1										

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
5th storey	x-direction	**Axis 1**	B417	417_1										
			B418	417_1										
			B419	33_1										
			B420	33_1										
			B421	417_1										
		Axis 2	B428	417_1										
			B429	33_1										
			B430	417_1										
			B431	417_1										
			B432	33_1										
		Axis 3	B439	417_1										
			B440	417_1										
			B443	417_1	0.001364	0.175	0.007794	0.009725	0.017519	⇒	εc=	7.378E-04	εs=	4.395E-03
			B444	417_1										

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
6th storey	x-direction	**Axis 1**	B513											
			B514											
			B515											
			B516											
			B517											
		Axis 2	B524											
			B525											
			B526											
			B527											
			B528											
		Axis 3	B535											
			B536											
			B539											
			B540											

Table 2.7d. Plastic curvature demand at beams in x-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

RIGHT END

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
4th storey	x-direction	Axis 1	B321	322_1	0.000502	0.175	0.002869	0.009892	0.012761	⇒	εc=	6.821E-04	εs=	3.057E-03
			B322	226_1	0.000420	0.175	0.002400	0.010070	0.012470	⇒	εc=	7.340E-04	εs=	2.918E-03
			B323	226_1										
			B324	322_1	0.002113	0.175	0.012074	0.009892	0.021966	⇒	εc=	9.400E-04	εs=	5.496E-03
			B325	33_1	0.002958	0.175	0.016903	0.009915	0.026818	⇒	εc=	1.039E-03	εs=	6.818E-03
		Axis 2	B332	226_1										
			B333	322_1	0.002654	0.175	0.015166	0.009892	0.025058	⇒	εc=	1.020E-03	εs=	6.321E-03
			B334	322_1	0.000784	0.175	0.004480	0.009892	0.014372	⇒	εc=	7.288E-04	εs=	3.482E-03
			B335	226_1	0.002034	0.175	0.011623	0.010070	0.021693	⇒	εc=	1.018E-03	εs=	5.337E-03
			B336	417_1	0.001805	0.175	0.010314	0.009733	0.020047	⇒	εc=	7.934E-04	εs=	5.079E-03
		Axis 3	B343	417_1	0.000926	0.175	0.005291	0.009733	0.015024	⇒	εc=	6.771E-04	εs=	3.723E-03
			B344	417_1	0.009502	0.175	0.054297	0.009733	0.064030	⇒	εc=	1.904E-03	εs=	1.685E-02
			B347	417_1	0.003340	0.175	0.019086	0.009733	0.028819	⇒	εc=	9.910E-04	εs=	7.451E-03
			B348	417_1	0.000898	0.175	0.005131	0.009733	0.01486443	⇒	εc=	6.732E-04	εs=	3.680E-03

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
5th storey	x-direction	Axis 1	B417	417_1										
			B418	33_1	0.000214	0.175	0.001223	0.009915	0.011138	⇒	εc=	6.230E-04	εs=	2.641E-03
			B419	33_1										
			B420	417_1										
			B421	417_1										
		Axis 2	B428	33_1										
			B429	417_1	0.000695	0.175	0.003971	0.009733	0.013704	⇒	εc=	6.444E-04	εs=	3.369E-03
			B430	417_1										
			B431	33_1	0.000524	0.175	0.002994	0.009915	0.012909	⇒	εc=	6.761E-04	εs=	3.106E-03
			B432	417_1										
		Axis 3	B439	417_1										
			B440	417_1	0.004013	0.175	0.022931	0.009733	0.032664	⇒	εc=	1.077E-03	εs=	8.491E-03
			B443	417_1										
			B444	417_1										

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
6th storey	x-direction	Axis 1	B513											
			B514											
			B515											
			B516											
			B517											
		Axis 2	B524											
			B525											
			B526											
			B527											
			B528											
		Axis 3	B535											
			B536	417_1	0.000815	0.175	0.004657	0.009733	0.014390	⇒	εc=	6.617E-04	εs=	3.553E-03
			B539											
			B540											

Table 2.8a. Plastic curvature demand at beams in y-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

LEFT END

Storey	Direction	Axis	Beam	Section	θ_p	L_p	ϕ_p	ϕ_y	ϕ_t					
1st storey	y-direction	Axis A	B38	141_1	0.009608	0.175	0.054903	0.009665	0.064568	⇒	ε_c=	2.063E-03	ε_s=	1.686E-02
			B49	141_1	0.015188	0.175	0.086789	0.009665	0.096454	⇒	ε_c=	3.276E-03	ε_s=	2.499E-02
			B75	417_1	0.017700	0.175	0.101143	0.009725	0.110868	⇒	ε_c=	3.644E-03	ε_s=	2.884E-02
			B86	141_1	0.007821	0.175	0.044691	0.009665	0.054356	⇒	ε_c=	1.719E-03	ε_s=	1.421E-02
		Axis B	B39	241_1	0.011257	0.175	0.064326	0.009699	0.074025	⇒	ε_c=	2.419E-03	ε_s=	1.927E-02
			B50	145_1	0.013140	0.175	0.075086	0.009668	0.084754	⇒	ε_c=	2.861E-03	ε_s=	2.197E-02
			B63	226_1	0.012244	0.175	0.069966	0.009736	0.079702	⇒	ε_c=	2.536E-03	ε_s=	2.088E-02
			B76	226_1	0.012646	0.175	0.072263	0.009736	0.081999	⇒	ε_c=	2.624E-03	ε_s=	2.143E-02
			B87	145_1	0.009559	0.175	0.054623	0.009668	0.064291	⇒	ε_c=	2.102E-03	ε_s=	1.674E-02
		Axis C	B40	417_1	0.011177	0.175	0.063869	0.009725	0.073594	⇒	ε_c=	2.185E-03	ε_s=	1.938E-02
			B51	417_1	0.011473	0.175	0.065560	0.009725	0.075285	⇒	ε_c=	2.242E-03	ε_s=	1.982E-02
			B64	417_1	0.009361	0.175	0.053491	0.009725	0.063216	⇒	ε_c=	1.876E-03	ε_s=	1.665E-02
			B77	417_1	0.009250	0.175	0.052857	0.009725	0.062582	⇒	ε_c=	1.857E-03	ε_s=	1.648E-02
			B88	417_1	0.010031	0.175	0.057320	0.009725	0.067045	⇒	ε_c=	1.990E-03	ε_s=	1.766E-02

Storey	Direction	Axis	Beam	Section	θ_p	L_p	ϕ_p	ϕ_y	ϕ_t					
2nd storey	y-direction	Axis A	B134	134_1	0.007530	0.175	0.043029	0.009700	0.052729	⇒	ε_c=	1.729E-03	ε_s=	1.372E-02
			B145	145_1	0.014050	0.175	0.080286	0.009668	0.089954	⇒	ε_c=	3.067E-03	ε_s=	2.329E-02
			B171	238_1	0.017809	0.175	0.101766	0.009744	0.111510	⇒	ε_c=	3.830E-03	ε_s=	2.884E-02
			B182	145_1	0.006299	0.175	0.035994	0.009668	0.045662	⇒	ε_c=	1.503E-03	ε_s=	1.188E-02
		Axis B	B135	135_1	0.005201	0.175	0.029720	0.010250	0.039970	⇒	ε_c=	1.703E-03	ε_s=	1.000E-02
			B146	146_1	0.008138	0.175	0.046503	0.010240	0.056743	⇒	ε_c=	2.313E-03	ε_s=	1.431E-02
			B159	135_1	0.004492	0.175	0.025669	0.010250	0.035919	⇒	ε_c=	1.565E-03	ε_s=	8.956E-03
			B172	135_1	0.006509	0.175	0.037194	0.010250	0.047444	⇒	ε_c=	1.972E-03	ε_s=	1.192E-02
			B183	146_1	0.003016	0.175	0.017234	0.010240	0.027474	⇒	ε_c=	1.278E-03	ε_s=	6.769E-03
		Axis C	B136	136_1	0.007259	0.175	0.041480	0.009971	0.051451	⇒	ε_c=	1.908E-03	ε_s=	1.316E-02
			B147	136_1	0.007765	0.175	0.044371	0.009971	0.054342	⇒	ε_c=	2.006E-03	ε_s=	1.391E-02
			B160	136_1	0.002809	0.175	0.016051	0.009971	0.026022	⇒	ε_c=	1.106E-03	ε_s=	6.516E-03
			B173	136_1	0.002897	0.175	0.016554	0.009971	0.026525	⇒	ε_c=	1.120E-03	ε_s=	6.649E-03
			B184	136_1	0.005771	0.175	0.032977	0.009971	0.042948	⇒	ε_c=	1.620E-03	ε_s=	1.096E-02

Storey	Direction	Axis	Beam	Section	θ_p	L_p	ϕ_p	ϕ_y	ϕ_t					
3rd storey	y-direction	Axis A	B230	134_1	0.003502	0.175	0.020011	0.009700	0.029711	⇒	ε_c=	1.057E-03	ε_s=	7.649E-03
			B241	145_1	0.008971	0.175	0.051263	0.009668	0.060931	⇒	ε_c=	1.986E-03	ε_s=	1.587E-02
			B267	241_1	0.013307	0.175	0.076040	0.009699	0.085739	⇒	ε_c=	2.891E-03	ε_s=	2.223E-02
			B278	145_1	0.001922	0.175	0.010983	0.009668	0.020651	⇒	ε_c=	8.110E-04	ε_s=	5.240E-03
		Axis B	B231	231_1	0.003409	0.175	0.019480	0.009955	0.029435	⇒	ε_c=	1.194E-03	ε_s=	7.427E-03
			B242	242_1	0.005777	0.175	0.033011	0.009905	0.042916	⇒	ε_c=	1.660E-03	ε_s=	1.091E-02
			B255	231_1	0.002986	0.175	0.017063	0.009955	0.027018	⇒	ε_c=	1.125E-03	ε_s=	6.789E-03
			B268	231_1	0.003886	0.175	0.022206	0.009955	0.032161	⇒	ε_c=	1.273E-03	ε_s=	8.147E-03
			B279	242_1	0.001165	0.175	0.006657	0.009905	0.016562	⇒	ε_c=	8.204E-04	ε_s=	4.031E-03
		Axis C	B232	136_1	0.003266	0.175	0.018663	0.009971	0.028634	⇒	ε_c=	1.181E-03	ε_s=	7.206E-03
			B243	136_1	0.003552	0.175	0.020297	0.009971	0.030268	⇒	ε_c=	1.228E-03	ε_s=	7.638E-03
			B256	136_1										
			B269	136_1										
			B280	136_1	0.001570	0.175	0.008971	0.009971	0.018942	⇒	ε_c=	9.034E-04	ε_s=	4.645E-03

Table 2.8b. Plastic curvature demand at beams in y-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

RIGHT END

Storey	Direction	Axis	Beam	Section	θp	Lp	ϕp	ϕy	ϕt					
1st storey	y-direction	Axis A	B38	141_1	0.010112	0.175	0.057783	0.010270	0.068053	⇒	εc=	2.717E-03	εs=	1.722E-02
			B49	417_1	0.019393	0.175	0.110817	0.009733	0.120550	⇒	εc=	4.304E-03	εs=	3.099E-02
			B75	141_1	0.014053	0.175	0.080303	0.010270	0.090573	⇒	εc=	3.608E-03	εs=	2.292E-02
			B86	141_1	0.011735	0.175	0.067057	0.010270	0.077327	⇒	εc=	3.079E-03	εs=	1.957E-02
		Axis B	B39	145_1	0.009994	0.175	0.057109	0.010490	0.067599	⇒	εc=	2.807E-03	εs=	1.693E-02
			B50	226_1	0.010550	0.175	0.060286	0.010070	0.070356	⇒	εc=	2.627E-03	εs=	1.798E-02
			B63	226_1	0.012139	0.175	0.069366	0.010070	0.079436	⇒	εc=	2.974E-03	εs=	2.029E-02
			B76	145_1	0.011780	0.175	0.067314	0.010490	0.077804	⇒	εc=	3.216E-03	εs=	1.950E-02
			B87	241_1	0.012123	0.175	0.069274	0.010210	0.079484	⇒	εc=	3.067E-03	εs=	2.015E-02
		Axis C	B40	417_1	0.011381	0.175	0.065034	0.009733	0.074767	⇒	εc=	2.236E-03	εs=	1.967E-02
			B51	417_1	0.009321	0.175	0.053263	0.009733	0.062996	⇒	εc=	1.873E-03	εs=	1.658E-02
			B64	417_1	0.010201	0.175	0.058291	0.009733	0.068024	⇒	εc=	2.027E-03	εs=	1.790E-02
			B77	417_1	0.012975	0.175	0.074143	0.009733	0.083876	⇒	εc=	2.559E-03	εs=	2.201E-02
			B88	417_1	0.013027	0.175	0.074440	0.009733	0.084173	⇒	εc=	2.570E-03	εs=	2.209E-02
					θp	Lp	ϕp	ϕy	ϕt					
2nd storey	y-direction	Axis A	B134	145_1	0.007526	0.175	0.043006	0.010490	0.053496	⇒	εc=	2.261E-03	εs=	1.336E-02
			B145	238_1	0.018579	0.175	0.106166	0.010020	0.116186	⇒	εc=	4.597E-03	εs=	2.953E-02
			B171	145_1	0.011166	0.175	0.063806	0.010490	0.074296	⇒	εc=	3.075E-03	εs=	1.862E-02
			B182	134_1	0.007105	0.175	0.040600	0.010650	0.051250	⇒	εc=	2.322E-03	εs=	1.265E-02
		Axis B	B135	146_1	0.006456	0.175	0.036891	0.010830	0.047721	⇒	εc=	2.282E-03	εs=	1.165E-02
			B146	135_1	0.005468	0.175	0.031246	0.010260	0.041506	⇒	εc=	1.758E-03	εs=	1.040E-02
			B159	135_1	0.006738	0.175	0.038503	0.010260	0.048763	⇒	εc=	2.019E-03	εs=	1.226E-02
			B172	146_1	0.007865	0.175	0.044943	0.010830	0.055773	⇒	εc=	2.607E-03	εs=	1.368E-02
			B183	135_1	0.009811	0.175	0.056063	0.010260	0.066323	⇒	εc=	2.676E-03	εs=	1.675E-02
		Axis C	B136	136_1	0.007457	0.175	0.042611	0.009980	0.052591	⇒	εc=	1.946E-03	εs=	1.346E-02
			B147	136_1	0.003012	0.175	0.017211	0.009980	0.027191	⇒	εc=	1.139E-03	εs=	6.825E-03
			B160	136_1	0.003794	0.175	0.021680	0.009980	0.031660	⇒	εc=	1.267E-03	εs=	8.006E-03
			B173	136_1	0.008775	0.175	0.050143	0.009980	0.060123	⇒	εc=	2.214E-03	εs=	1.540E-02
			B184	136_1	0.008849	0.175	0.050566	0.009980	0.060546	⇒	εc=	2.229E-03	εs=	1.551E-02
					θp	Lp	ϕp	ϕy	ϕt					
3rd storey	y-direction	Axis A	B230	145_1	0.003058	0.175	0.017474	0.010490	0.027964	⇒	εc=	1.362E-03	εs=	6.802E-03
			B241	241_1	0.013733	0.175	0.078474	0.010210	0.088684	⇒	εc=	3.434E-03	εs=	2.247E-02
			B267	145_1	0.005554	0.175	0.031737	0.010490	0.042227	⇒	εc=	1.850E-03	εs=	1.048E-02
			B278	134_1	0.002935	0.175	0.016771	0.010650	0.027421	⇒	εc=	1.430E-03	εs=	6.577E-03
		Axis B	B231	242_1	0.002506	0.175	0.014320	0.010840	0.025160	⇒	εc=	1.392E-03	εs=	5.910E-03
			B242	231_1	0.003303	0.175	0.018874	0.010230	0.029104	⇒	εc=	1.327E-03	εs=	7.197E-03
			B255	231_1	0.002634	0.175	0.015051	0.010230	0.025281	⇒	εc=	1.206E-03	εs=	6.199E-03
			B268	242_1	0.003745	0.175	0.021400	0.010840	0.032240	⇒	εc=	1.660E-03	εs=	7.696E-03
			B279	231_1	0.005294	0.175	0.030251	0.010230	0.040481	⇒	εc=	1.699E-03	εs=	1.016E-02
		Axis C	B232	136_1	0.003241	0.175	0.018520	0.009980	0.028500	⇒	εc=	1.176E-03	εs=	7.171E-03
			B243	136_1	0.000191	0.175	0.001091	0.009980	0.011071	⇒	εc=	6.601E-04	εs=	2.581E-03
			B256	136_1	0.000401	0.175	0.002291	0.009980	0.012271	⇒	εc=	6.973E-04	εs=	2.897E-03
			B269	136_1	0.004151	0.175	0.023720	0.009980	0.033700	⇒	εc=	1.325E-03	εs=	8.545E-03
			B280	136_1	0.004904	0.175	0.028023	0.009980	0.038003	⇒	εc=	1.451E-03	εs=	9.678E-03

Table 2.8c. Plastic curvature demand at beams in y-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

LEFT END

Storey	Direction	Axis	Beam	Section	θp	Lp	ϕp	ϕy	ϕt					
4th storey	y-direction	Axis A	B326	141_1										
			B337	241_1	0.003111	0.175	0.017777	0.009699	0.027476	⇒	εc=	9.905E-04	εs=	7.059E-03
			B363	238_1	0.007063	0.175	0.040360	0.009744	0.050104	⇒	εc=	1.570E-03	εs=	1.311E-02
			B374	241_1										
		Axis B	B327	327_1										
			B338	338_1	0.000772	0.175	0.004411	0.009938	0.014349	⇒	εc=	7.520E-04	εs=	3.452E-03
			B351	327_1										
			B364	327_1										
			B375	338_1										
		Axis C	B328	417_1	0.000344	0.175	0.001966	0.009725	0.011691	⇒	εc=	5.920E-04	εs=	2.833E-03
			B339	417_1	0.000384	0.175	0.002194	0.009725	0.011919	⇒	εc=	5.984E-04	εs=	2.893E-03
			B352	33_1										
			B365	33_1										
			B376	417_1										

Storey	Direction	Axis	Beam	Section	θp	Lp	ϕp	ϕy	ϕt					
5th storey	y-direction	Axis A	B422	226_1										
			B433	433_1										
			B459	322_1	0.001537	0.175	0.008783	0.009726	0.018509	⇒	εc=	7.566E-04	εs=	4.666E-03
			B470	433_1										
		Axis B	B423	322_1										
			B434	226_1										
			B447	322_1										
			B460	322_1										
			B471	226_1										
		Axis C	B424	417_1										
			B435	417_1										
			B448	417_1										
			B461	417_1										
			B472	417_1										

Storey	Direction	Axis	Beam	Section	θp	Lp	ϕp	ϕy	ϕt					
6th storey	y-direction	Axis A	B518	417_1										
			B529	417_1										
			B555	417_1										
			B566	417_1										
		Axis B	B519	417_1										
			B530	417_1										
			B543	417_1										
			B556	417_1										
			B567	417_1										
		Axis C	B520	417_1										
			B531	417_1										
			B544	417_1										
			B557	417_1										
			B568	417_1										

Table 2.8d. Plastic curvature demand at beams in y-direction

PLASTIC CURVATURE DEMAND AT BEAMS & STRAIN VALUES

RIGHT END

Storey	Direction	Axis	Beam	Section	θp	Lp	φp	φy	φt					
4^{th} storey	y-direction	Axis A	B326	241_1										
			B337	238_1	0.008778	0.175	0.050160	0.010020	0.060180	⇒	εc=	2.163E-03	εs=	1.551E-02
			B363	241_1	0.001356	0.175	0.007749	0.010210	0.017959	⇒	εc=	9.400E-04	εs=	4.303E-03
			B374	141_1										
		Axis B	B327	338_1										
			B338	327_1	0.000516	0.175	0.002949	0.010200	0.013149	⇒	εc=	7.740E-04	εs=	3.043E-03
			B351	327_1										
			B364	338_1	0.000632	0.175	0.003611	0.010370	0.013981	⇒	εc=	8.760E-04	εs=	3.219E-03
			B375	327_1	0.000397	0.175	0.002269	0.010200	0.012469	⇒	εc=	7.526E-04	εs=	2.867E-03
		Axis C	B328	417_1	0.000496	0.175	0.002834	0.009733	0.012567	⇒	εc=	6.155E-04	εs=	3.064E-03
			B339	33_1										
			B352	33_1										
			B365	417_1	0.001043	0.175	0.005960	0.009733	0.015693	⇒	εc=	6.934E-04	εs=	3.902E-03
			B376	417_1	0.001562	0.175	0.008926	0.009733	0.018659	⇒	εc=	7.622E-04	εs=	4.704E-03
					θp	Lp	φp	φy	φt					
5^{th} storey	y-direction	Axis A	B422	433_1										
			B433	322_1	0.004443	0.175	0.025389	0.009892	0.035281	⇒	εc=	1.286E-03	εs=	9.052E-03
			B459	433_1										
			B470	226_1										
		Axis B	B423	226_1										
			B434	322_1										
			B447	322_1										
			B460	226_1										
			B471	322_1										
		Axis C	B424	417_1										
			B435	417_1										
			B448	417_1										
			B461	417_1										
			B472	417_1										
					θp	Lp	φp	φy	φt					
6^{th} storey	y-direction	Axis A	B518	417_1										
			B529	417_1	0.001865	0.175	0.010657	0.009733	0.020390	⇒	εc=	8.010E-04	εs=	5.172E-03
			B555	417_1										
			B566	417_1										
		Axis B	B519	417_1										
			B530	417_1										
			B543	417_1										
			B556	417_1										
			B567	417_1										
		Axis C	B520	417_1										
			B531	417_1										
			B544	417_1										
			B557	417_1										
			B568	417_1										

Table 2.9a. Plastic curvature demand at columns

THE PLASTIC CURVATURE DEMAND AT COLUMNS

Storey	Dir.	Axis	BOTTOM	θp	Lp	φp	φy	φt	P	TOP	θp	Lp	φp	φy	φt	P
1st storey	x-dir.	Axis 1	C1	0.008040	0.20	0.040200	0.011950	0.052150	-512.919	C1						
			C2	0.008528	0.20	0.042640	0.012280	0.054920	-827.512	C2						
			C3	0.010118	0.20	0.050590	0.010930	0.061520	-294.792	C3						
			C4	0.007379	0.20	0.036895	0.011000	0.047895	-1119.016	C4						
			C5	0.008034	0.20	0.040170	0.010600	0.050770	-1203.758	C5						
			C6	0.007029	0.20	0.035145	0.011630	0.046775	-998.545	C6						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
1st storey	y-dir.	Axis 1	C1	0.009366	0.20	0.046830	0.011510	0.058340	-427.962	C1						
			C2	0.009376	0.20	0.046880	0.012480	0.059360	-614.439	C2						
			C3	0.009380	0.20	0.046900	0.011300	0.058200	-379.336	C3						
			C4	0.009410	0.20	0.047050	0.011300	0.058350	-369.098	C4						
			C5	0.009363	0.20	0.046815	0.012490	0.059305	-611.302	C5						
			C6	0.009329	0.20	0.046645	0.011460	0.058105	-423.830	C6						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
2nd storey	x-dir.	Axis 1	C99	0.00154	0.20	0.007700	0.010790	0.018490	-267.784	C99						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
3rd storey	x-dir.	Axis 1	C195	0.000295	0.20	0.001475	0.010780	0.012255	-257.751	C195	0.00079	0.20	0.003970	0.010710	0.014680	-247.151
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
4th storey	x-dir.	Axis 1	C291							C291	0.00115	0.20	0.005770	0.010640	0.016410	-239.033
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
1st storey	x-dir.	Axis 2	C7	0.007866	0.20	0.039330	0.012490	0.051820	-738.343	C7						
			C8	0.009163	0.25	0.036652	0.009761	0.046413	-1198.025	C8						
			C9	0.011341	0.20	0.056705	0.009591	0.066296	47.276	C9						
			C10	0.007054	0.20	0.035270	0.008832	0.044102	-1561.603	C10						
			C11	0.008789	0.25	0.035156	0.008951	0.044107	-1586.701	C11						
			C12	0.007129	0.20	0.035645	0.010650	0.046295	-1199.489	C12						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
1st storey	y-dir.	Axis 2	C7	0.010043	0.20	0.050215	0.012690	0.062905	-706.424	C7						
			C8	0.010616	0.25	0.042464	0.009524	0.051988	-1024.595	C8						
			C9	0.009574	0.20	0.047870	0.012460	0.060330	-603.589	C9						
			C10	0.009597	0.20	0.047985	0.012380	0.060365	-593.493	C10						
			C11	0.010601	0.25	0.042404	0.009509	0.051913	-1020.548	C11						
			C12	0.010005	0.20	0.050025	0.012620	0.062645	-702.248	C12						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
2nd storey	x-dir.	Axis 2	C105	0.00234	0.20	0.011700	0.009749	0.021449	-18.704	C105						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
3rd storey	x-dir.	Axis 2	C201							C201	0.00016	0.20	0.000800	0.010060	0.010860	-111.083
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
1st storey	x-dir.	Axis 3	C13	0.008497	0.20	0.042485	0.012670	0.055155	-641.825	C13						
			C15	0.007651	0.20	0.038255	0.011490	0.049745	-1019.189	C15						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
1st storey	y-dir.	Axis 3	C13	0.010558	0.20	0.052790	0.012310	0.065100	-580.169	C13						
			C15	0.010549	0.20	0.052745	0.012270	0.065015	-574.966	C15						
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
2nd storey	y-dir.	Axis 3	C109	0.001465	0.20	0.007325	0.012010	0.019335	-526.494	C109	0.00305	0.20	0.015260	0.011970	0.027230	-515.895
			C111	0.001465	0.20	0.007325	0.012020	0.019345	-524.700	C111	0.00308	0.20	0.015395	0.011970	0.027365	-514.101
				θp	Lp	φp	φy	φt	P		θp	Lp	φp	φy	φt	P
3rd storey	y-dir.	Axis 3	C205	0.002894	0.20	0.014470	0.011850	0.026320	-496.617	C205	0.00117	0.20	0.005860	0.011800	0.017660	-486.017
			C207	0.002934	0.20	0.014670	0.011850	0.026520	-496.463	C207	0.00118	0.20	0.005915	0.011800	0.017715	-485.863

Table 2.9b. Plastic curvature demand at columns

THE PLASTIC CURVATURE DEMAND AT COLUMNS

Storey	Dir.	BOTTOM		θp	Lp	φp	φy	φt	P	TOP	θp	Lp	φp	φy	φt	P
1st storey	x-dir.	Axis 4	C18	0.008483	0.20	0.042415	0.012650	0.055065	-642.126	C18						
			C20	0.007634	0.20	0.038170	0.011490	0.049660	-1021.390	C20						
	y-dir.	Axis 4	C18	0.009096	0.20	0.045480	0.011030	0.056510	-1119.431	C18						
			C20	0.009084	0.20	0.045420	0.011100	0.056520	-1112.836	C20						
3rd storey	y-dir.	Axis 4	C210	0.000883	0.20	0.004415	0.012660	0.017075	-642.368	C210	0.00029	0.20	0.001450	0.012610	0.014060	-631.768
			C212	0.000918	0.20	0.004590	0.012650	0.017240	-641.776	C212	0.00029	0.20	0.001460	0.012600	0.014060	-631.176
1st storey	x-dir.	Axis 5	C21	0.007818	0.20	0.039090	0.012520	0.051610	-736.614	C21						
			C22	0.009111	0.25	0.036444	0.009808	0.046252	-1198.226	C22						
			C23	0.011293	0.20	0.056465	0.009610	0.066075	48.017	C23						
			C24	0.007003	0.20	0.035015	0.008843	0.043858	-1560.333	C24						
			C25	0.008735	0.25	0.034940	0.008929	0.043869	-1589.251	C25						
			C26	0.007067	0.20	0.035335	0.010580	0.045915	-1206.672	C26						
	y-dir.	Axis 5	C21	0.009016	0.20	0.045080	0.010160	0.055240	-1284.897	C21						
			C22	0.009757	0.25	0.039028	0.008508	0.047536	-1751.343	C22						
			C23	0.008664	0.20	0.043320	0.011410	0.054730	-1041.526	C23						
			C24	0.008677	0.20	0.043385	0.011450	0.054835	-1031.246	C24						
			C25	0.009738	0.25	0.038952	0.008502	0.047454	-1747.540	C25						
			C26	0.008971	0.20	0.044855	0.010200	0.055055	-1281.085	C26						
2nd storey	x-dir.	Axis 5	C119	0.002353	0.20	0.011765	0.009808	0.021573	-18.869	C119						
3rd storey	x-dir.	Axis 5	C215							C215	0.00016	0.20	0.000795	0.010060	0.010855	-111.314
1st storey	x-dir.	Axis 6	C27	0.007921	0.20	0.039605	0.011960	0.051565	-512.460	C27						
			C28	0.008407	0.20	0.042035	0.012260	0.054295	-828.131	C28						
			C29	0.009995	0.20	0.049975	0.010950	0.060925	-295.441	C29						
			C30	0.007255	0.20	0.036275	0.011000	0.047275	-1120.914	C30						
			C31	0.007911	0.20	0.039555	0.010580	0.050135	-1206.066	C31						
			C32	0.006904	0.20	0.034520	0.011600	0.046120	-1001.266	C32						
	y-dir.	Axis 6	C27	0.008168	0.20	0.040840	0.011040	0.051880	-1125.911	C27						
			C28	0.008448	0.20	0.042240	0.009630	0.051870	-1408.251	C28						
			C29	0.007688	0.20	0.038440	0.011500	0.049940	-1025.151	C29						
			C30	0.007700	0.20	0.038500	0.011490	0.049990	-1015.732	C30						
			C31	0.008430	0.20	0.042150	0.009601	0.051751	-1405.614	C31						
			C32	0.008125	0.20	0.040625	0.011000	0.051625	-1122.297	C32						
2nd storey	x-dir.	Axis 6	C125	0.001541	0.20	0.007705	0.010820	0.018525	-267.530	C125						
3rd storey	x-dir.	Axis 6	C221	0.000295	0.20	0.001475	0.010830	0.012305	-257.372	C221	0.00079	0.20	0.003930	0.010740	0.014670	-246.772
4th storey	x-dir.	Axis 6	C317							C317	0.00115	0.20	0.005765	0.010640	0.016405	-238.605

Table 2.10. Plastic curvature demand at shear walls

PLASTIC CURVATURE DEMAND AT SHEAR WALLS									
				θp	Lp	ϕp	ϕy	ϕt	P
1st storey	**POEX**	Axis 3	W14	0.012852	1.00	0.012852	0.002202	0.015054	-1329.078
	POEX	Axis 5	W19	0.012839	1.00	0.012839	0.002201	0.015040	-1334.438
	POEY	Axis 3	W14	0.003869	0.125	0.030952	0.016630	0.047582	-736.786
	POEY	Axis 5	W19	0.002500	0.125	0.020000	0.018180	0.038180	-1618.913
2nd storey	**POEX**	Axis 3	W110	0.001794	1.00	0.001794	0.002185	0.003979	-1135.156
	POEX	Axis 5	W115	0.001794	1.00	0.001794	0.002185	0.003979	-1134.724
4th storey	**POEX**	Axis 3	W302	0.002611	1.00	0.002611	0.002162	0.004773	-717.441
	POEX	Axis 5	W307	0.002610	1.00	0.002610	0.002160	0.004770	-716.693
5th storey	**POEX**	Axis 3	W398	0.002759	1.00	0.002759	0.002153	0.004912	-488.129
	POEX	Axis 5	W403	0.002758	1.00	0.002758	0.002153	0.004911	-487.644
6th storey	**POEX**	Axis 3	W494	0.000906	1.00	0.000906	0.002146	0.003052	-247.897
	POEX	Axis 5	W499	0.000906	1.00	0.000906	0.002146	0.003052	-247.669
1st storey	**POEX**	Axis F	W17	0.001603	0.125	0.012824	0.018460	0.031284	-1821.228
	POEY	Axis A	W16	0.013869	1.00	0.013869	0.002260	0.016129	-1283.069
	POEY	Axis F	W17	0.013817	1.00	0.013817	0.002259	0.016076	-1276.174
2nd storey	**POEY**	Axis A	W112	0.001155	1.00	0.001155	0.002243	0.003398	-1080.640
	POEY	Axis F	W113	0.001155	1.00	0.001155	0.002241	0.003396	-1078.540
3rd storey	**POEY**	Axis A	W208	0.001207	1.00	0.001207	0.002228	0.003435	-872.588
	POEY	Axis F	W209	0.001108	1.00	0.001108	0.002227	0.003335	-871.363
4th storey	**POEY**	Axis A	W304	0.002322	1.00	0.002322	0.002213	0.004535	-657.142
	POEY	Axis F	W305	0.002331	1.00	0.002331	0.002214	0.004545	-656.457
5th storey	**POEY**	Axis A	W400	0.001889	1.00	0.001889	0.002202	0.004091	-437.757
	POEY	Axis F	W401	0.001900	1.00	0.001900	0.002202	0.004102	-437.292
6th storey	**POEY**	Axis A	W496	0.000697	1.00	0.000697	0.002196	0.002893	-206.056
	POEY	Axis F	W497	0.000699	1.00	0.000699	0.002196	0.002895	-205.809

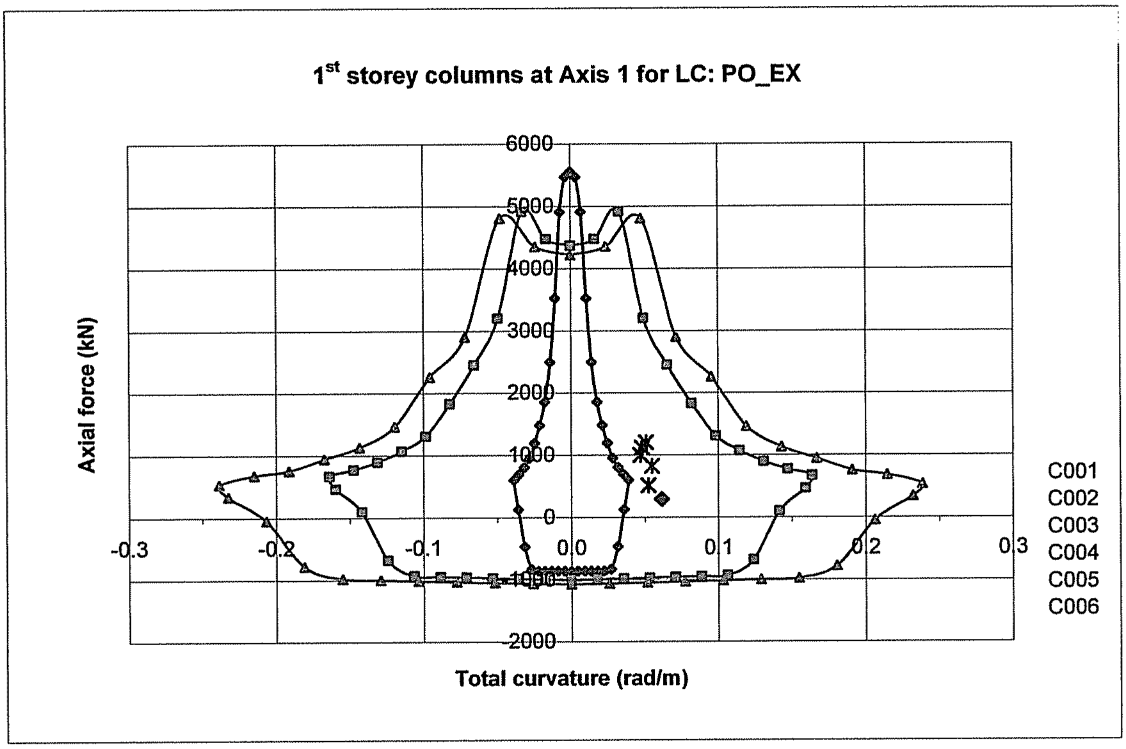


Figure 2.11a. Axial force-total curvature diagram for columns of the 1st storey at Axis 1 for LC: PO_EX

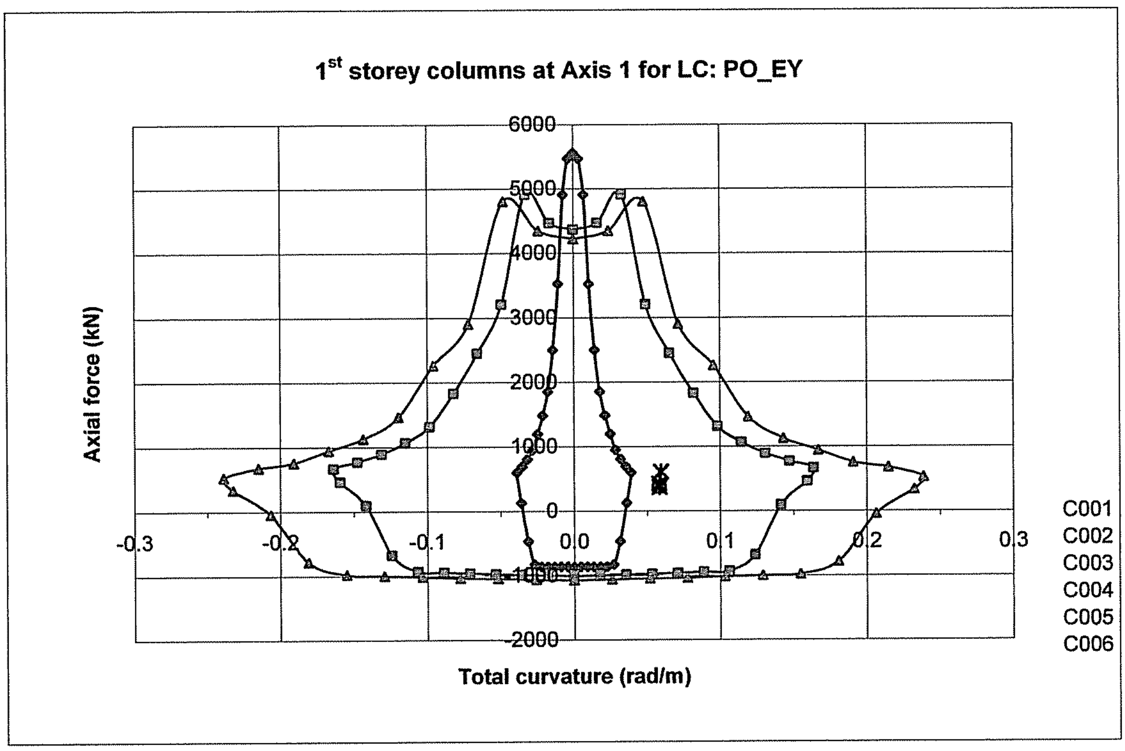


Figure 2.11b. Axial force-total curvature diagram for columns of the 1st storey at Axis 1 for LC: PO_EY

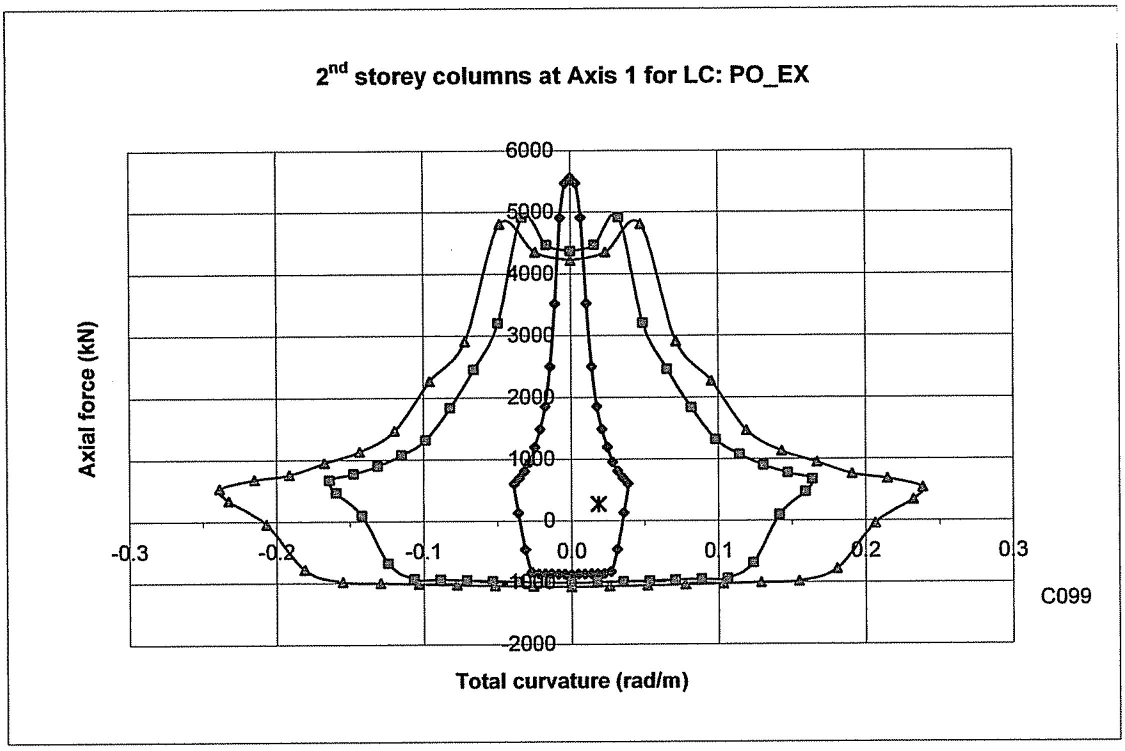


Figure 2.11c. Axial force-total curvature diagram for columns of the 2nd storey at Axis 1 for LC:PO_EX

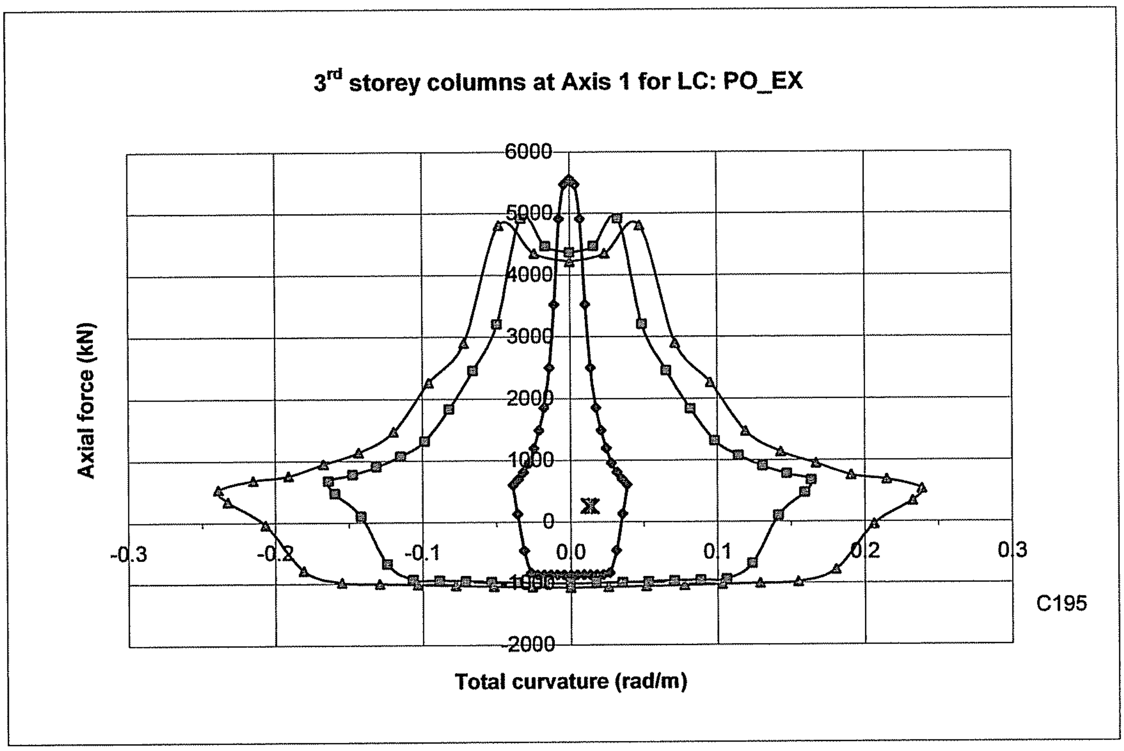


Figure 2.11d. Axial force-total curvature diagram for columns of the 3rd storey at Axis 1 for LC:PO_EX

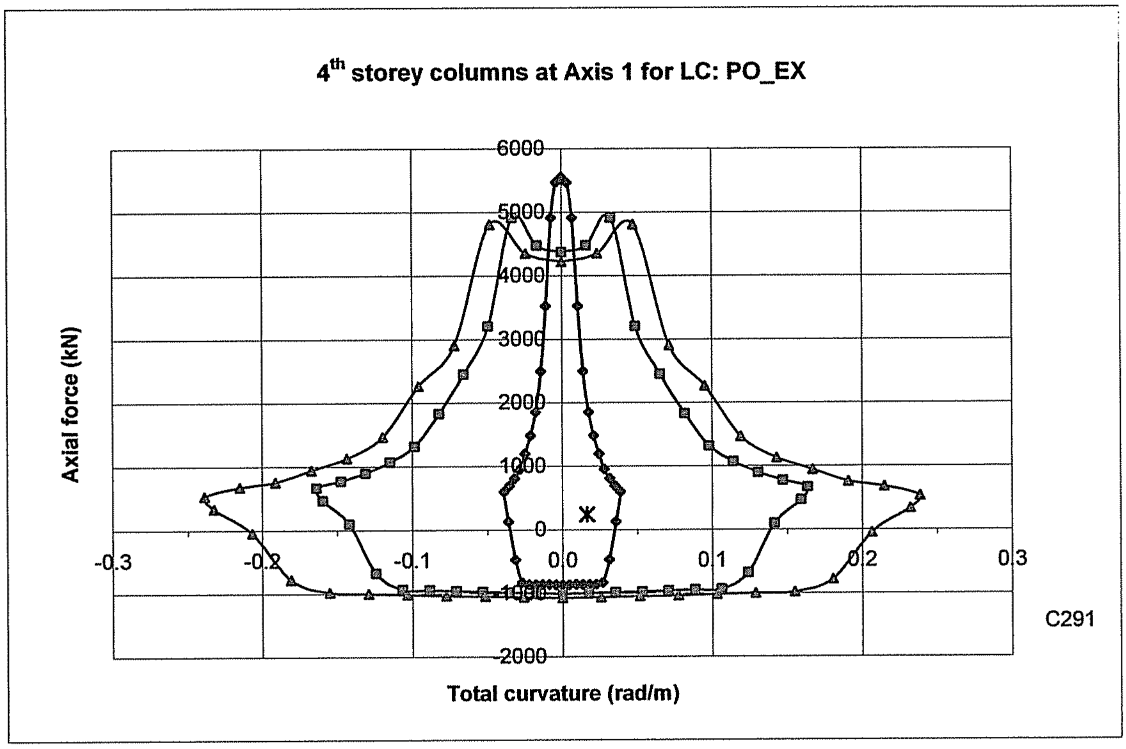


Figure 2.11e. Axial force-total curvature diagram for columns of the 4th storey at Axis 1 for LC:PO_EX

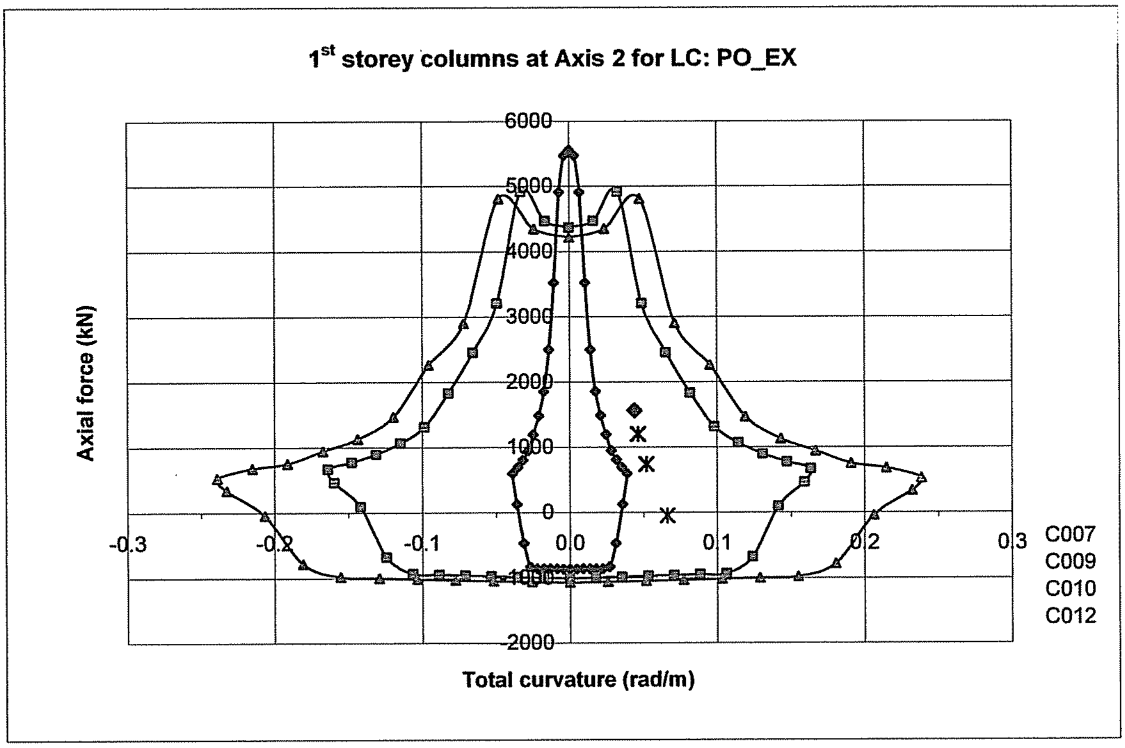


Figure 2.12a. Axial force-total curvature diagram for columns of the 1st storey at Axis 2 for LC:PO_EX

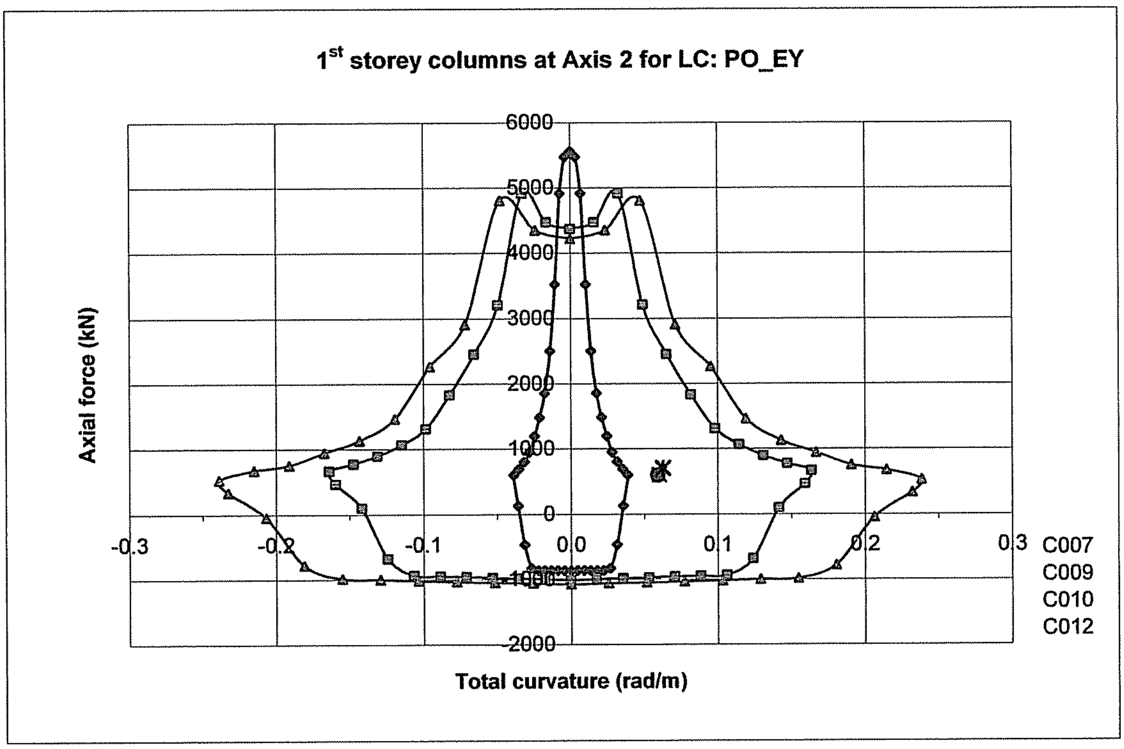


Figure 2.12b. Axial force-total curvature diagram for columns of the 1st storey at Axis 2 for LC:PO_EY

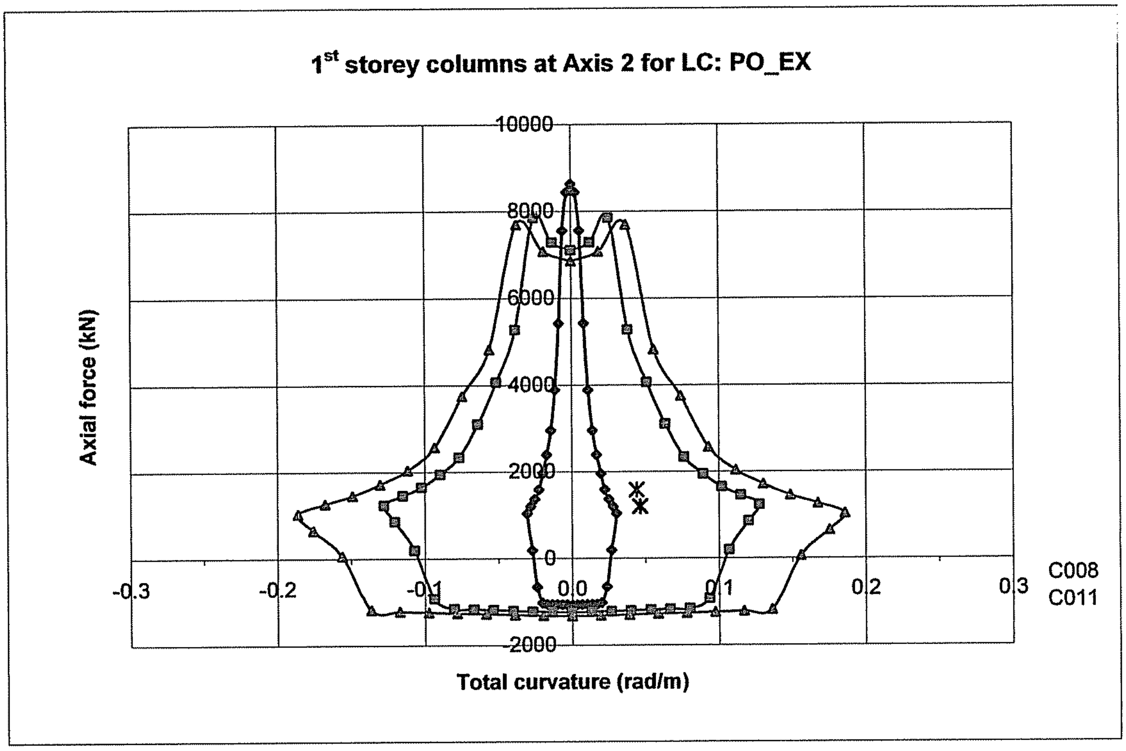


Figure 2.12c. Axial force-total curvature diagram for columns of the 1st storey at Axis 2 for LC:PO_EX

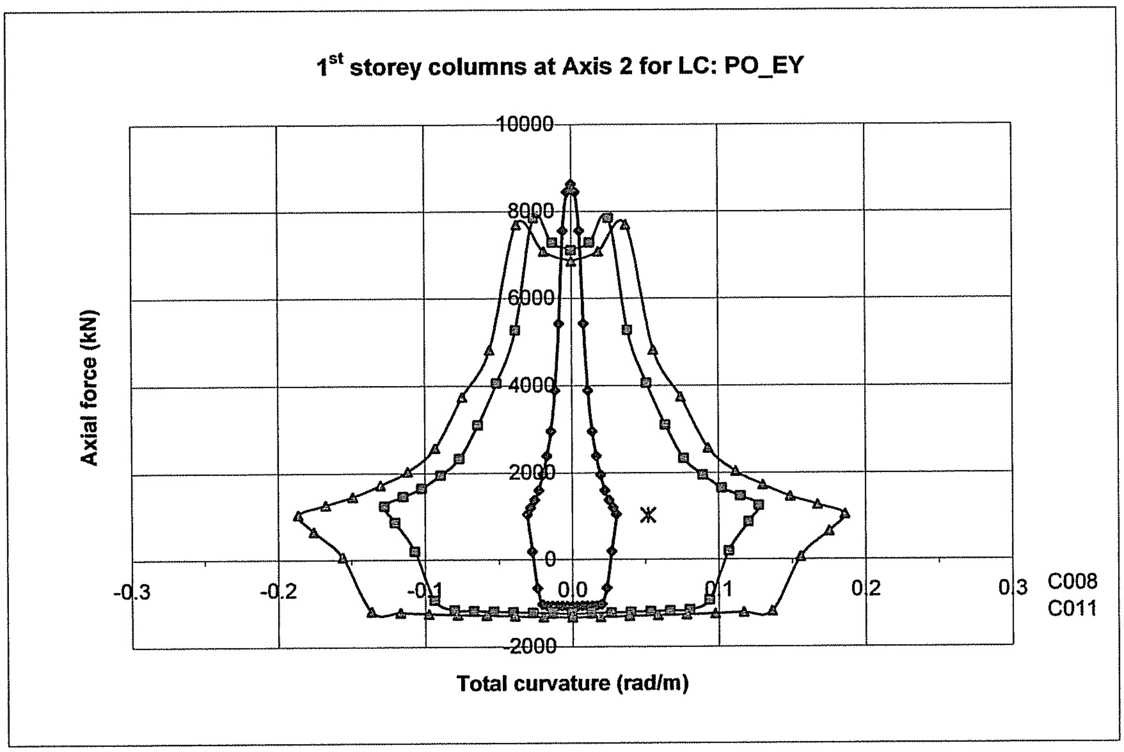


Figure 2.12d. Axial force-total curvature diagram for columns of the 1st storey at Axis 2 for LC:PO_EY

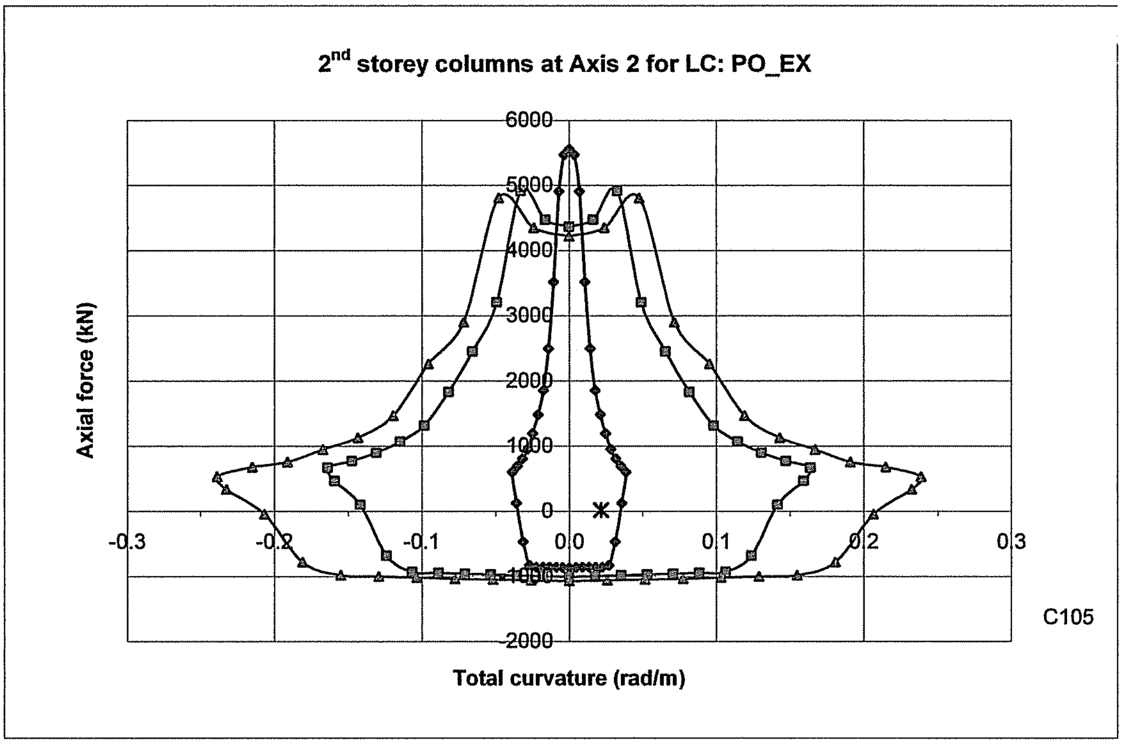


Figure 2.12e. Axial force-total curvature diagram for columns of the 2nd storey at Axis 2 for LC:PO_EX

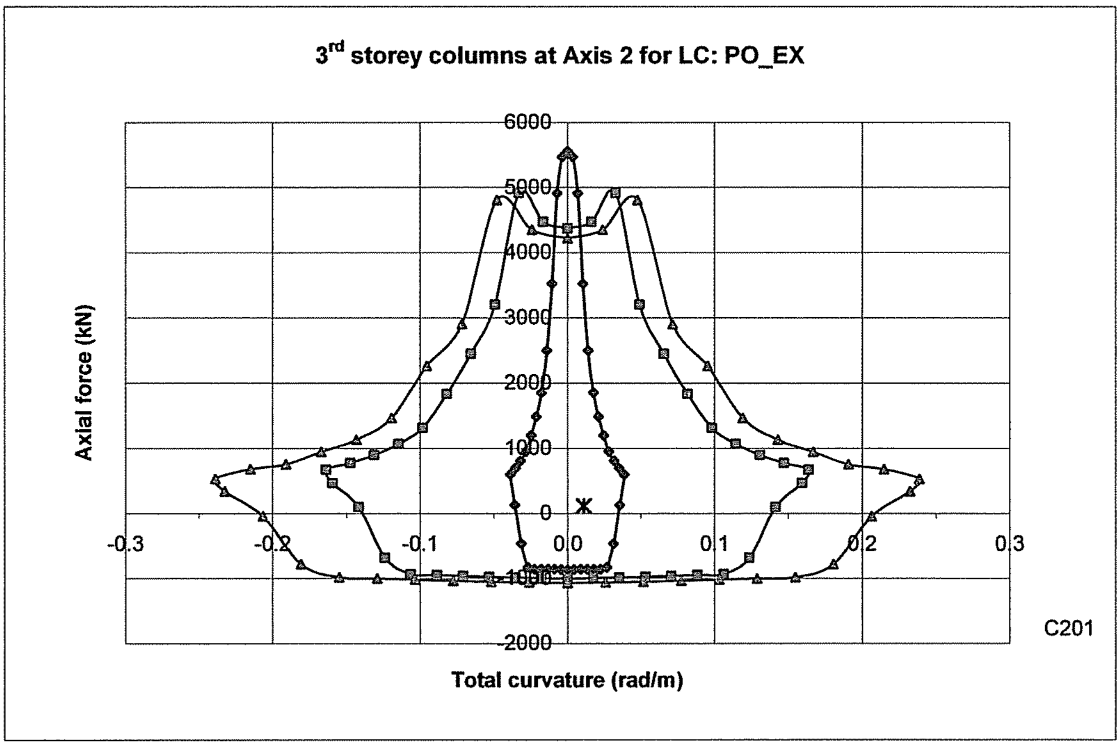


Figure 2.12f. Axial force-total curvature diagram for columns of the 3rd storey at Axis 2 for LC:PO_EX

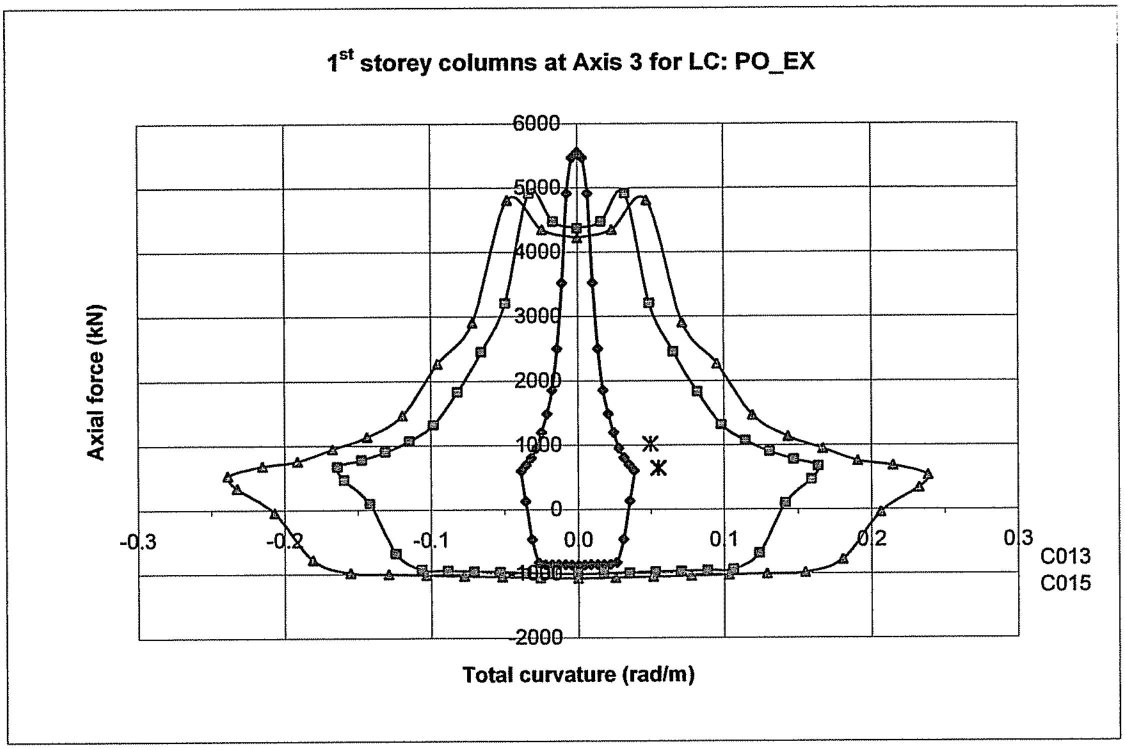


Figure 2.13a. Axial force-total curvature diagram for columns of the 1st storey at Axis 3 for LC:PO_EX

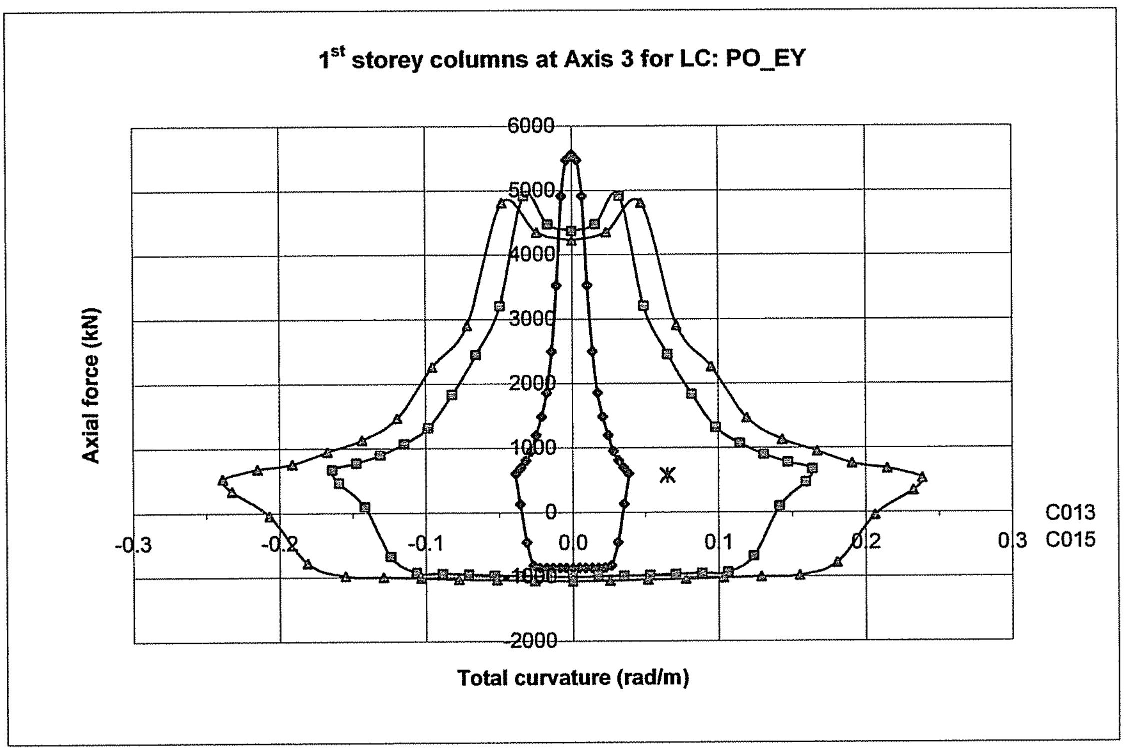


Figure 2.13b. Axial force-total curvature diagram for columns of the 1st storey at Axis 3 for LC:PO_EY

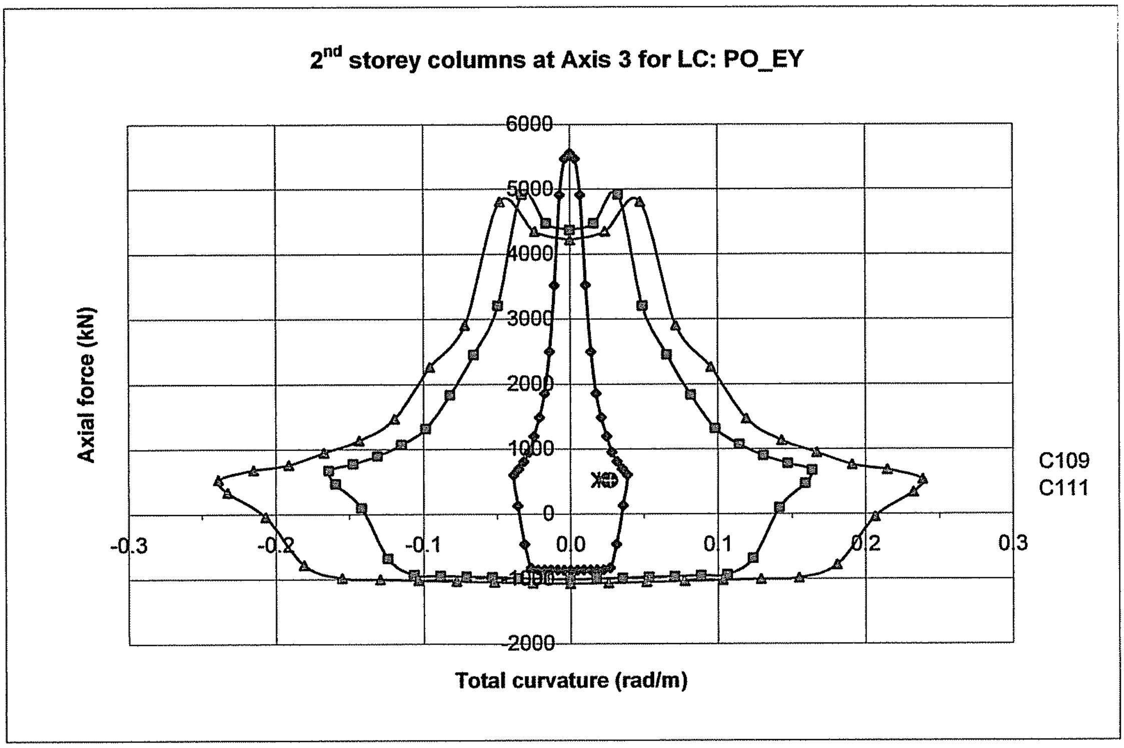


Figure 2.13c. Axial force-total curvature diagram for columns of the 2nd storey at Axis 3 for LC:PO_EY

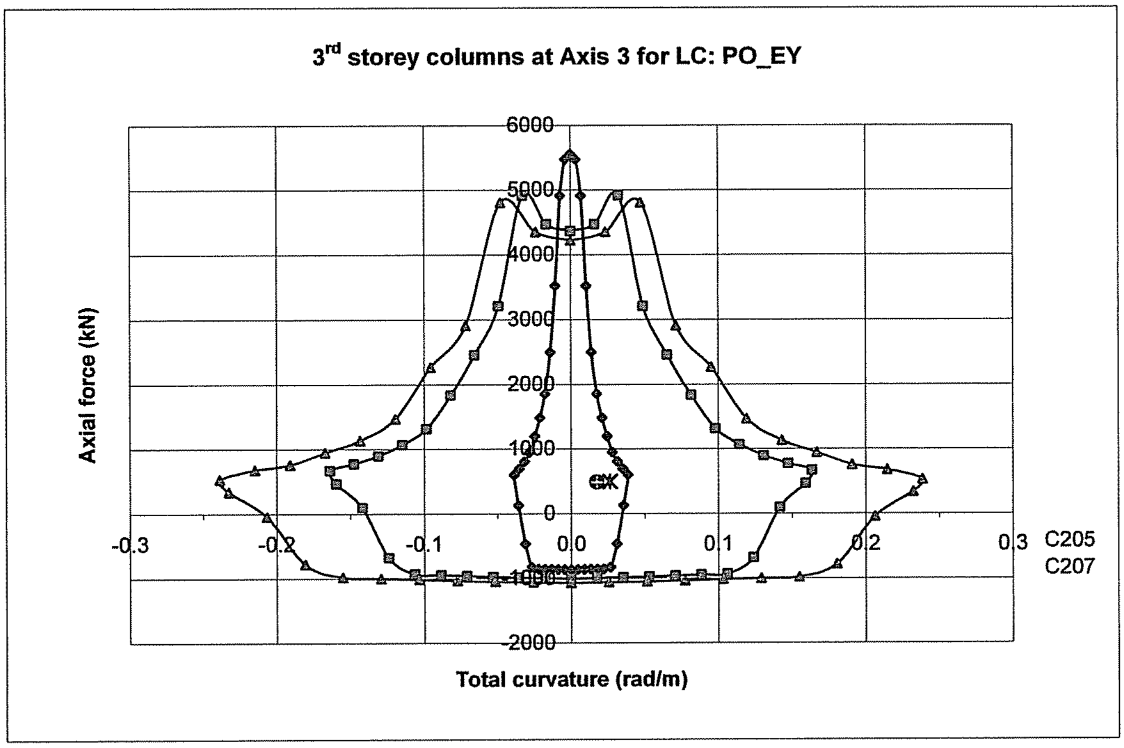


Figure 2.13d. Axial force-total curvature diagram for columns of the 3rd storey at Axis 3 for LC:PO_EY

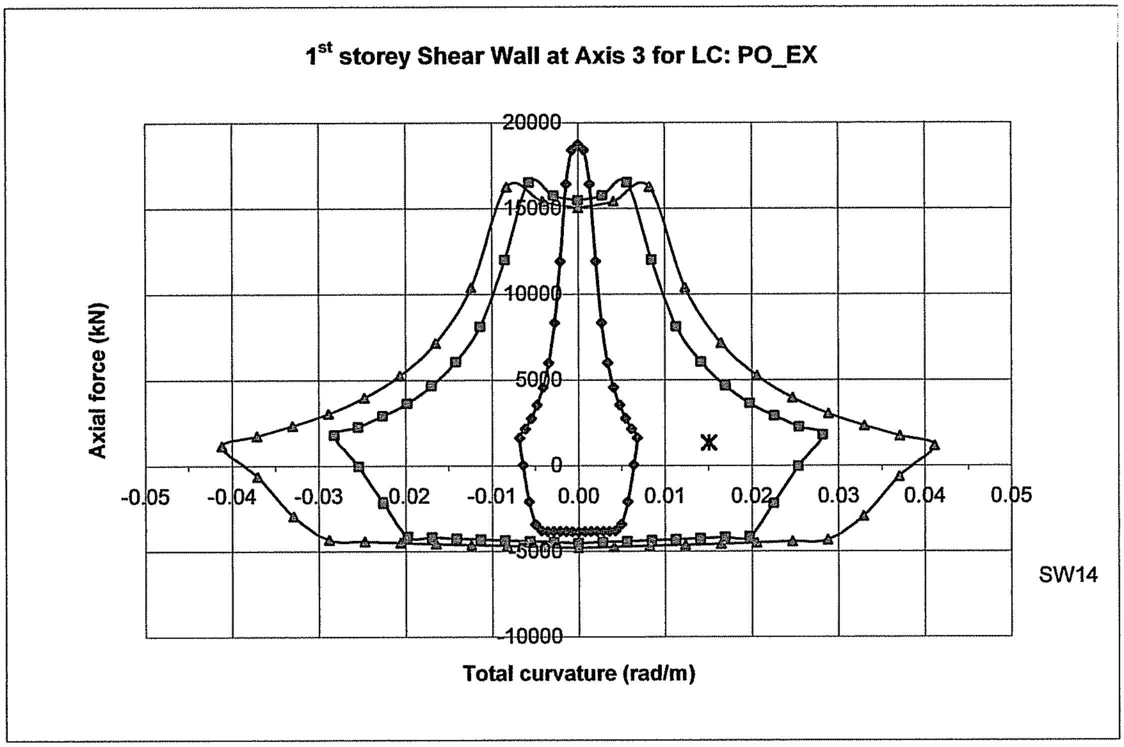


Figure 2.14a. Axial force-total curvature diagram for shear wall of the 1st storey at Axis 3 for LC:PO_EX

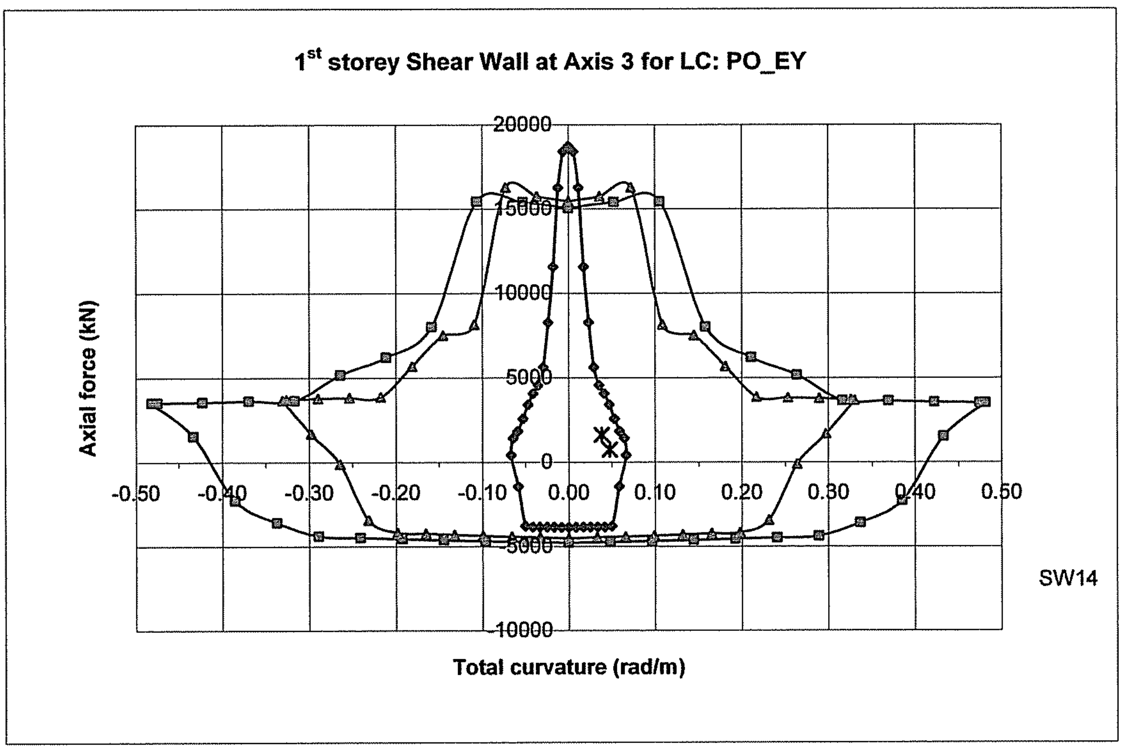


Figure 2.14b. Axial force-total curvature diagram for shear wall of the 1st storey at Axis 3 for LC:PO_EY

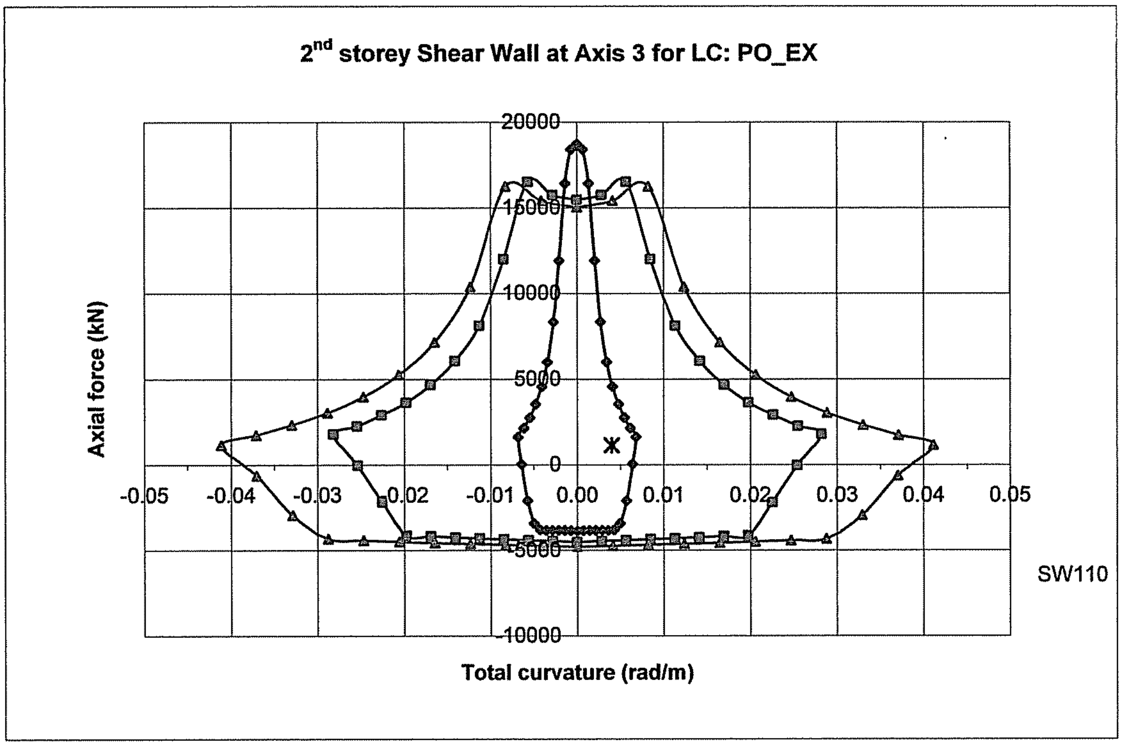


Figure 2.14c. Axial force-total curvature diagram for shear wall of the 2nd storey at Axis 3 for LC:PO_EX

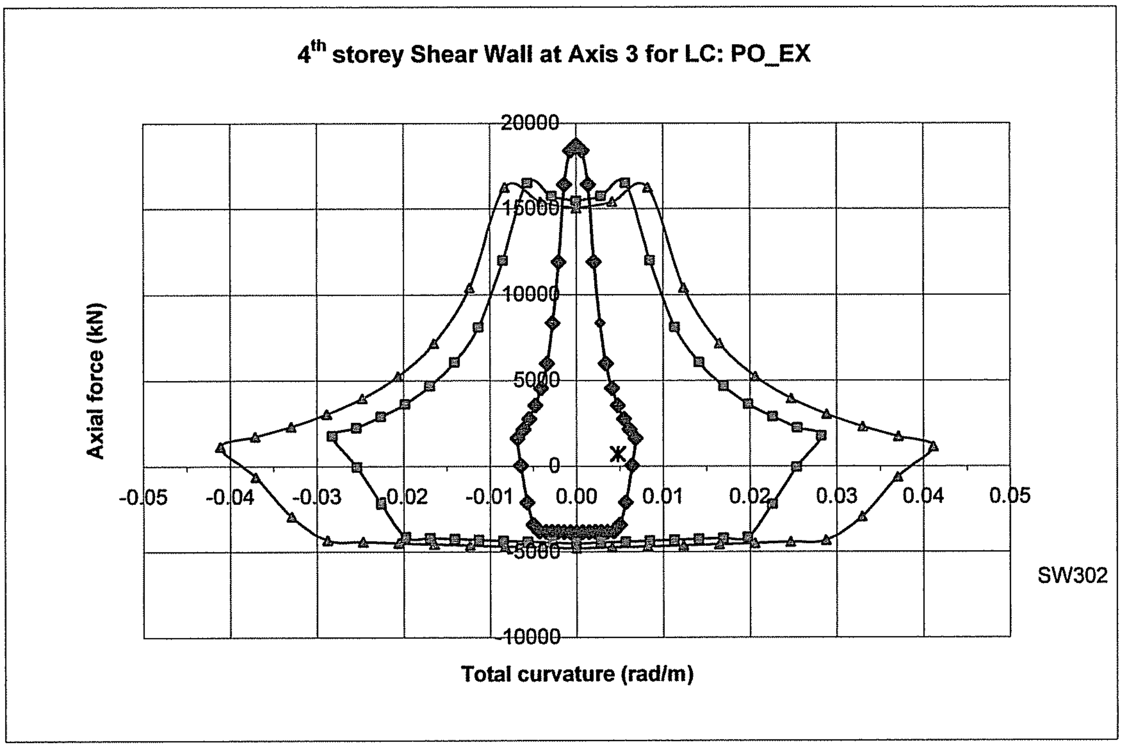


Figure 2.14d. Axial force-total curvature diagram for shear wall of the 4th storey at Axis 3 for LC:PO_EX

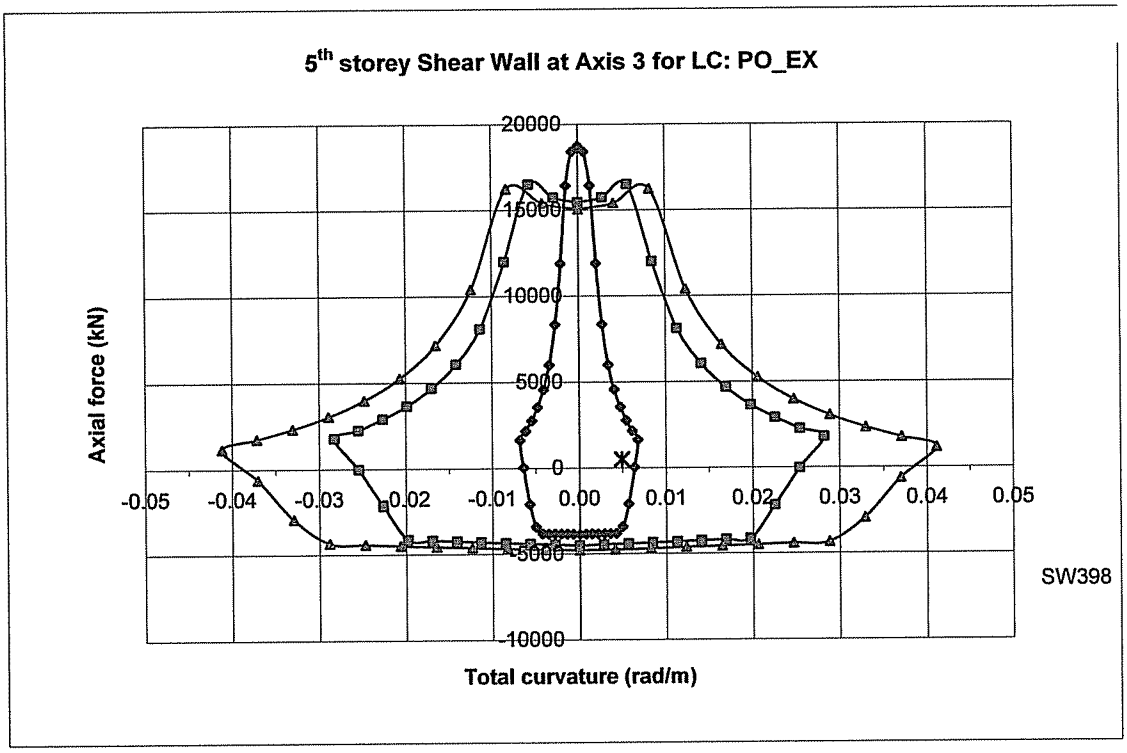


Figure 2.14e. Axial force-total curvature diagram for shear wall of the 5th storey at Axis 3 for LC:PO_EX

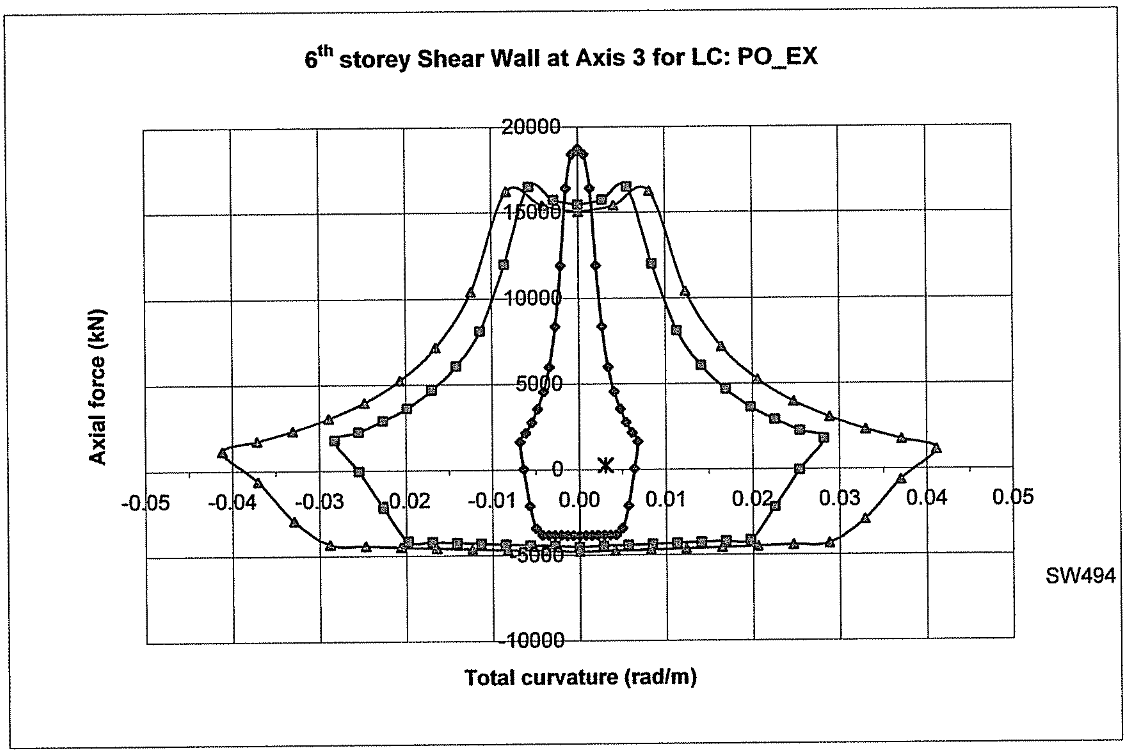


Figure 2.14f. Axial force-total curvature diagram for shear wall of the 6th storey at Axis 3 for LC:PO_EX

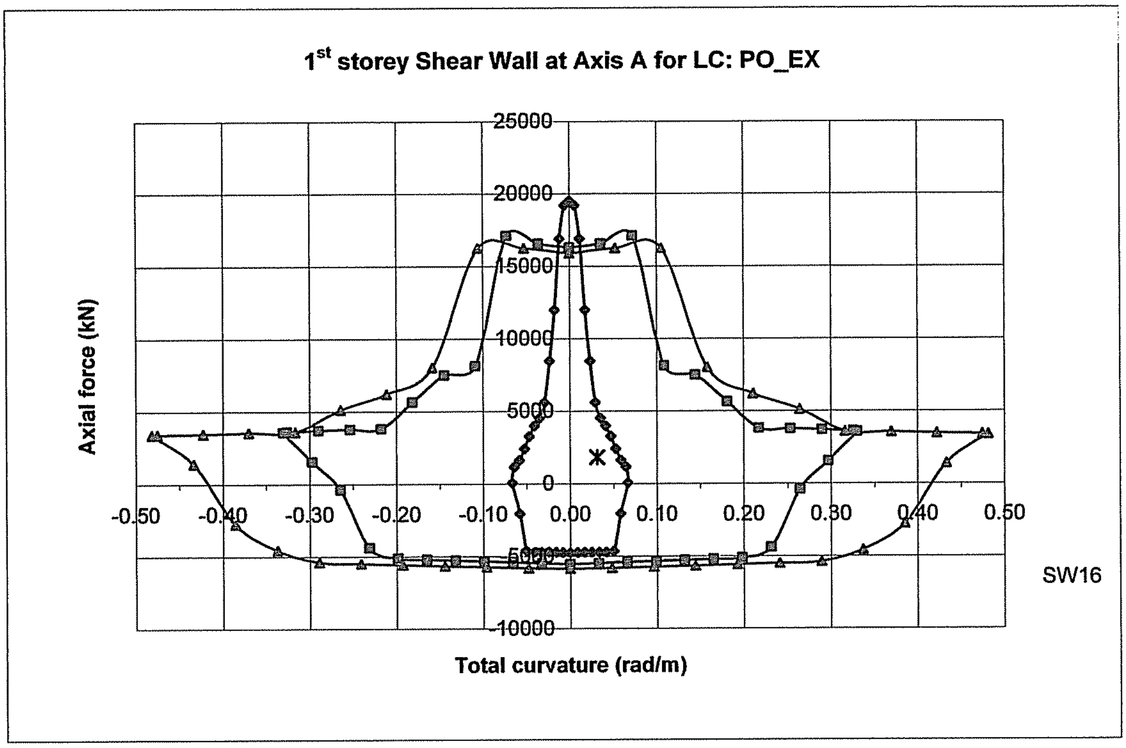


Figure 2.15a. Axial force-total curvature diagram for shear wall of the 1st storey at Axis A for LC:PO_EX

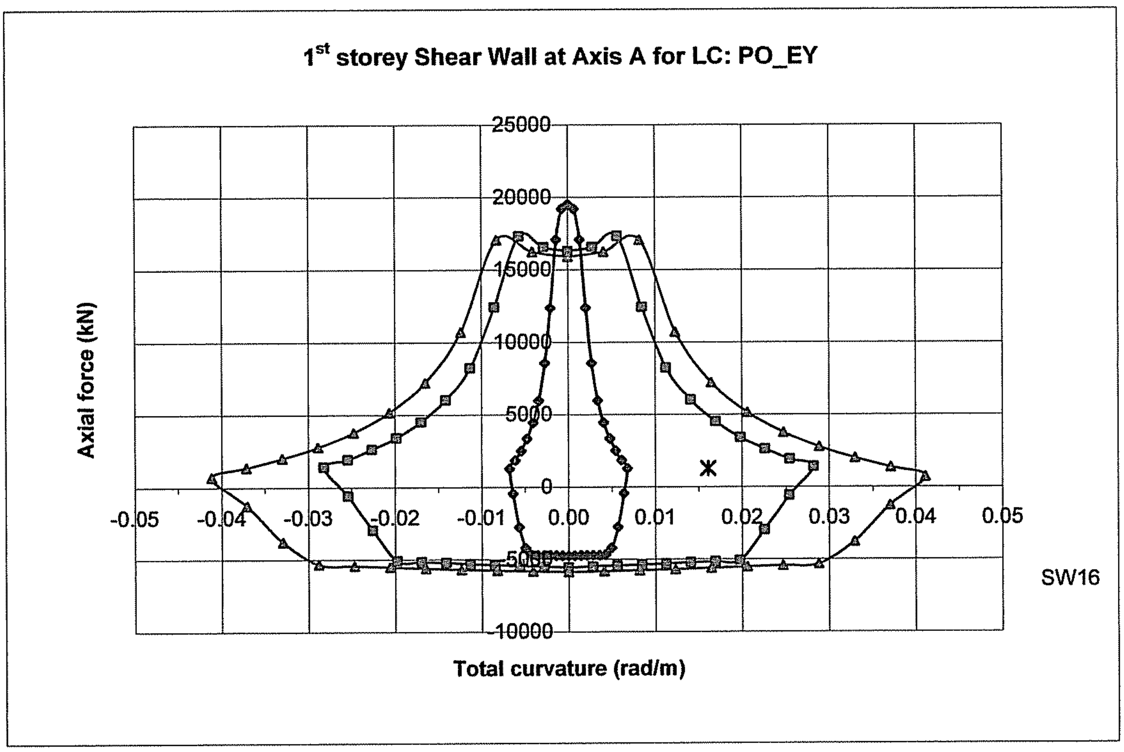


Figure 2.15b. Axial force-total curvature diagram for shear wall of the 1st storey at Axis A for LC:PO_EY

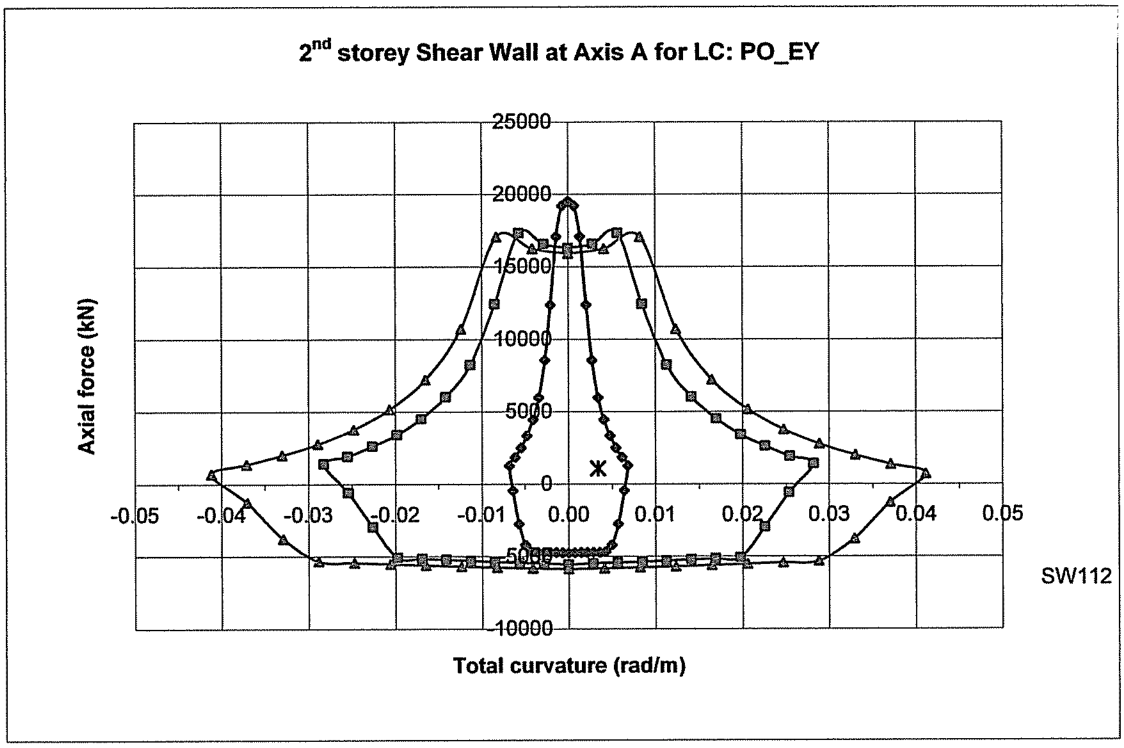


Figure 2.15c. Axial force-total curvature diagram for shear wall of the 2nd storey at Axis A for LC:PO_EY

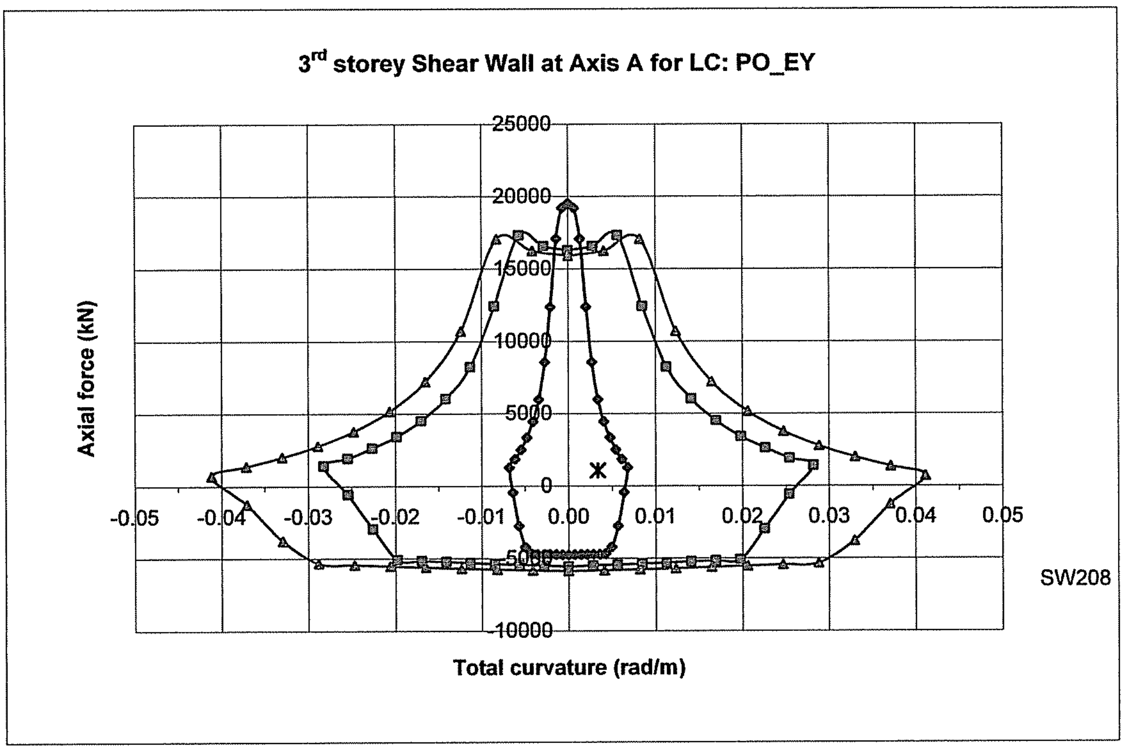


Figure 2.15d. Axial force-total curvature diagram for shear wall of the 3rd storey at Axis A for LC:PO_EY

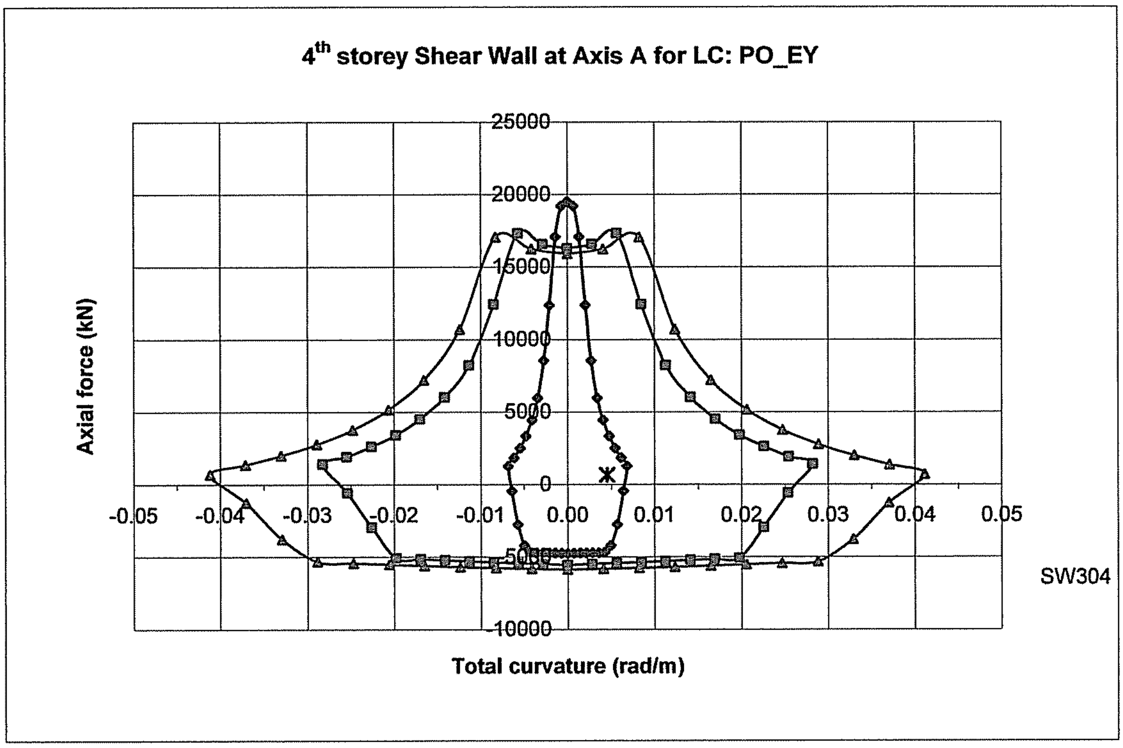


Figure 2.15e. Axial force-total curvature diagram for shear wall of the 4th storey at Axis A for LC:PO_EY

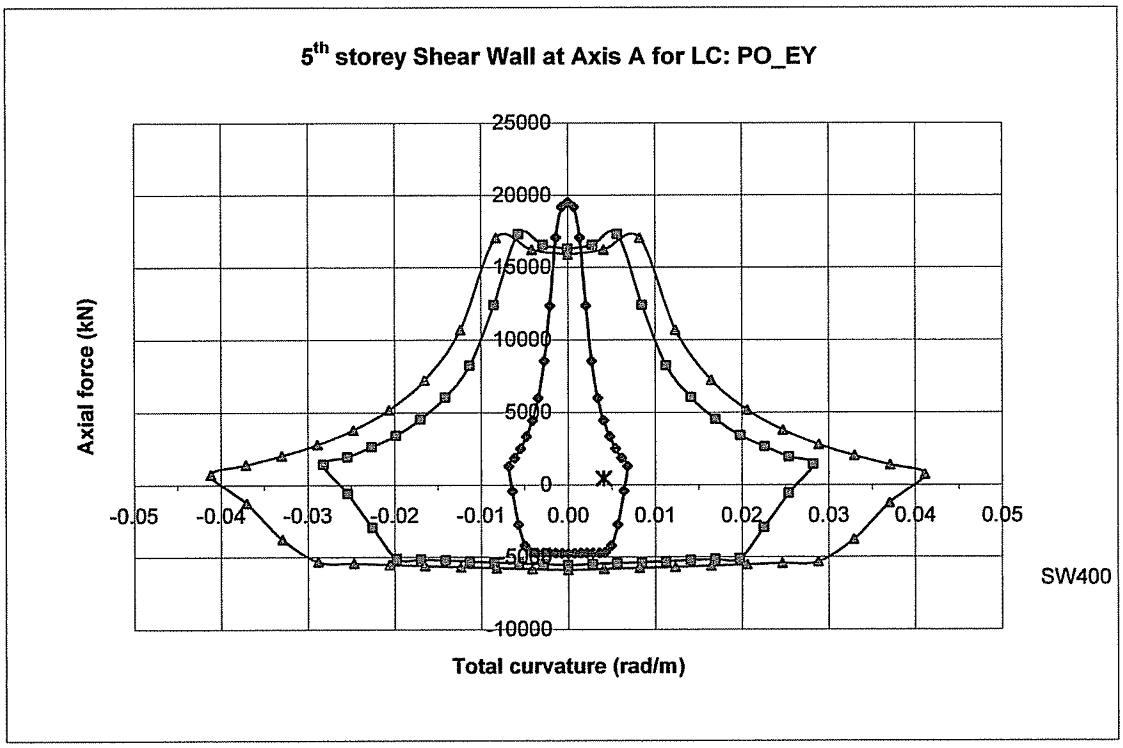


Figure 2.15f. Axial force-total curvature diagram for shear wall of the 5th storey at Axis A for LC:PO_EY

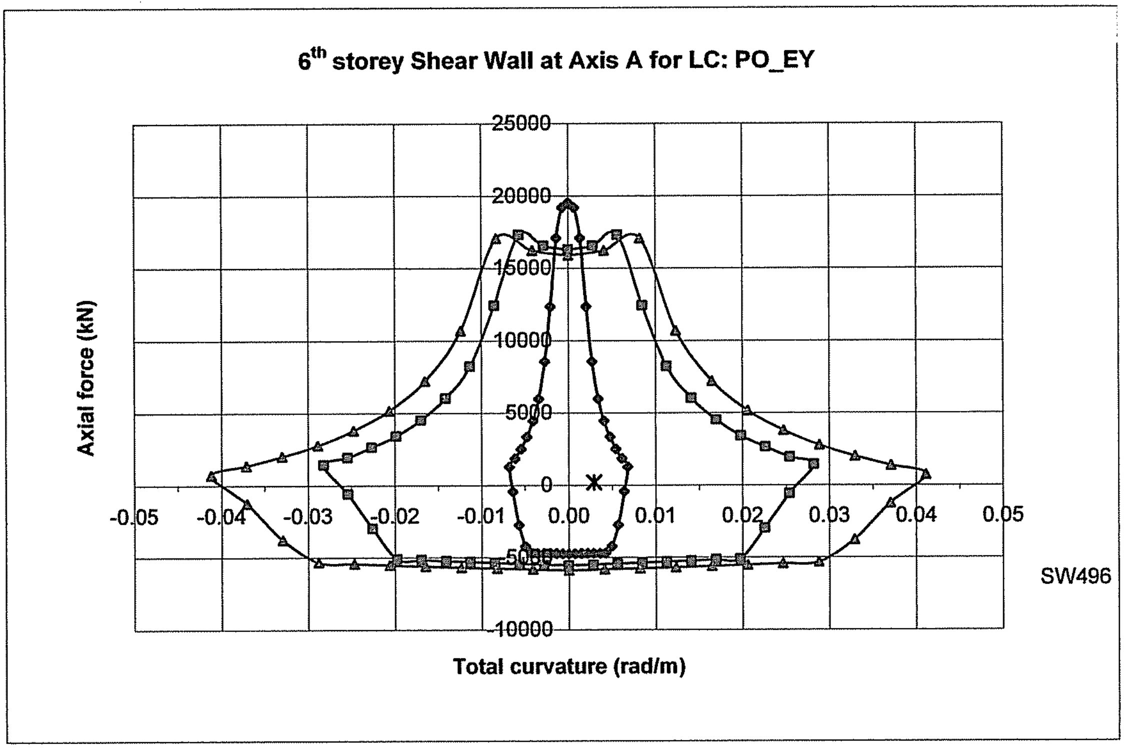


Figure 2.15g. Axial force-total curvature diagram for shear wall of the 6th storey at Axis A for LC:PO_EY

2.3.3. Checking the Shear Strength Capacity at Beams

In calculating the shear strength capacity at beams, contribution of concrete and transverse reinforcement to shear strength is determined in accordance with TS-500.

Contribution of concrete :

Beam dimension at each storey is 750 / 350 mm.

$$f_{ctm} = 0.35 * \sqrt{f_{cm}} \tag{2.7}$$

$$V_c = 0.8 * 0.65 * f_{ctm} * b_w * d \tag{2.8}$$

$$V_c = 0.8 * 0.65 * 0.35 * \sqrt{25} * 750 * 320 = 218400 \text{ N}$$
$$= 218.4 \text{ kN}$$

Contribution of transverse reinforcement :

Transverse reinforcement at beams 4ϕ10 / 75 mm

$$V_s = A_s f_{ys} (d / s) \tag{2.9}$$

$$V_s = 4 * 78.54 * 420 * (320 / 75) = 562975 \text{ N}$$
$$= 563.0 \text{ kN}$$

$$V_r = V_c + V_s = 218.4 + 563.0 = 781.4 \text{ kN}$$

Shear force demand for each beam at each storey is shown in Table 2.11a, 2.11b. As shown in tables, the shear force demand calculated by the pushover analysis satisfies the condition given below.

$$V < Vr$$

Table 2.11a. Shear force demand of beams in x-direction obtained from the Pushover Analysis

		Beam Nr	Load Case	V2 (kN)		Vr (kN)		Beam Nr	Load Case	V2 (kN)		Vr (kN)		Beam Nr	Load Case	V2 (kN)		Vr (kN)
1st storey	Axis 1	33	PO_EX	88.298	<	781.4	Axis 2	44	PO_EX	76.996	<	781.4	Axis 3	55	PO_EX	67.786	<	781.4
		34	PO_EX	136.458	<	781.4		45	PO_EX	130.121	<	781.4		56	PO_EX	84.129	<	781.4
		35	PO_EX	200.938	<	781.4		46	PO_EX	219.362	<	781.4		59	PO_EX	85.571	<	781.4
		36	PO_EX	136.458	<	781.4		47	PO_EX	137.481	<	781.4		60	PO_EX	67.374	<	781.4
		37	PO_EX	88.420	<	781.4		48	PO_EX	69.311	<	781.4						
2nd storey	Axis 1	129	PO_EX	97.296	<	781.4	Axis 2	140	PO_EX	81.978	<	781.4	Axis 3	151	PO_EX	67.798	<	781.4
		130	PO_EX	150.482	<	781.4		141	PO_EX	136.3	<	781.4		152	PO_EX	83.91	<	781.4
		131	PO_EX	232.906	<	781.4		142	PO_EX	233.275	<	781.4		155	PO_EX	85.571	<	781.4
		132	PO_EX	150.341	<	781.4		143	PO_EX	144.542	<	781.4		156	PO_EX	67.302	<	781.4
		133	PO_EX	88.225	<	781.4		144	PO_EX	69.224	<	781.4						
3rd storey	Axis 1	225	PO_EX	96.293	<	781.4	Axis 2	236	PO_EX	81.852	<	781.4	Axis 3	247	PO_EX	67.65	<	781.4
		226	PO_EX	152.031	<	781.4		237	PO_EX	133.535	<	781.4		248	PO_EX	83.956	<	781.4
		227	PO_EX	236.472	<	781.4		238	PO_EX	226.897	<	781.4		251	PO_EX	85.299	<	781.4
		228	PO_EX	148.85	<	781.4		239	PO_EX	144.531	<	781.4		252	PO_EX	67.391	<	781.4
		229	PO_EX	88.317	<	781.4		240	PO_EX	69.018	<	781.4						
4th storey	Axis 1	321	PO_EX	89.371	<	781.4	Axis 2	332	PO_EX	75.685	<	781.4	Axis 3	343	PO_EX	64.519	<	781.4
		322	PO_EX	148.96	<	781.4		333	PO_EX	129.706	<	781.4		344	PO_EX	83.937	<	781.4
		323	PO_EX	220.852	<	781.4		334	PO_EX	219.525	<	781.4		347	PO_EX	85.209	<	781.4
		324	PO_EX	138.211	<	781.4		335	PO_EX	137.421	<	781.4		348	PO_EX	63.542	<	781.4
		325	PO_EX	80.679	<	781.4		336	PO_EX	67.903	<	781.4						
5th storey	Axis 1	417	PO_EX	68.204	<	781.4	Axis 2	428	PO_EX	52.86	<	781.4	Axis 3	439	PO_EX	45.476	<	781.4
		418	PO_EX	122.202	<	781.4		429	PO_EX	115.485	<	781.4		440	PO_EX	82.68	<	781.4
		419	PO_EX	110.409	<	781.4		430	PO_EX	95.681	<	781.4		443	PO_EX	82.407	<	781.4
		420	PO_EX	115.706	<	781.4		431	PO_EX	115.014	<	781.4		444	PO_EX	44.194	<	781.4
		421	PO_EX	67.188	<	781.4		432	PO_EX	49.04	<	781.4						
6th storey	Axis 1	513	PO_EX	33.307	<	781.4	Axis 2	524	PO_EX	37.02	<	781.4	Axis 3	535	PO_EX	31.333	<	781.4
		514	PO_EX	82.361	<	781.4		525	PO_EX	89.424	<	781.4		536	PO_EY	70.021	<	781.4
		515	PO_EX	27.001	<	781.4		526	PO_EX	-47.745	<	781.4		539	PO_EX	51.79	<	781.4
		516	PO_EX	74.832	<	781.4		527	PO_EX	90.013	<	781.4		540	PO_EY	30.844	<	781.4
		517	PO_EX	32.369	<	781.4		528	PO_EX	32.076	<	781.4						

Table 2.11b. Shear force demand of beams in y-direction obtained from the Pushover Analysis

		Beam Nr	Load Case	V2 (kN)		Vr (kN)		Beam Nr	Load Case	V2 (kN)		Vr (kN)		Beam Nr	Load Case	V2 (kN)		Vr (kN)
1st storey	Axis A	38	PO_EY	158.744	<	781.4	Axis B	39	PO_EY	147.425	<	781.4	Axis C	40	PO_EY	75.386	<	781.4
		49	PO_EY	144.661	<	781.4		50	PO_EY	185.015	<	781.4		51	PO_EY	131.615	<	781.4
		75	PO_EY	176.873	<	781.4		63	PO_EY	240.125	<	781.4		64	PO_EY	176.148	<	781.4
		86	PO_EY	158.730	<	781.4		76	PO_EY	203.044	<	781.4		77	PO_EY	133.135	<	781.4
								87	PO_EY	139.428	<	781.4		88	PO_EY	75.635	<	781.4
2nd storey	Axis A	134	PO_EY	162.244	<	781.4	Axis B	135	PO_EY	175.999	<	781.4	Axis C	136	PO_EY	91.467	<	781.4
		145	PO_EY	157.483	<	781.4		146	PO_EY	229.564	<	781.4		147	PO_EY	159.59	<	781.4
		171	PO_EY	182.587	<	781.4		159	PO_EY	309.702	<	781.4		160	PO_EY	218.296	<	781.4
		182	PO_EY	166.691	<	781.4		172	PO_EY	253.734	<	781.4		173	PO_EY	161.055	<	781.4
								183	PO_EY	161.651	<	781.4		184	PO_EY	91.682	<	781.4
3rd storey	Axis A	230	PO_EY	162.262	<	781.4	Axis B	231	PO_EY	163.602	<	781.4	Axis C	232	PO_EY	91.841	<	781.4
		241	PO_EY	165.09	<	781.4		242	PO_EY	209.219	<	781.4		243	PO_EY	159.749	<	781.4
		267	PO_EY	182.46	<	781.4		255	PO_EY	280.087	<	781.4		256	PO_EY	215.36	<	781.4
		278	PO_EY	166.757	<	781.4		268	PO_EY	231.616	<	781.4		269	PO_EY	155.071	<	781.4
								279	PO_EY	150.885	<	781.4		280	PO_EY	91.813	<	781.4
4th storey	Axis A	326	PO_EY	147.681	<	781.4	Axis B	327	PO_EY	143.138	<	781.4	Axis C	328	PO_EY	75.285	<	781.4
		337	PO_EY	157.219	<	781.4		338	PO_EY	201.906	<	781.4		339	PO_EY	126.228	<	781.4
		363	PO_EY	171.578	<	781.4		351	PO_EY	219.827	<	781.4		352	PO_EY	130.563	<	781.4
		374	PO_EY	145.677	<	781.4		364	PO_EY	212.845	<	781.4		365	PO_EY	117.626	<	781.4
								375	PO_EY	132.814	<	781.4		376	PO_EY	72.208	<	781.4
5th storey	Axis A	422	PO_EY	119.466	<	781.4	Axis B	423	PO_EY	113.822	<	781.4	Axis C	424	PO_EY	53.817	<	781.4
		433	PO_EY	151.923	<	781.4		434	PO_EY	159.634	<	781.4		435	PO_EY	91.215	<	781.4
		459	PO_EY	155.122	<	781.4		447	PO_EY	119.715	<	781.4		448	PO_EY	79.955	<	781.4
		470	PO_EY	119.978	<	781.4		460	PO_EY	160.122	<	781.4		461	PO_EY	87.883	<	781.4
								471	PO_EY	105.781	<	781.4		472	PO_EY	53.686	<	781.4
6th storey	Axis A	518	PO_EY	81.489	<	781.4	Axis B	519	PO_EY	91.503	<	781.4	Axis C	520	PO_EY	35.587	<	781.4
		529	PO_EY	110.434	<	781.4		530	PO_EY	106.775	<	781.4		531	PO_EY	56.445	<	781.4
		555	PO_EY	100.179	<	781.4		543	PO_EY	51.227	<	781.4		544	PO_EY	45.485	<	781.4
		566	PO_EY	80.761	<	781.4		556	PO_EY	114.676	<	781.4		557	PO_EY	56.194	<	781.4
								567	PO_EY	80.507	<	781.4		568	PO_EY	33.275	<	781.4

2.3.4. Checking the Shear Strength Capacity at Columns

In calculating the shear strength capacity at columns, the contribution of concrete and transverse reinforcement to shear strength is determined in accordance with TS-500.

Contribution of concrete :
Column dimension at each storey is the same.
Column dimensions are 400/400mm and 500/500mm.
For columns 400/400 :

$\gamma = 0.07$ (by axial compression force)

$$V_c = 0.8 * 0.65 * f_{ctm} * b_w * d \ (1 + \gamma\,(N/A_c)) \tag{2.10}$$

$$V_c = 0.8 * 0.65 * 0.35 * \sqrt{25} * 400 * 400 * (1 + 0.07*(1212.23 / (400*400)) = 145677 \text{ kN}$$
$$= 145.7 \text{ kN}$$

As the above equation is dependent on the axial force subjected to each column, the contribution of concrete is shown in Table 2.12a, 2.12b, 2.12c.

Contribution of transverse reinforcement :
Transverse reinforcement at beams 2*(ϕ10 + ϕ10.cos 45°) / 100 mm

$$V_s = A_s f_{ys} (d / s) = 2 * (78.54 + 78.54 \cos 45^\circ)* 420 * (370 / 100) = 416708 \text{ N}$$
$$= 416.7 \text{ kN}$$

$$V_r = V_c + V_s = 145.7 + 416.7 = 562.4 \text{ kN}$$

Shear force demand for each column at each storey is also shown in Table 2.12a, 2.12b, 2.12c. As shown in tables, the shear force, calculated by the pushover analysis satisfies the condition given below.

$$\max V = 181.735 \text{ kN} < Vr = 562.4 \text{ kN}$$

For columns 500/500 :

$\gamma = 0.07$ (by axial compression force)

Using Eq.(2.10) :

$$V_c = 0.8 * 0.65 * 0.35 * \sqrt{25} * 500 * 500 * (1 + 0.07*(1559.27 / (500 * 500)) = 227599 \text{ N}$$
$$= 227.6 \text{ kN}$$

As the above equation is dependent on the axial force subjected to each column, the contribution of concrete is shown in Table 2.12a, 2.12b, 2.12c.

Contribution of transverse reinforcement :

Transverse reinforcement at beams $2*(\phi 10 + \phi 10.\cos 45°) / 100$ mm

Using Eq.(2.9) :

$$V_s = 2 * (78.54 + 78.54 \cos 45°)* 420 * (470 / 100) = 529331 \text{ N}$$
$$= 529.3 \text{ kN}$$

$$V_r = V_c + V_s = 227.6 + 529.3 = 756.9 \text{ kN}$$

Shear force demand for each column at each storey is also shown in Table 2.12a, 2.12b, 2.12c. As shown in tables, the shear force, calculated by the pushover analysis satisfies the condition given below.

$$\max V = 206.401 \text{ kN} < Vr = 756.9 \text{ kN}$$

Table 2.12a. Shear force demand of columns obtained from the Pushover Analysis

		Column Nr	Dimension	Load Case	P (kN)	V2 (kN)		Vr = Vc+Vs (kN)	Vc (kN)	Vs (kN)
1st storey	Axis 1	1	400*400	PO_EX	-765.443	93.165	<	562.357	145.649	416.708
		2	400*400	PO_EX	-1026.87	122.314	<	562.373	145.665	416.708
		3	400*400	PO_EX	-694.307	111.534	<	562.352	145.644	416.708
		4	400*400	PO_EX	-1119.016	137.033	<	562.379	145.671	416.708
		5	400*400	PO_EX	-1203.758	133.148	<	562.384	145.677	416.708
		6	400*400	PO_EX	-998.545	113.346	<	562.371	145.664	416.708
2nd storey	Axis 1	97	400*400	PO_EX	-632.541	52.799	<	562.348	145.640	416.708
		98	400*400	PO_EX	-847.031	112.479	<	562.362	145.654	416.708
		99	400*400	PO_EX	-570.848	126.656	<	562.344	145.636	416.708
		100	400*400	PO_EX	-909.776	120.905	<	562.366	145.658	416.708
		101	400*400	PO_EX	-1001.336	112.687	<	562.372	145.664	416.708
		102	400*400	PO_EX	-816.325	53.162	<	562.360	145.652	416.708
3rd storey	Axis 1	193	400*400	PO_EX	-498.442	61.172	<	562.340	145.632	416.708
		194	400*400	PO_EX	-668.574	122.371	<	562.350	145.643	416.708
		195	400*400	PO_EX	-457.947	131.962	<	562.337	145.629	416.708
		196	400*400	PO_EX	-682.628	135.118	<	562.351	145.643	416.708
		197	400*400	PO_EX	-784.236	126.713	<	562.358	145.650	416.708
		198	400*400	PO_EX	-632.716	65.846	<	562.348	145.640	416.708
4th storey	Axis 1	289	400*400	PO_EX	-364.229	45.834	<	562.331	145.623	416.708
		290	400*400	PO_EX	-491.018	103.386	<	562.339	145.631	416.708
		291	400*400	PO_EX	-338.481	121.546	<	562.329	145.622	416.708
		292	400*400	PO_EX	-449.52	117.204	<	562.336	145.629	416.708
		293	400*400	PO_EX	-569.077	97.551	<	562.344	145.636	416.708
		294	400*400	PO_EX	-448.778	51.296	<	562.336	145.629	416.708
5th storey	Axis 1	385	400*400	PO_EX	-229.773	23.183	<	562.322	145.615	416.708
		386	400*400	PO_EX	-314.253	71.781	<	562.328	145.620	416.708
		387	400*400	PO_EX	-230.336	93.282	<	562.322	145.615	416.708
		388	400*400	PO_EX	-218.83	74.118	<	562.322	145.614	416.708
		389	400*400	PO_EX	-357.042	62.481	<	562.330	145.623	416.708
		390	400*400	PO_EX	-272.208	39.526	<	562.325	145.617	416.708
6th storey	Axis 1	481	400*400	PO_EX	-94.625	-24.024	<	562.314	145.606	416.708
		482	400*400	PO_EX	-137.665	51.322	<	562.317	145.609	416.708
		483	400*400	PO_EX	-128.913	49.799	<	562.316	145.608	416.708
		484	400*400	PO_EX	-97.916	31.712	<	562.314	145.606	416.708
		485	400*400	PO_EX	-153.649	50.322	<	562.318	145.610	416.708
		486	400*400	PO_EX	-108.569	34.246	<	562.315	145.607	416.708

Table 2.12b. Shear force demand of columns obtained from the Pushover Analysis

		Column Nr	Dimension	Load Case	P (kN)	V2 (kN)		Vr = Vc+Vs (kN)	Vc (kN)	Vs (kN)
1^{st} storey	Axis 2	7	400*400	PO_EX	-949.319	134.557	<	562.368	145.660	416.708
		8	500*500	PO_EX	-1339.403	199.928	<	756.917	227.585	529.331
		9	400*400	PO_EX	-812.175	118.367	<	562.359	145.652	416.708
		10	400*400	PO_EX	-1561.603	150.159	<	562.407	145.699	416.708
		11	500*500	PO_EX	-1586.701	213.301	<	756.933	227.601	529.331
		12	400*400	PO_EX	-1199.489	134.381	<	562.384	145.676	416.708
2^{nd} storey	Axis 2	103	400*400	PO_EX	-780.265	140.943	<	562.357	145.650	416.708
		104	500*500	PO_EX	-1116.259	212.126	<	756.903	227.571	529.331
		105	400*400	PO_EX	-672.736	119.708	<	562.351	145.643	416.708
		106	400*400	PO_EX	-1218.985	119.719	<	562.385	145.678	416.708
		107	500*500	PO_EX	-1325.373	211.604	<	756.916	227.584	529.331
		108	400*400	PO_EX	-979.377	140.34	<	562.370	145.662	416.708
3^{rd} storey	Axis 2	199	400*400	PO_EX	-615.517	131.711	<	562.347	145.639	416.708
		200	500*500	PO_EX	-893.777	205.213	<	756.888	227.557	529.331
		201	400*400	PO_EX	-535.619	126.858	<	562.342	145.634	416.708
		202	400*400	PO_EX	-846.788	126.907	<	562.362	145.654	416.708
		203	500*500	PO_EX	-1056.918	205.869	<	756.899	227.567	529.331
		204	400*400	PO_EX	-763.253	132.364	<	562.356	145.649	416.708
4^{th} storey	Axis 2	295	400*400	PO_EX	-452.74	117.505	<	562.337	145.629	416.708
		296	500*500	PO_EX	-670.346	164.902	<	756.874	227.543	529.331
		297	400*400	PO_EX	-399.976	104.142	<	562.333	145.625	416.708
		298	400*400	PO_EX	-499.586	104.132	<	562.340	145.632	416.708
		299	500*500	PO_EX	-786.819	164.731	<	756.882	227.550	529.331
		300	400*400	PO_EX	-549.088	117.402	<	562.343	145.635	416.708
5^{th} storey	Axis 2	391	400*400	PO_EX	-291.547	95.235	<	562.326	145.619	416.708
		392	500*500	PO_EX	-446.333	119.573	<	756.860	227.528	529.331
		393	400*400	PO_EX	-269.597	71.022	<	562.325	145.617	416.708
		394	400*400	PO_EX	-265.385	71.022	<	562.325	145.617	416.708
		395	500*500	PO_EX	-520.433	119.603	<	756.865	227.533	529.331
		396	400*400	PO_EX	-337.677	95.234	<	562.329	145.622	416.708
6^{th} storey	Axis 2	487	400*400	PO_EX	-132.396	81.328	<	562.316	145.608	416.708
		488	500*500	PO_EX	-223.409	94.101	<	756.846	227.514	529.331
		489	400*400	PO_EX	-170.432	48.339	<	562.319	145.611	416.708
		490	400*400	PO_EX	-132.182	48.332	<	562.316	145.608	416.708
		491	500*500	PO_EX	-256.736	94.154	<	756.848	227.516	529.331
		492	400*400	PO_EX	-147.384	81.289	<	562.317	145.609	416.708

Table 2.12c. Shear force demand of columns obtained from the Pushover Analysis

		Column Nr	Dimension	Load Case	P (kN)	V2 (kN)		Vr = Vc+Vs (kN)	Vc (kN)	Vs (kN)
1st storey	Axis 3	13	400*400	PO_EX	-838.614	137.214	<	562.361	145.653	416.708
		15	400*400	PO_EX	-1019.189	136.937	<	562.373	145.665	416.708
2nd storey	Axis 3	109	400*400	PO_EX	-695.155	155.95	<	562.352	145.644	416.708
		111	400*400	PO_EX	-851.612	155.905	<	562.362	145.654	416.708
3rd storey	Axis 3	205	400*400	PO_EX	-553.075	155.011	<	562.343	145.635	416.708
		207	400*400	PO_EX	-682.772	155.102	<	562.351	145.643	416.708
4th storey	Axis 3	301	400*400	PO_EX	-450.928	140.146	<	562.336	145.629	416.708
		303	400*400	PO_EX	-514.878	140.163	<	562.341	145.633	416.708
5th storey	Axis 3	397	400*400	PO_EX	-347.209	88.981	<	562.330	145.622	416.708
		399	400*400	PO_EX	-347.724	88.964	<	562.330	145.622	416.708
6th storey	Axis 3	493	400*400	PO_EX	-181.389	63.808	<	562.319	145.612	416.708
		495	400*400	PO_EX	-181.652	52.572	<	562.319	145.612	416.708

Table 2.12d. Shear force demand of shear walls obtained from the Pushover Analysis

Storey		Shear Wall Nr	Dimension	Load Case	P (kN)	V2 (kN)		Vr = Vc+Vs (kN)	Vc (kN)	Vs (kN)
Axis 3	1st	14	2000*250	PO_EX	-1329.078	266.975	<	3819.730	455.085	3364.646
	2nd	110	2000*250	PO_EX	-1135.156	769.491	<	3819.718	455.072	3364.646
	3rd	206	2000*250	PO_EX	-933.433	345.991	<	3819.668	455.022	3364.646
	4th	302	2000*250	PO_EX	-717.441	255.502	<	3819.662	455.016	3364.646
	5th	398	2000*250	PO_EX	-488.129	181.941	<	3819.657	455.012	3364.646
	6th	494	2000*250	PO_EX	-247.897	-117.340	<	3819.653	455.007	3364.646
Axis A	1st	16	250*2000	PO_EY	-1388.313	-394.212	<	3819.671	455.025	3364.646
	2nd	112	250*2000	PO_EY	-1161.674	-616.525	<	3819.685	455.039	3364.646
	3rd	208	250*2000	PO_EY	-926.889	-260.550	<	3819.662	455.017	3364.646
	4th	304	250*2000	PO_EY	-688.254	-218.029	<	3819.660	455.014	3364.646
	5th	400	250*2000	PO_EY	-446.597	-189.464	<	3819.658	455.012	3364.646
	6th	496	250*2000	PO_EY	-206.056	105.361	<	3819.652	455.007	3364.646

2.3.5. Evaluation of the Performance of the Sample Building

2.3.5.1. Evaluation of the Performance after the Pushover Analysis in x-direction. The damage assessment at beams and columns:

- All beams at Axis 1, 2, 3 at the 1st and 2nd stories are all in the performance level between MN and GV.
- 14% of the beams at Axis 1, 2, 3 at the 3rd storey is in the performance level smaller than MN where 86% is betweeen MN and GV.
- 90% of the beams at Axis 1, 2, 3 at the 4th storey is in the performance level smaller than MN where 10% is betweeen MN and GV.
- 90% of the beams at Axis 1, 2, 3 at the 4th storey is in the performance level smaller than MN where 10% is betweeen MN and GV.
- All of the beams at the 5th and 6th stories are in the performance level smaller than MN.
- All of the columns of the 1st storey are between MN and GV as performance level. The columns at the 2nd, 3rd and 4th stories are in the performance level smaller than MN.
- The shear walls in the x-direction at the 1st storey are also between MN and GV as performance level while the shear walls in upper stories are in the performance level smaller than MN.

2.3.5.2. Evaluation of the Performance after the Push-Over Analysis in y-direction. The damage assessment at beams and columns:

- All beams at Axis 1, 2, 3 at the 1st storey are all in the performance level between MN and GV.
- 21% of the beams at Axis 1, 2, 3 at the 2nd storey is in the performance level smaller than MN where 79% is betweeen MN and GV.
- 77% of the beams at Axis 1, 2, 3 at the 3rd storey is in the performance level smaller than MN where 23% is betweeen MN and GV.
- 82% of the beams at Axis 1, 2, 3 at the 4th storey is in the performance level smaller than MN where 18% is betweeen MN and GV.

- All of the beams at the 5th and 6th stories are in the performance level smaller than MN.
- All of the columns of the 1st storey are between MN and GV as performance level. The columns at the 2nd and 3rd stories are in the performance level smaller than MN.
- The shear walls in the y-direction at the 1st storey are also between MN and GV as performance level while the shear walls in upper stories are in the performance level smaller than MN.

The results show that the use of structural walls in such systems of norminal ductility level is mandatory so that they can be built in the 1st and 2nd seismic zones.

5. CONCLUSION

In this study, it is intended to determine the performance level of a dual reinforced concrete wall-frame system of mixed ductility level under earthquake effects by using a nonlinear static analysis procedure which is used to determine the performance level of the structure by considering structural capacity obtained from the pushover analysis. For this purpose, a six-storey reinforced concrete 3D wall-frame sysytem of mixed ductility level is considered where the the ratio of the sum of base shear developed at the bases of solid structural walls under seismic loads to the total base shear developed for the entire building is between the values 0.4 and 2/3 ($0.4<\alpha_S<2/3$).

As indicated in TSC '07 (6.5.3), infilled joist slab systems which are treated as systems of nominal ductility level can be built in the first and second seismic zones if structural walls are used along the full height of the building. The purpose of this study is to verify the condition on mandatory use of structural walls in certain systems of mixed ductility level. The six-storey reinforced concrete 3D wall-frame system is designed geometrically and materially in accordance with TS 500 and TSC '07 (Part 3). Life safety (LS) structural performance level is chosen as a target for the model structure under a design earthquake that may be exceeded in a 50 year period with 10 % probability.

The central focus of this nonlinear static analysis method is the generation of the capacity curve or pushover curve which represents the lateral displacement as a function of the force applied to the structure. At the end of the last pushover step, all demand quantities are estimated. Seismic demand in reinforced concrete section is obtained in terms of concrete and reinforcing steel strains which are then checked against the limiting values given in TSC '07 (7.6.9) for various damage limits. The strain values at beams are between the limit values of MN and GV levels or smaller than MN. As shown in Table 2.11, 2.12, 2.13, the strain values of the columns and shear walls at the first storey are between the limit values of MN and GV where others are smaller than MN. Life safety (LS) performance level is achieved.

APPENDIX A
REINFORCEMENT DETAILS OF BEAMS, COLUMNS AND SHEAR WALLS

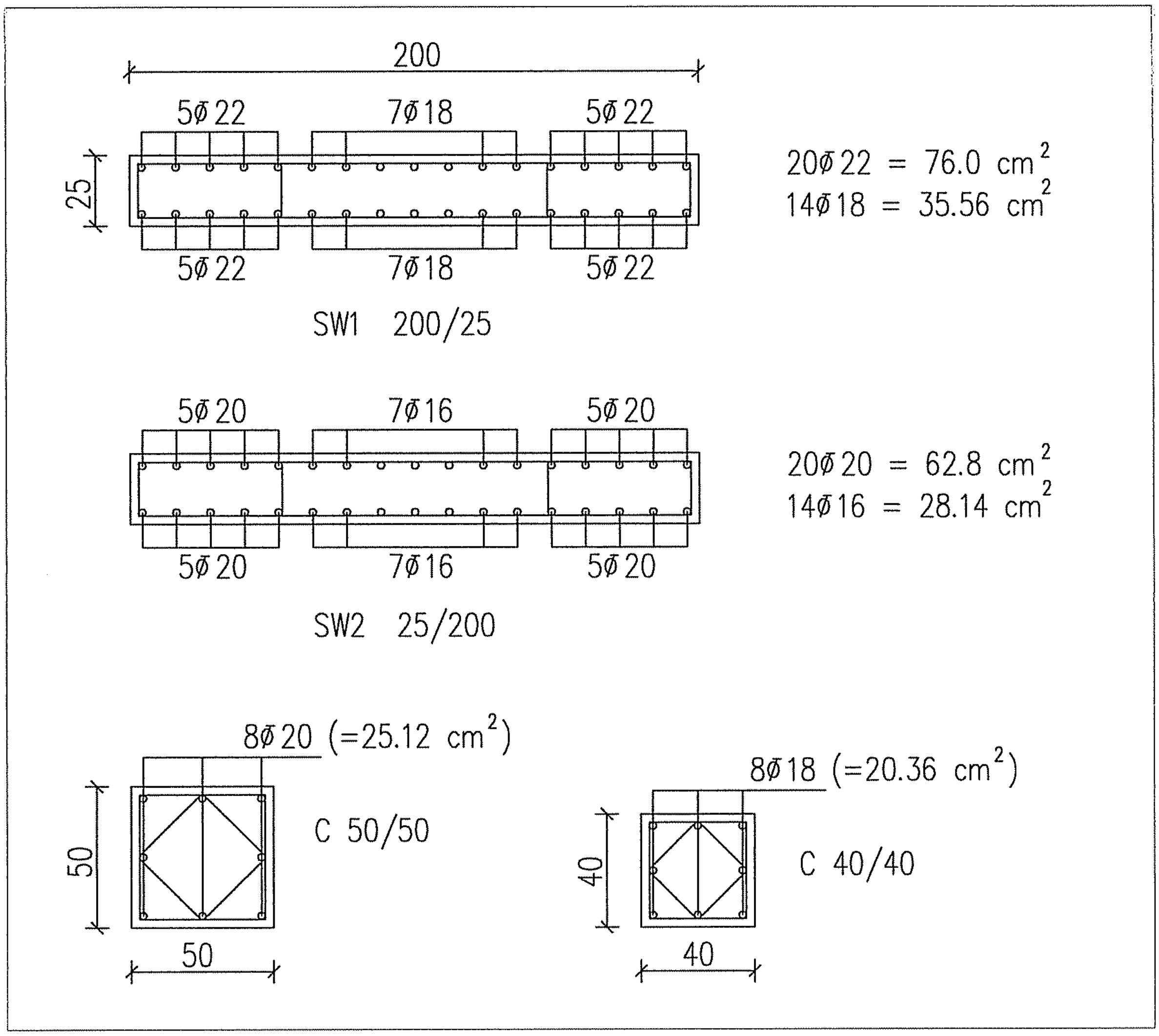


Figure A.1. Reinforcement details of columns and shear walls

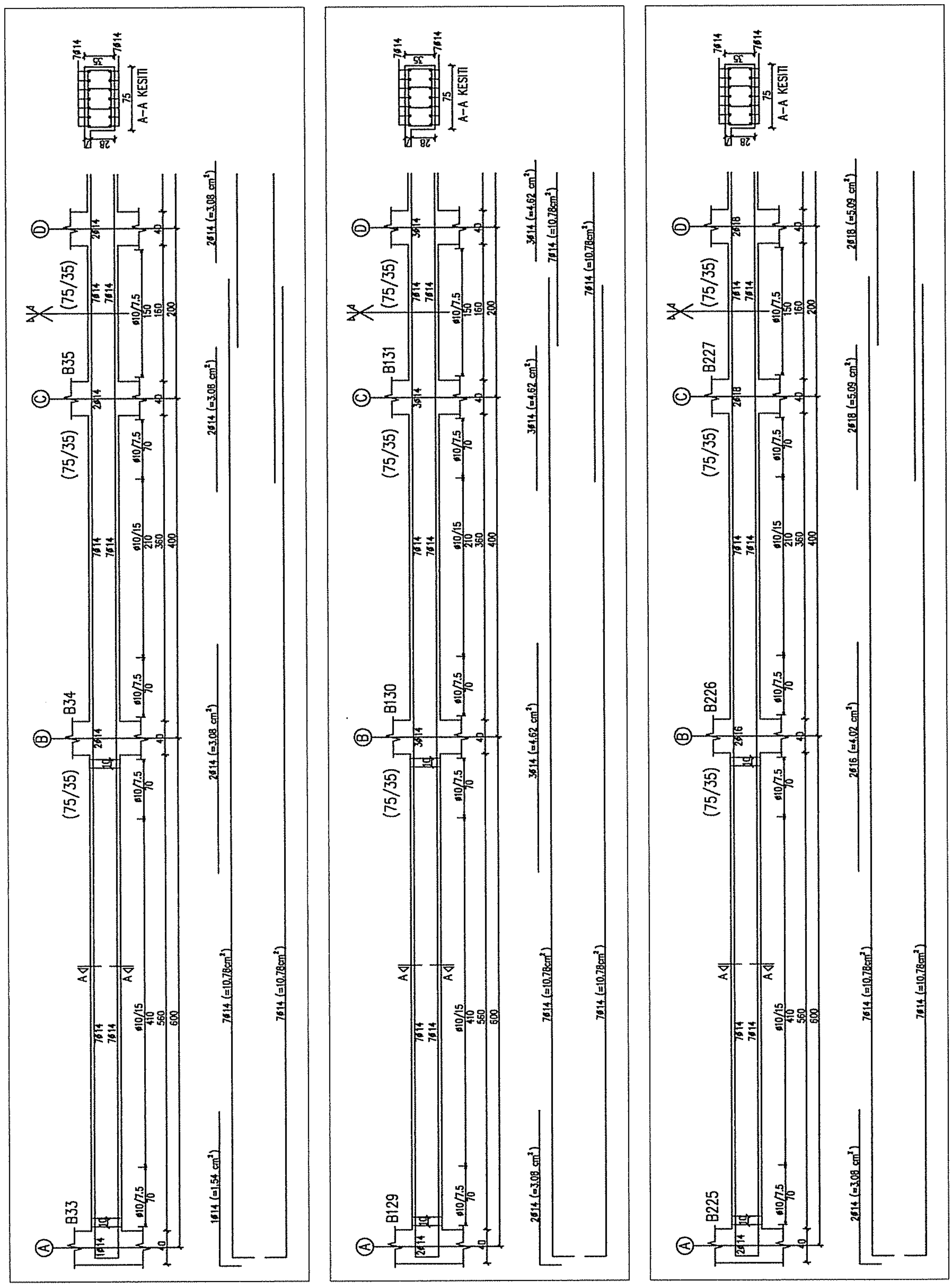


Figure A.2a. Reinforcement details of beams at Axis 1 (1^{st}, 2^{nd}, 3^{rd} stories)

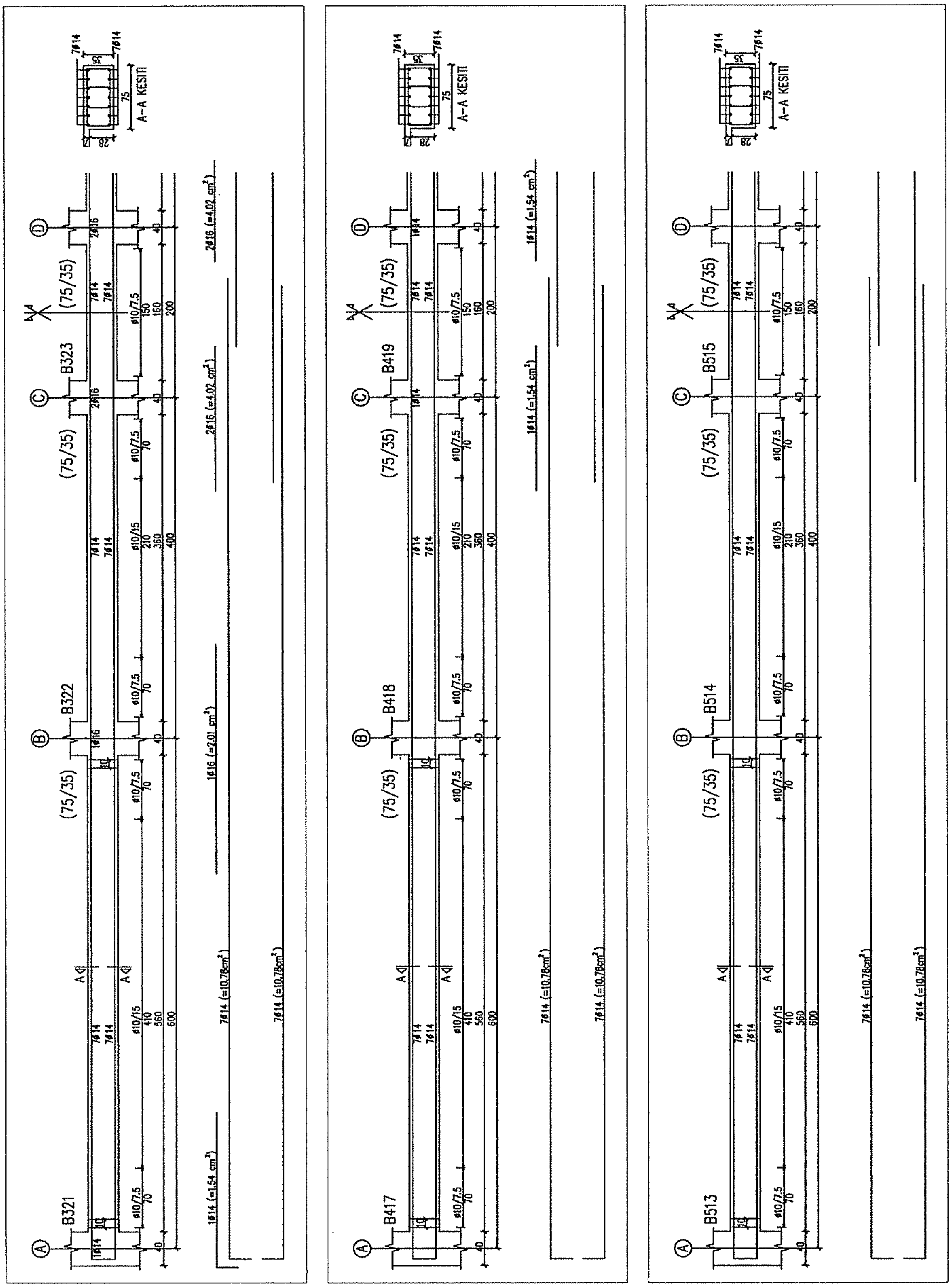


Figure A.2b. Reinforcement details of beams at Axis 1 (4th, 5th, 6th stories)

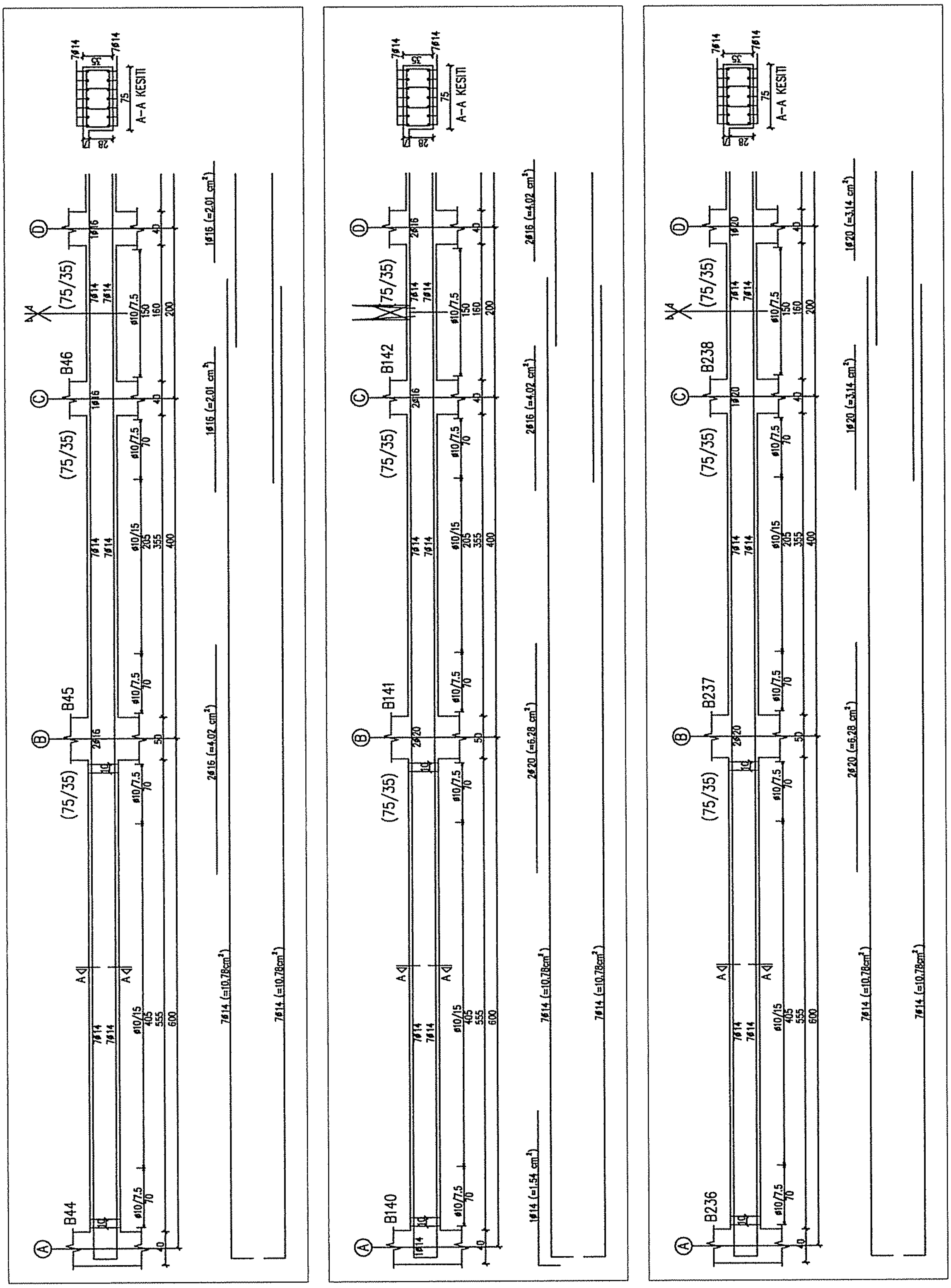


Figure A.3a. Reinforcement details of beams at Axis 2 (1st, 2nd, 3rd stories)

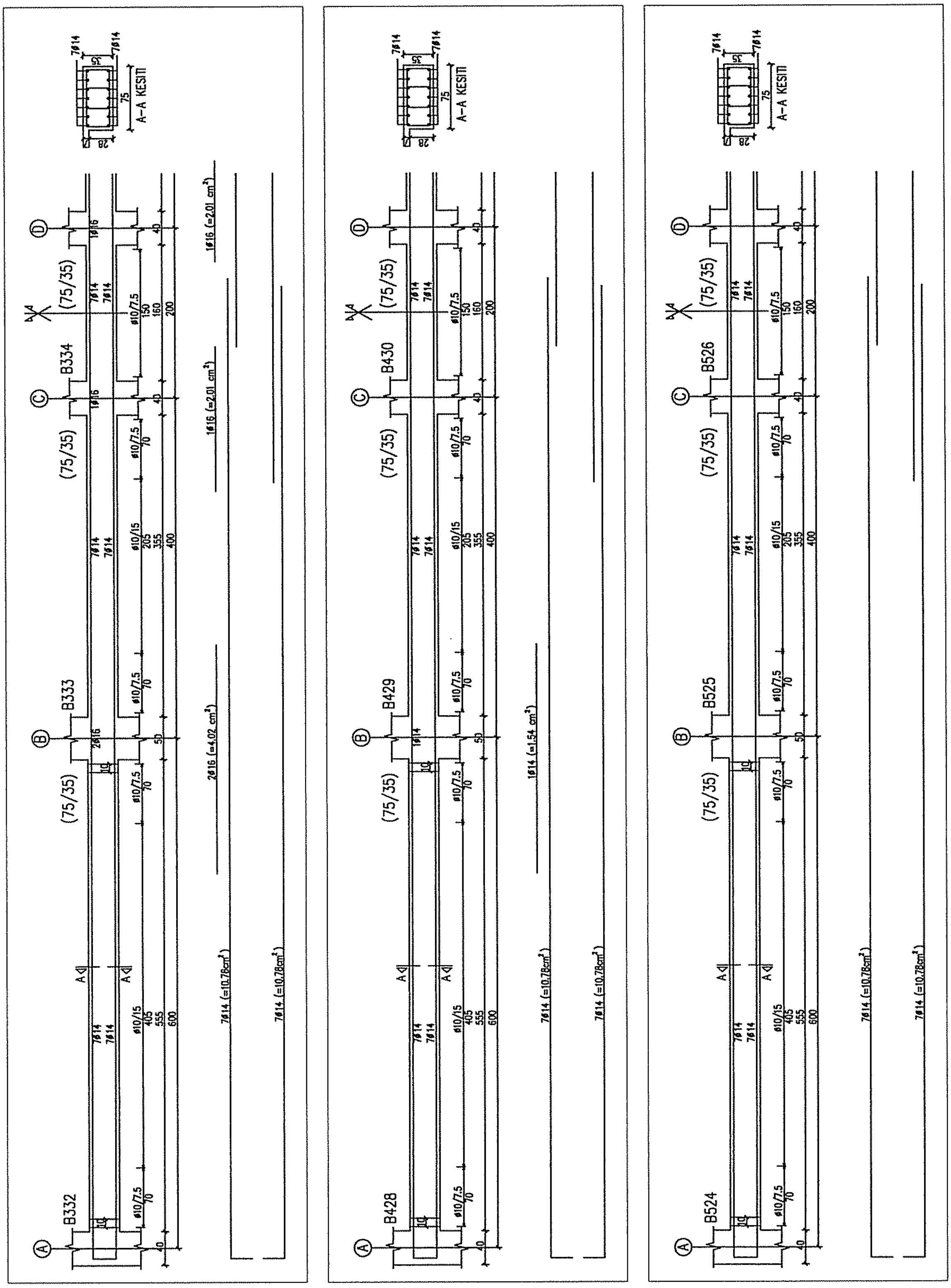


Figure A.3b. Reinforcement details of beams at Axis 2 (4th, 5th, 6th stories)

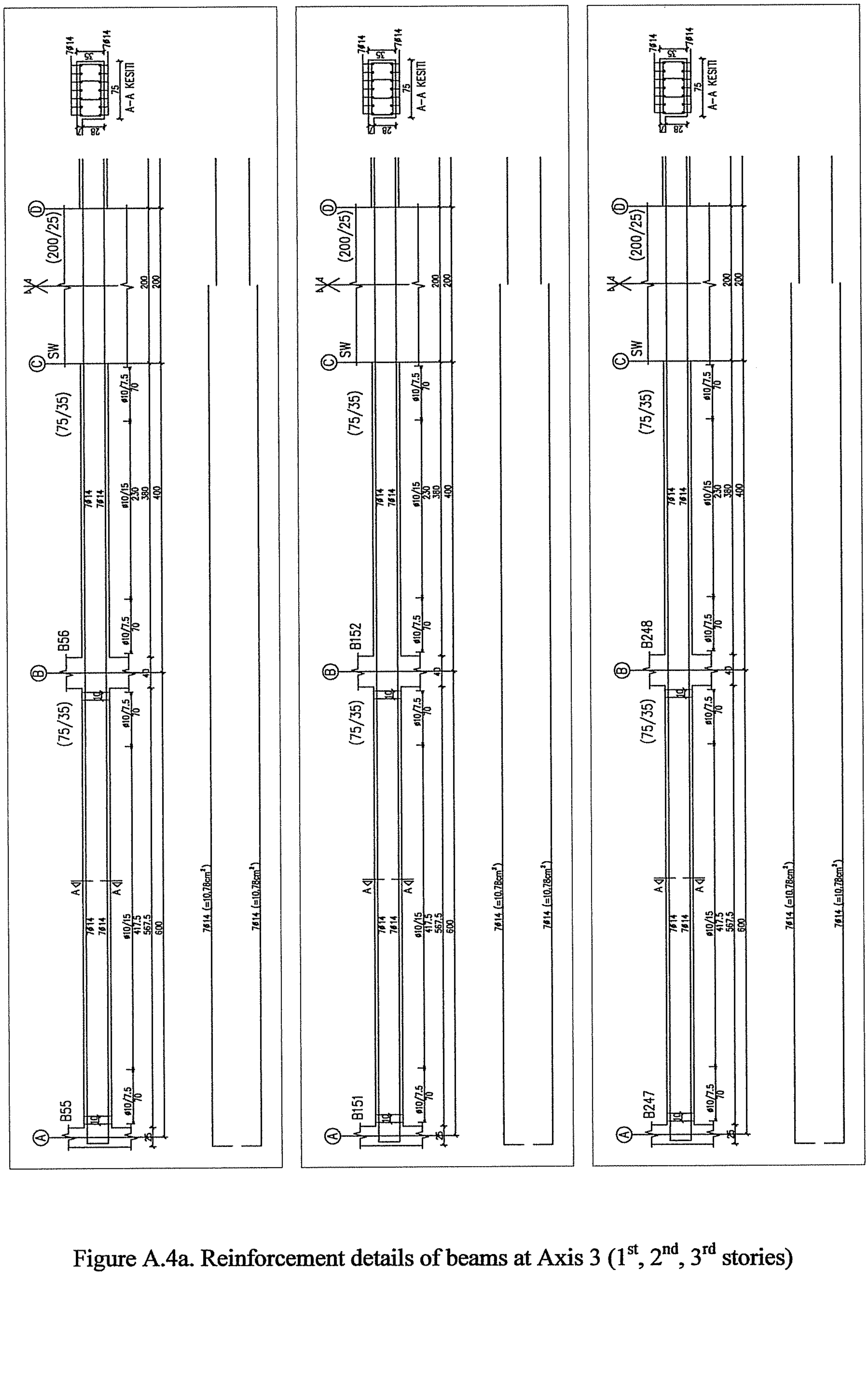


Figure A.4a. Reinforcement details of beams at Axis 3 (1st, 2nd, 3rd stories)

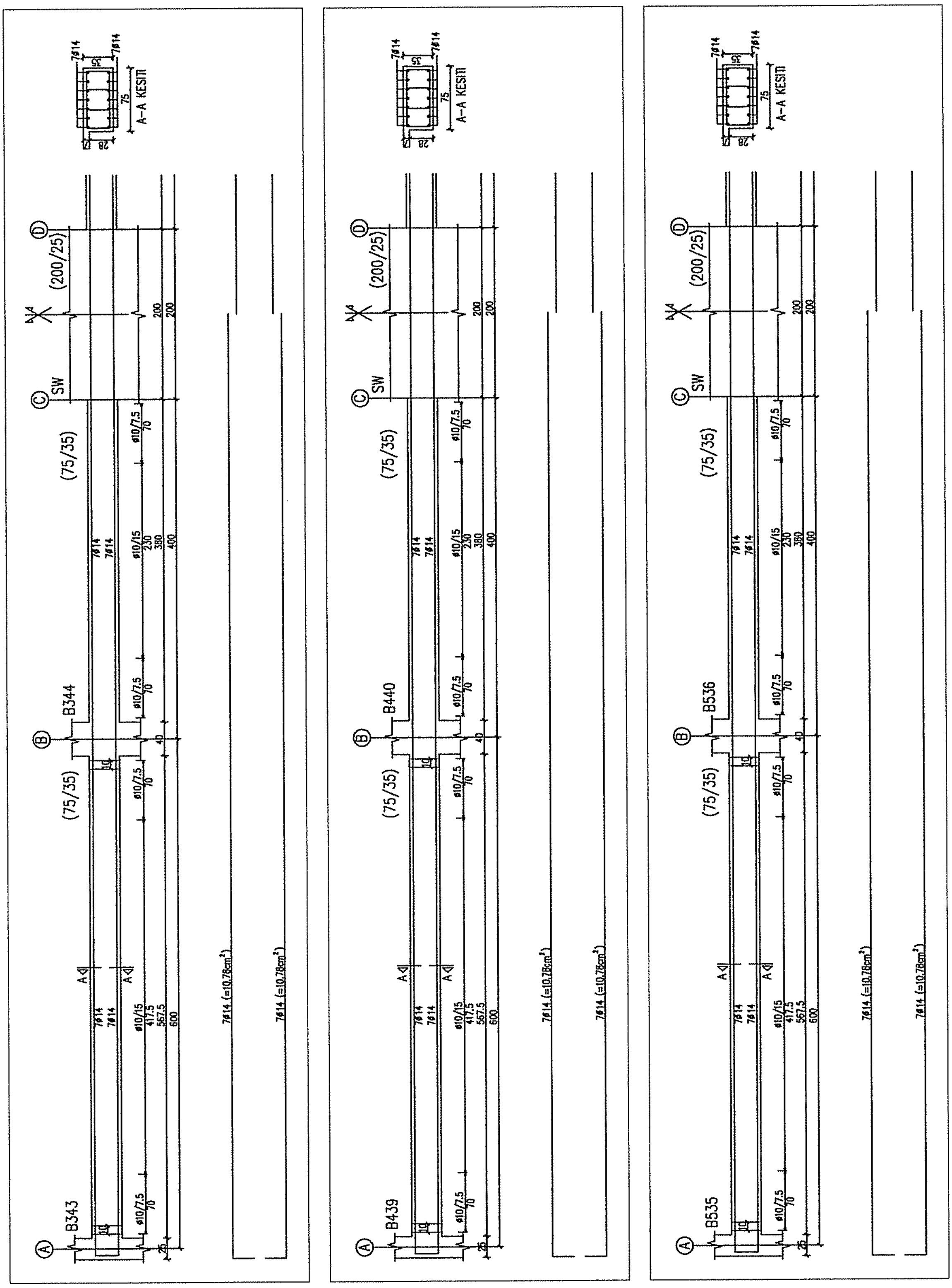


Figure A.4b. Reinforcement details of beams at Axis 3 (4^{th}, 5^{th}, 6^{th} stories)

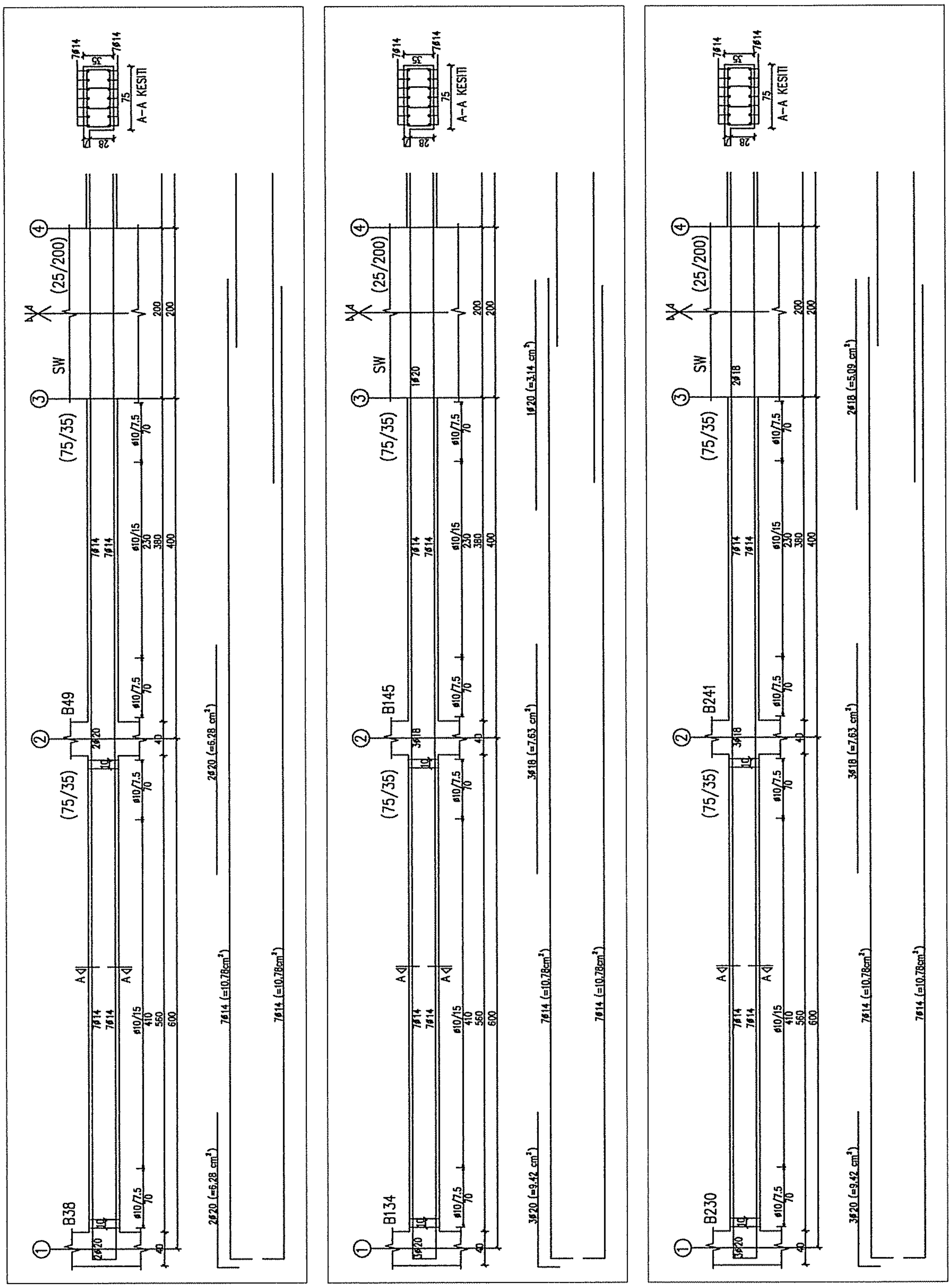


Figure A.5a. Reinforcement details of beams at Axis A (1st, 2nd, 3rd stories)

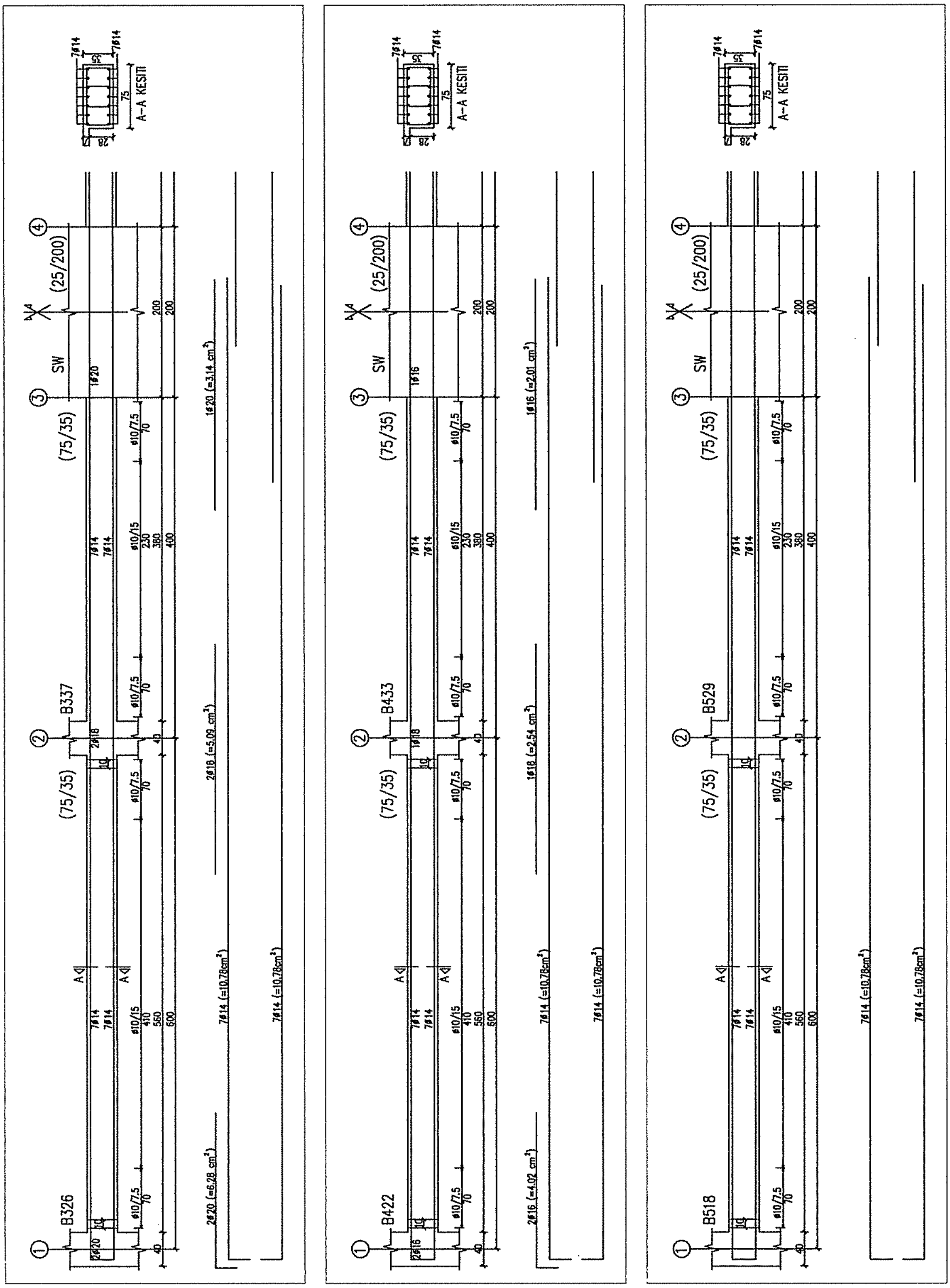


Figure A.5b. Reinforcement details of beams at Axis A (4^{th}, 5^{th}, 6^{th} stories)

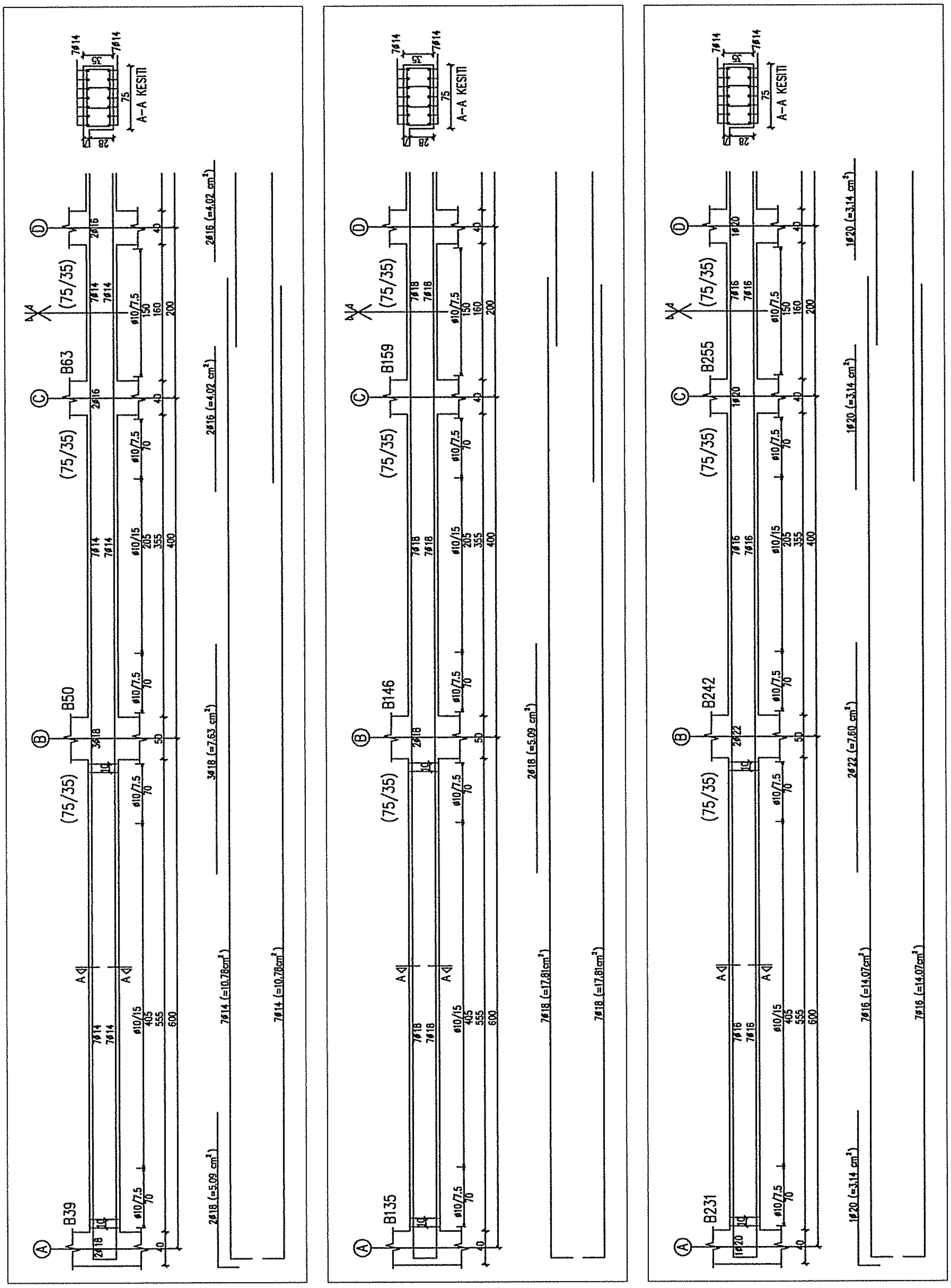


Figure A.6a. Reinforcement details of beams at Axis B (1^{st}, 2^{nd}, 3^{rd} stories)

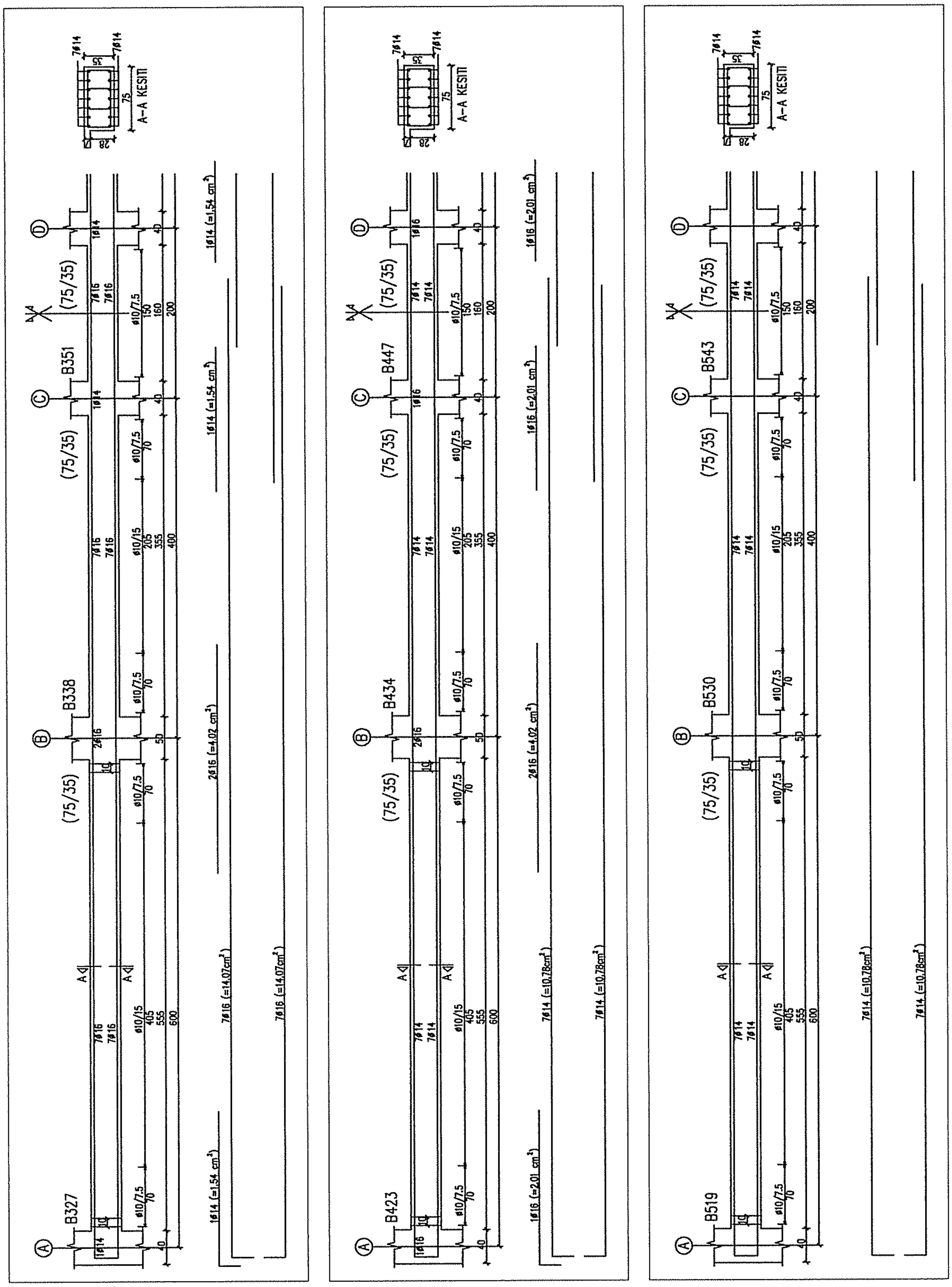


Figure A.6b. Reinforcement details of beams at Axis B (4th, 5th, 6th stories)

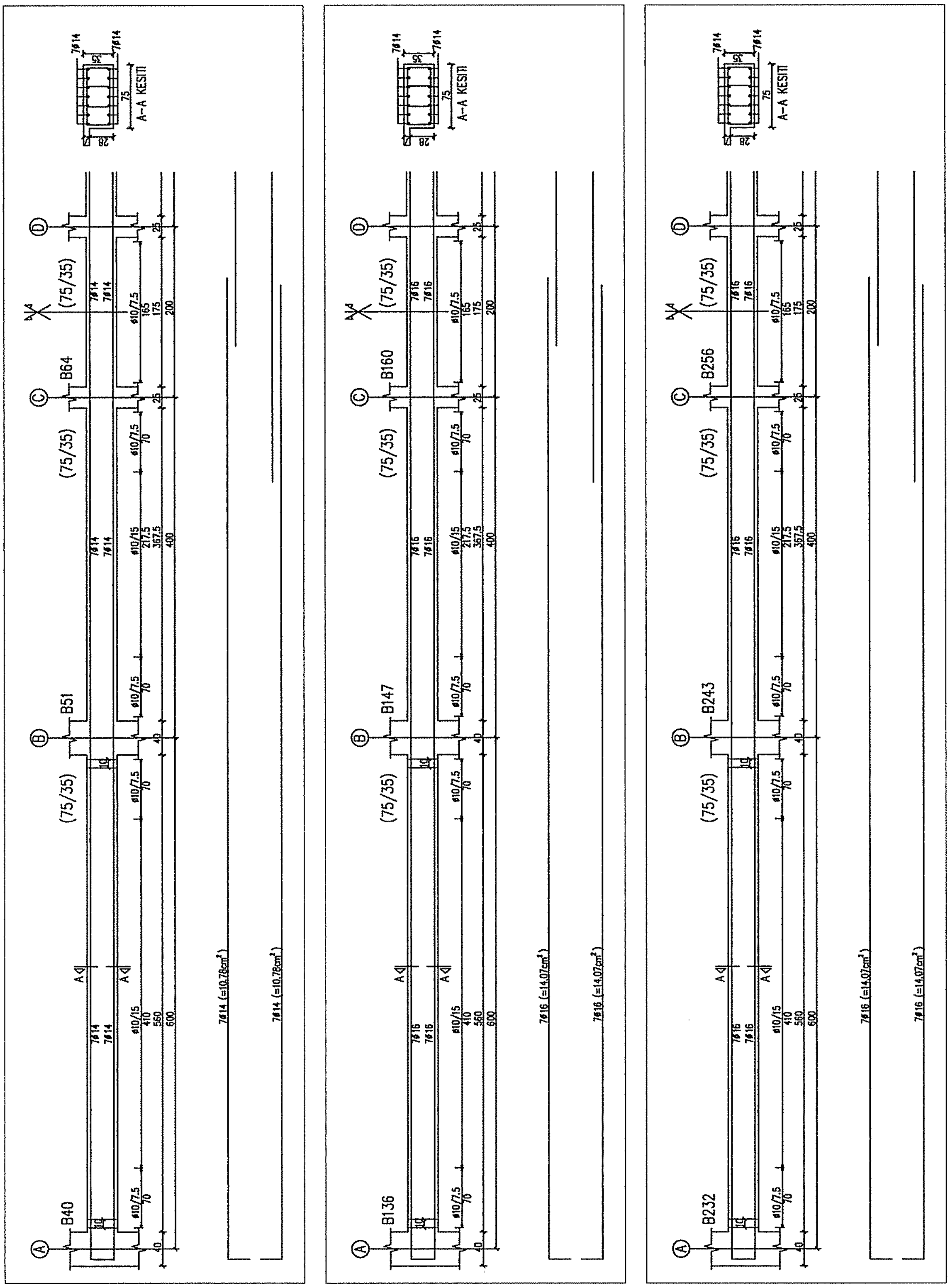


Figure A.7a. Reinforcement details of beams at Axis C (1st, 2nd, 3rd stories)

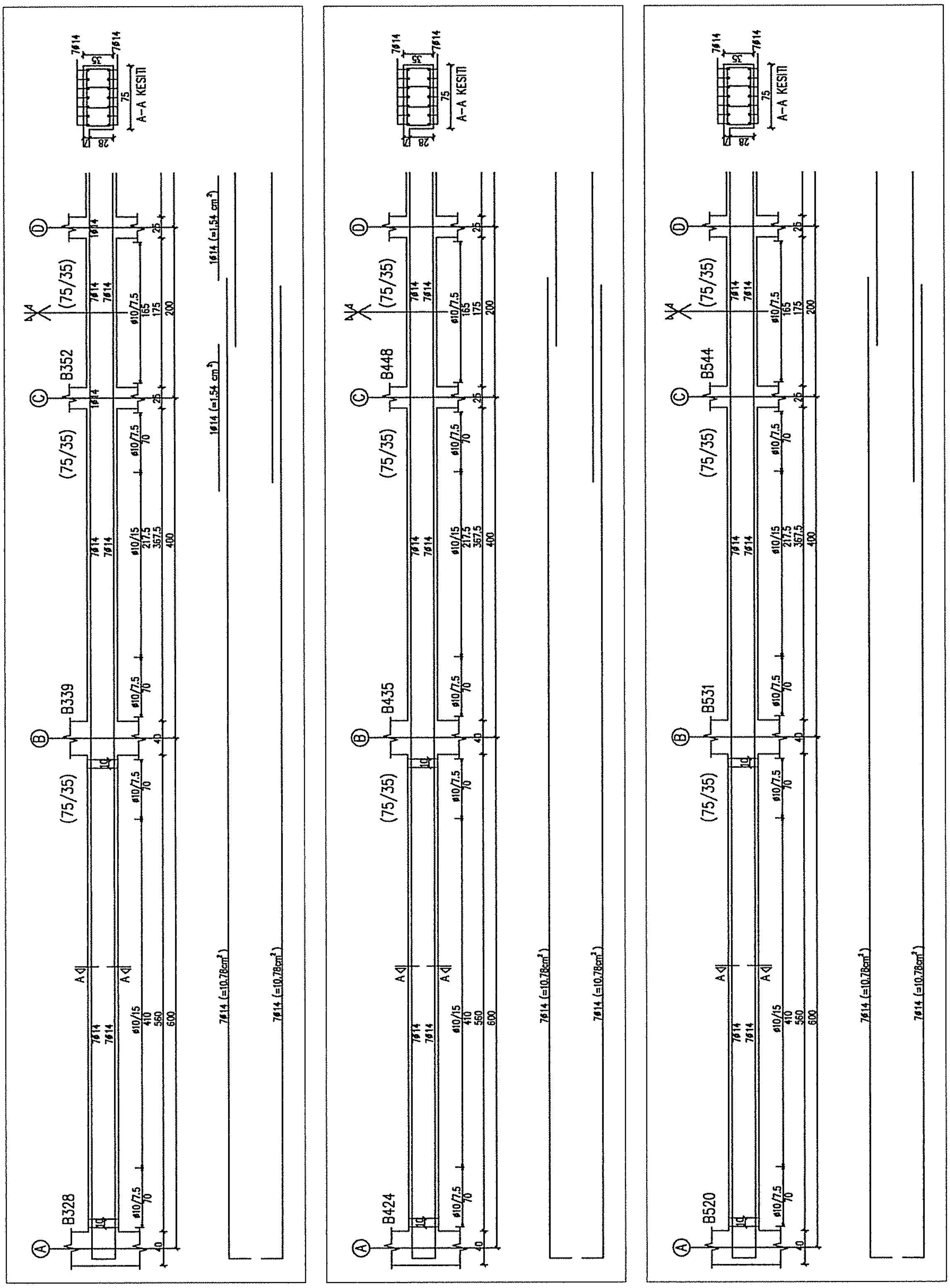


Figure A.7b. Reinforcement details of beams at Axis C (4^{th}, 5^{th}, 6^{th} stories)

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