CHAPTER 3

Methodology and Modelling and Analysis

3.1 Introduction

In this study, a plan of three models were investigated as shown in **Figure (3.1)**. The first step is to choose three types of tall building frames according to the general classification of steel tall building systems mentioned in chapter 2.

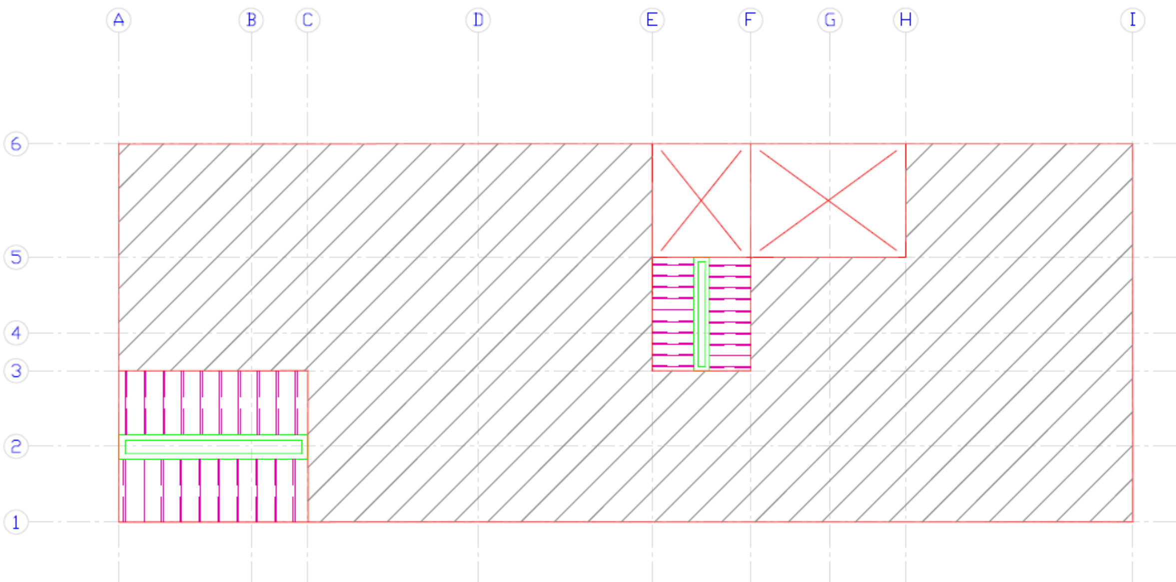

Figure (3.1): The plan of tall building models.

The types of tall building frame which studied are as follows:

1- Rigid frame system as shown in **Figure (3.2)**.

2- Shear-wall frame system as shown in **Figure (3.3)**.

3- Tube frame system as shown in **Figure (3.4)**.

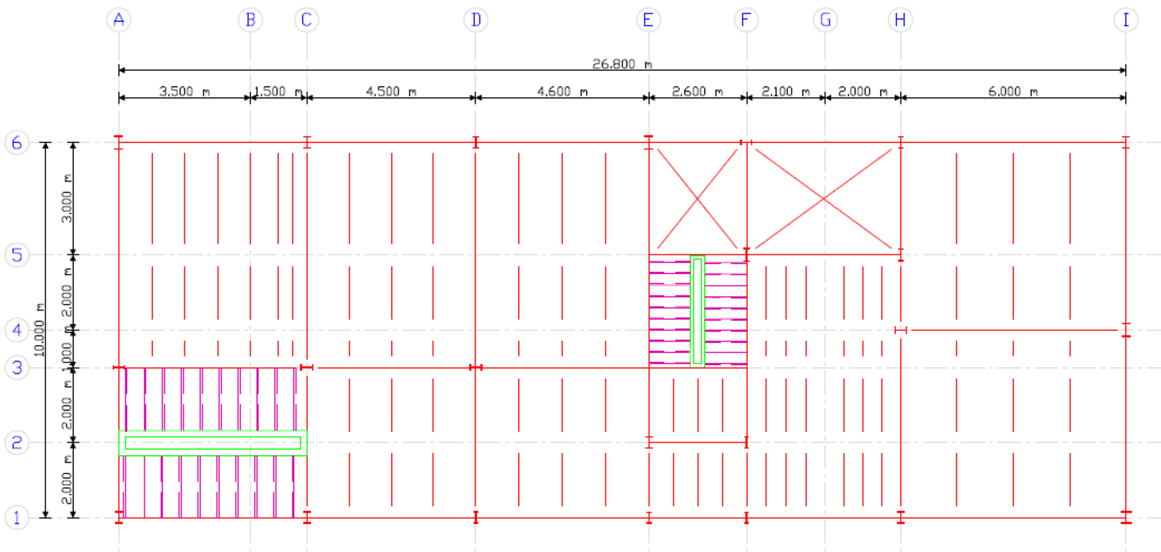

Figure (3.2): Plan of rigid frame system.

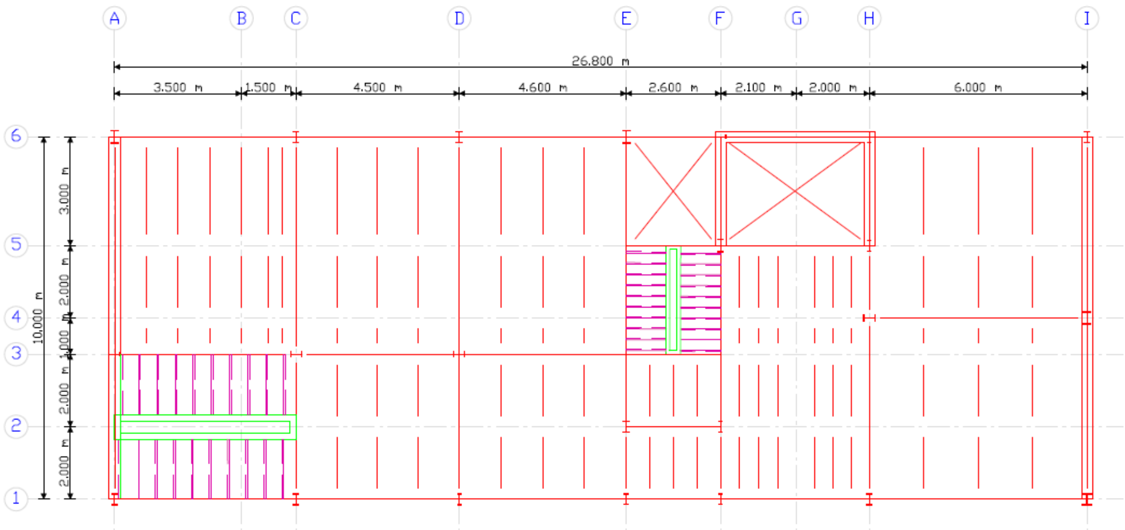

Figure (3.3): Plan of shear-wall frame system.

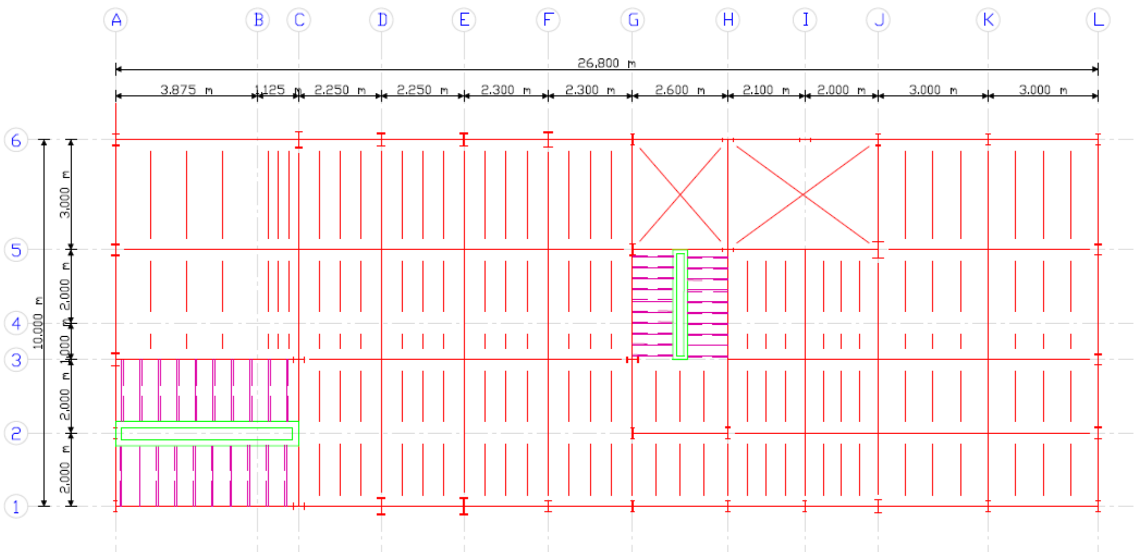

Figure (3.4): Plan of tube frame system.

In order to make an adequate study, the height of the structural system frames were equal (25-storey building) as shown in **Appendix (B)**. The storey drift limit considered to be as indicator to measure the degree of stability, because it is the most important comparing with the parameter that affecting on the tall buildings when subjected to wind load e.g. joint displacements, maximum bending moment at the end of columns, and axial forces in bracing members.

In order to study the structural behaviour of the three mentioned steel frames, three types of bracing systems used for each frame system, as well as, unbraced frame. Thus, a comparative study was made between different types of bracing.

3.2 Modelling Steps

The modelling, analysis, and design for all frames were carried out using structural analysis program (ETABS 2013 version 13.1.3). The steps to carryout modelling, analysis and design are as follows:

1. Draw the model by the available tools in the software.
2. Define the materials and sections properties whether for concrete or steel, for all elements of tall building.
3. Define the subjected loads, which were gravity loads and wind loads.
4. Assign the defined sections, materials, and loadings for the draw model.
5. Run analysis of the tall building frame.
6. Run design of the tall building frame

3.3 Building's Assigned Properties

The steel design code that used was (AISC 360-10). The steel section database that used was (AISC 14) manual. The concrete code design was (BS 8110-97), and all display units by metric system (SI). The material properties was presented as shown in **Table (3.1)**.

Table (3.1): Material properties.

Name	Type	E MPa	ν	Unit Weight kN/m³	Design Strengths
A615Gr 60	Rebar	200000	0.3	77	Fy=413.7 MPa Fu=620.5 MPa
Concrete 35	Concrete	24855.6	0.2	24	Fc=35 MPa
Steel 520	Steel	200000	0.3	77	Fy=380 MPa Fu=450 MPa

3.3.1 Assigned Loads

In order to define the loads in computer software, each load type has to identify the factor of self-weight multiplier. The applied loads information were shown in **Table (3.2)**.

Table (3.2): Load patterns used for frames of tall building analysis.

Name	Type	Self-Weight Multiplier	Note
Dead	Dead	1	
Live	Live	0	
Wind	Wind	0	ASCE 7-10
Live Load reducible	Reducible Live	0	

3.3.2 Dead Load

The dead load of structural system of tall building was calculated by ETABS 2013, and the finishing loads and partitions were assumed according to (ASCE 7-10) to be 2.5 KN/m^2.

3.3.3 Live Load

The live load was taken according to (ASCE 7-10) equal to 3.5KN/m^2.

3.3.4 Wind Load

The wind Loads were calculated according to (ASCE 7-10) as follows:

1. Exposure Parameters

a. Exposure From = Shell Objects

b. Exposure Category = B

c. Wind Direction = 0 degrees

d. Top Storey = Last Storey

e. Bottom Storey = Base

f. Include Parapet = No

2. Factors and Coefficients

a. Solid/Gross Area Ratio = 0.2

b. Gradient Height, z_g [**Appendix (A)** in **Table (A.3)**]

$$z_g = 1200 \text{ ft.}$$

c. Empirical Exponent, α [**Appendix (A)** in **Table (A.3)**]

$$\alpha = 7$$

d. Velocity Pressure Exposure Coefficient, K_z [**Appendix (A)** in **Table (A.5)**]

$$K_z = 2.01(\frac{z}{z_g})^{2/\alpha} \qquad \text{For } 15ft. \leq z \leq z_g$$

$$K_z = 2.01(\frac{15}{z_g})^{2/\alpha} \qquad \text{For } 15 \leq z$$

e. Topographical Factor, K_{zt} [**Appendix (A)** in **Figure (A.2)**]

$$K_{zt} = 1$$

f. Directionality Factor, K_d [**Appendix (A)** in **Table (A.2)**]

$$K_d = 0.85$$

g. Gust Effect Factor, G [ASCE 26.9]

$$G = 0.85$$

3. Lateral Loading

a. Velocity Pressure, q_z [**ASCE 27.3.2 Eq. 27.3-1**]

$$q_z = 0.613 K_z K_{zt} K_d V^2$$

b. Design Wind Pressure, *p* [**ASCE 27.4.2 Eq. 27.4-2**]

$$p = qGC_p$$

c. Pressure Coefficient, C_p [**Appendix (A)** in **Figure (A.3)**]

C_p=0.8 (windward)

$C_{p=}$-0.234 (Leeward)

3.3.5 Load Combinations

All load combinations were selected according to (ASCE 7-10) as follows.

- Combination (1): 1.4*D*.
- Combination (2): 1.2*D* +1.6L_0 +0.5*L*.
- Combination (3): 1.2*D*+L_0+1.6*L*.
- Combination (4): 1.2*D*+1.6*L*+0.5*W*.
- Combination (5): 1.2*D*+L_0+0.5*L*+*W*.

Where: *D*≡ dead loads.

L_0≡ Live loads.

W≡ Wind loads.

L≡ reducible live loads.

3.4 Structural Analysis of Tall Building Rigid Frames

The rigid tall building frames without bracing system have a stability resulted from joints and connections. The unbraced frames were recommended for mid-rise buildings, but also considered as an ideal field for comparison with braced frames of tall building. The bracing system increases the stability of the buildings. So, the analysis results, storeys drift and the storey displacements were reduced.

In this section, three rigid frames with bracing and unbraced frame were analysed using structural analysis program (ETABS 2013). The analysis results were summarized below.

3.4.1 Analysis Results of Unbraced Rigid Frame System

1. Column Forces

In order to study a structural behaviour of rigid frame, it was taken edge, and internal column denoted by C24 and C1, respectively. The column forces summarised as shown in **Table (3.3)**, where P, M2, and M3 were axial forces, moment in x- direction, and moment in y- direction respectively.

2. Beam Forces

It also was taken the maximum values of bending moment and shear forces of the whole building's beams. The Beam results summarised as shown in **Tables (3.4)-(3.5)**.

3. Storey Displacements

The storey displacement gave an indication to the lateral effect due to wind loads on the building. The **Figures (3.5)-(3.6)** show the displacement of the storeys for all loads combinations.

Table (3.3): The distribution of axial forces and bending moments on columns C1 and C24 for load combination 3 of unbraced rigid frame system.

Storey	Column 1			Column 24		
	P	M2	M3	P	M2	M3
	kN	kN-m	kN-m	kN	kN-m	kN-m
Storey25	-395.6	-14.1	-9.4	-272	-5.2	110.4
Storey24	-759.8	-15.5	-17.1	-550.2	-3.5	132.3
Storey23	-1126	-27.5	-7.5	-841.6	-6.9	167.4
Storey22	-1486.8	-27.9	-22.2	-1130	-4.4	219.7
Storey21	-1834.9	-35	-8.5	-1423.9	-8.6	195.8
Storey20	-2172.6	-37	-14.3	-1708.1	-6.8	122.6
Storey19	-2523.6	-36.9	-20.1	-1977	-5	213.3
Storey18	-2882.5	-43.4	-18.2	-2251.5	-9.9	105.1
Storey17	-3238.4	-48.8	-23.8	-2539.4	-2.9	132.8
Storey16	-3600	-36.1	-20.8	-2814.4	-4.8	70.3
Storey15	-3968	-42.3	-24.6	-3041.7	-5.5	105.2
Storey14	-4337.1	-45.5	-31	-3275.4	-4.2	93.2
Storey13	-4712.9	-48.1	-27.9	-3521.3	-8.8	87
Storey12	-5093.8	-44.5	-28.8	-3770.7	-10.7	103.5
Storey11	-5500.9	-30.4	-30.6	-4021.1	-13.8	74.5
Storey10	-5902.6	-36.6	-28.1	-4273.2	-12.5	134.2
Storey9	-6307.5	-38	-32.7	-4548.1	-15	162.3
Storey8	-6716.9	-39.7	-33.8	-4819.2	-11.5	123.2
Storey7	-7136.3	-42.5	-26.6	-5089.5	-12.1	106
Storey6	-7560.7	-41.3	-24.3	-5357.3	-14.2	113.4
Storey5	-7988.7	-47.2	-24.3	-5622.4	-15.6	109.7
Storey4	-8423.2	-37.8	-22.7	-5888	-14.8	130.8
Storey3	-8863.4	-42	-10.4	-6154.9	-14.6	73.1
Storey2	-9312.3	-29.7	11.1	-6393.9	-13.8	72.8
Storey1	-9675.7	-6	42.7	-6582.8	-7.8	55.1

Table (3.4): Beams' maximum bending moments of unbraced rigid frame system.

Storey	Beam 190		Beam 348	
	S.F.	Max. (-ve) B.M.	S.F.	Max. (+ve) B.M.
	kN	kN-m	kN	kN-m
Storey25	127.2	-32.9	-61	-80.3
Storey24	140.4	-214.1	-66.2	-101.7
Storey23	155.6	-312.8	-57.3	-70.9
Storey22	171.3	-405.4	-44.2	-40.1
Storey21	181.3	-448.7	-51.9	-53.5
Storey20	178.2	-426.1	-32.5	-7.4
Storey19	161.6	-362.5	-22.9	19.3
Storey18	179.3	-449.2	-13.8	43.3
Storey17	216.2	-469.4	-33.4	8.4
Storey16	206.3	-295.9	-28.7	23.6
Storey15	141	-178.2	19.3	136.4
Storey14	133.3	-266.3	25.8	152.1
Storey13	142.1	-241	-13.3	66
Storey12	143.6	-252	18.6	135.5
Storey11	144.3	-256.8	-33	14
Storey10	148.7	-253.7	44.7	204
Storey9	216.2	-531.7	83.5	305.9
Storey8	221.8	-570.5	85.6	315.6
Storey7	267.2	-529.3	93.6	333.8
Storey6	274.7	-549.6	92.5	330.3
Storey5	225.3	-556.4	109.3	372.9
Storey4	224.6	-558	122	408.4
Storey3	223.9	-557	124.1	414.6
Storey2	175.3	-239.5	31.5	211
Storey1	107.9	-139.6	-10.2	72.1

Table (3.5): Beams' maximum shear forces of unbraced rigid frame system.

Storey	Beam 1		Beam 350	
	Max. (-ve) S.F.	B.M.	Max. (+ve) S.F.	B.M.
	kN	kN-m	kN	kN-m
Storey25	-111.9	-105.2	48.2	-91
Storey24	-124.5	-161.2	-28.5	7.6
Storey23	-125.1	-166.6	-29.1	3.2
Storey22	-127.4	-179.4	-8.1	-26.7
Storey21	-135.7	-201.5	-27.7	29.9
Storey20	-144	-226.9	-5.8	0.7
Storey19	-140.5	-224.9	-2	-4.4
Storey18	-139.6	-221.5	-17.7	44
Storey17	-143.6	-231.1	24.1	-15.3
Storey16	-148.2	-252.5	36.4	-2.4
Storey15	-151.3	-258.8	51.4	-11.2
Storey14	-159.5	-288.6	23.1	-10.9
Storey13	-162.1	-288.2	23.9	-11.7
Storey12	-170.7	-323.3	24.5	-11.9
Storey11	-166.6	-309.1	34.9	-7.3
Storey10	-167.5	-306.3	170.5	-183
Storey9	-169.1	-312.2	65.4	-52.9
Storey8	-168	-304.7	43.6	-29
Storey7	-159.1	-282.9	89.9	-19.7
Storey6	-151.4	-257.4	116.1	-40.6
Storey5	-153.4	-263.3	172.9	-99.6
Storey4	-155.2	-271.7	136	-85.6
Storey3	-154.1	-264.9	123	-98.3
Storey2	-150.7	-261.9	507.9	-482.8
Storey1	-131.4	-211.5	75.3	-47.6

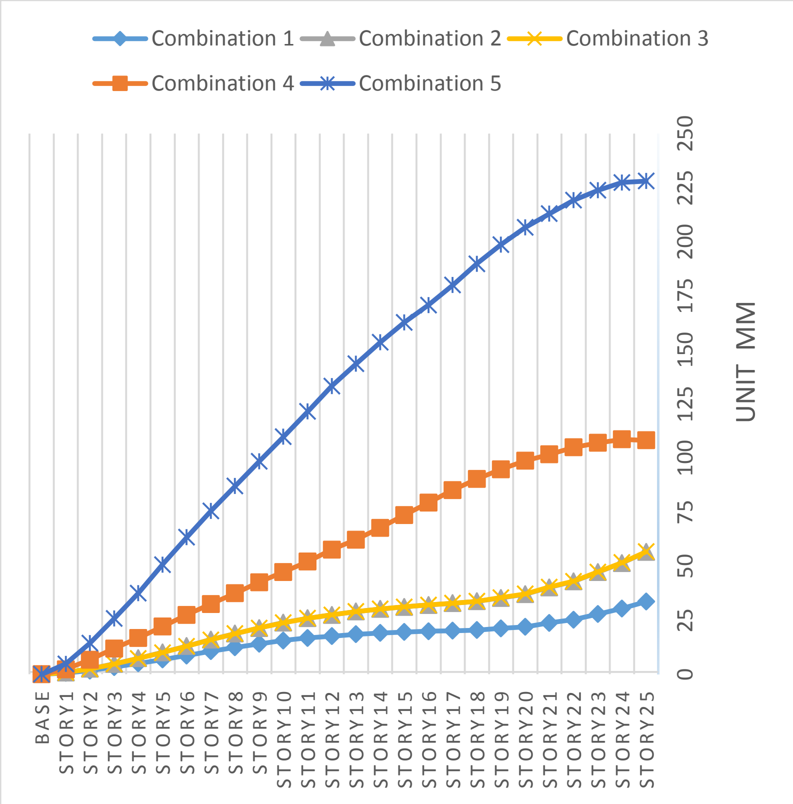

Figure (3.5): The distribution of maximum storey displacement in x-direction for all load combinations of unbraced rigid frame system.

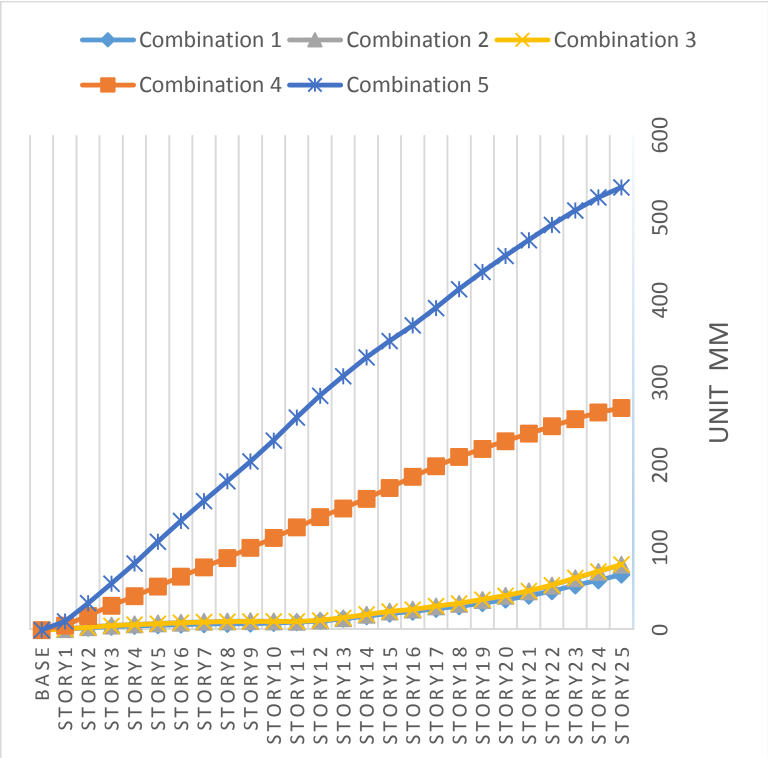

Figure (3.6): The distribution of maximum storey displacement in y-direction for all load combinations of unbraced rigid frame system.

3.4.2 Analysis Results of Rigid Frame With Cross Bracing System

1. Column Forces

In order to study a structural behaviour of rigid frame, it was taken edge, and internal column denoted by C24 and C1, respectively. The column forces summarised as shown in **Table (3.6)**, where P, M2, and M3 were axial forces, moment in x- direction, and moment in y- direction respectively.

2. Beam Forces

It also was taken the maximum values of bending moment and shear forces of the whole building's beams. The Beam results summarised as shown in **Tables (3.7)-(3.8)**.

3. Storey Displacements

The storey displacement gave an indication to the lateral effect due to wind loads on the building. The **Figures (3.7)-(3.8)** show the displacement of the storeys for all loads combinations.

Table (3.6): The distribution of axial forces and bending moments on columns C1 and C24 for load combination 3 of cross bracing rigid frame system.

Storey	Column 1			Column 24		
	P	M2	M3	P	M2	M3
	kN	kN-m	kN-m	kN	kN-m	kN-m
Storey25	-414.9	-13.3	-19.4	-274.3	-15.2	291.4
Storey24	-800.4	-15.8	-16.2	-540.3	-19.6	251.5
Storey23	-1186.9	-30	-19	-786.4	-14.7	247.8
Storey22	-1579.9	-32.5	-22.1	-1002.8	-27.4	214.7
Storey21	-1970.3	-49.6	-16.6	-1206.8	-12.7	213.4
Storey20	-2363.5	-46.9	-24.3	-1415.2	-5.6	329.3
Storey19	-2755	-59.7	-20	-1588.2	-9	164.8
Storey18	-3147.2	-62.8	-21.4	-1738.5	-4.6	198.2
Storey17	-3540.8	-52.6	-20.1	-1868.6	-8.6	99
Storey16	-3937.8	-67.5	-24.8	-1936.7	-7.3	95.4
Storey15	-4335.2	-65.3	-27.2	-2002.7	-6.5	95
Storey14	-4735.5	-70.7	-20.7	-2069.5	-6.5	94
Storey13	-5140.9	-55.2	-27.8	-2124.6	-6	87.2
Storey12	-5547.9	-58.9	-26.5	-2187	-5.7	68
Storey11	-5957	-58.7	-28.1	-2184.3	-5.8	47.4
Storey10	-6367.8	-62.8	-31.6	-2198.6	-6.1	82.7
Storey9	-6779.5	-61.8	-31.9	-2232.6	-6.4	49.9
Storey8	-7194.7	-56	-31.4	-2297.1	-8.2	95.6
Storey7	-7613.3	-64	-31.3	-2392.6	-8.6	64.1
Storey6	-8030.6	-62.7	-39.4	-2462.8	-7.5	64.6
Storey5	-8451.8	-57.2	-35	-2554.3	-11.2	71.4
Storey4	-8875.1	-57.7	-30.5	-2666.5	-11.6	88.6
Storey3	-9301.3	-62.4	-18.9	-2784.5	-14	67.4
Storey2	-9727	-59.2	-40.5	-2863.8	-11.5	91
Storey1	-10073.4	-9	-15	-2798.6	-3	28.6

Table (3.7): Beams' maximum bending moments of cross bracing rigid frame system.

Storey	Beam 190		Beam 348	
	S.F.	Max. (-ve) B.M.	S.F.	Max. (+ve) B.M.
	kN	kN-m	kN	kN-m
Storey25	132.1	-254.4	-38.2	-21.1
Storey24	178	-433.6	-40.8	-31.1
Storey23	167.9	-398.4	-40.5	-29.9
Storey22	161.7	-378.2	-40.9	-31.5
Storey21	160.3	-371.5	-40.9	-31.5
Storey20	179	-439.8	-40.9	-31.5
Storey19	170.6	-418.4	-40.9	-31.7
Storey18	163.7	-383.2	-42.3	-35.6
Storey17	155.1	-237.2	-42.4	-35.9
Storey16	106.4	-143.3	-40.5	-30.4
Storey15	104.6	-135.7	-41	-32.5
Storey14	99.3	-147	-41.3	-33.2
Storey13	102.2	-129.8	-41	-32.5
Storey12	123.9	-133.3	-40.9	-32.2
Storey11	90.3	-96.9	-41	-32
Storey10	80.6	-85.1	-40.3	-29.1
Storey9	102.5	-110.7	-39.9	-27.7
Storey8	84.9	-88.2	-40.1	-28.7
Storey7	98.5	-134.7	-39.8	-27.4
Storey6	79.4	-82.2	-40	-28.5
Storey5	80.2	-85.7	-40.3	-29.6
Storey4	105.2	-113.3	-40.3	-29.5
Storey3	97.3	-125.8	-40.3	-29.6
Storey2	105.6	-109.7	-40.4	-29.7
Storey1	93.4	-114.9	-37.5	-27.4

Table (3.8): Beams' maximum shear forces of cross bracing rigid frame system.

Storey	Beam 1		Beam 350	
	Max. (-ve) S.F.	B.M.	Max. (+ve) S.F.	B.M.
	kN	kN-m	kN	kN-m
Storey25	-32.9	-6.5	46.5	-53.8
Storey24	-45.8	-33.4	25.2	-21.7
Storey23	-45.7	-33.3	33.3	-32.9
Storey22	-43.9	-30.3	31.8	-28.9
Storey21	-45.1	-28.9	35.3	-31.9
Storey20	-45.1	-27.7	36.1	-31.1
Storey19	-45.6	-27.3	38	-31.9
Storey18	-46.2	-27.7	41.8	-35.2
Storey17	-45	-26	43.3	-36.2
Storey16	-44	-23.4	44.2	-37.1
Storey15	-43.7	-21.9	44.6	-37.6
Storey14	-42	-18.9	44	-36.7
Storey13	-39.5	-15.1	43.7	-36.2
Storey12	-38.6	-13.8	43.8	-36
Storey11	-38	-12.5	45.1	-37.8
Storey10	-38.1	-12.6	46.8	-39.6
Storey9	-38.4	-12.9	45.6	-35.7
Storey8	-38.2	-13	44.8	-36.3
Storey7	-38.4	-13.2	44	-33.8
Storey6	-38.7	-13.3	39.2	-27.5
Storey5	-38.4	-13.3	43.4	-33.6
Storey4	-38.8	-14.5	43.3	-34.4
Storey3	-39.4	-14.7	43.3	-35.5
Storey2	-37.2	-10.2	33.4	-23.7
Storey1	-34.7	-10.7	33.7	-25.7

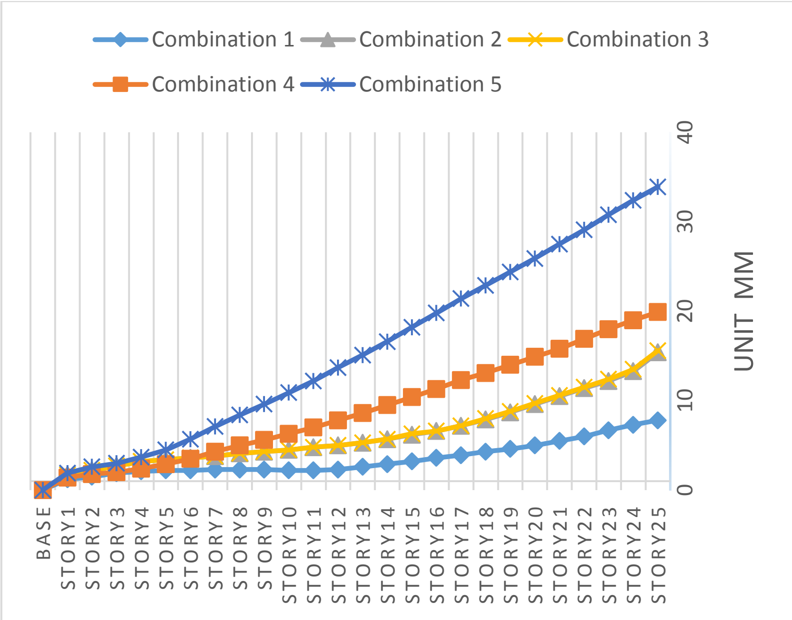

Figure (3.7): The distribution of maximum storey displacement in x-direction for all load combinations of cross bracing rigid frame system.

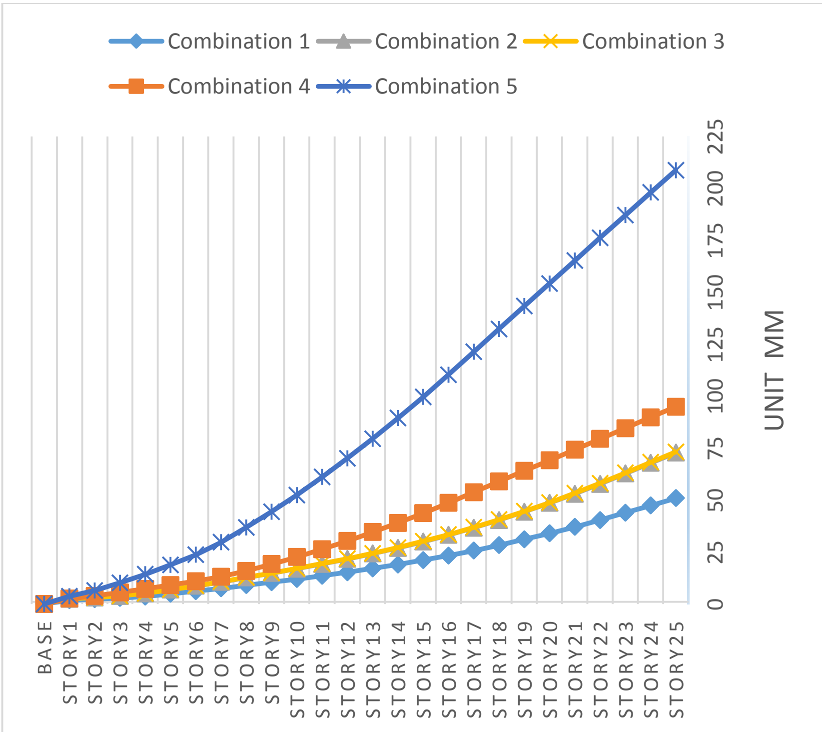

Figure (3.8): The distribution of maximum storey displacement in y-direction for all load combinations of cross bracing rigid frame system.

3.4.3 Analysis Results of Rigid Frame With Diagonal Bracing System

1. Column Forces

In order to study a structural behaviour of rigid frame, it was taken edge, and internal column denoted by C24 and C1, respectively. The column forces summarised as shown in **Table (3.9)**, where P, M2, and M3 were axial forces, moment in x- direction, and moment in y- direction respectively.

2. Beam Forces

It also was taken the maximum values of bending moment and shear forces of the whole building's beams. The Beam results summarised as shown in **Tables (3.10)-(3.11)**.

3. Storey Displacements

The storey displacement gave an indication to the lateral effect due to wind loads on the building. The **Figures (3.9)-(3.10)** show the displacement of the storeys for all loads combinations.

Table (3.9): The distribution of axial forces and bending moments on columns C1 and C24 for load combination 3 of diagonal bracing rigid frame system.

Storey	Column 1			Column 24		
	P	M2	M3	P	M2	M3
	kN	kN-m	kN-m	kN	kN-m	kN-m
Storey25	-413.8	-12	-20.9	-297.8	-2.1	109.5
Storey24	-799.7	-14.8	-12.1	-421.8	-2.8	97.5
Storey23	-1185.4	-24.8	-33.2	-736.5	-1.5	167.9
Storey22	-1571.9	-29.4	-14.9	-834.2	-3.8	127.7
Storey21	-1957.4	-39.7	-36.6	-1134.1	-0.7	130.2
Storey20	-2350.3	-42.2	-17.3	-1182.6	-4.5	94.1
Storey19	-2748.8	-47.5	-49.4	-1471.6	1.9	94.9
Storey18	-3151.9	-59.3	-9.2	-1524.5	-3.4	76.7
Storey17	-3557.3	-43.7	-58.5	-1788.5	3.4	93.6
Storey16	-3965	-71.3	-2	-1806.9	-4.2	79.8
Storey15	-4378.8	-56.4	-77.8	-2067.1	8	80
Storey14	-4801	-62.7	49.3	-2033.3	-5.6	59.5
Storey13	-5223.3	-45.9	-132.5	-2278.2	10.2	88.6
Storey12	-5649.7	-64.9	61.8	-2210.2	-5.3	43.5
Storey11	-6075.5	-48.5	-147.8	-2442	9.8	94.8
Storey10	-6503.5	-71.7	46.1	-2372.2	-7.3	55.8
Storey9	-6934.6	-43	-123.4	-2607.7	7.6	87.6
Storey8	-7368.3	-75.7	44.3	-2548.1	-8.5	78
Storey7	-7806.6	-43.5	-129.3	-2795.5	9.1	82.3
Storey6	-8243.3	-71.3	73	-2761.6	-15.4	55
Storey5	-8683.4	-52.3	-164.3	-3006.7	3.8	94.2
Storey4	-9118.4	-78.6	81.9	-3095.3	-12.9	96.4
Storey3	-9559.1	-47.3	-181.5	-3337.3	1.7	68.1
Storey2	-10003.9	-78.4	86.8	-3508.2	-15.9	65.1
Storey1	-10365	-0.7	-117.8	-3706.8	4.2	36.6

Table (3.10): Beams' maximum bending moments of diagonal bracing rigid frame system.

Storey	Beam 190		Beam 348	
	S.F.	Max. (-ve) B.M.	S.F.	Max. (+ve) B.M.
	kN	kN-m	kN	kN-m
Storey25	121.3	-70.8	-36.4	3.9
Storey24	136.4	-158.5	-39	-22.3
Storey23	143	-215.7	-38.3	-20.5
Storey22	155.4	-263.7	-39.1	-23.3
Storey21	137.4	-217.4	-39	-23.8
Storey20	129.4	-201.9	-38.9	-23.6
Storey19	129.6	-138.2	-38.6	-23.1
Storey18	124.1	-130.5	-37.9	-21.8
Storey17	109.9	-132.4	-38.4	-23
Storey16	107.1	-129.6	-37.9	-21.5
Storey15	115.4	-125.3	-38.1	-22.3
Storey14	111.4	-118.9	-38.2	-22.9
Storey13	111.8	-121.4	-37.5	-22
Storey12	114.2	-124.8	-37.8	-21.5
Storey11	112.9	-121.1	-37.2	-20.5
Storey10	109.6	-120.9	-38.1	-22.8
Storey9	100.4	-121.2	-38.6	-24.8
Storey8	110	-119.4	-38.2	-23.7
Storey7	111.9	-123.7	-37.1	-19.9
Storey6	96	-117.5	-37.8	-21.7
Storey5	105.9	-126.7	-38.1	-22.2
Storey4	112.2	-119.3	-37.9	-21.8
Storey3	105.7	-131	-38	-21.9
Storey2	108.9	-110.9	-36.9	-19.8
Storey1	97.1	-115.3	-33.6	-16.9

Table (3.11): Beams' maximum shear forces of diagonal bracing rigid frame system.

Storey	Beam 1		Beam 350	
	Max. (-ve) S.F.	B.M.	Max. (+ve) S.F.	B.M.
	kN	kN-m	kN	kN-m
Storey25	-32.1	-4	92.1	-153
Storey24	-45.2	-31.7	14.1	-28.1
Storey23	-45.3	-32.6	49.7	-92.2
Storey22	-46.2	-34.3	22.4	-35.8
Storey21	-46.2	-30.6	29.6	-41.3
Storey20	-45.3	-27.2	85.2	-138.9
Storey19	-43.9	-23.2	44.9	-52.6
Storey18	-44.4	-23.1	45.4	-48.9
Storey17	-42.4	-19.8	46.4	-49.4
Storey16	-43	-21	46.1	-48.7
Storey15	-40.2	-15.4	46.9	-48.7
Storey14	-37.3	-11.2	45.7	-48
Storey13	-35.8	-8.3	45.4	-45.5
Storey12	-34.8	-6.4	47.8	-50.5
Storey11	-34.1	-4.7	51.7	-52.4
Storey10	-35.2	-6.8	45.6	-40.5
Storey9	-34.1	-5	43.7	-40.1
Storey8	-34.2	-5	48.3	-41.2
Storey7	-32.2	-1.4	47.5	-43.1
Storey6	-33.3	-3.4	41.3	-32.1
Storey5	-32.9	-2.1	40.6	-34
Storey4	-34.3	-5.4	43.9	-33.4
Storey3	-34.8	-6.2	46.8	-36.1
Storey2	-33.7	-4	54.8	-46.5
Storey1	-30.8	-3.1	50	-41.1

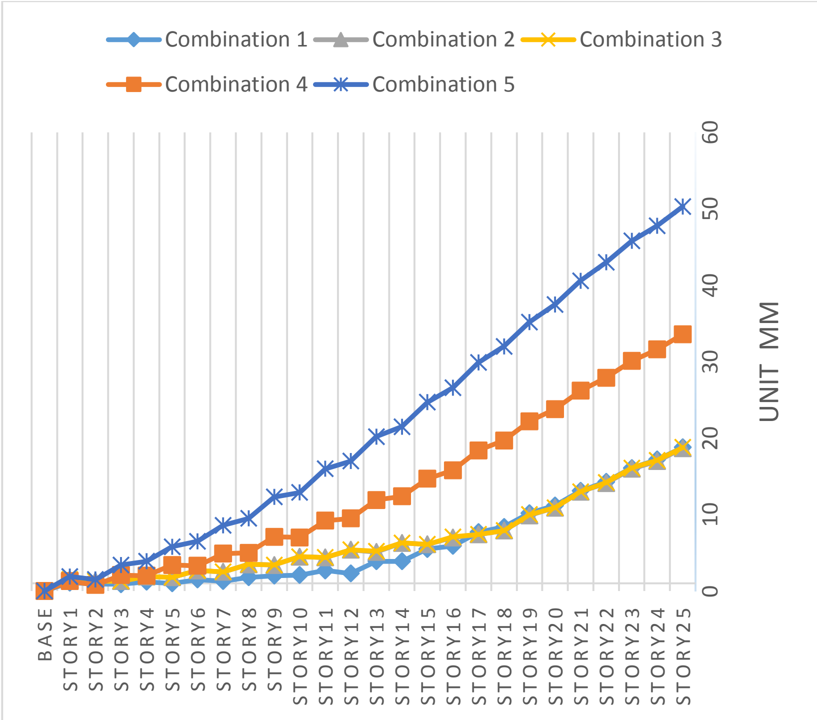

Figure (3.9): The distribution of maximum storey displacement in x-direction for all load combinations of diagonal bracing rigid frame system.

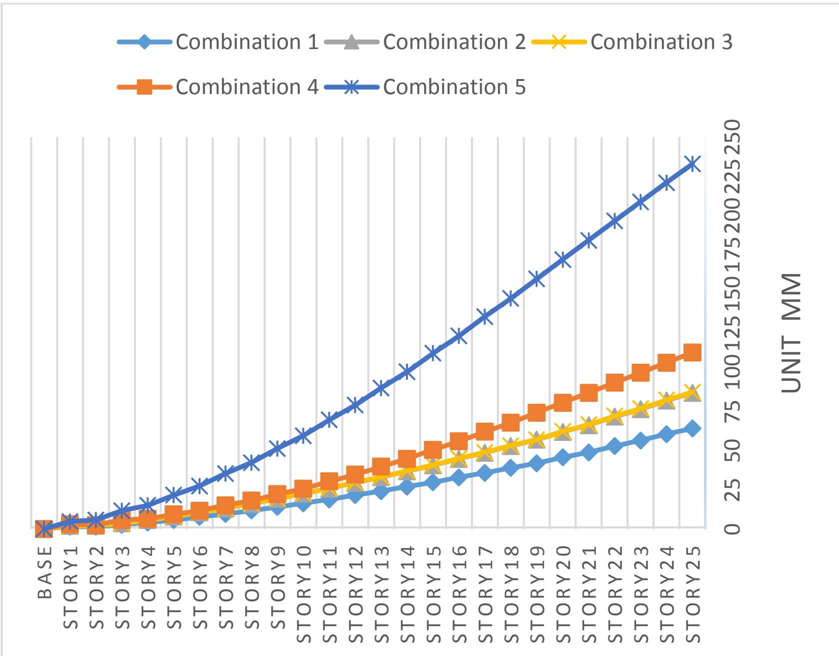

Figure (3.10): The distribution of maximum storey displacement in y-direction for all load combinations of diagonal bracing rigid frame system.

3.4.4 Analysis Results of Rigid Frame With V-shape Bracing System

1. Column Forces

In order to study a structural behaviour of rigid frame, it was taken edge, and internal column denoted by C24 and C1, respectively. The column forces summarised as shown in **Table (3.12)**, where P, M2, and M3 were axial forces, moment in x- direction, and moment in y- direction respectively.

2. Beam Forces

It also was taken the maximum values of bending moment and shear forces of the whole building's beams. The Beam results summarised as shown in **Tables (3.13)-(3.14)**.

3. Storey Displacements

The storey displacement gave an indication to the lateral effect due to wind loads on the building. The **Figures (3.11)-(3.12)** show the displacement of the storeys for all loads combinations.

Table (3.12): The distribution of axial forces and bending moments on columns C1 and C24 for load combination 3 of V-shape bracing rigid frame system.

Storey	Column 1			Column 24		
	P	M2	M3	P	M2	M3
	kN	kN-m	kN-m	kN	kN-m	kN-m
Storey25	-416.1	-11.7	-24.5	-281.2	-4.4	128
Storey24	-811.1	-13.9	-26.1	-494.6	3.6	131.8
Storey23	-1208.3	-26.8	-26.9	-711.5	3.4	186.1
Storey22	-1608.9	-29.7	-32.6	-923.4	4.5	191
Storey21	-2009.4	-44.5	-24.2	-1103.7	4.2	148.8
Storey20	-2411.6	-40.7	-38.4	-1251	4.3	104.6
Storey19	-2814.5	-54.5	-31.2	-1377.7	4.5	89.6
Storey18	-3216.5	-60.4	-26.7	-1500.2	4.3	86.1
Storey17	-3620.6	-43	-40.9	-1609.3	3.4	78.5
Storey16	-4026.4	-64.4	-32.9	-1717.5	3.5	81.9
Storey15	-4435.8	-62.3	-37.6	-1815	3.2	72.6
Storey14	-4846.9	-64.8	-24.1	-1901.1	1.7	75.7
Storey13	-5263.2	-55.2	-37.9	-1986.5	1.1	67.6
Storey12	-5681.2	-55.6	-33.4	-2066.1	1.3	75.8
Storey11	-6102	-57.4	-37.2	-2135	1.7	60.3
Storey10	-6524.1	-61	-36.8	-2191.6	0.8	76.3
Storey9	-6947	-61.1	-38.9	-2256.9	1.3	63.4
Storey8	-7371.5	-53.6	-32.7	-2346.9	2.2	65.3
Storey7	-7797.6	-62.5	-41.9	-2447.4	1.7	60.4
Storey6	-8223.9	-60.9	-33.6	-2570.4	0.6	68.5
Storey5	-8652.1	-63	-41.6	-2738.1	-0.9	86.4
Storey4	-9082	-56.2	-30.9	-2921.2	-2.2	99
Storey3	-9513.6	-62.1	-46	-3127	-4	80.4
Storey2	-9947.5	-68.7	28	-2103.9	3.1	80.2
Storey1	-10300.4	-8.8	-48.4	-2248.6	5.4	24.3

Table (3.13): Beams' maximum bending moments of V-shape bracing rigid frame system.

Storey	Beam 190		Beam 348	
	S.F.	Max. (-ve) B.M.	S.F.	Max. (+ve) B.M.
	kN	kN-m	kN	kN-m
Storey25	116.8	-81.6	-41.3	-15.4
Storey24	144.1	-205.1	-10.8	-5.1
Storey23	152.5	-255.4	-10.8	-3.1
Storey22	161.8	-311.4	-14.1	-6.5
Storey21	158.3	-301.2	-15.8	-8.3
Storey20	136.5	-218.6	-17.4	-10
Storey19	115.1	-144.1	-18.5	-10.9
Storey18	120.5	-127.9	-18.9	-11.3
Storey17	115.8	-122.9	-19.4	-11.7
Storey16	111.6	-119	-19.4	-11.8
Storey15	109.6	-117	-20.1	-12
Storey14	103	-110	-19.8	-12
Storey13	91.5	-109.9	-20.2	-12
Storey12	90.4	-107.3	-19.5	-11.2
Storey11	92.9	-108.9	-18.8	-10.7
Storey10	93.2	-99.9	-19.8	-11.9
Storey9	91.6	-111	-20.2	-12
Storey8	96.8	-103.8	-19.5	-10.9
Storey7	97.1	-104.4	-18.4	-9.9
Storey6	98	-104	-18.1	-9.5
Storey5	108.7	-115	-18.4	-9.9
Storey4	106.6	-128	-18.4	-9.4
Storey3	106	-129.8	-17.2	-8
Storey2	108.4	-112.8	-17.7	-9.8
Storey1	93.1	-103.9	-2.7	1.9

Table (3.14): Beams' maximum shear forces of V-shape bracing rigid frame system.

Storey	Beam 1		Beam 350	
	Max. (-ve) S.F.	B.M.	Max. (+ve) S.F.	B.M.
	kN	kN-m	kN	kN-m
Storey25	-33.6	-5.8	53.1	-67.1
Storey24	-46.5	-32.6	-3.9	16.9
Storey23	-46.7	-33.2	5.7	2.1
Storey22	-44.9	-31	6.3	1.9
Storey21	-45.7	-29.4	9.3	-1
Storey20	-45.2	-26.8	14.2	-5.2
Storey19	-45.3	-25.9	16.4	-7.1
Storey18	-45.7	-26.6	17.7	-8.2
Storey17	-44.5	-25.4	18	-8.6
Storey16	-43.9	-22.9	19.6	-10
Storey15	-43.7	-22.4	20.8	-11.1
Storey14	-41.9	-18.6	23.8	-13.6
Storey13	-39.9	-15.7	27	-16.3
Storey12	-38.3	-12.8	29.2	-18.2
Storey11	-37.3	-11.1	31.7	-19.9
Storey10	-37.6	-11.6	33.9	-21.7
Storey9	-37.7	-11.6	36.7	-24
Storey8	-37.2	-10.7	37.5	-24.9
Storey7	-37.2	-10.7	35.9	-23.5
Storey6	-37.7	-11.6	34.2	-22.2
Storey5	-37.3	-11.2	32.9	-21
Storey4	-37.4	-11.5	33.8	-21.7
Storey3	-37	-10.2	32.9	-21
Storey2	-39.3	-14.3	29.6	-18.5
Storey1	-36.8	-14.4	21.1	-11.1

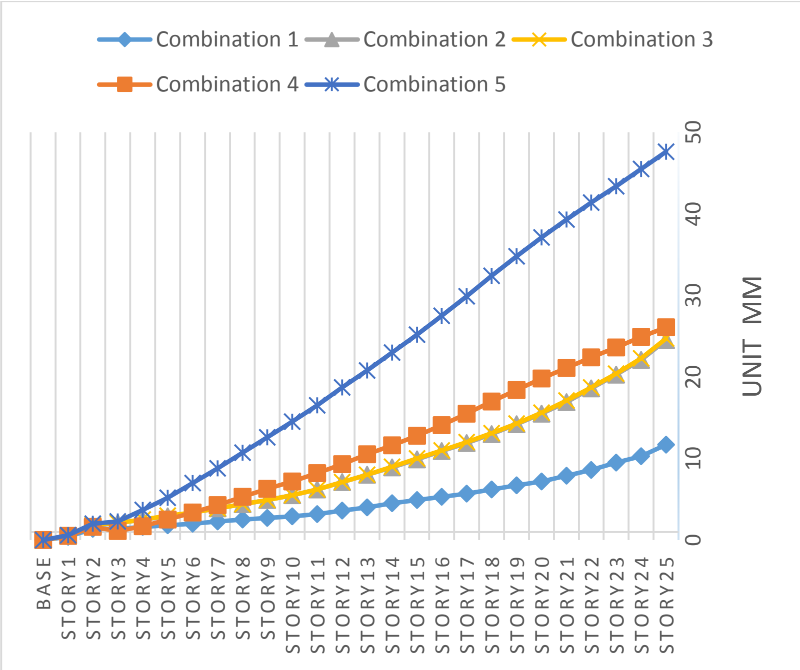

Figure (3.11): The distribution of maximum storey displacement in x-direction for all load combinations of V-shape bracing rigid frame system.

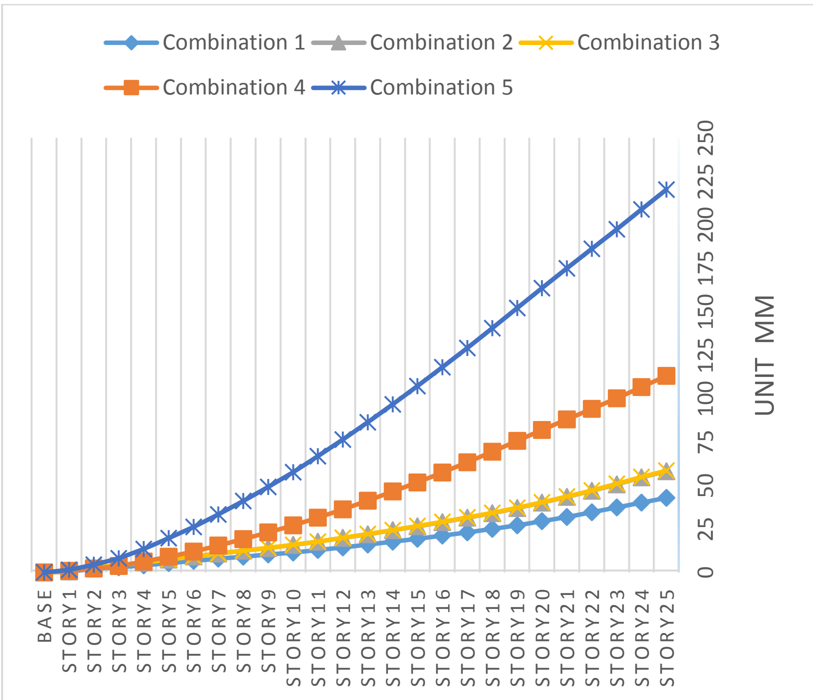

Figure (3.12): The distribution of maximum storey displacement in y-direction for all load combinations of V-shape bracing rigid frame system.

3.5 Structural Analysis of Tall Buildings Shear-wall and Tube Frames

The shear-wall tall building frames without bracing system gain stability resulted from couple shear-walls. The unbraced tube frame obtain the stability from columns and spandrel beams around the building. The bracing system increases the stability of the buildings. So, the analysis results and the storey displacements were reduced. By the same way, the analysis results that obtained from ETABS 2013 for the shear-wall and tube frames were presented and tabulated in **Appendix (B).**

3.6 Graphical Presentation of Analysis Results of Tall Building Frames

To make an adequate comparative study, the height of all three frames was equal as shown in section 3.3. Thus, three types of bracing systems that used were cross, diagonal, and V-shape bracings. The analysis results were summarized for three types of the frames in the previous section. In order to study the structural behavior, comparison between braced and unbraced frames was made for each steel frame of tall building. These results will be presented in charts to get the stress distribution for each frame set. The results of forces, for all braced systems of three mentioned steel tall building frames were presented below.

3.6.1 Analysis Results of Rigid Frames

In order to study the structural behavior of three selected types of tall building frames, it was considered stresses in beams and columns and storey displacements. As known, each frame was analyzed for three types of bracing. Also, for each frame the unbraced type was considered as basic reference for the comparison with bracing types. Therefore, beam and column samples were presented graphically to show the distribution of forces between braced and unbraced system of rigid frames.

1. Beams Forces

For a comparison purpose, rigid frame beams were selected, which have the maximum (+ve) and (-ve) bending moment for plan area. The results of bending moments and shear forces were drawn in graphical presentations with respect of the storey heights. The stresses of (B190), (B1), (B348) and (B350) shown in **Figures (3.13)–(3.14), (3.15)-(3.16), (3.17)-(3.18) and (3.19)-(3.20)** respectively.

2. Column Forces

The distribution of axial forces and bending moments of the interior and edge columns (C1 and C24) was represented for unbraced and braced rigid frame system as shown in **Figure (3.21)–(3.22)** and **(3.23)-(3.24)**. Note that, the M3 is the bending moment about the major axis, and M2 was neglected because it was too small comparing with M3.

3. Storey Displacements

In order to compare between unbraced and braced frames, the combination that gave the maximum storey displacement of the unbraced system was taken as reference. Then, the comparison of displacements with respect of storey heights was made about x- and y- axis and depicted in **Figures (3.25)–(3.26)**.

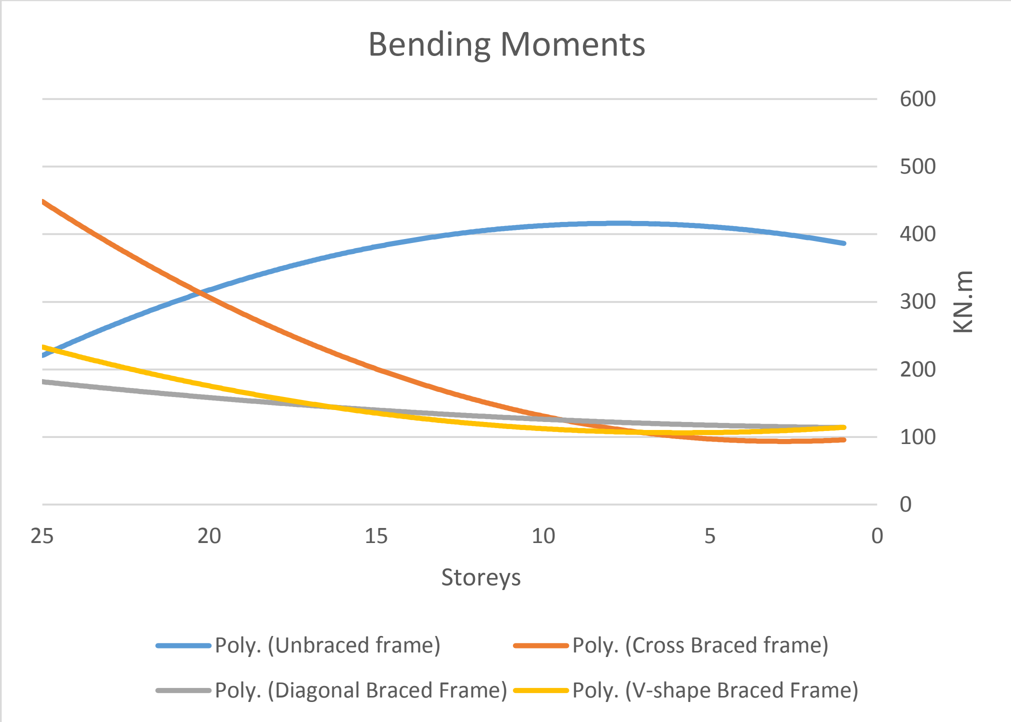

Figure (3.13): Distribution of bending moments of B190 of rigid frames.

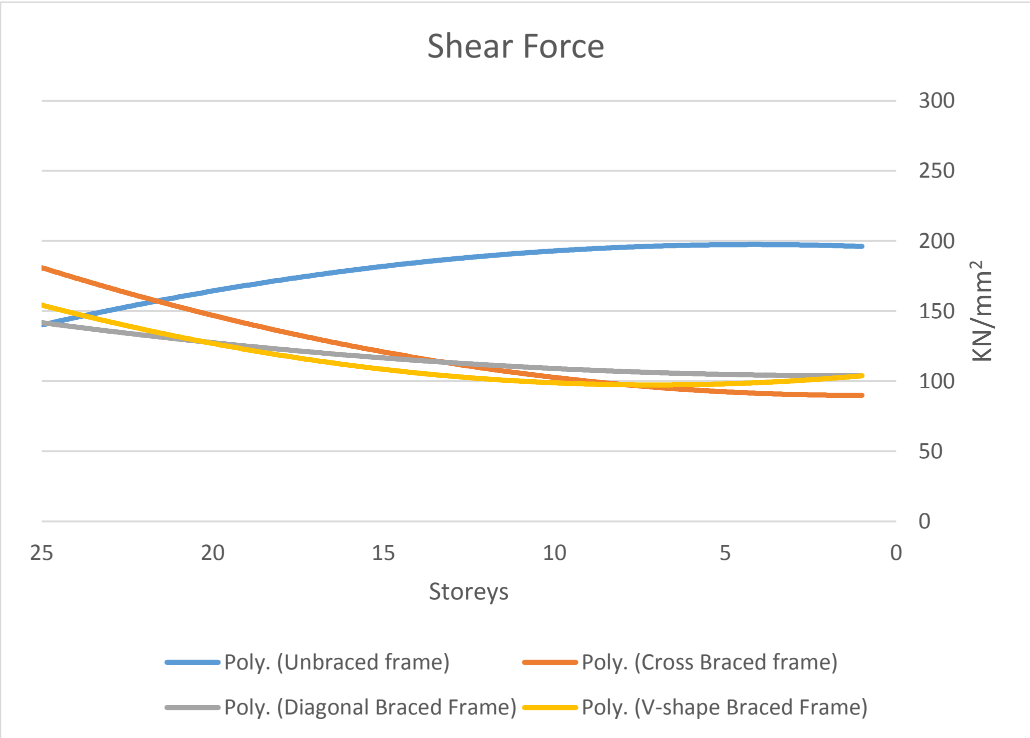

Figure (3.14): Distribution of shear forces of B190 of rigid frames.

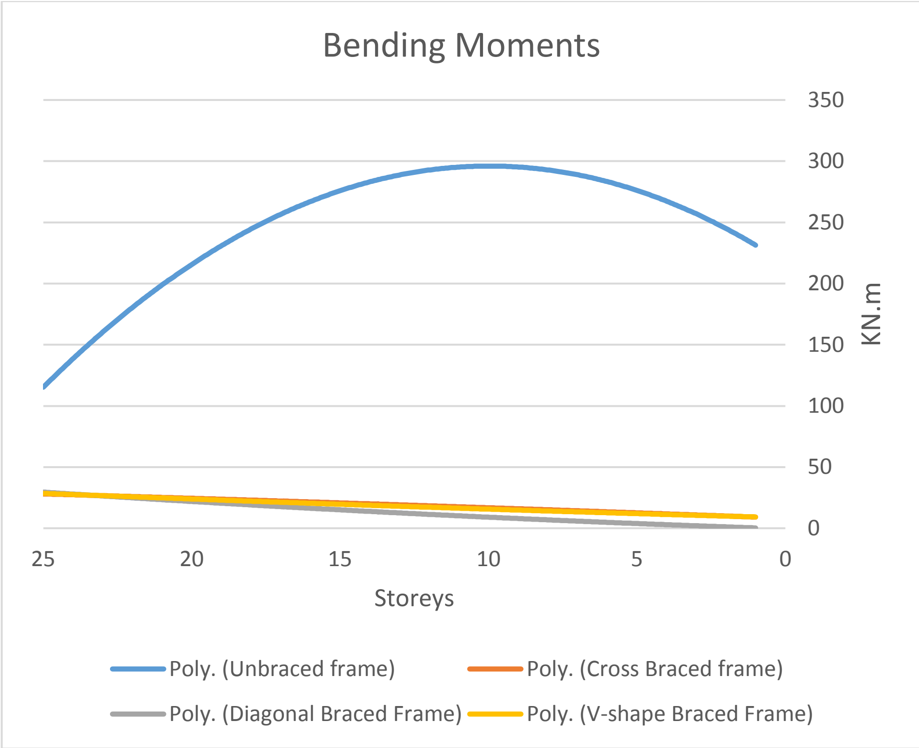

Figure (3.15): Distribution of bending moment of B1 of rigid frames.

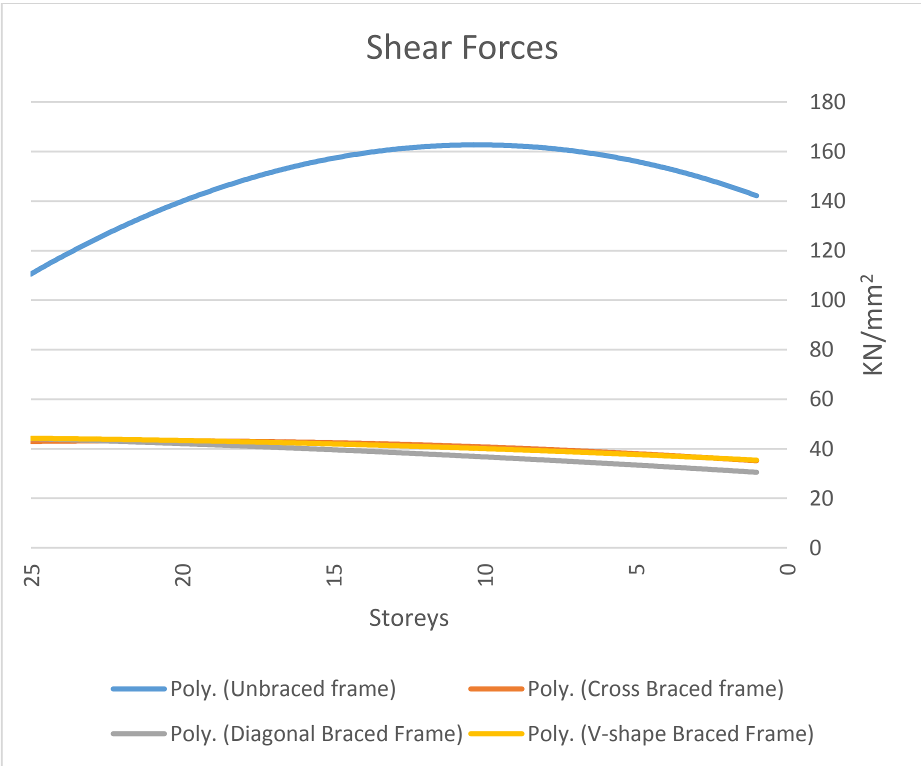

Figure (3.16): Distribution of shear forces of B1 of rigid frames.

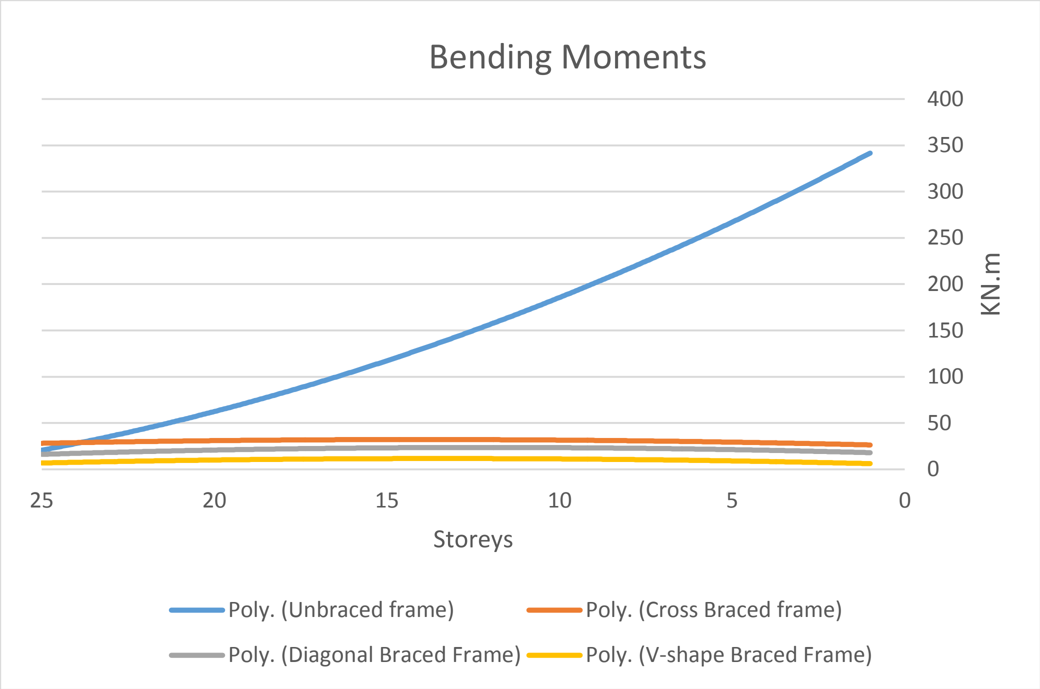

Figure (3.17): Distribution of bending moment of B348 of rigid frames.

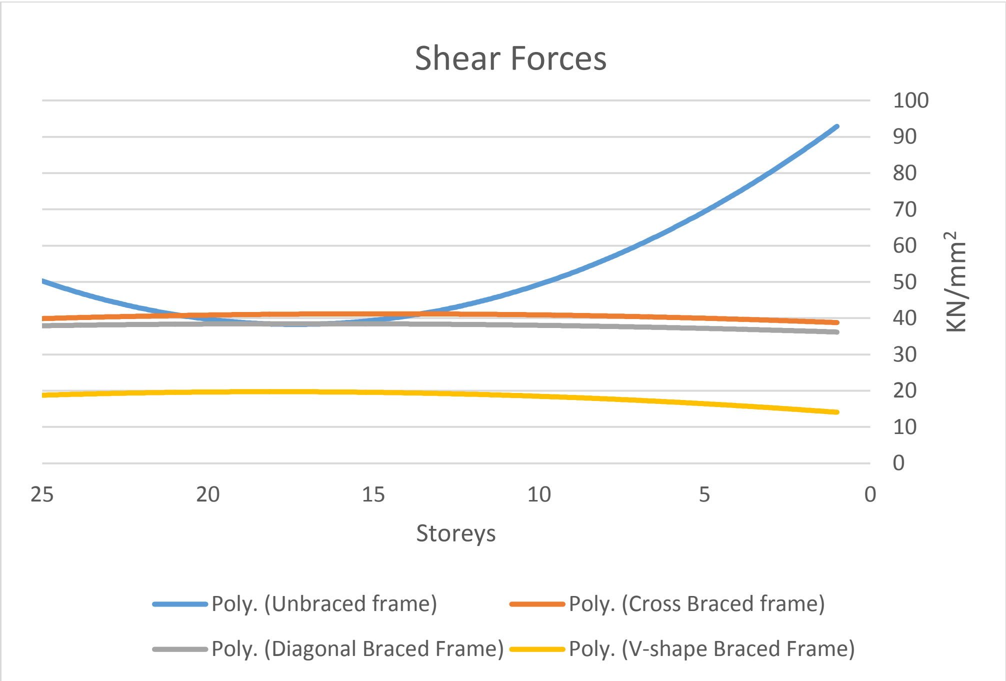

Figure (3.18): Distribution of shear forces of B348 of rigid frames.

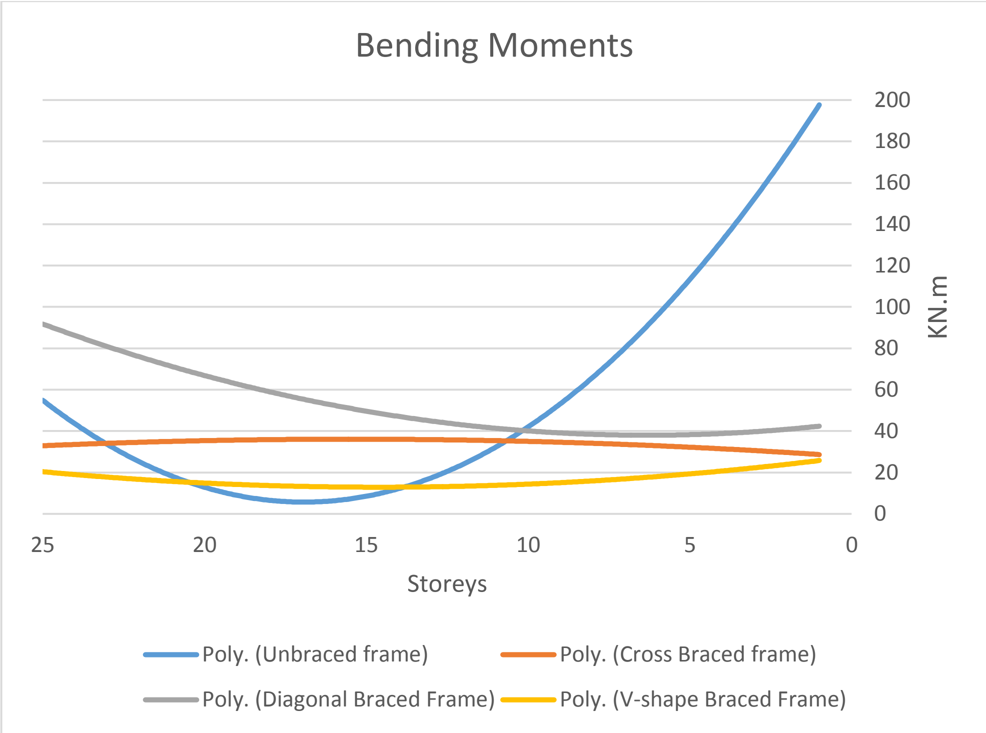

Figure (3.19): Distribution of bending moment of B350 of rigid frames.

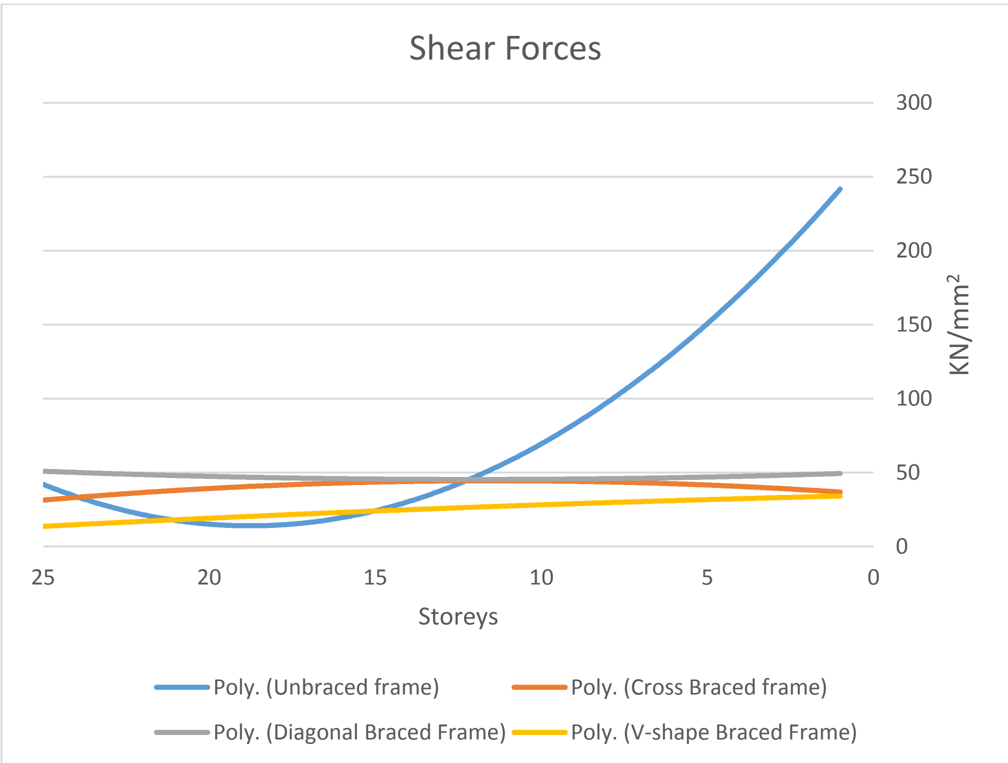

Figure (3.20): Distribution of shear forces of B350 of rigid frames.

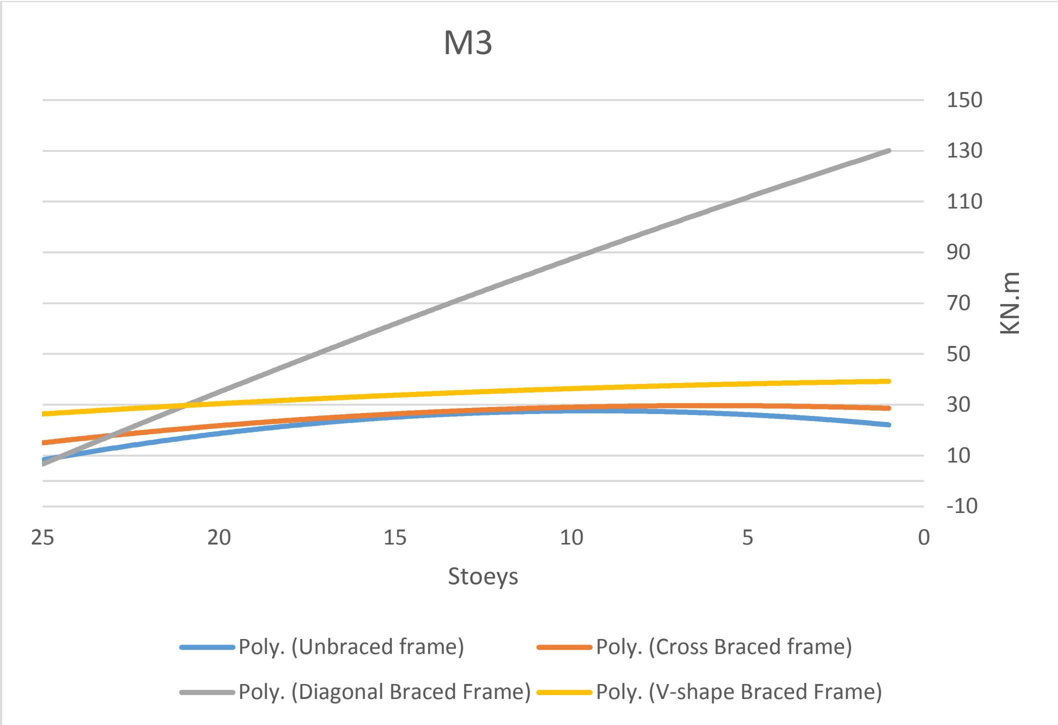

Figure (3.21): Distribution of bending moments of C1 of rigid frames.

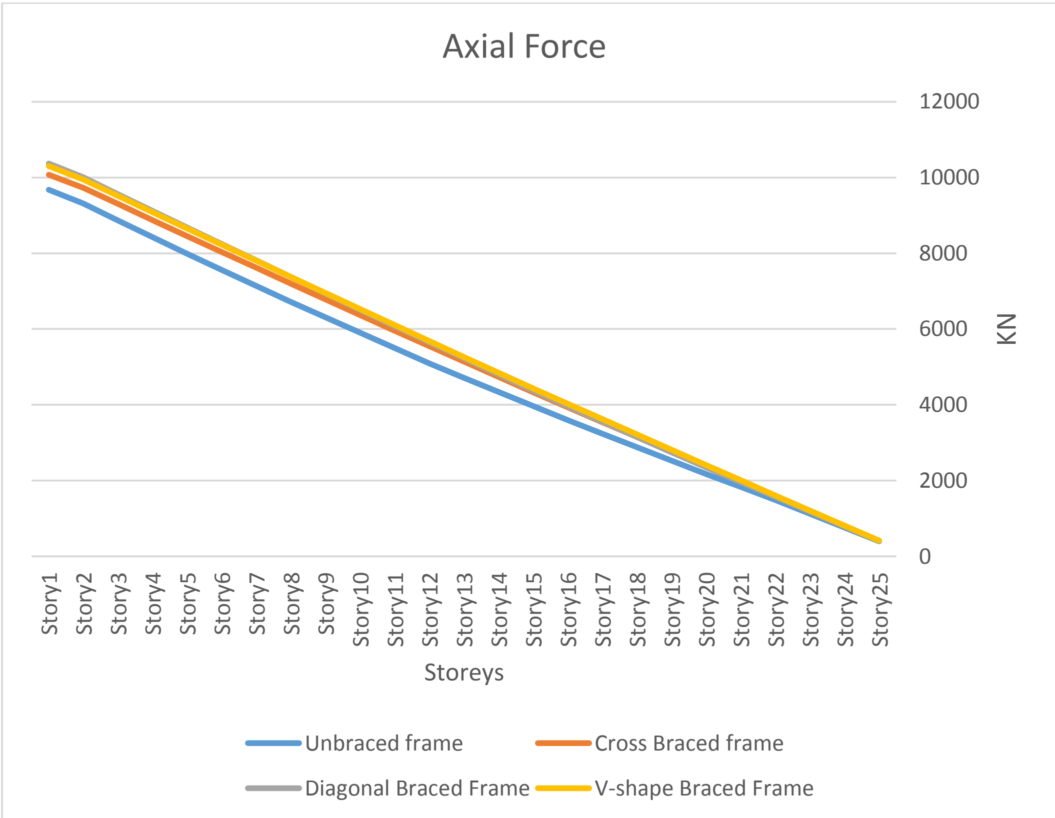

Figure (3.22): Distribution of axial forces of C1 of rigid frames.

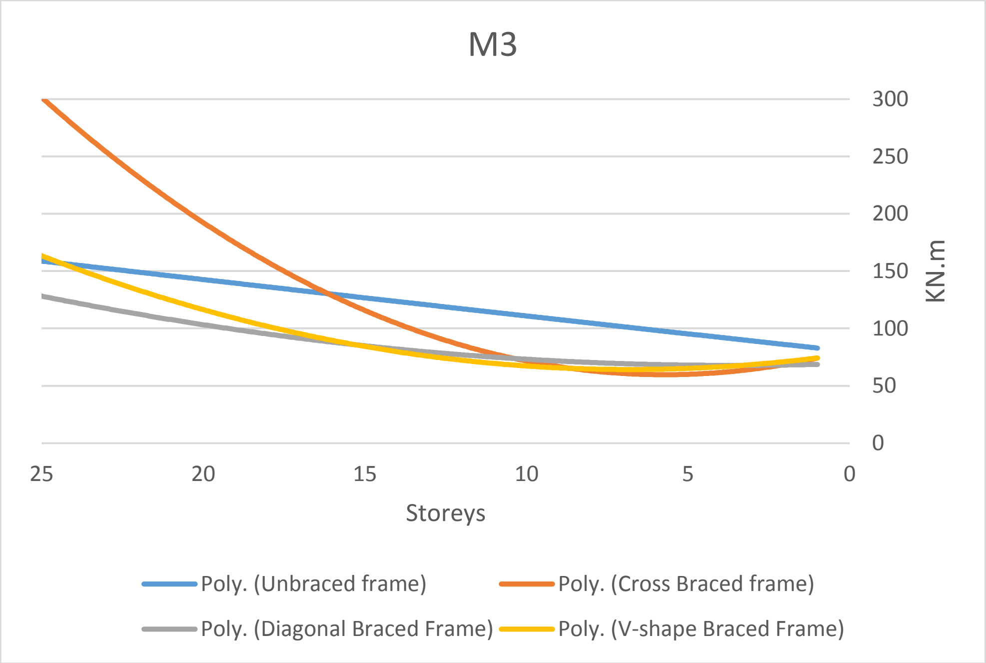

Figure (3.23): Distribution of bending moments of C24 of rigid frames.

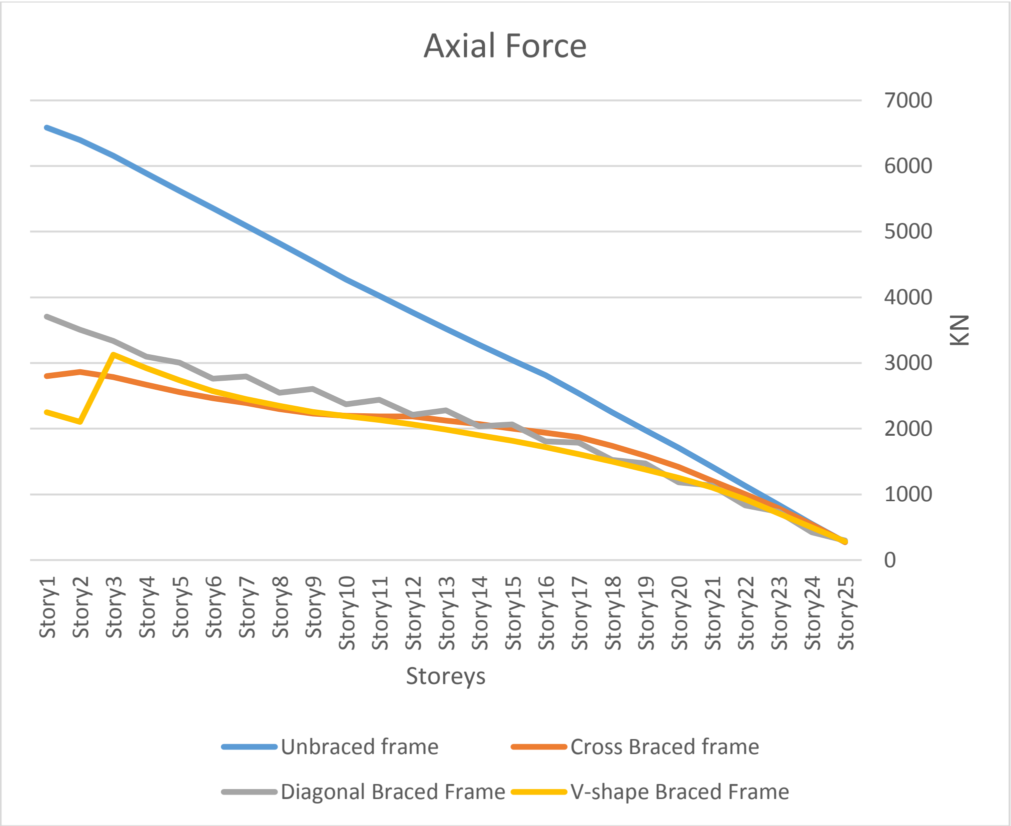

Figure (3.24): Distribution of axial forces of column 24 of rigid frames.

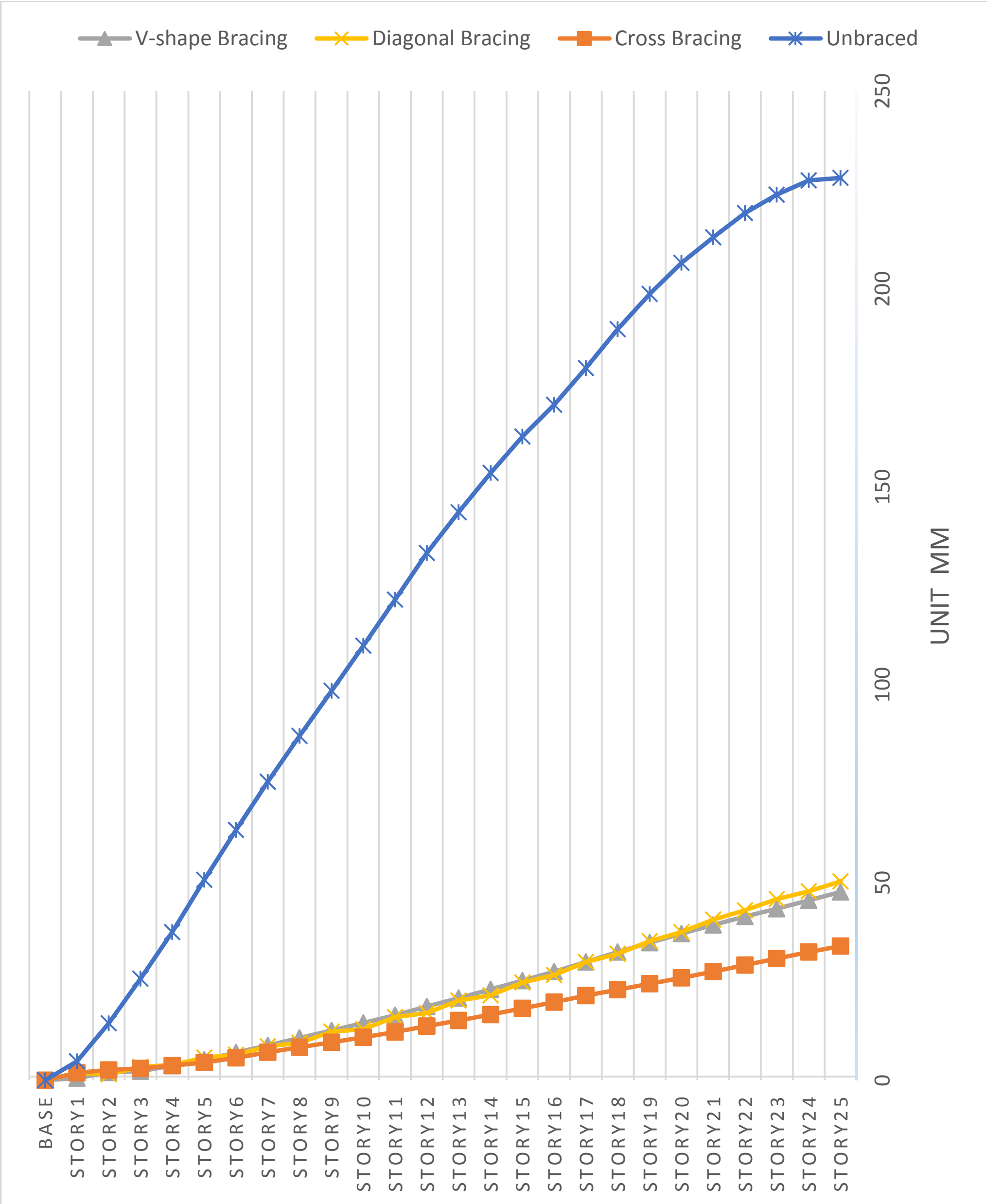

Figure (3.25): The distribution of maximum storey displacements in x-direction for all rigid frames models.

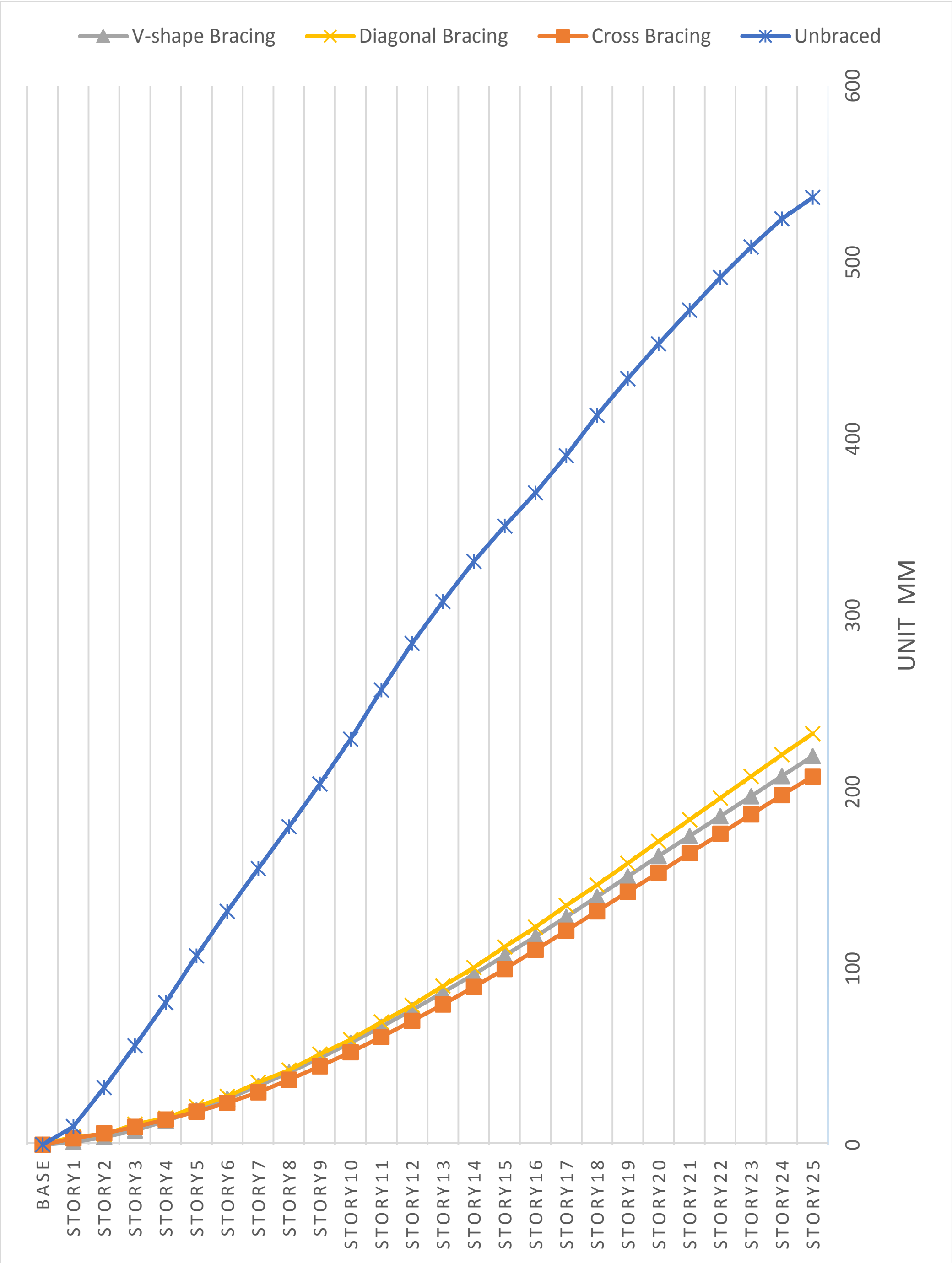

Figure (3.26): The distribution of maximum storey displacements in y-direction for all rigid frames models.

3.6.2 Analysis Results of Shear-wall and Tube Frames

By the same way, for each frame the unbraced type was considered as basic reference for the comparison with bracing types. Therefore, beam and column stresses were presented graphically to show the distribution of forces between braced and unbraced system for shear-wall and tube frames. This charts prefaced to discuss the analysis results after all frames would be designed. The graphical presentation was previewed in **Appendix (C).**