Analysis of Rigid Steel Frames With and Without Bracing Systems under the Effect of Wind Loads in Maysan Province.

Dr.Abbas Oda Dawood Ameen Ismael Atya

Civil Engineering Department
Misan University

Abstract:

Analysis of rigid steel frame with and without X- bracings at corners subjected to along wind loads in the Maysan province is presented. The nonlinear analysis using P-delta effect is accomplished by SAP 2000 V16 program. The basic wind speed for analysis purposes is specified according to Iraqi standards IQ 301. The static wind loads on the building is determined according to ACSE 7-05 standards. The main objective of this study is to investigate the effect of X-bracing system on the behavior a 12-storysquare rigid frame multi-story steel building. Variations of base shear, base moment, drift ratio, torsion bending moment, axial stresses, bending stresses, shear stress, axial force, shear force and displacement are considered for discussion and comparison. Its concluded that the presence of X-bracings is reduced the drift or lateral displacement by about 20% and also reduced the base moment by about 5% due to smaller drift led to smaller additional base moment due to P-Delta effect. Thus for rigid frame steel structure with up to 12 stories subjected to wind in Maysan province, the x-bracings is effective in stability and serviceability requirements.

Keywords: Maysan province, static wind analysis, along wind, x-bracing at corner and multi-story steel building.

تحليل البنايات الفولاذية مع أنظمة التقوية وبدونها تحت تأثير الأحمال الرياح في محافظة ميسان

ا.م.د. عباس عوده داود أمين إسماعيل عطية

كلية الهندسة / جامعة ميسان

المستخلص:

تحليل البنايات الحديدية مع وبدون X- bracings في الأركان التي تتعرض إلى أحمال الرياح في محافظة ميسان. يتم إجراء التحليل غير الخطي باستخدام تأثير P-delta بواسطة برنامج 16SAP 2000 V. تم تحديد سرعة الرياح الأساسية لأغراض التحليل وفقًا للمعايير العراقية 301 IQ. يتم تحديد أحمال الرياح الثابتة في المبنى وفقًا لمعايير 05-7 ACSE. الهدف الرئيسي من هذه الدراسة هو التحقق من تأثير نظام X-bracing على سلوك مبنى صلب متعدد الطوابق مكون من 12 طابقًا. يتم النظر في الاختلافات في القص القاعدة ، وعزم القاعدة ، ونسبة الانجراف ، وعزلة الانحناء ، والاجتهادات بأنواعها ، والقوة المحورية ، وقوة القص والإزاحة للمناقشة والمقارنة. وكانت الإزاحة الجانبية تقل بنسبة 20٪ تقريبًا ويقلل عزم القاعدة أيضًا بنسبة 5٪ تقريبًا بسبب الانجراف القليل ، مما أدى إلى زيادة عزم القاعدة بسبب تأثير P-Delta. وبالتالي ، لذلك فان للهيكل الحديدي 12 طابقًا تتعرض للرياح في محافظة ميسان ، فإن x-bracings فعالة في متطلبات الاستقرار وإمكانية الخدمة.

الكلمات المفتاحية: محافظة ميسان ، تحليل ثابت للرياح ، على طول الرياح ، تدعيم البناية الحديدية متعدد الطوابق في الأركان.

1. Introduction

Lateral loads due to wind which acting on a multi-story building can cause shake in the upper stories, because at upper stories the wind intensity is increasing with graduating heights [1]. Wind exerts forces and moments on the structure and its cladding exerting the wind pressure, which is the air distributed in and around the building. Sometimes because of unpredictable nature of wind it takes so devastating form that it can upset the internal ventilation system when it passes into the building. Hence, it has become of utmost importance to study the effect of wind and air flow on the building and its environment [2].

Winds and earthquakes represent the major environmental loads on structures in Misan province. There are two main winds in south of Iraq, North and North-Western winds and south and south-Eastern winds. The North winds prevail in south of Iraq during all seasons of the year and its dry and hot at summer while dry and cool at winter. The East winds are relatively warm and with high humidity. In additional to above two common winds, Iraq as a whole be under the effect of 120 weak cyclones per year, these cyclones disturb the flow air and lead to winds with variation directions [4].

In this study, along wind component is considered in the analysis. In the along wind direction, the wind velocities are obtained from Iraqi Code IQS.301 (Iraqi Code for forces and loadings) [3], which corresponds to the 3 second-gust speed at 10 m above ground in open terrain. The basic design wind speeds for Iraq is shown in Fig. (1) which it's clear that basic wind speed for example (Misan province) is 42 m/sec.

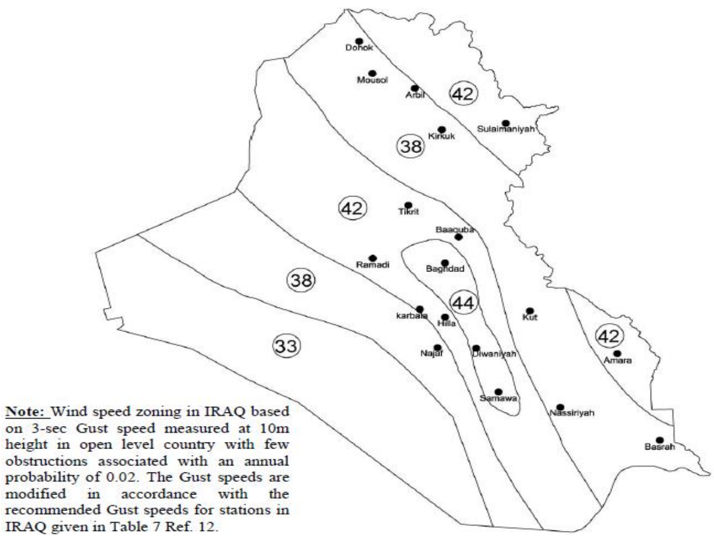

Fig. (1): Contour map for basic wind speeds m/s of Iraq [3].

2. Related Work

Suresh et al, 2012 [5], investigated both rigid and flexible structural behavior of sixteen story high-rise building under the action of static wind loads which represented by gust factor method as per IS 875-Part III. Their results are obtained via STAAD Pro software and the comparisons are based on drift values in which both cases of with and without x- bracings at all the four corners. They concluded that axial loads are almost same in both braced and unbraced structures and moments have reduced significantly in the braced structure compared to the unbraced structure . Bakhshi and Nikbakht,2011 [8], studied the distribution of wind load with two basic wind speeds (47 m/s and 76 m/s) according to ASCE7-05.They concluded that the structures with bracing system are more flexible that ones with shear wall system . Amol et al, 2016 [2],analyzed a high rise reinforced concrete building subjected to wind loading, with different bracing systems such as diagonal bracing, x-bracing, v-bracing, chevron bracing at different locations using STAAD Pro software. They concluded that both the type of bracing and the locations of bracings are of great importance in resisting lateral load . Hussain K.M, Sowjanya G.V, 2014 [9], studied the stability of rigid steel frames with and without bracing systems under the effect of seismic and wind loads using ETABS. They concluded that for highly affected earthquake zone-IV and for higher wind speed 50m/s, the structure having x- type bracings are more effective than other types of bracing .

3. Description of the Structure

The structure consists of five bays in both x-direction and in y-direction; each bay is (5x5m) center to center with a total height of 37 m. Thus have similar plan dimensions in XY plane of 25x25m as shown in Fig. (2). Typical floor to floor heights measured from centers of beams is 4 m for the ground floor and 3m for the other stories. The column bases are modeled as fixed at the ground level.

3.1. Modeling and Analysis:

A twelve stories building is modeled using SAP V2000 software. Two types of lateral resistance systems are modeled and analyzed for gravity and wind loads in Misan province, namely rigid steel frame with x-bracing and rigid steel frame unbracing as shown in Fig. (3).

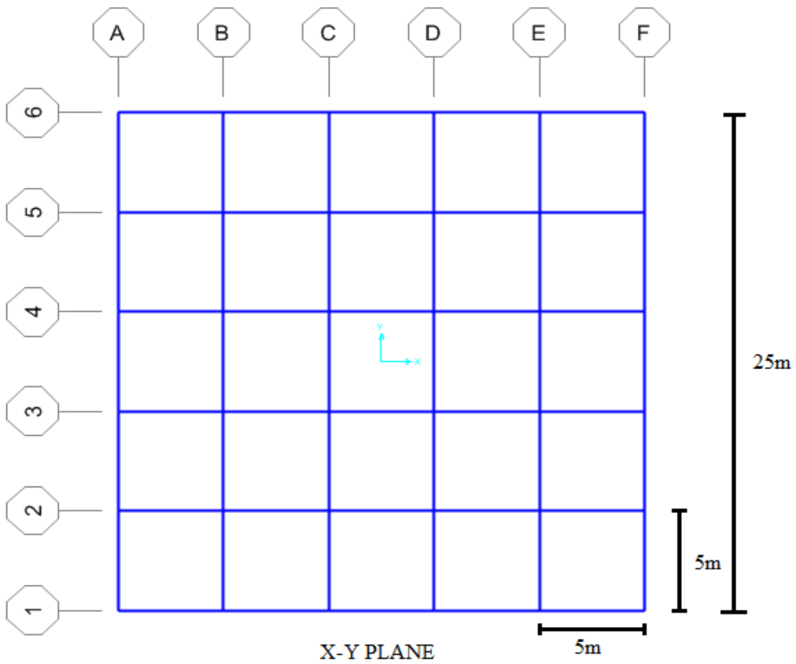

Fig. (2): X-Y Plan top view for steel building.

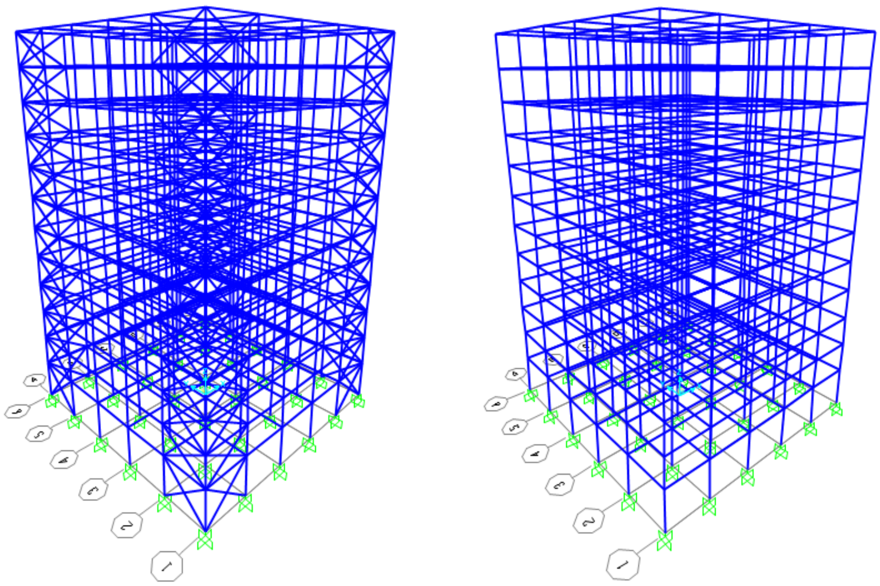

Fig. (3): 12 story rigid steel frame building with and without bracing

3.2. Material Properties:

The material properties of the steel used for beams, columns and bracings are presented in Table (1). A constant damping ratio of ($\zeta = 0.02$) is assumed and cross section properties can be clearly seen in Table (2).

Table (1): Steel material properties.

Item	Description	Unit	Value
Fy	Minimum yield stress	ksi_N/mm2	36_250
Es	Modulus of elasticity	N/mm2	210000
ρs	Density	kN/m3	77
νs	Poisson's ratio	__	0.3

Table (2): Cross section properties for steel building.

Story NO.	Beam Section	Colume Section	Bracing Section
1	W14x38	W18x119	L8x8x0.5
2	W14x38	W18x119	L8x8x0.5
3	W14x38	W18x119	L8x8x0.5
4	W14x38	W18x119	L8x8x0.5
5	W14x38	W18x97	L8x8x0.5
6	W14x38	W18x97	L8x8x0.5
7	W14x38	W18x97	L8x8x0.5
8	W14x38	W18x97	L8x8x0.5
9	W14x38	W18x55	L8x8x0.5
10	W14x38	W18x55	L8x8x0.5
11	W14x38	W18x55	L8x8x0.5
12	W14x38	W18x55	L8x8x0.5

4. Description of Loading and Displacements Tolerances

4.1. Loading Conditions:

Floor and roof dead load is taken as ($4kN/m^2$), assuming steel deck slab rested on W-shape beams for industrial building. Live load is taken as ($6kN/m^2$) for industrial building according to ASCE/SEI 7–05 [6].

4.2. Static Wind Load Calculations:

The results of the static wind pressure are obtained from Dawood [4] according to ACSE 7-10 standards. Wind load along the building is summarized in Fig. (4) below as pressure units for south of Iraq, which can be easily to transformed to forces through multiplying by area upon which wind acts, then divided to numbers of nodes to become forces distribution on nodes. These pressures for 37m height (12stories), the static wind analysis pressures quantities are based on the following data:

1. Exposure: The building is located in Misan City (Urban area) so exposure B is used.

2. Importance factor, I=1.0.
3. Basic wind speed, V = 42 m/s.
4. The buildings are considered rigid building, namely H/B<4. Since the ratio of height to least horizontal dimension is less than 4, the fundamental natural frequency is judged to be greater than 1Hz, G = 0.85.
5. Topography factor, Kzt = 1.0.
6. Directionality factor, Kd = 0.85.

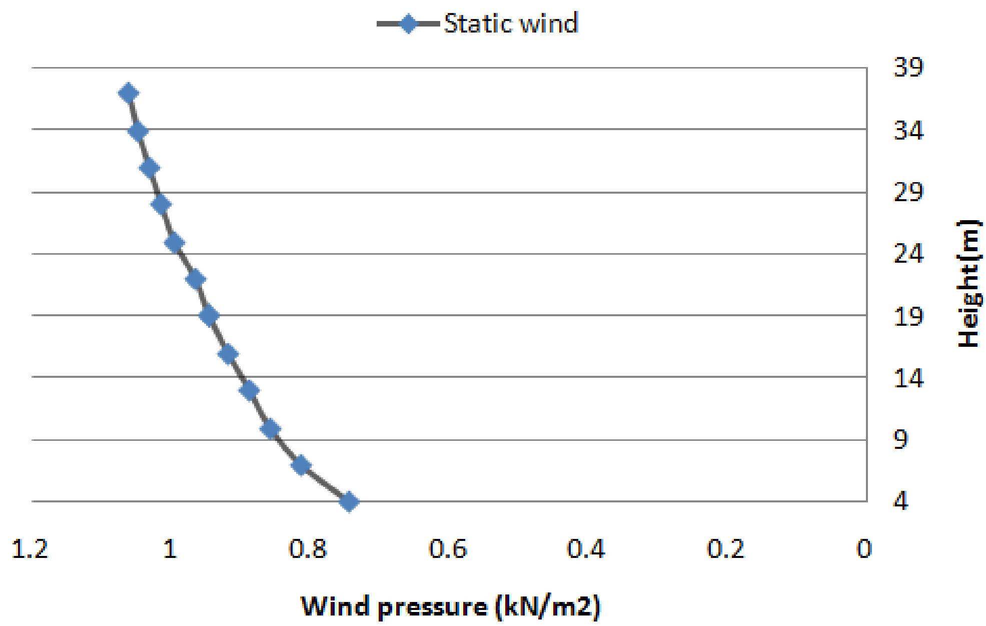

Fig. (4): Static wind pressures data [4].

4.3. Structural Tolerances for Wind Load:

According to BS 8110-Part 2: 1985 [7] the maximum allowable displacement is calculated as h/500, where h is the story height. Thus for a building with height of h=37m, the maximum top displacement (drift story) should be less than h/500=74mm so that the building is considered within allowable limit under wind load.

5. Results and Discussions

A Multi-story steel building of 37m height with two types of lateral resisting systems, namely rigid steel frame with x- bracing and rigid steel frame without bracing under the action of static force is analyzed via nonlinear with P-delta effect using the finite element analysis of SAP V2000 16 software. The static wind load obtained from Dawood [4] which includes static wind pressures for each floor in Misan province. The response of buildings are investigated through several parameters such as the maximum base shear, base moment, bending moment, axial stresses, torsion, bending stresses, shear stress, axial force, shear force and displacement in x-dir.

5.1. Base Shear X-Dir. and Base Moment in Y-Dir.

From the Table (3) it can clearly be seen that there is similarity between rigid frame without bracing and rigid frame with x-bracing in maximum base shear while slightly difference in base moment between them, the maximum base moment for rigid frame without bracing and rigid frame with x-bracing are equal to 20330and 19335.6 kN.m respectively, the difference between them is 5%. Thus under the same loadings and geometric conditions the base moment in case of braced system is less than that in case of unbraced system which reflect that x-bracing reduced the lateral displacement of the building which led to reduction in additional bending moment due to P-Delta.

Table (3): Base shear x-dir. and base moment in y-dir.

Static wind load		
OutputCase	**Bace Shear X**	**Bace moment Y**
Text	KN	KN-m
Braced	790.8	19335.6
Unbraced	790.8	20330.2

5.2 Maximum Drift Ratio in X-Dir.

The comparison between rigid frame without bracing and rigid frame with X-bracing in drift ratio in x-direction for 12 stories give the results shown in Fig. (5), these results showed that unbraced frame yield larger drift ratio than braced frame due to efficiency of x-bracing. The maximum values due to static wind load is 0.12% for rigid frame without bracing in third story while the maximum value for rigid frame with x-bracing under some conditions equal to 0.1%, the difference between them is 20%.

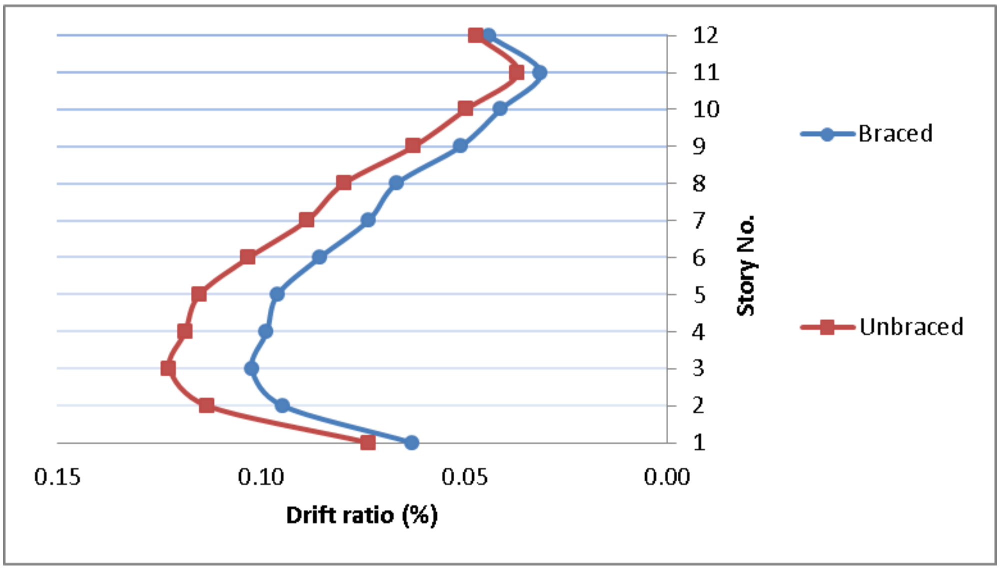

Fig. (5): Drift ratio % vs. story number for rigid steel frame building with and without bracing.

5.3. Maximum Stresses (S11, S12 and S13) due to Static Wind:

The stresses results are shown in Table (4), the maximum axial stress (S11) for both rigid frame without x-bracing and rigid frame with x-bracing occurred on the first story and equal to 292804kN/m² and296537kN/m² respectively, the difference between them is1%. The maximum bending stress (S12) due to static wind for both rigid frames without bracing and rigid frame with x-bracing occurred on the eleventh story and equal to 62441kN/m² and64367.86kN/m² respectively, the difference between them is3%. The maximum shear stress (S13) due to static wind with rigid frame with x-bracing occurred on the eleventh story and equal to 15664kN/m² while for rigid frame without bracing occurred in seventh story and equal to14875kN/m², the difference between them is 5%. It's found that there is very little difference between rigid frame without bracing and rigid frame with x-bracing in stresses with closed values for axial stresses (S11) between them is observed due to the axial stress depend on gravity load in column, as shown in Fig. (6) while the maximum distribution of bending and shear stresses (S12 and S13) are clearly difference between rigid frame without bracing and rigid frame with x-bracing structure as shown in Figs. (7) and (8). The maximum (S11) occurred in column while maximum of (S12 and S13) occurred in beam.

Table (4): Max. stresses due to static wind loads.

Static	Without bracing			With bracing		
Story NO.	**S13**	**S12**	**S11**	**S13**	**S12**	**S11**
Text	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2	KN/m2
1	13351.420	56749.200	296537.360	13184.000	55967.000	292804.000
2	13931.000	59215.000	262647.000	13746.000	58311.000	260327.000
3	14279.660	60689.290	242983.810	14127.000	59800.000	239314.000
4	14487.530	61566.510	224059.450	14468.230	60751.130	220389.840
5	14660.950	62278.500	251070.320	14805.230	61657.210	246956.990
6	14794.910	62806.810	226954.940	15088.740	62660.230	225685.500
7	14874.760	63086.450	212045.980	15305.340	63396.940	231300.290
8	14830.370	62881.900	218976.980	15375.120	63559.090	232906.760
9	14742.710	62490.740	279136.680	15449.810	63661.800	272147.710
10	14801.540	62683.640	278389.630	15624.760	64301.740	274538.040
11	14756.240	62441.020	257738.420	15664.300	64367.860	253591.070
12	13651.420	57858.120	270273.690	14487.250	59499.050	271356.110

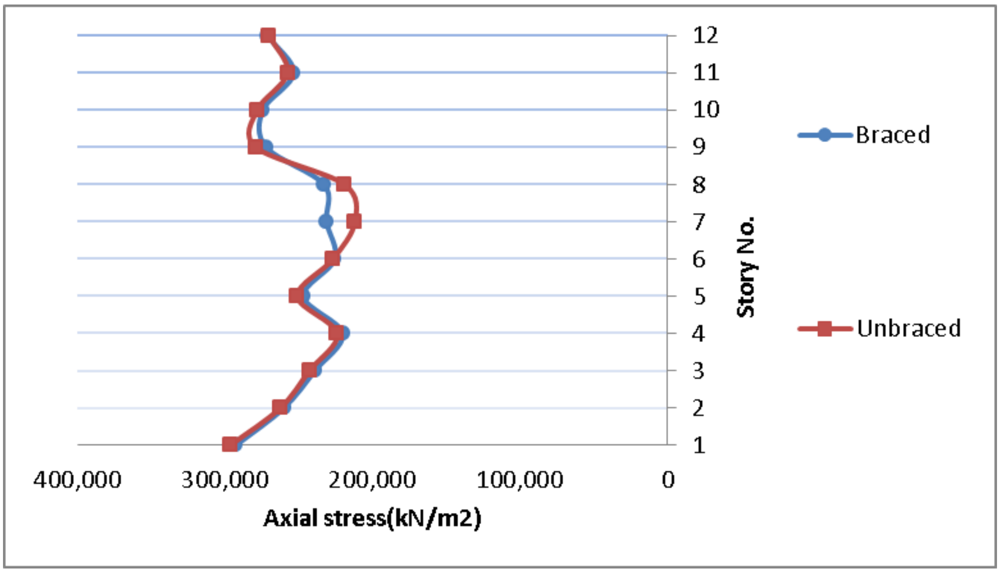

Fig. (6): Axial stress vs. story number rigid steel frame building with and without bracing.

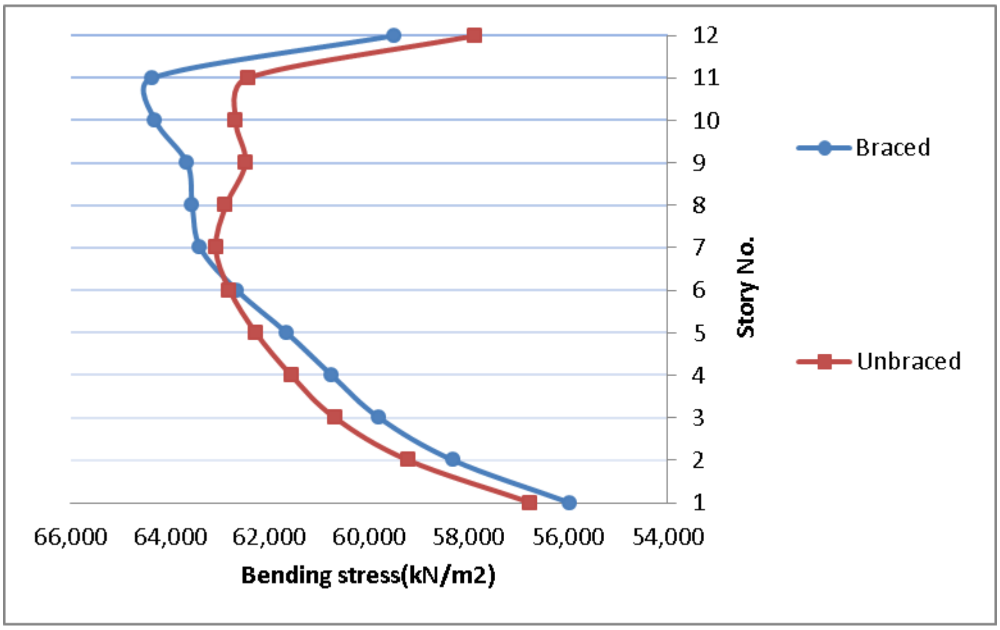

Fig. (7): Bending stress vs. story number for rigid steel frame building with and without bracing.

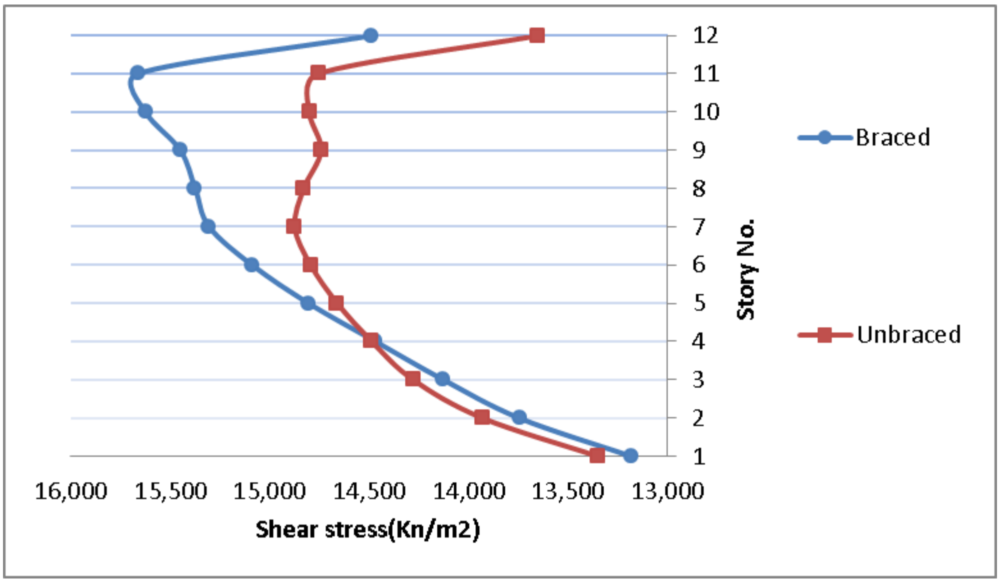

Fig. (8): Shear stress vs. story number for rigid steel frame building with and without bracing.

5.4. Maximum Torsion due to Static Wind:

Due to simple plan and simple elevation of the building, the torsion due to wind loads is negligible as shown in Table (5).

Table (5): Torsion per story number due to static wind loads.

Static	Braced	Unbraced
Story NO.	**T**	**T**
Text	KN-m	KN-m
1	0.016	0.004
2	0.022	0.003
3	0.020	0.003
4	0.018	0.004
5	0.009	0.005
6	0.008	0.005
7	0.007	0.005
8	0.012	0.007
9	0.019	0.012
10	0.020	0.012
11	0.020	0.012
12	0.025	0.016

5.5. Maximum Bending Moment due to Static Wind:

The results of bending moments are shown in Table (6), the maximum bending moment for rigid frame with x-bracing is occurred in a beams of the eleventh story and equal to 195.3kN.m while the maximum bending moment for rigid frame without bracing is occurred in the beams of seventh story and equal to 189kN.m as shown in Fig. (10), the difference between them is 3% namely slightly differences.

Table (6): Bending moment per story no. due to static wind loads.

Static	Braced	Unbraced
Story NO.	**M3**	**M3**
Text	KN-m	KN-m
1	143.631	148.693
2	158.877	164.726
3	168.343	174.116
4	174.253	179.576
5	179.505	183.921
6	185.817	187.238
7	190.415	188.966
8	190.957	187.276
9	190.630	183.891
10	194.669	185.088
11	195.317	183.797
12	159.710	149.930

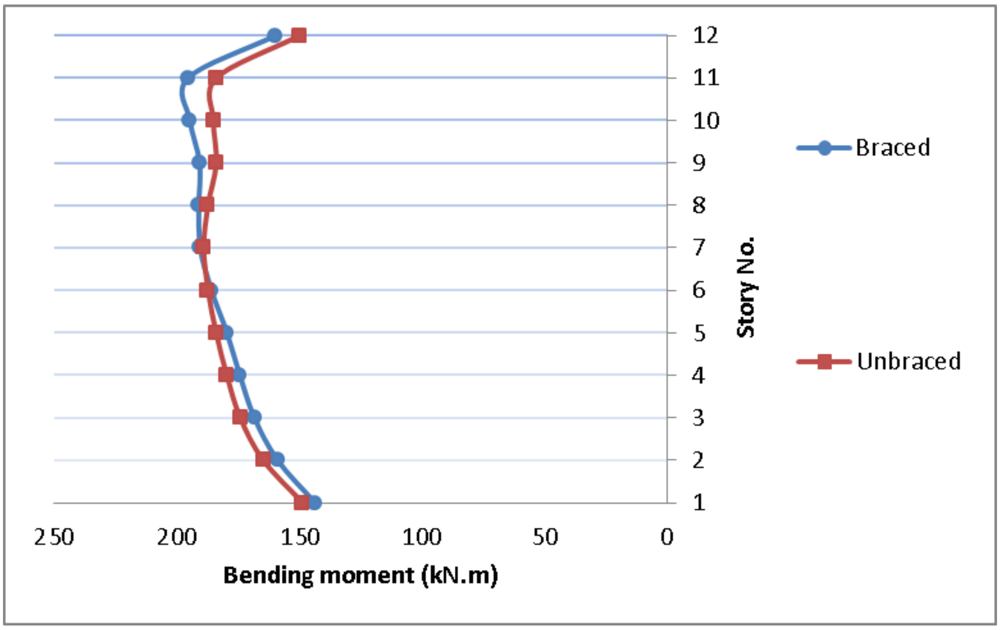

Fig. (10): Bending moment vs. story number for rigid steel frame building with and without bracing.

5.6. Maximum Axial Force and Shear Force due to Static Wind:

The maximum axial force and shear force results are shown in Table (7).The maximum axial force (compression) for both rigid frame without bracing and rigid frame with x-bracing are occurred in the in columns of first story with value of 6132kN, namely there is no difference between them due to the axial forces depending on gravity load.

The maximum shear force for rigid frame with x-bracing occurred in beams of eleventh story and to equal to 163kN, while for rigid frame without bracing its occurred beams of seventh story and equal to160kN, thus there is slightly a difference between them. But there is clear difference in shear forces at tenth story as shown in Figs. (11).

Table (7): Max. axial force and shear force due to static wind loads.

Static	Unbraced		Braced	
Story NO.	**V2**	**P**	**V2**	**P**
Text	KN	KN	KN	KN
1	144.203	6132.181	142.210	6132.357
2	150.470	5620.198	148.161	5620.383
3	154.216	5109.186	151.937	5109.384
4	156.444	4598.306	154.348	4598.523
5	158.252	4087.235	156.552	4087.475
6	159.593	3576.878	159.080	3577.139
7	160.304	3066.400	160.929	3066.688
8	159.780	2555.374	161.295	2555.69
9	158.783	2043.741	161.525	2044.053
10	151.476	1534.117	163.126	1534.38
11	158.650	1023.982	163.278	1024.167
12	147.011	514.992	150.933	515.127

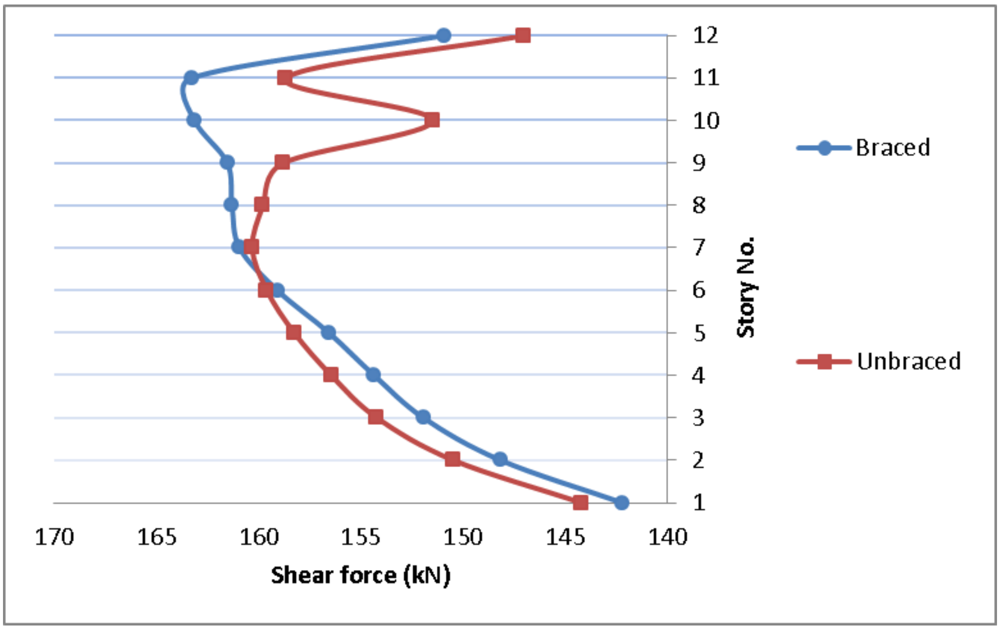

Fig. (11): Shear force vs. story number for rigid steel frame building with and without bracing.

5.7. Maximum Displacements in X-Dir. due to Static Wind:

From Table (8) it's found that clear difference of displacement in x-direction is increasing with increasing height under the effects of static wind loads, the maximum displacement for both rigid frames with x-bracing and rigid frame without bracing happened in last story and equal to 26, 31mm respectively, the difference between them is 20%. In general x-bracing play positive role in reduction lateral displacement of the building under wind loads as shown in Fig. (12).

According to BS 8110-Part 2:1985 the maximum allowable deflection is calculated as h/500, where h is the total height of building. Therefore, maximum allowable displacement value for building height of 37m is 74mm. The maximum value of displacement in serviceability limit condition obtained for static wind loads from the finite element 3-D model of SAPV2000.Pro is 31 mm is less than allowable (74 mm) for criteria failure, so the building in safe in both cases.

Table (8): Max. Displacement in x-dir due to static wind loads.

Static	Braced	Unbraced
Story NO.	**Ux**	**Ux**
Text	mm	mm
1	2.51	2.94
2	5.35	6.34
3	8.42	10.01
4	11.37	13.57
5	14.25	17.02
6	16.82	20.11
7	19.02	22.77
8	21.02	25.15
9	22.55	27.03
10	23.78	28.52
11	24.72	29.62
12	26.03	31.03

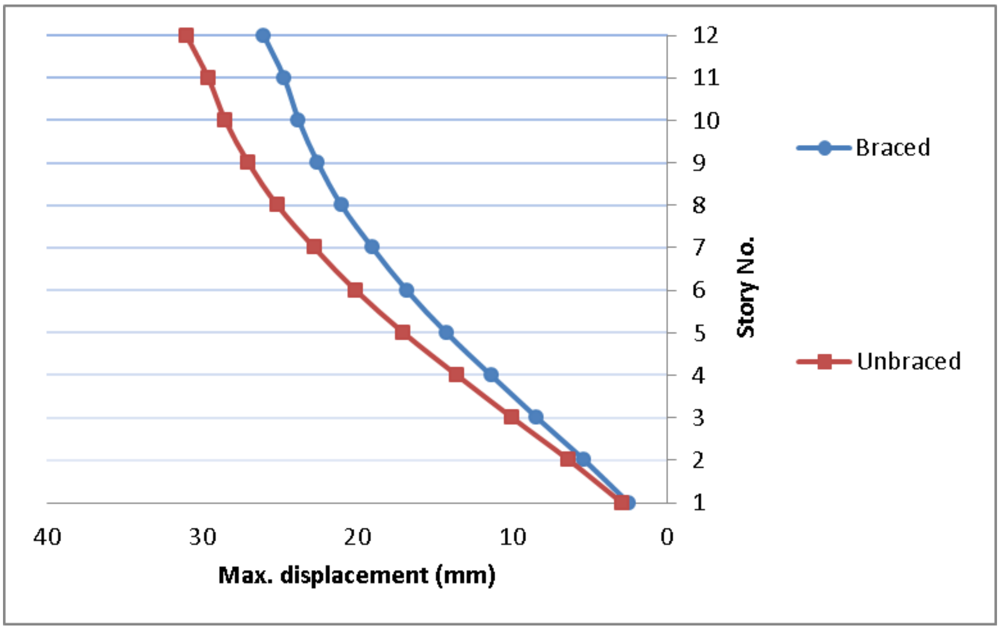

Fig. (12): Max. displacement vs. story number for rigid steel frame building with and without bracing.

6. Conclusions

From the present study and depending on its results the following points are concluded:

1. Base moment from unbraced structure is large than braced structure by 5% under the effect static wind loads due to x-bracing system.
2. Axial forces and axial stresses are identical in both braced and unbraced frame and the difference is approximately negligible because they are depending mainly on gravity loads.
3. Drift ratio and displacement from without bracing system is large than bracing state by 20% under the effect static wind load, but there are considerable differences at stories affected by wind pressure in Misan province.
4. Bending stress, shear stress, bending moment and shear force from unbracing system are large than bracing system by 3%, 0%, 3% and 0% respectively, under the effect static wind load so, there is slightly differences between them. But there are considerable differences at others stories by wind loads.

5. From above results and conclusions, it is clear that for rigid frame steel structure with up to 12 stories subjected to wind in Misan province, the x-bracings is effective in stability and serviceability requirements.

References

1. Muffassir S.R, L.G.Kalurkar. "Study Of Wind Analysis Of Multi-Story Composite Structure For Plan Irregularity ", IJATES, Volume 4, Issue 9, September (2016).
2. Amol S. Rajas, N.L.Shelke, "Wind Analysis of High Rise Building with Different Bracing Systems ", IJARSET, Vol. 3, Issue 4, April 2016, pp: 137-142.
3. Iraqi Standards IQ.301,"Iraqi Code for forces and loadings ", Iraqi Ministry of Building and Construction, 2014.

4. Dawood, A.O. Wind design load on high-rise reinforced concrete building in Mayan province southern Iraq ", Vol. 6, Issue 7, July 2017.
5. Suresh, P., Panduranga, R. B., Kalyana, R. J. S., " Influence of diagonal braces in RCC multi-storied frames under wind loads : A case study", International Journal of Civil and Structural Engineering, Volume 3, Issue 1, 2012.
6. ASCE/SEI 7-05," Minimum Design Loads for Buildings and Other Structures "American Society of Civil Engineers, 2005.
7. BS 8110-2:1985, "Structural use of concrete - Part 2: Code of practice for special Circumstances", 30 August 1985.
8. Ali Bakhshi and HamedNikbakht, "Loading Pattern and Spatial Distribution of Dynamic Wind Load and Comparison of Wind and Earthquake Effects along the Height of Tall Buildings" ASCE, Sharif University of Technology, Tehran, Iran, 8th International Conference on Structural Dynamics, Eurodyn, Leuven, Belgium, 4-6 July 2011.
9. Hussain K.M, Sowjanya G.V, "Stability Analysis of Rigid Steel Frames With and Without Bracing Systems under the Effect of Seismic and Wind Loads" International Journal of Civil and Structural Engineering Research,Vol. 2, Issue 1, pp: (137-142), September 2014.