



Structural Behavior of an RC Building Frame due to Wind Pressure in Bangladesh

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KEYWORDS

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Human Risk
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ABSTRACT

Since the necessity for larger and slimmer structures has arisen in Bangladesh, wind engineering has become increasingly important. The traditional approach of manual high-rise building design is time-consuming and prone to human mistakes. ETABS is a structural program that is currently widely used by structural engineers to handle common problems such as static analysis, wind analysis, and confirming multiple codes using various load combinations. The study's purpose is to compare wind pressure's impacts on eight distinct places in Bangladesh. ETABS 9.6 software with the BNBC provision was used to conduct this research on a 106-foot residential building. The study's major goal is to examine the reactions of stories, narrative displacement, and drift under the influence of wind in eight major distinct areas out of five divisions of Bangladeshi areas. Based on the investigation findings, we attempted to determine their attitude to various wind pressures. Analysis shows that wind pressure in the South-East and South-West is higher than in the North-East and North-West and most of it is found in the South-East.

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1. INTRODUCTION

When structures are taller than average, wind pressure analysis is required for the building design. Buildings become more flexible as they get taller, allowing them to accelerate away more quickly due to the high frequency of wind pressure. The wind analyses of high-rise buildings in different zones of Bangladesh's region are described in this research. In Bangladesh, wind engineering is frequently confused with wind energy. Wind engineering, on the other hand, is a distinct branch of engineering that studies the effects of wind on structures and their surroundings. Wind loads on formwork are necessary for the selection of formwork, so that wind loads on structural frames are required for the design of beams, columns, lateral bracing, and foundations. A ten-story reinforced concrete-framed structure has been chosen for the purpose of analysis. The BNBC code is used to determine wind analysis.

1.1 Literature Review

With the rise of human civilization, towering building designs have gained relevance. So, it is crucial to take into account the impact of lateral loads, such as earthquakes and

wind loads. Because the Key causes of structural collapse include dynamic excitations like winds and earthquakes [1][12][13]. The term "wind" refers to moving air and is frequently used to refer to the atmosphere's horizontal motion within a building. Building wind action is dynamic and affected by outside elements such as terrain type, height, exposure category, building type, location, fundamental wind speed, and building configuration. According to the BNBC recommendations for calculating the wind load for the study [2][15]. Bangladesh is situated at the longitudes of 88°01' and 92°4E and the latitudes of 20°34' and 26°38'N, which are made up of a number of tiny islands and a 724 km-long coastline [3]. The yearly average wind speed at 30 meters is more than 5 meters per second during the summer months. While the rest of Bangladesh has winds of about 3.5 m/s, northeast Bangladesh experiences winds of over 4.5 m/s [3]. In some circumstances, the wind load is more significant than the earthquake load. This depends on the location and zone factor, which are identified by regulations [5]. Because the effects of wind speed are so terrible, wind studies of structures are now required. Therefore, we must first evaluate the structure for wind speed. The worst outcomes will be

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experienced in the future if we choose to disregard this [4]. These structures' exterior surfaces are stroked directly by the wind, passing through the external surfaces' porosity to move the inside surfaces side to side. When the wind blows, it creates stresses that are perpendicular to the surface of the building or on certain cladding components. So, it has a significant impact on vertically standing walls, columns, and beams, among other architectural components like roof structures, such as truss structures, and flat slabs, which can be easily analyzed [6][9]. As a result, the shape of the structure and the computation of the wind forces on the various sides of the structure will be the focus of our analysis of wind load actions and its design. The two variables—wind velocity and building size—have an impact on how wind loads are calculated. As the need for higher, lighter, and more slender structures grows, so does the significance of wind-induced building motion design. Tall structures that fulfill the lateral drift standards of the code can nonetheless waver in high winds. As a result, a study of the computation strategies currently in use for determining wind load is required [7]. So, it is important to be able to predict the area affected by the plume resulting from an accidental or deliberate release of a dangerous substance inside a city and the concentrations of the pollutant in the area [8][9]. In addition, wind force is influenced by the geography and terrain of the area, the type of wind, the size and shape of the structure; and the dynamic qualities of the building [10][11]. When designing, it is crucial to take the variable wind pressure component into account. Generally speaking, the study compares the impacts of wind pressure in eight different locations in eight divisions around Bangladesh. Using the program ETABS 9.6, this analysis of a 106-foot residential structure was carried out. The major goal of the investigation is to analyze how stories respond to, move, and drift as a result of wind in eight distinct Bangladeshi areas. We attempted to determine their attitude zone-wise for various wind pressures from the study.

1.2 Objectives

- Wind analysis at eight different locations of a multi-story G+10 reinforced concrete building: story drift, story response, and displacement and
- to determine the design wind pressure at eight different sites.

2. BUILDING PROPERTIES

A model of G+10 stories is developed for analysis and design using ETABS software. The building plan dimensions are 59ft x 40ft.

Table 1. Building Properties

Column Size		Beam Size	
C 1	18"x18"	B1	14"x16"
C 2	20"x20"	B2	16"x18"
C 3	22"x22"	B3	17"x19"
		GB	16"x18"
		SB	14"x18"
Live load = 110 psf		f_c	=4 ksi
PW = 40 psf		f_y	=60 ksi

FF = 30 psf	Numerical Coefficient, R_w (5 for Z-I & Z-II and 12 for Z-III)	=5 and 12
Stair live load = 100 psf	Important Factor, I	=1
Wall = 5 inch	Building height, h	=106'
Shear wall = 10 inch		

These values are input to the ETABS software for drawing, analysis, and designing purposes.

2.1 Building Plan View

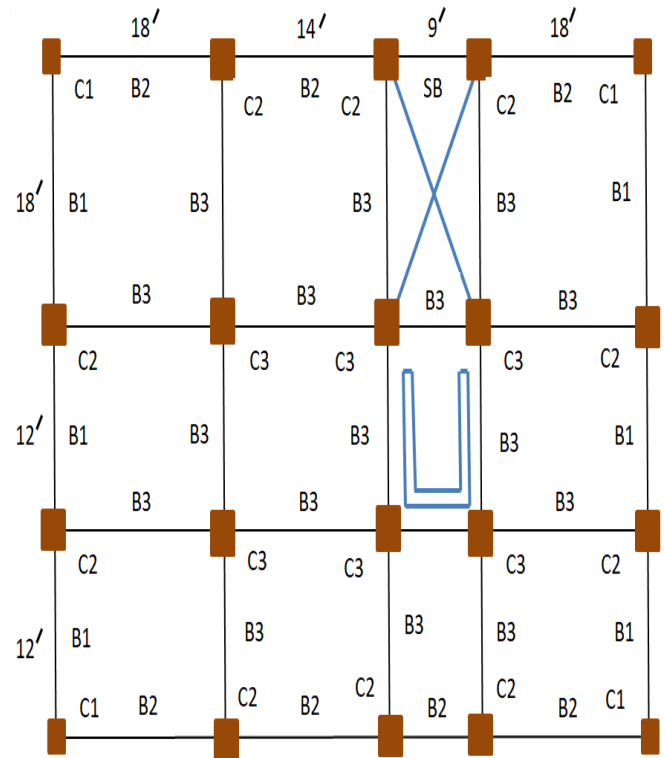


Fig. 1. Plan View of G +10 Storied RCC Frame Structure

2.2 Location Description

Table 2. Location Description as per BNBC Guidelines

Name of District	Zone Coefficient, (Z)	Site Soil Coefficient, (S) [Table 6.2.9]	Structure importance coefficient, (I) [Table 6.2.9]	Basic Wind Speed, (mph) [Table 6.2.8]
Dhaka	Z-II = 0.20	S-2 = 1.2	1	130
Chittagong	Z-III = 0.28	S-2 = 1.2	1	160
Rajshahi	Z-I = 0.12	S-2 = 1.2	1	95
Khulna	Z-I = 0.12	S-2 = 1.2	1	150
Gaibandha	Z-III = 0.28	S-2 = 1.2	1	146
Comilla	Z-II = 0.20	S-2 = 1.2	1	136
Jessore	Z-I = 0.12	S-2 = 1.2	1	142
Sirajganj	Z-III = 0.28	S-2 = 1.2	1	112

[The values of all coefficients and other information have been used as guided by BNBC.]

Wind speed variations at different location

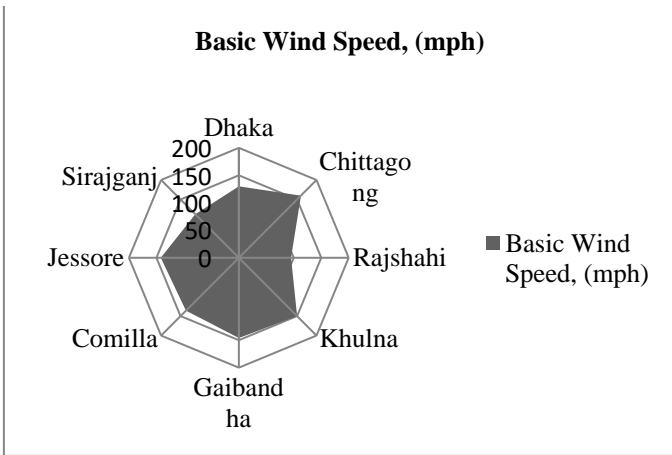
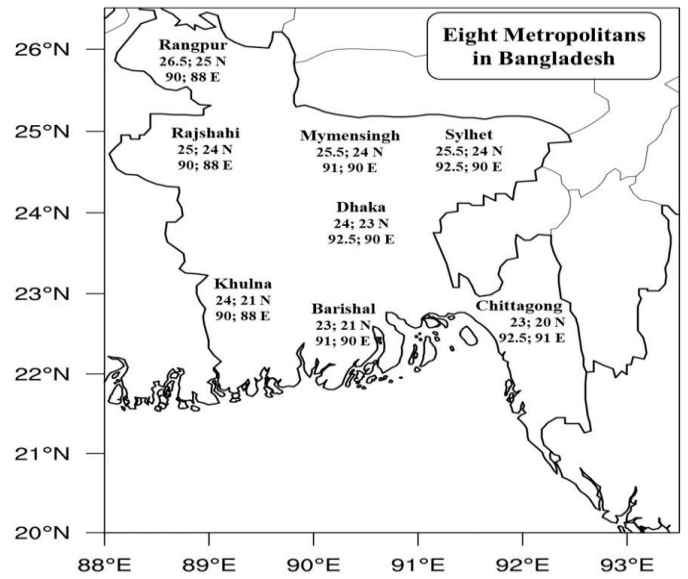


Fig. 2. Wind Speed at Different Location



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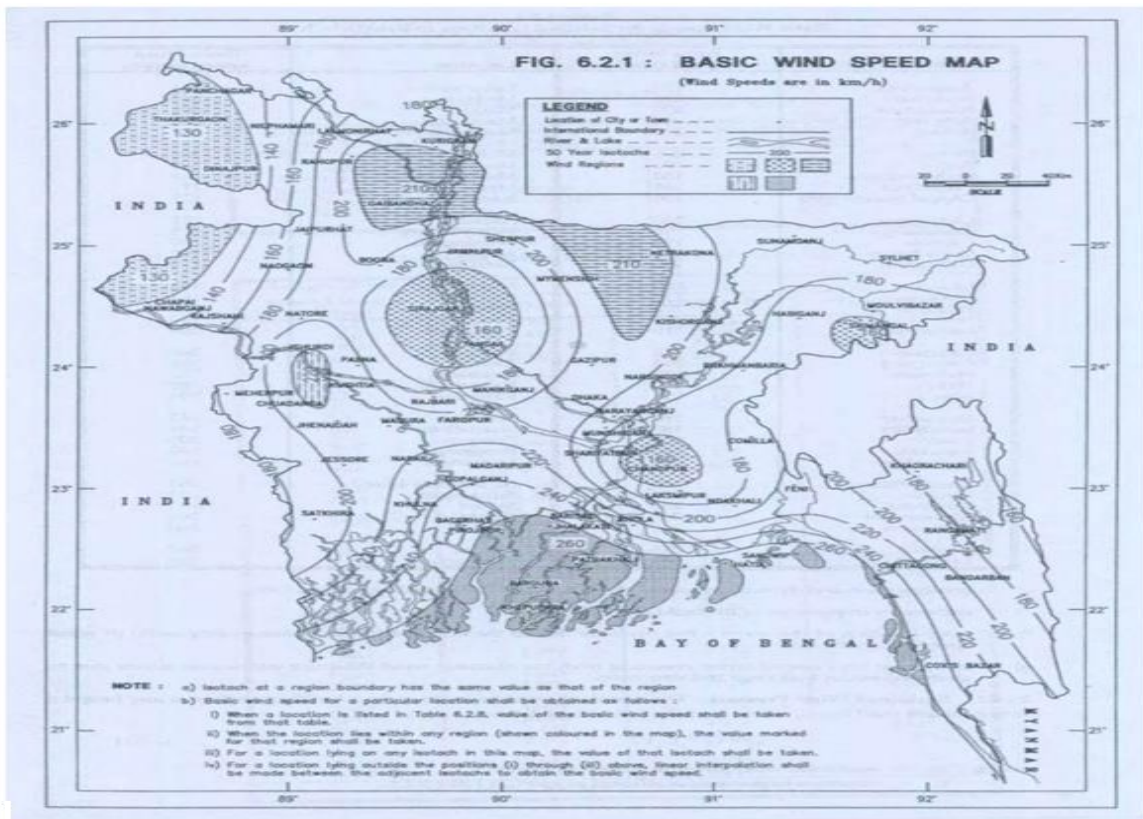


Fig. 4. Basic Wind Speed map

3. STATIC LOAD CASE

For Dhaka City

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 0
 Windward Coeff. Cq: 1.15
 Leeward Coeff. Cq: 0.62

Wind Coefficients
 Wind Speed (mph): 130
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 5. Case of Static Load in the X-Direction

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 90
 Windward Coeff. Cq: 1.56
 Leeward Coeff. Cq: 0.84

Wind Coefficients
 Wind Speed (mph): 160
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 8. Case of Static Load in the Y-Direction

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 90
 Windward Coeff. Cq: 1.56
 Leeward Coeff. Cq: 0.84

Wind Coefficients
 Wind Speed (mph): 130
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 6. Case of Static Load in the Y-Direction

Rajshahi City

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 0
 Windward Coeff. Cq: 1.15
 Leeward Coeff. Cq: 0.62

Wind Coefficients
 Wind Speed (mph): 95
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 9. Case of Static Load in the X-Direction

Chittagong City

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 0
 Windward Coeff. Cq: 1.15
 Leeward Coeff. Cq: 0.62

Wind Coefficients
 Wind Speed (mph): 160
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 7. Case of Static Load in the X-Direction

Exposure and Pressure Coefficients
 Exposure from Extents of Rigid Diaphragms
 Exposure from Area Objects

Wind Exposure Parameters
 Wind Direction Angle: 90
 Windward Coeff. Cq: 1.56
 Leeward Coeff. Cq: 0.84

Wind Coefficients
 Wind Speed (mph): 95
 Exposure Type: B
 Importance Factor: 1

Exposure Height
 Top Story: ROOF
 Bottom Story: S1
 Include Parapet
 Parapet Height: 36

Modify/Show Exposure Widths...
 OK
 Cancel

Fig. 10. Case of Static Load in the Y-Direction

GaibandhaWind Speed $V_b = 146$ mph"Structure importance coefficient" $I=1$

The pressure coefficient is 1.77 in the X direction and 2.40 in the Y direction.

KhulnaWind Speed $V_b = 150$ mph"Structure importance coefficient" $I=1$

The pressure coefficient is 1.77 in the X direction and 2.40 in the Y direction.

ComillaWind Speed $V_b = 136$ mph"Structure importance coefficient" $I=1$

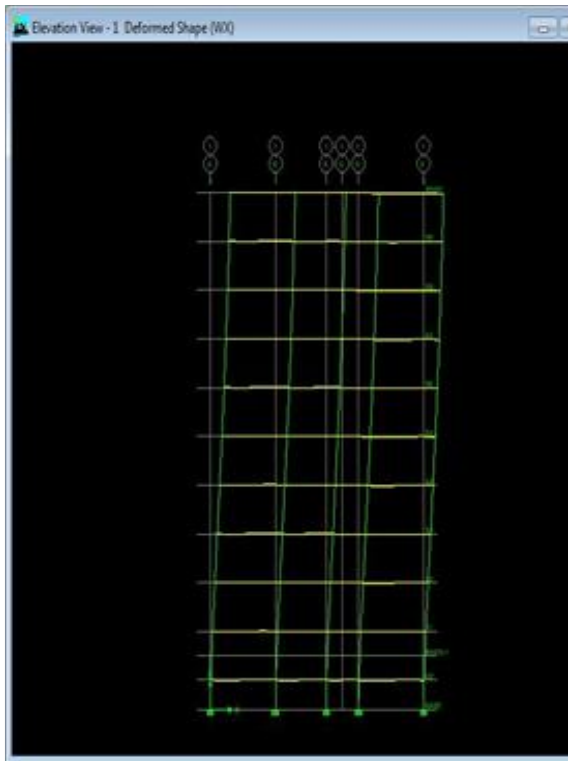
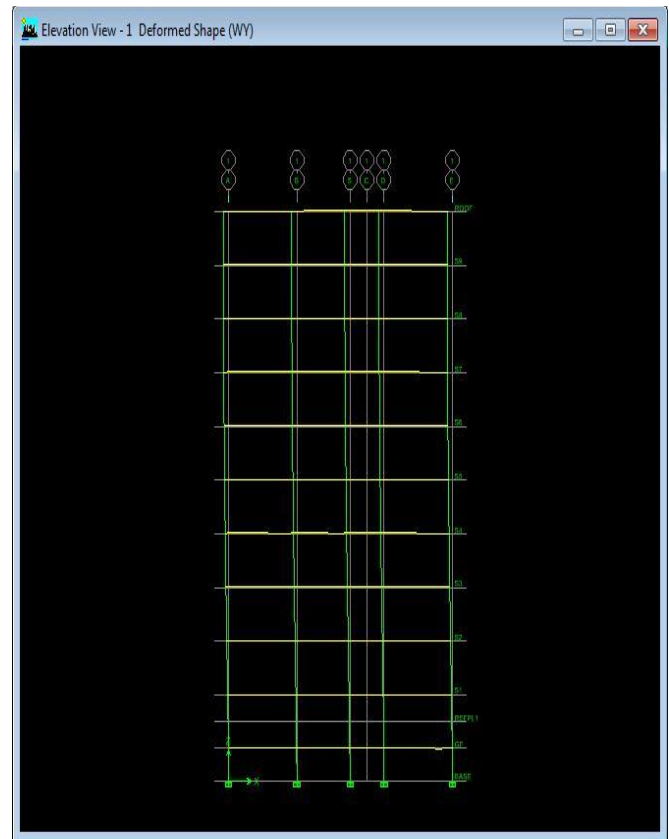
The pressure coefficient is 1.77 in the X direction and 2.40 in the Y direction.

JessoreWind Speed $V_b = 142$ mph"Structure importance coefficient" $I=1$

The pressure coefficient is 1.77 in the X direction and 2.40 in the Y direction.

SirajganjWind Speed $V_b = 112$ mph"Structure importance coefficient" $I=1$

The pressure coefficient is 1.77 in the X direction and 2.40 in the Y direction.

3.1 Analysis**Fig. 11.** deformed shape at Dhaka in the X-direction**Fig. 12.** deformed shape at Dhaka in the X-direction**3.2 Displacement(inch) on the Top Floor****Table 3.** Displacement(inch) on the top floor (X-direction)

LOCATION	STORY	DISP-X	DISP-Y
Dhaka	Top	0.661542	-0.039688
Chittagong	Top	1.002099	-0.060119
Rajshahi	Top	0.353279	-0.021194
Khulna	Top	0.880751	-0.052839
Gaibandha	Top	0.834404	-0.050058
Comilla	Top	0.724016	-0.043436
Jessore	Top	0.789309	-0.047353
Sirajganj	Top	0.491028	-0.029458

Table 4. Displacement(inch) on the top floor (Y-direction)

LOCATION	STORY	DISP-X	DISP-Y
Dhaka	Top	-0.239188	1.070779
Chittagong	Top	-0.36232	1.622009
Rajshahi	Top	-0.127732	0.571821
Khulna	Top	-0.318445	1.425593
Gaibandha	Top	-0.301688	1.350576
Comilla	Top	-0.261776	1.171901
Jessore	Top	-0.285383	1.277585
Sirajganj	Top	-0.177537	0.794784

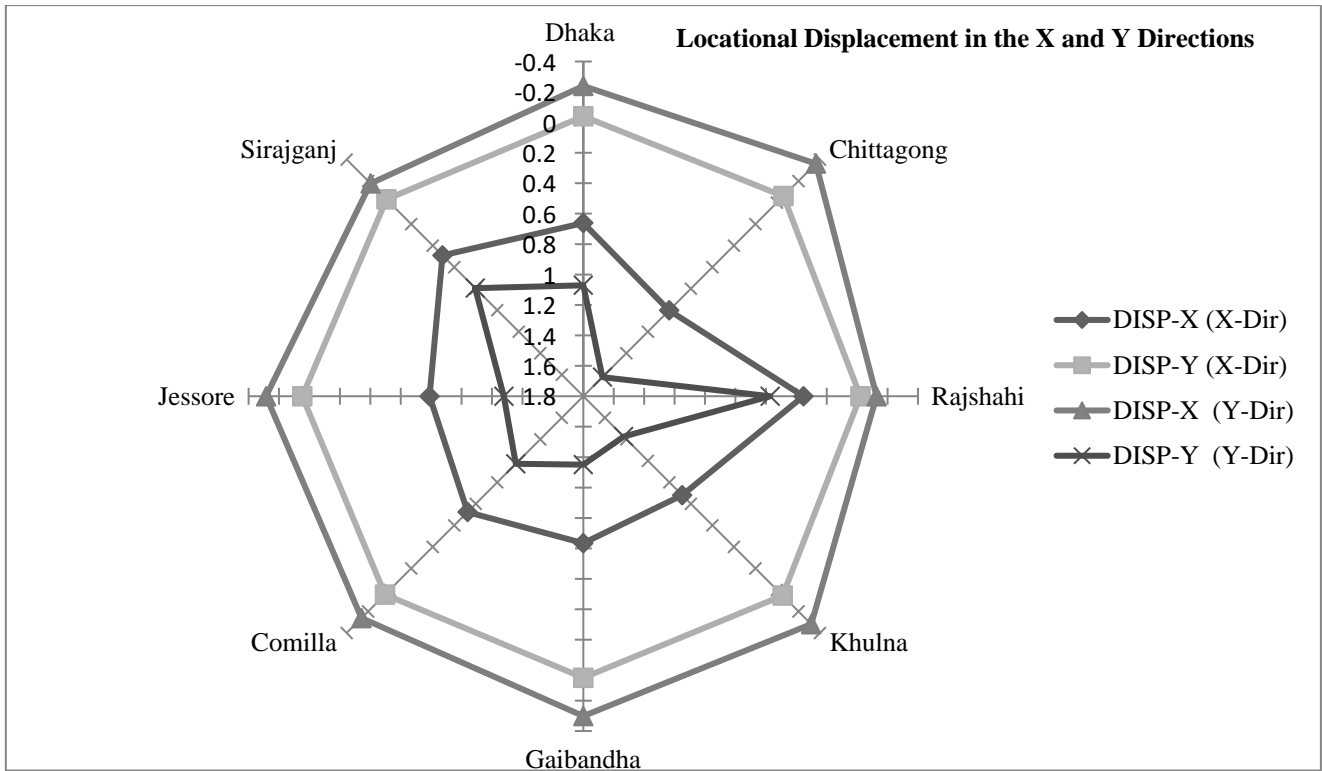


Fig. 13. Locational Displacement in the X and Y Directions

3.3 Drift On the upper floor

Table 5. Drift(inch) on the top floor (X-direction)

LOCATION	STORY	DRIFT-X	DRIFT-Y
Dhaka	Top	0.000327	0.000016
Chittagong	Top	0.000495	0.000025
Rajshahi	Top	0.000174	0.000009
Khulna	Top	0.000435	0.000022
Gaibandha	Top	0.000412	0.000021
Comilla	Top	0.000357	0.000018
Jessore	Top	0.00039	0.000002
Sirajganj	Top	0.000242	0.000012

Table 6. Drift(inch) on the top floor (Y-direction)

LOCATION	STORY	DRIFT-X	DRIFT-Y
Dhaka	Top	0.000014	0.000498
Chittagong	Top	0.000022	0.000754
Rajshahi	Top	0.000008	0.000266
Khulna	Top	0.000019	0.000663
Gaibandha	Top	0.000018	0.000628
Comilla	Top	0.000016	0.000545
Jessore	Top	0.000017	0.000594
Sirajganj	Top	0.000011	0.00037

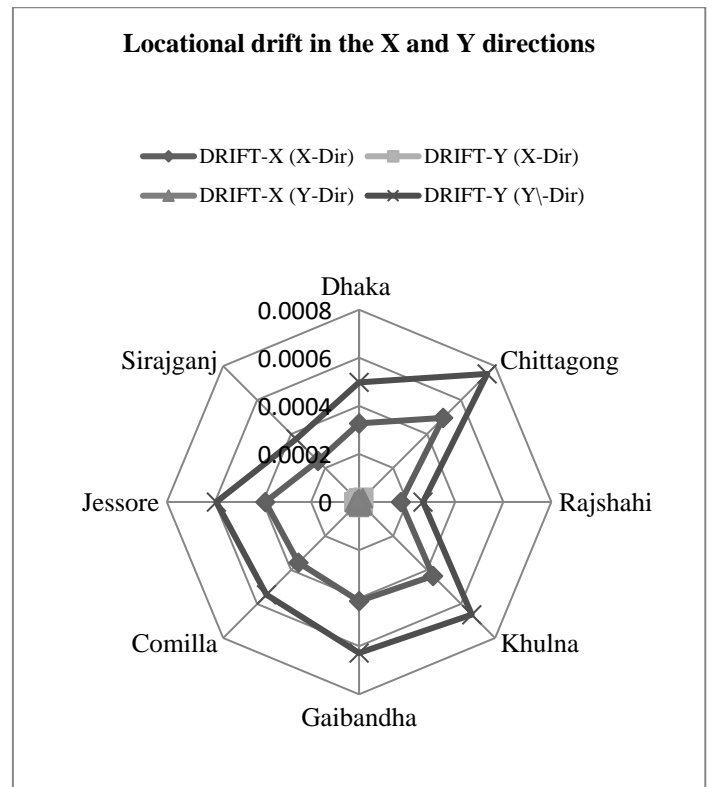


Fig. 14. Locational Drift in the X and Y Directions

3.4 Story Response(inch) on the Top Floor

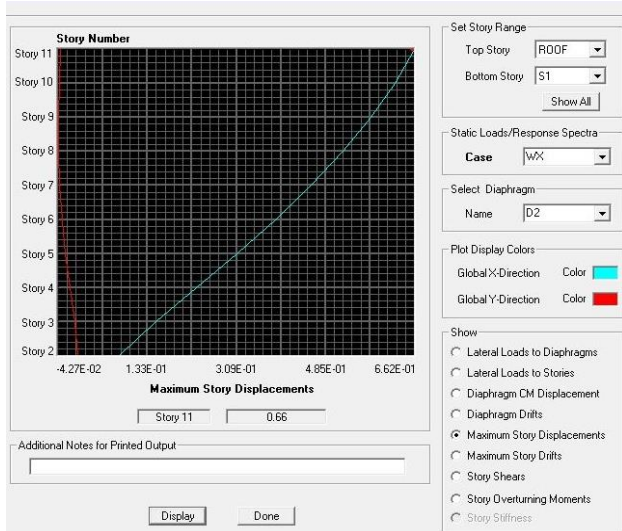


Fig. 15. Story Response on the Top Floor at X Direction (Dhaka)

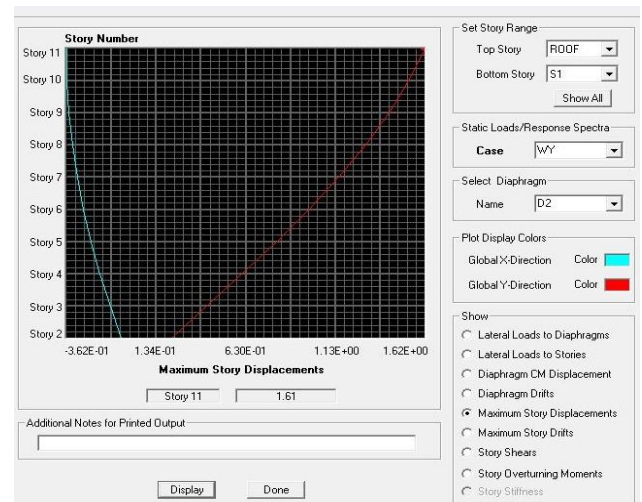


Fig. 18. Story Response on the Top Floor at Y Direction (Chittagong)

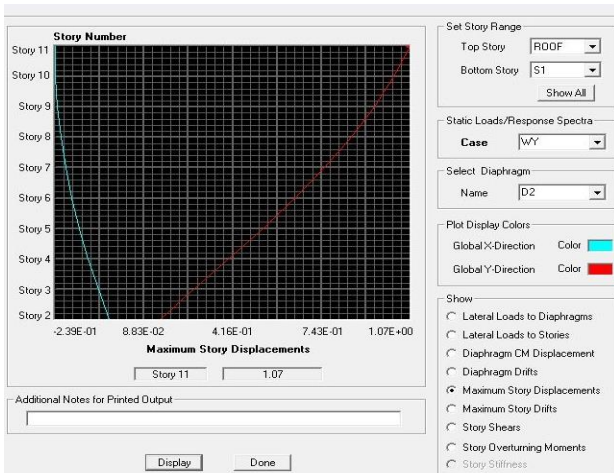
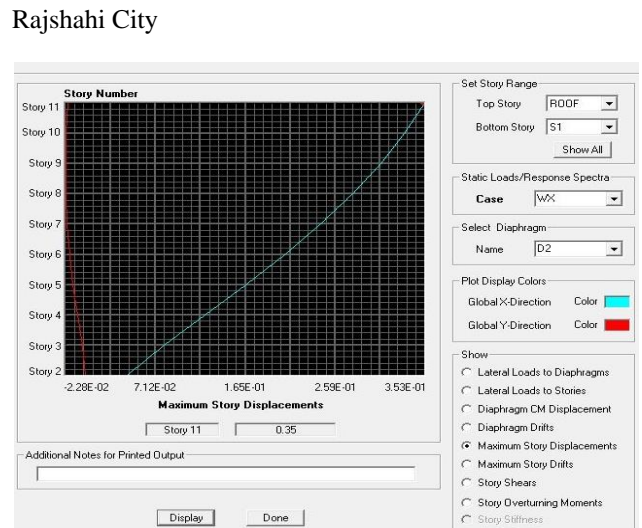


Fig. 16. Story Response on the Top Floor at X Direction (Dhaka)



Rajshahi City

Fig. 19. Story Response on the Top Floor at X Direction (Rajshahi)

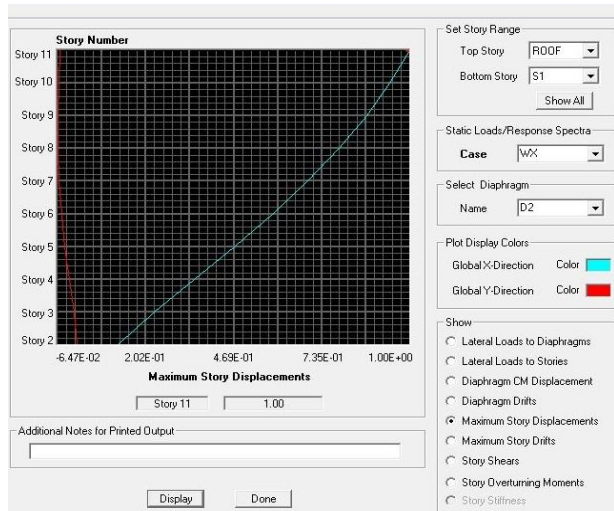


Fig. 17. Story Response on the Top Floor at X Direction (Chittagong)

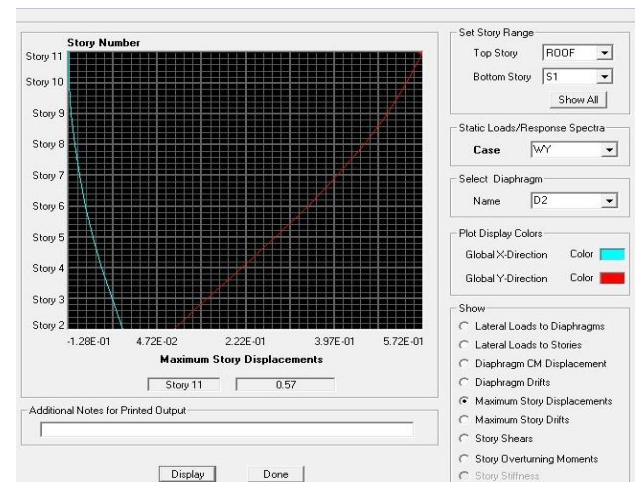


Fig. 19. Story Response on the Top Floor at Y Direction (Rajshahi)

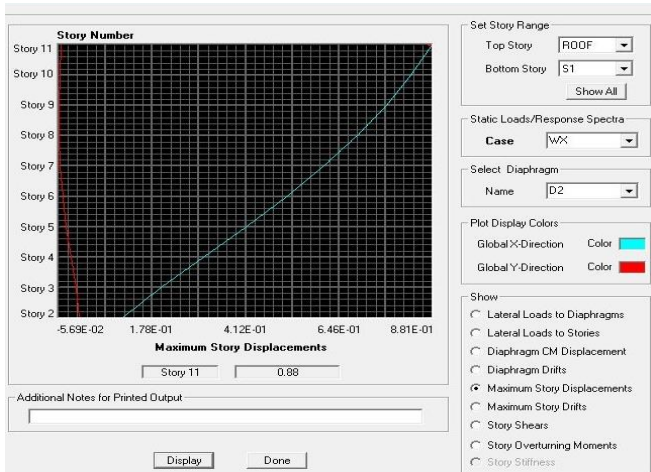


Fig. 21. Story Response on the Top Floor at X Direction (Khulna)

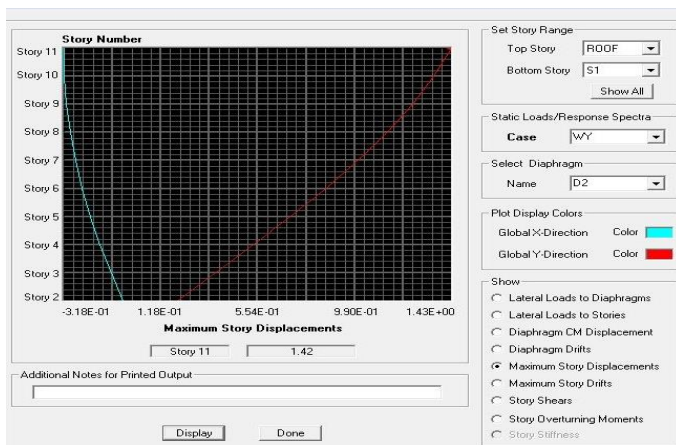


Fig. 22. Story Response On the Top Floor at Y Direction (Khulna)

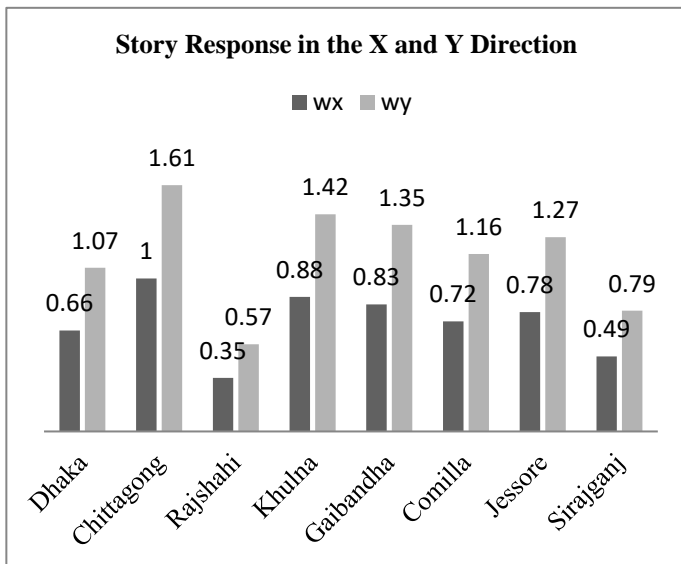


Fig. 23. Story Response On the Top Floor

3.5 Numerically calculated design wind pressure in the X-direction (Dhaka City)

[The values of all coefficients and other information have been used as guided by BNBC.]

The design wind pressure at a height z is given by p_z

$$p_z = 0.00256 C_I C_Z C_G C_T C_P V_b^2$$

Since the building is located in Dhaka, the basic wind speed is $V_b = 130$ mph.

The structural importance coefficient $C_I=1.0$) for essential facility.

In flat terrain, the local topography coefficient, $C_T=1.0$

Building height, $h = 106'$

Dimensions, $L = 59'$ and $B = 40'$;

i.e., $h/B = 2.65$ and $L/B = 1.48$. So, $C_p = .77$ [From BNBC Provisions]

Here, $C_p =$ pressure coefficient

$C_G =$ gust coefficient and $C_Z =$ height and exposure coefficient.

So, $p_z = 0.00256 \times 1.00 \times C_Z \times C_G \times 1.00 \times 1.77 \times 130^2$ (Dhaka)

Same as,

$p_z = 0.00256 \times 1.00 \times C_Z \times C_G \times 1.00 \times 1.77 \times 160^2$ (Chittagong)

$p_z = 0.00256 \times 1.00 \times C_Z \times C_G \times 1.00 \times 1.77 \times 95^2$ (Rajshahi)

$p_z = 0.00256 \times 1.00 \times C_Z \times C_G \times 1.00 \times 1.77 \times 150^2$ (Khulna)

The corresponding force $F_z = B h_{eff} p_z = 40 h_{eff} p_z$

Where $h_{eff} =$ effective height of the tributary area, $h_{eff} = 3' + 5' = 8'$ at 1st floor, $(5' + 5') = 10'$ between 2nd and 10th floor, and $5'$ at the 11th floor.

The coefficients C_z , C_G and the design wind pressure p_z and force F_z at different heights are shown below.

Table 6. Design Wind Pressure at Dhaka City

Story	Z(ft.)	C_z	C_G	p_z (psf)	F_z (kips)
1	6	0.368	1.654	46.61	14.92
2	16	0.375	1.661	47.70	19.08
3	26	0.385	1.731	51.04	20.41
4	36	0.455	1.801	62.75	25.10
5	46	0.525	1.871	75.22	30.09
6	56	0.595	1.941	88.44	35.38
7	66	0.665	2.011	102.41	40.96
8	76	0.735	2.081	117.13	46.85
9	86	0.805	2.151	132.60	53.04
10	96	0.875	2.221	148.82	59.53
11	106	0.945	2.291	165.80	33.16

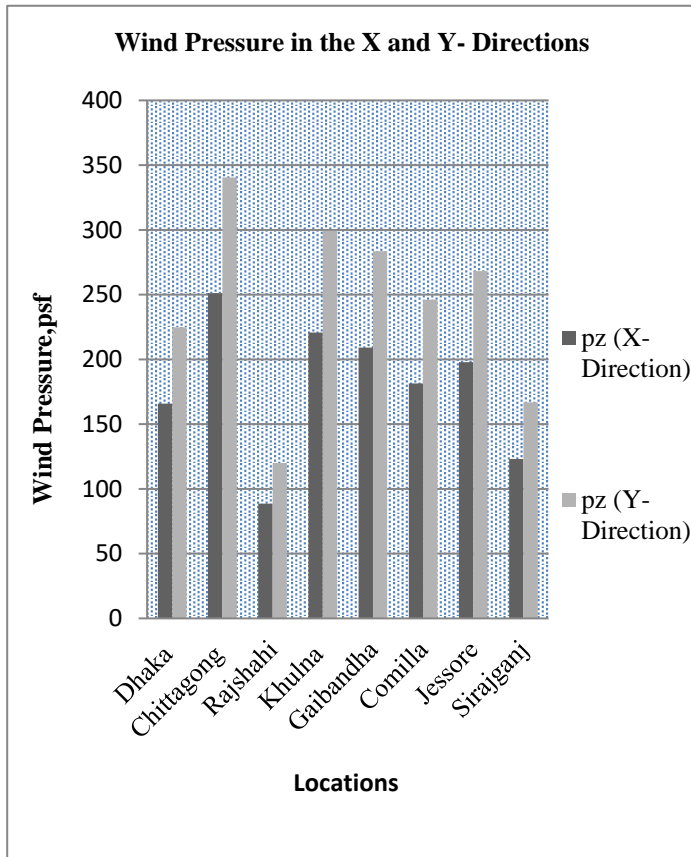
3.6 Design Wind Pressure on the Top Floor

Table 7. Design Wind Pressure on the Top Floor (X-Direction)

Design Wind Pressure, p_z (X-direction)		
Location	Story	p_z (psf)
Dhaka	Top	165.79
Chittagong	Top	251.13
Rajshahi	Top	88.54
Khulna	Top	220.72
Gaibandha	Top	209.11
Comilla	Top	181.45
Jessore	Top	197.81
Sirajganj	Top	123.06

Table 8. Design Wind Pressure on the Top Floor(X-Direction)

Design Wind Pressure, p_z (Y-direction)		
Location	Story	p_z (psf)
Dhaka	Top	224.791
Chittagong	Top	340.532
Rajshahi	Top	120.049
Khulna	Top	299.289
Gaibandha	Top	283.54
Comilla	Top	246.03
Jessore	Top	268.22
Sirajganj	Top	166.86

**Fig. 24.** Design Wind Pressure on the Top Floor

4. DISCUSSIONS

Table 3 shows that when the wind operates in the x-direction on the structure, the greatest displacement is 1.00 inch in Chittagong city and the smallest displacement is 0.035 inch in Rajshahi city at the top level. When the wind operates in the y-direction on the structure, the maximum displacement of 1.62 inches in Chittagong city and the minimum displacement of 0.571 inches in Rajshahi city at the top level are shown in Table 4. When the wind load acts on the structure in the x-direction, the maximum drift of 0.00049 inch in Chittagong city and the minimum drift of 0.00017 inch in Rajshahi city at the top level is shown in Table 5. The highest drift of 0.00002 inch in Chittagong city and the minimum drift of 0.000008 inch in Rajshahi city at the top level is shown in Table 6. when the wind load acts

on the structure in the y-direction. As shown in Fig. 23, the largest story response in Chittagong city and the least story response in Rajshahi city occur at the top level when the wind acts on the structure in both directions. Table 6. shows the maximum design wind pressure of 251.13 psf in Chittagong city and the minimum design wind pressure of 88.54 in Rajshahi city at the top level when the wind load acts on the structure in the x-direction. Table 8. shows the highest design wind pressure of 340.53 psf in Chittagong city and the lowest design wind pressure of 120.059 psf in Rajshahi city at the top floor, which happens when the wind blows on the structure in the y-direction.

5. CONCLUSION

The drift variation, displacement, and design wind pressure of eight districts are obtained in this paper. The impact of wind pressure increased gradually with the increase in the height of the structure. From software analysis and numerical analysis, we found that all impacts of wind activities are high in Chittagong and low in Rajshahi. The research has convinced me that the wind pressure in the South-East and South-West is higher than in the North-East and North-West, and most of it is found in the South-East.

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