RESPONSE STUDYOF HIGH RISE BUILDING UNDER WIND LOAD

A DISSERTATION

SUBMITTED IN THE PARTIAL FULFILLMENT OF REQUIREMENTS

FOR THE AWARD OF THE DEGREE

OF

MASTER OF TECHNOLOGY

IN

STRUCTURAL ENGINEERING

Submitted by:

SAURAV CAPASIA

(2K16/STE/19)

Under the supervision of

Dr. RITU RAJ

(Assistant Professor, Department of CE, DTU)

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College Of Engineering)

Bawana Road, Delhi-110042

June 2018

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CANDIDATE'S DECLARATION

I Saurav Capasia, Roll No. 2K16/STE/19 of M.Tech (Structural Engineering), hereby declare that the project Dissertation titled "**Response Study of High Rise Building under Wind Load**" which is submitted by me to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi **SAURAV CAPASIA**

Date:

DEPARTMENT OF CIVIL ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled "**Response Study of High Rise Building under Wind Load**" which is submitted by Saurav Capasia, 2K16/STE/19 Department of Civil Engineering (Structural Engineering), Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: **Dr. RITU RAJ**

Delhi: **SUPERVISOR**

ABSTRACT

Wind is a phenomenon of great complexity because of the many flow situations arising from the interaction of wind with structures. Wind is of the most significant forces of nature that must be considered in design of buildings. The characteristics of wind-induced loads on buildings continuously vary in temporal and spatial dimensions. Adequate design of buildings depends on the success in predicting the actual effects of turbulent wind forces to account for the most critical design scenarios which may occur during a certain design period. Under the action of lateral load, a tall building can subjected to lateral or torsional deflection. Due to this lateral stiffness is a major criterion in the design of high rise building. From the past studies, it is found that to resist the lateral force, bracing system in a frame model is highly economical and efficient method.

Wind loading computed from wind tunnel test carried out on square shape of frame model. This thesis is composed of two major parts (1) Experimental study and (2) Response study. In the first part of thesis, square shape model is tested in wind tunnel in order to find differential pressure on the surface of model at 140 pressure points under isolated condition with three different wind incidence angle named as 0^0, 30^0 and 60^0.

In the second part of thesis, study is carried out to investigate the behaviour of building under wind load obtained experimentally in first part of thesis. A G+17 frame model having RCC beams and columns of plan area 20m X 20m and first storey height is 4.75m and remaining storey's height is 3.25m, is subjected to wind speed of 47m/s. And the same model is reinforced with X-bracing system at each corner of the building with an angle of size ISA 200X200X25mm.

STAAD PRO software is used to analyze the building model subjected to wind load. The response study includes axial force, moment about both axes and displacement under various wind incidence angle. Behaviour of frame with and without bracings is also compared.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my supervisor **Dr. Ritu Raj** (Department of Civil Engineering, Delhi Technological University) for the continuous support of my M.Tech study and research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this thesis.

I would express my deepest and sincere appreciation to my father **Mr. Mamchand Singh,** for their continual emotional and financial support. They have always remained my source of encouragement. I am also very thankful to my friend **Sanjeet**, who always encouraged me and supported me. It is the support, push and good wishes of all the people mentioned above, without which I would not have been able to complete my thesis.

SAURAV CAPASIA

LIST OF TABLES

LIST OF FIGURES

CONTENTS

CHAPTER 04. EXPERIMENTAL STUDY PRESSURE MEASUREMENT

CHAPTER 05. WIND RESPONSE STUDY

CHAPTER 06. RESULT AND COMPARISON

CHAPTER 07. CONCLUSION

REFERENCES

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The movement of air along a particular direction in the atmosphere is called wind. The behavior of structure should be depending upon the characteristics of the wind. The wind can be divided into two categories, rotating and non-rotating wind. The rotating winds caused by tropical cyclones and tornadoes. While non rotating winds are caused by difference in pressures as per directions of wind. This is called pressure system of wind. The wind can be persist for the distance 50 – 100 kms known as fully developed pressure system winds. Under storms winds always move highly speed for a few minutes. Winds causes by difference temperatures on the surface of earth because sun’s radiations received in different latitudes varies and land areas heat and cool speedily than the sea. The temperatures up-downs always due to pressure of air.

The motion of wind is opposed near the earth surface. The speed of wind is got reduced due to the surface friction. The speed of wind starts from zero and increases with increases in elevation and at some height known as the gradient height where friction due to earth surface has no influence on it, and will attains its “gradient velocity”.

The pressure of the air strike the surface of the structure, it will exert force on it. These forces are known aswind load. There may be components of force in the directions other than the direction of wind. The component of force along the direction is called drag force and in normal direction is called as lift force(across-wind force) and side force(transverse force). The moment which tries to bend the structure along the direction of wind is known as over turning moment, the moment tries to twist the structure about a vertical axis is known as torque and in transverse direction known as sideways moment.

High rise buildings are always designed for gravity loads and horizontal load. The wind is very important as earthquake load considered in horizontal direction for the designing of multi story buildings. Thus, for tall building it is very important to calculate the estimation of horizontal loads specially wind load to be done very carefully for the safety of tall buildings.

1.2 TYPES OF STRUCTURAL SYSTEM FOR HIGH RISE BUILDING

The system or component of the tall building structural systems is followed as under:

a) Floor system
b) Vertical Load resisting system
c) Lateral Load resisting system
d) Connections
e) Energy dissipation system and damping

1.3 WIND LOAD

1.3.1. Factors Affecting Wind Loads

Many kind of parameters which affects wind loads on structures may be classified into two groups a) Flow parameter b) structural parameter

In Flow parameters wind velocity profile, terrain category, direction of wind, topography structural parameters, building heights, solidity ratio, slope of the roof, shielding effect and opening are included.

1.3.2 Evaluation Procedure

The loads on structure are required to be calculated in general wind for (a) Individual structure elements that are roofs and wall or cladding unit (b) the whole building. There are two methods for analytic evaluation of static wind load on structure (i) pressure coefficient method and (ii) force coefficient method.

The wind load can be determined as follows:

$F = C_f * A_e * P_d$

$F = (C_{pe} – C_{pi}) * A* P_d$

F = wind load;

C_f = force coefficient;

A_e = effective frontal area obstructing wind;

P_d = design wind pressure;

(C_{pe} - C_{pi})= external and internal pressure coefficients;

A = surface area of structural elements.

As per IS: 875 (part 3)-1987

Design wind speed can be calculated as

$V_z = V_b * k_1 * k_2 * k_3$

V_b = Basic Wind Speed

k_1 = Probability Factor(or Risk Coefficient)

k_2 = Terrain and Height Factor

k_3 = Topography Factor

Design wind pressure can be computed as:

$P_d = 0.6 V_z^2$

1.4 BRACED FRAMES

Bracing systems are generally provided in building to resist the lateral forces or wind load or earthquake load acting on the building. Members in a bracing system act as a truss element, are subjected to axial load. The Shapes of diagonal members mainly depends upon on axial force, length, required stiffness, and clearances, connection considerations. The diagonal members can be of double angles, channels, tees, tubes, or even wide flange shapes. The bracing system are often provided around service cores, elevators, and corners of the building. To resist the torsion loads, bracing system are provided to form a closed or partially closed three-dimensional cell so that torsional loads can be resisted effectively. A height-to-width ratio of 8-10 is considered to form a reasonably effective bracing system.

The braced frame in a building is designed to fulfill the following purposes :-

1) Resist the lateral loads (wind load or earthquake load)

2) p-Δ moment due to gravity loads

3) Prevention from buckling of frame

4) Improvement in sway behaviour

1.4.1Types of Bracing System

1. Concentric Bracing

Concentric bracings are those bracing whose diagonal axis coincides with each other. Both ends of the concentric bracing connected with ends of other members of the frame. The Diagonal bracing (single, K bracing), cross bracing(X bracing) Chevron bracing are types of concentrically braced, and are shown in below figure.

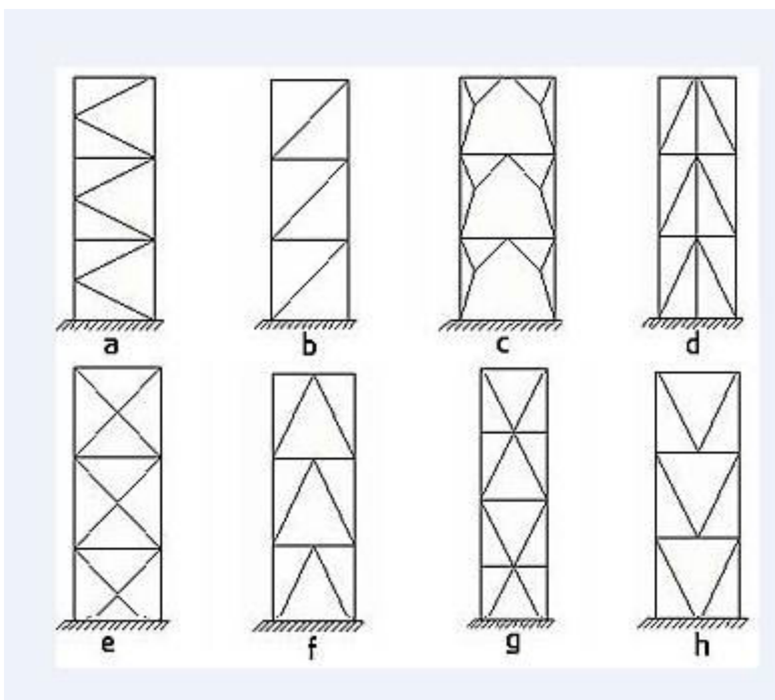


Fig.1.1 Types of concentrically braced frames

2. **Eccentric Bracing**

   Eccentric bracing are those bracing whose diagonal braces are placed out of line with the centerlines of columns and beams. In the eccentric bracing, one or both ends are not connected with ends of other members of the frame. Eccentric bracing improves energy dissipation capacity of the frame as compared from concentric bracing.

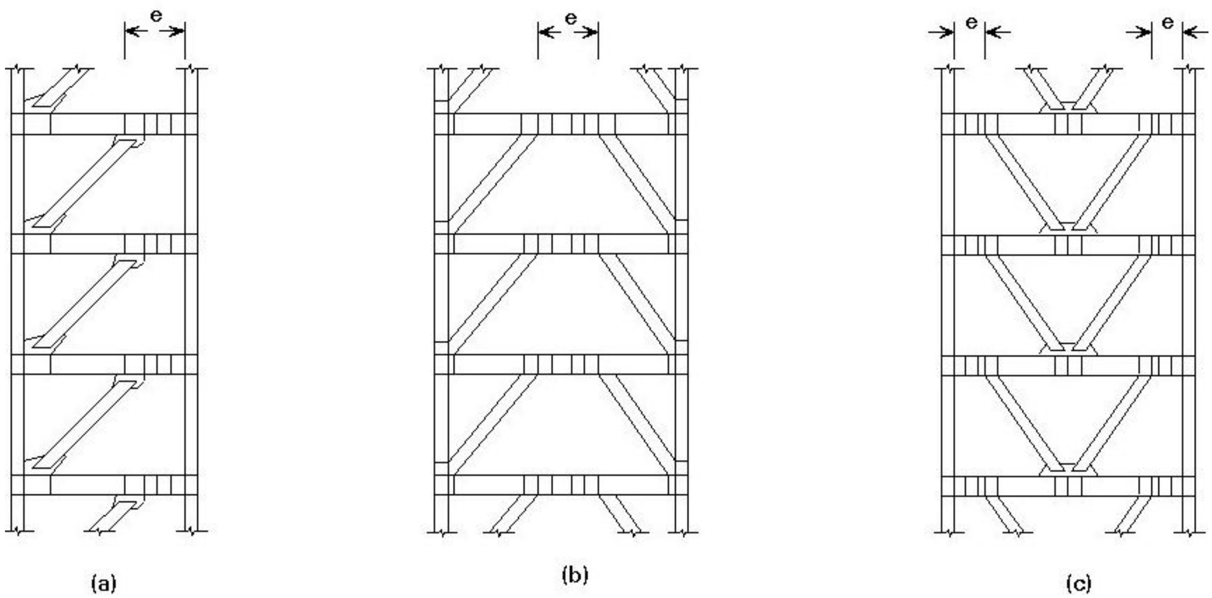


Fig.1.2 Different types of Eccentrically Braced Frames

1.5 **NEED OF PROPOSED STUDY**

Majority of structures in India are Unreinforced masonry (URM) which are vulnerable to wind loading, most of study through literature shows that most of research efforts is on R.C.C structures, so there is need to give more effort on understanding masonry building subjected to wind loading.

The need for structural rehabilitation of URM structures is generally motivating by one or more following cases:

i. Reduction of load caring capacity of buildings due to deterioration.
ii. Environmental Degradation
iii. Damage due to sudden loading (viz. earthquake, wind, blast etc.)

1.6 OBJECTIVE OF STUDY

The purpose of study is to evaluate the position of tall buildings with square shapes under wind loads got from experimental measurements. The linear static method is used to analyze buildings using STAAD.PRO software. For various wind incidents the response of building frame is obtained with angles of 0 degree, 30 degree, 60 degree under isolated conditions.

1.7 LIMITATIONS OF THE STUDY

1. Results can vary with the different shape of the building model.
2. Location and type of bracing system in building, can have the various influence effects on the building.
3. Building located in different zones, can lead to different results.
4. Different factors like topography, locations(k1, k2, k3), can have various influence on the building.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

Aim of the present study is to understand the behavior of square shape of tall building with and without bracing system on (i) wind loading acting on high rise building which consist of base share, base moments and twisting moments, (ii) distribution of wind pressure on the surface of high rise buildings and (iii) response of high rise building under wind loading.

Many researchers have been done on wind tunnel and analytical studies of tall building during the last four decades. Many of researchers are also listed in this chapter.

2.2 CODAL INFORMATION

2.2.1 Australia and New-Zealand Standard (AS/NZS-1170-2, 2011)

This kind of code covers the structures which falls within the criteria i.e. (i) buildings less than or equal to 200 m height (ii) structure with roof span less than 100 m. There is inclusion of this code in the wind load for structures other than off shore structure, transmission towers and bridges. The is no inclusion of this code in cross sectional safe and other than square and rectangular shape.

2.2.2 American Standard (ASCE-7, 2002)

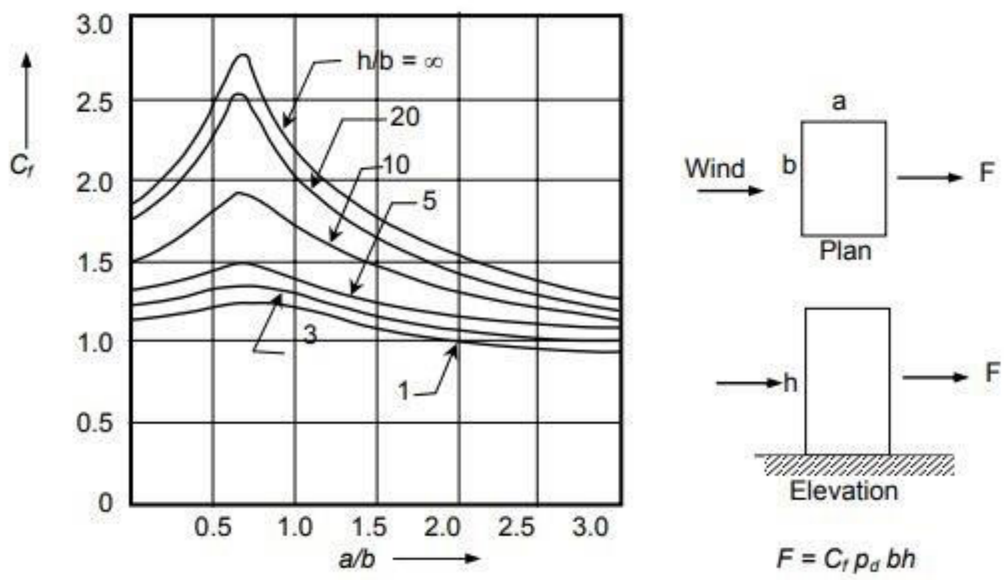
There is detailed information's about wind loads on low rise buildings having different types of roof in ASCE-7. There is information of low rise building also with aspect ratio in this standard. Yet, there is lack of information about wind loads in high rise buildings with many kind of shapes. Further no information is available in case of skew wind.

2.2.3 British Standard (BS EN 1991-1-4, 2005)

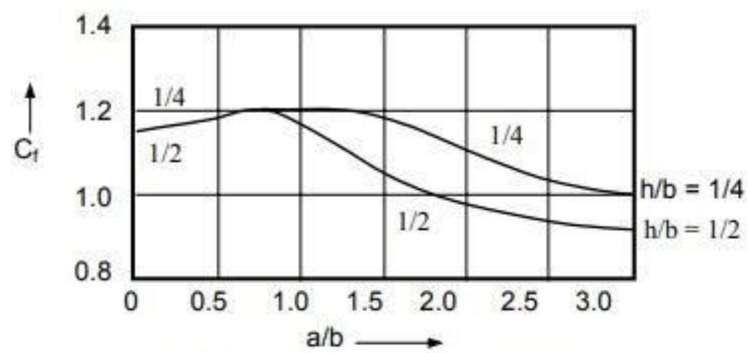
The structural design of building and civil engineering work for each of the load conditions follow the code of practice with such guidance on the determination of the natural wind actions. This code of practice is applicable for highest buildings upto 200 m and bridge which has no span greater than 200 m. So far as the wind pressure distribution for un even cross sectional safes there is no information. The different skew angle wind also not included in the code of practice in this information.

2.1.4. Indian Standard(IS:875(part 3)-1987)

As per code IS:875 (part 3)-1987, clause(6.2.2.1, Table 4), the external pressure coefficient(C_p) for rectangular building for uniform cross-section along the height. The external pressure coefficient for varying height to width ratios and length to width ratios are also given in the code. And for two different wind incidence angles 0^0 and 90^0, wind pressure coefficients are given.



Values of C_f versus a/b for $h/b \geq 1$



Values of C_f versus a/b for $h/b < 1$

Fig 2.1 Force coefficient for rectangular clad building in uniform flow

2.3 RECENT RESEARCH PUBLICATIONS

Balendra et al. (1988) studied the experimental behaviour of triangular shape of building model having aspect ratio of 1:4.6 in an atmospheric boundary layer. The experimental result includes longitudinal, lateral and torsional response of triangular shape of building. For the determination of critical angles for longitudinal, lateral and torsional motion, variation of wing incidents angle had been done. It was found that displacement of building model varies exponentially with reducing velocity

Kwok et al. (1987) conducted tests on wind tunnel model to investigate the behavior of rectangular shape high rise building. It was found that modification to the edge of high rise building has a effect on excitation process and the response characteristics.

Z.A. Siddiqi et al (2014) studied the compression of different types of bracing system installed in tall building. A model of having plan area of 144 ft X 144 ft and elevation of 720 ft is analyzed under various bracing system (single diagonal, double diagonal, K/chevron, V, knee). The result include the comparison of structural weight (under various bracing system), lateral displacement of building with bracing system (single diagonal, double diagonal, K/chevron, V, knee) along major and minor axis.

Himanshu Gaur et al (2015) studied the comparison of correlating stiffness and shear lag behavior of building with braced frame. For building model, plan area of 42 m × 42 m. Columns are placed at a spacing of 3.5 m center to center, floor height is set to 3.5 m. For 120 stories, a central core is provided to control the lateral deflect limit. A building's facade beam–column connections are moment connections. Central core area is about of 25% of the total plan area. Spacing between central core and building facade is column free which spans 10.5 m. The result include the Variation of shear lag ratio with different angle of bracing system paced in buildings and top lateral deflection with different angle of bracing system placed in buildings.

Lekshmi soman et al (2017) investigated the comparison of outriggers system using braced frame core and shear core in tall building. A G+40 storied structure of plan area 432 m^2, floor height is limited to 3m is modeled using ETABS software. Eight models are made with different position of outriggers structures. Various positions of outriggers in tall building were 1) $1/4^{th}$ and top, 2) $2/4^{th}$ and top, 3) $3/4^{th}$ and top, 4) top only. The result includes the comparison of story drift and base shear calculated as per various position of outriggers structures with braced frame and shear core in tall building.

Abdul karim et al (2015) studied the response of outrigger system in high rise building structure with steel bracing.

Jirsa et al (1990) studied the response of braced frames (analytically & experimentally. Deep beams and short columns are provided for the purpose of retrofitting in the frame. Under Lateral cyclic loading, retrofitted frame is tested. Interior column is selected for analytical study in a braced frame under lateral loading. The result concluded that designer strength and stiffness changes by changing the cross-sections of braced system. Reducing slenderness ratio would help to prevent inelastic buckling effects.

G Navya et al (2015) investigated the behavior of structure using steel bracing as retrofitting techniques. A G+6 storied building having plan area of $15_{Mx}15$m, floor height is set to 3m located in zone IV with medium type soil condition is modeled. The result includes the comparison of Moment Curvature curve, Push Over curve, Performance point in the building, Fragility Curves, Capacity curves before and after retrofitting of building.

Kowk et al. (1988) conducted tests on wind tunnel model to investigate the behavior of rectangular shape high rise building. It was found that model of building with horizontal slots, chamfered corner caused reduction in both the along and across wing response

Mendis et al. (2006) presented the changes in tall building design code after the world trade centre building collapse.

Gu (2009) conducted wind tunnel test on 27 models of high rise building by using wind pressure scanning.

Narasimha Murthy et al (2016) studied the behaviour of Bracing Systems for Irregular shapes of high rise buildings. A G+19 storied, T-shaped framed structure of plan area 75$_{Mx}$75m is modeled. Storey height of 3m, 15 no of bays of 5m each in X and Z dir is provided for structure. The columns and beams are designed to bear up the dead load and live load sufficiently. The various bracing systems (X bracing, diagonal bracing, inverted V, eccentric bracing, knee bracing) are provided at the corners of the whole section of the building. The lateral loads applied on the structure are computed as per Indian standards. The result includes variation of nodal displacement, axial force, maximum bending moment for different bracing system.

Cooper et al (1997) computed the unsteady wind loading acting on a high rise building of beveled corners and tapered cross-section as a fns of reducing velocity and motion amplitude.

Lin et al. (2005) studied the behavior of high rise building under wing load. Nine models of different rectangular shape were tested in wind tunnel. For analyses of coefficient of wind force various parameters such as side ratio, elevation and aspect ratio were highlighted. Result includes comparison of data obtain from high frequency force balance in two wind tunnels.

Kumar et al. (2013) studied the distribution of wind pressure on the surface of high rise building with step configuration. It was found that base share and movement develop due to wind loading are not affect by wind direction but highly affected by step configuration.

Kushal (2013) conducted experimental study on building model of T-shape and L-shape cross-section of aspect ratio 1:200. It was presented that pressure and force coefficient around the surface of high rise building model under isolated and interfering condition.

CHAPTER 3

EXPERIMENTAL PROGRAMME

3.1 GENERAL

As per description of chapter 1 to carry out the wind tunnel testing of tall building with square was mentioned, we have used rigid model studies for the simulation of the natural wind flow for tall buildings. The purpose of this experimental study was to carry out extensive wind tunnel test on rigid model of the square shape building to evaluate pressure on different phases of the building model.

3.2. DETAILS OF MODEL

Square shape model:

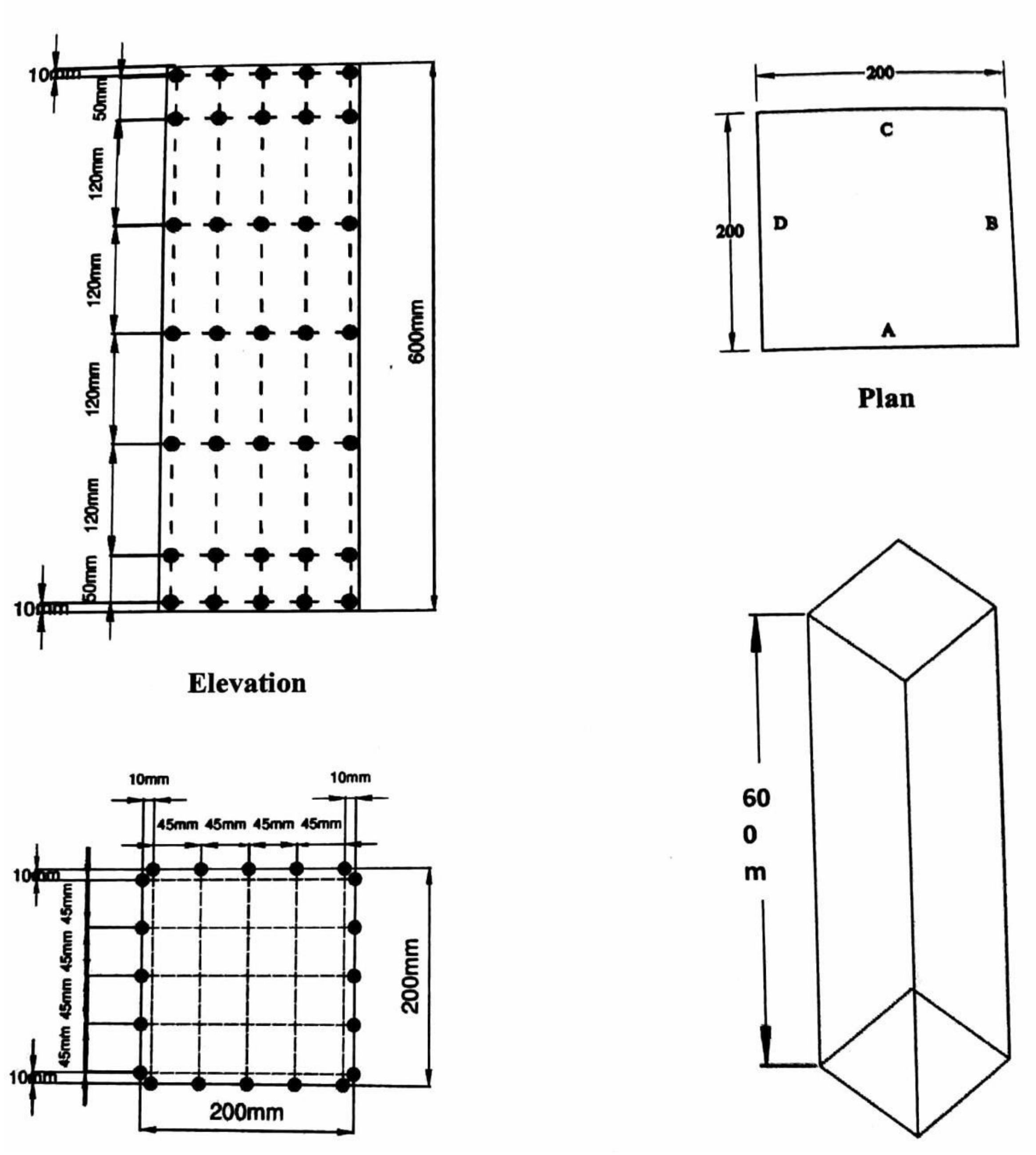
For experiment one model of square shape buildings is used. This model is made of Perspex sheet (six mm thickness) is used pressure measurement. On the other hand, the square shape model is made in geometrical model ratio 1:100. The open terrain wind tunnel classified as terrain category – 2 is being used for set of small cubical blocks.

Dimension of model

Height of model – 600 mm

Length and width – 200 mm

To obtain a good distribution of pressure on all the phases of the model. The model is instrumented with 140 numbers at pressure taps and at seven different type height levels. To maintain electronic pressure, transducers is used in which the pressure tapings are connected by the plastic tubes.



Plan Isometric View

Fig 3.1 Details of pressure points on Square Shape Building

(All Dimensions are in mm)

3.3 DETAILS OF WIND TUNNEL

The tunnel is known as open circuit tunnel with continuation flow of wind in suction flow is made with a blower ton (125 hp) this has a test section of 2.1 m x 2.0 m size. The length of test section is 1.5 m. In general to control load cell and turn table are installed at 10.4 m and 12 m respectively downstream at the test section entrance.

3.4 EVALUTION OF PRESSURES

The Baratron pressure gauge is used for the measurement of the fluctuating pressure at each pressures point for duration of sixty seconds. The measured readings at each point are in unit of **mmhg.**

Values of pressure measured at all pressure points for duration of 60 seconds are averaged to get mean wind pressure**.**

CHAPTER 4

EXPERIMENTAL STUDY – PRESSURE MEASUREMENT

4.1 GENERAL

The present study is experimental investigation of wind pressure distribution on the wall surface of tall buildings which are made of square shape section and have the same floor area. The wall surface are tested in wind tunnel by placing them at the centre of turn table one by one in isolated conditions.

The wind is allowed to strike the models having symmetry about both X-X and Y-Y axis at three different incidence angles i.e. 0degree, 30 degree, 60 degree. Wind velocity is set to 9.87 m/sec at a height of 1 m.

The mean wind pressure ($\mathbf{P}_{avg}$) values are calculated experimentally.

4.2 WIND PRESSURE DISTRIBUTION ON SQURAE SHAPE MODEL

Squre shape model which is made up of Perspex sheet with a total of 140 pressure points is analyzed under isolated condition with 3 wind incidence angles named as 0^0, 30^0, 60^0. Wind pressure values obtained from transducer are in the form of **mmhg** unit which later on converted into **N/m^2.**

Fig shows the fluctuation of mean wind pressure ($\mathbf{P}_{avg}$) on all the faces of square shaped model in the form of contour line at 0 degree wind incidence angle. Pressure on the windward face A increases from base to top of the surface due to increase in wind speed with height. The value of mean wind pressure varies from 0.1 to 0.27.

When wind is allowed to strike the surface of model at an angle of 30 degree, the value of pressure distribution decrease from windward edge to leeward edge on windward face. It is found that pressure on face B is now decreased whereas pressure on face C & face D is still nearly same. At an angle of 60 degree, wind pressure distribution on face B becomes related to face A that in case of 30 degree wind incidence angle.

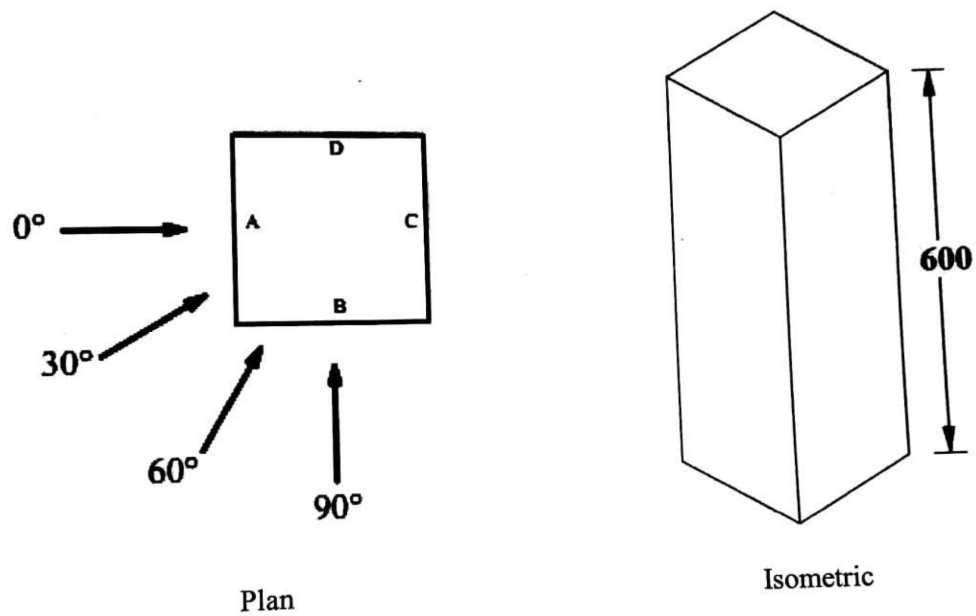
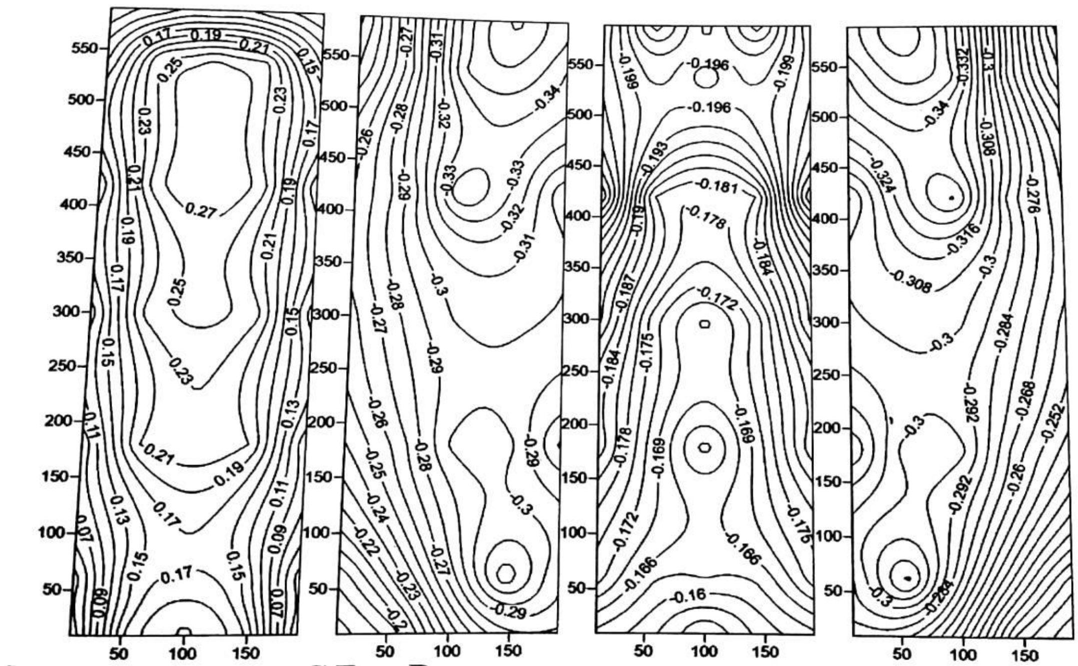


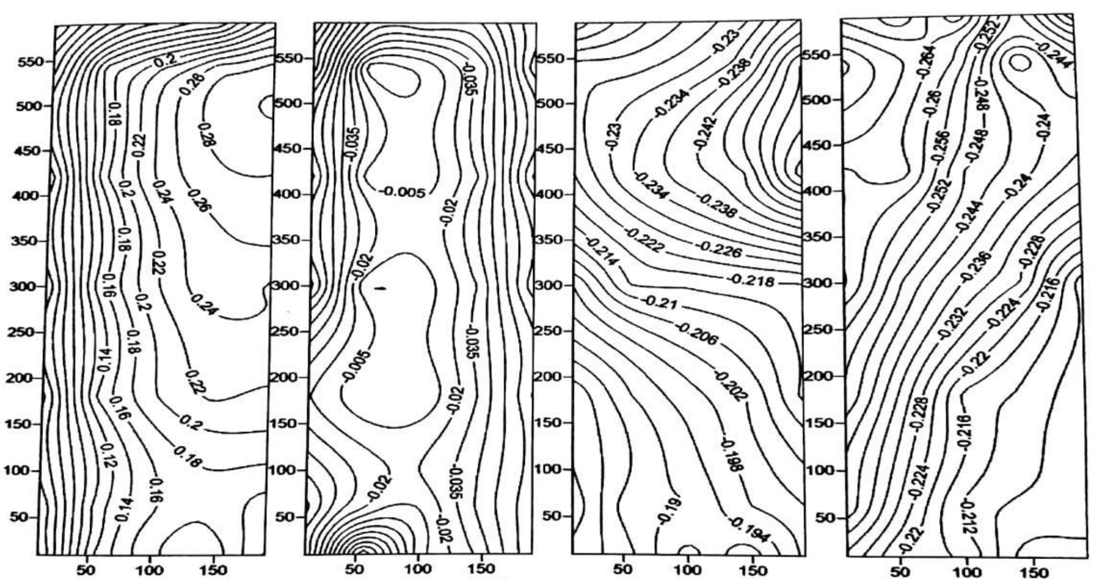
Fig 4.1 Wind incidence angel on square shape model in isolated condition

(All dimension in mm)



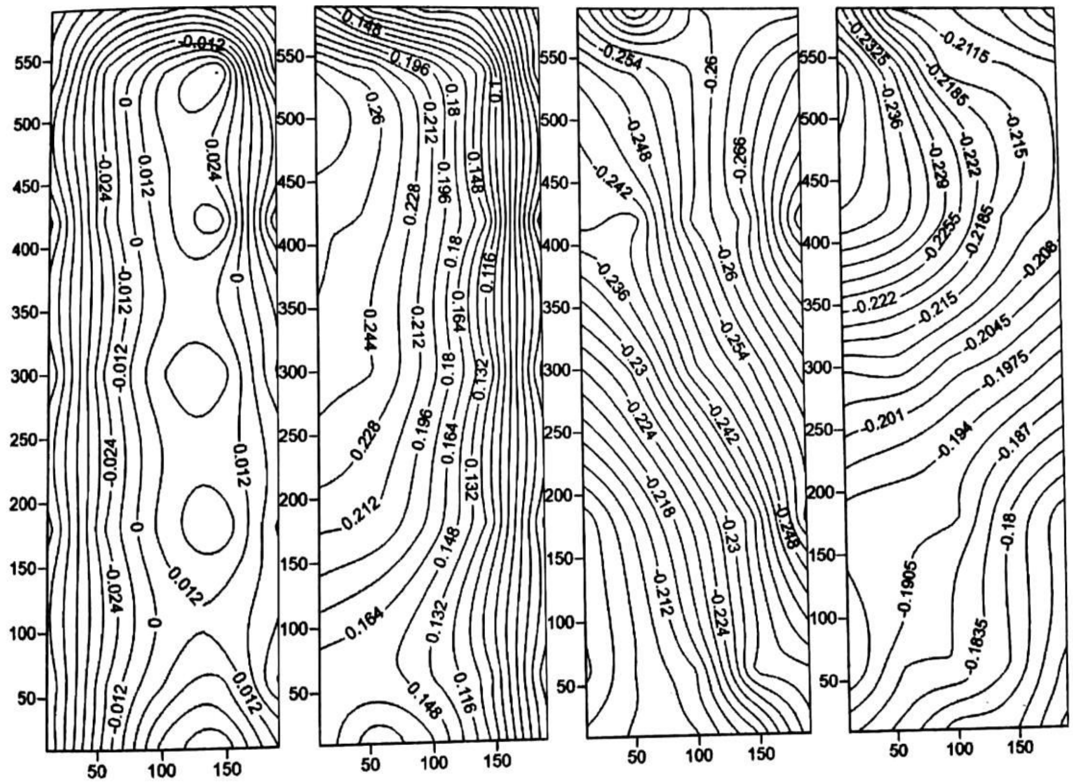
Face A **Face B** **Face C** **Face D**

Fig 4.2 Distribution of mean wind pressure on different surfaces of square shape model at 0 degree wind incidence angle



Face A **Face B** **Face C** **Face D**

Fig 4.3 Distribution of mean wind pressure on different surfaces of square shape model at 30 degree wind incidence angle



Face A **Face B** **Face C** **Face D**

Fig 4.4 Distribution of mean wind pressure on different surfaces of square shape model at 60 degree wind incidence angle

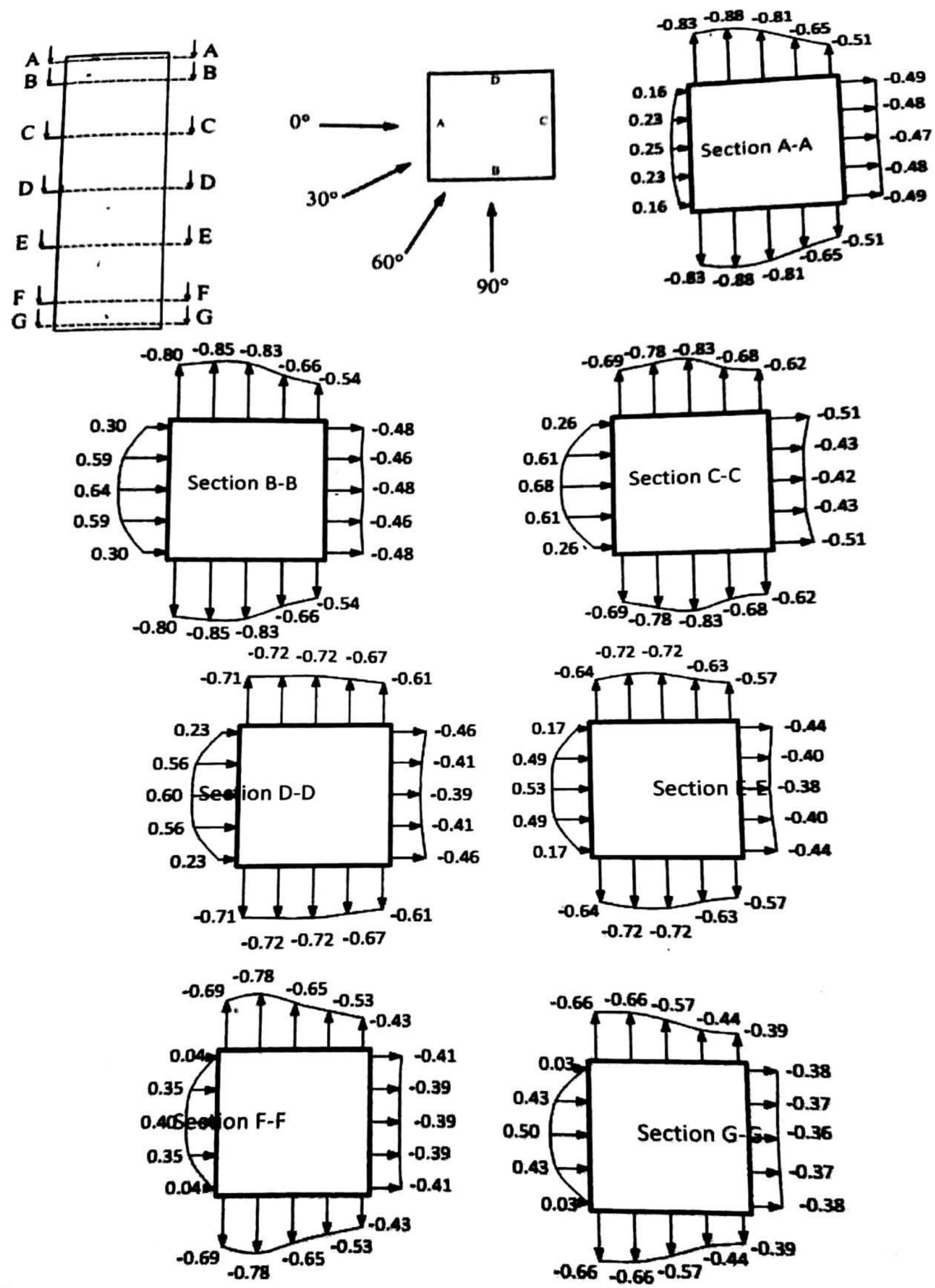


Fig 4.5 Cross-sectional variation of mean wind pressure on square shape at 0 degree wind incidence angle

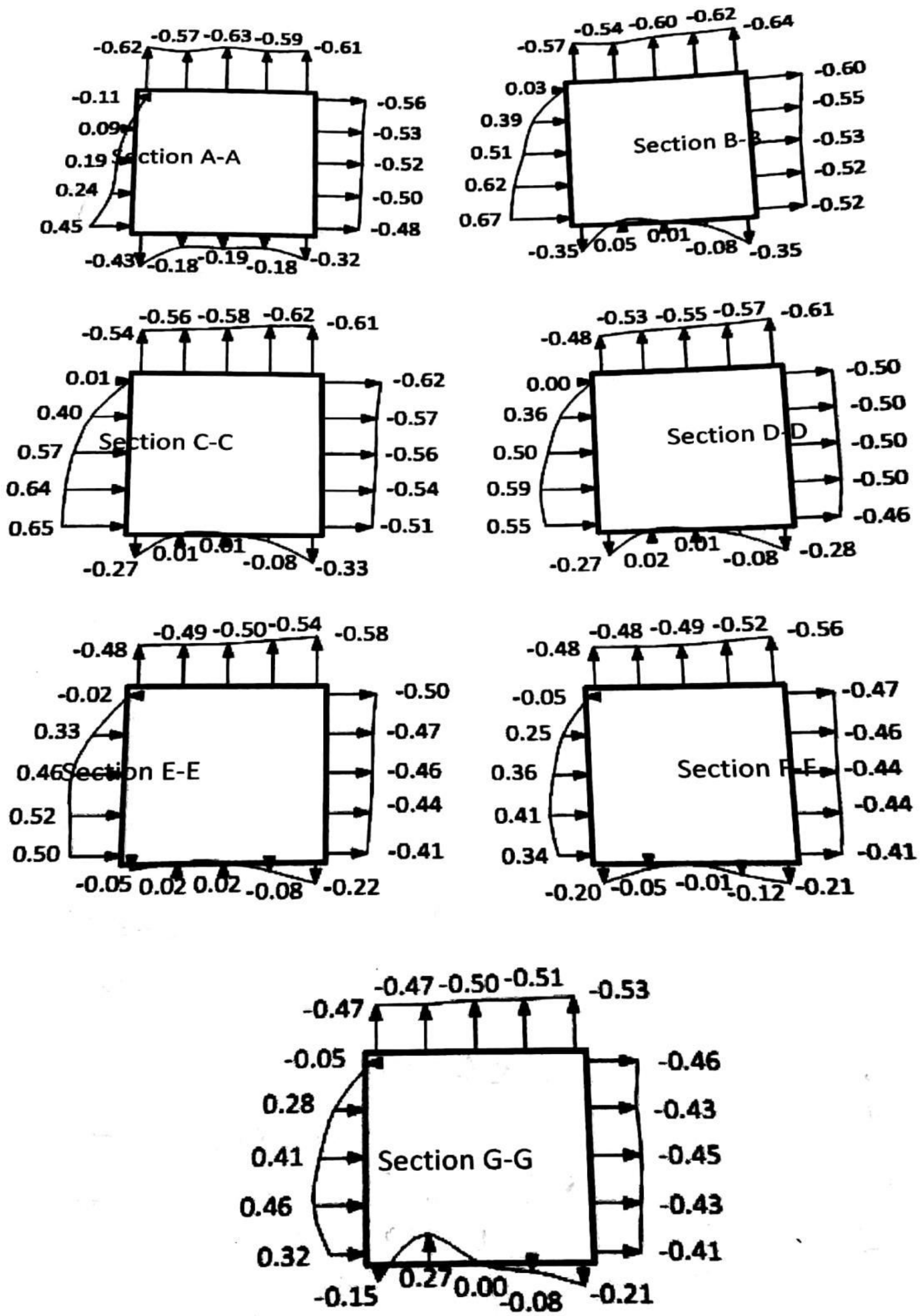


Fig 4.6 Cross-sectional variation of mean wind pressure on square shape at 30 degree wind incidence angle

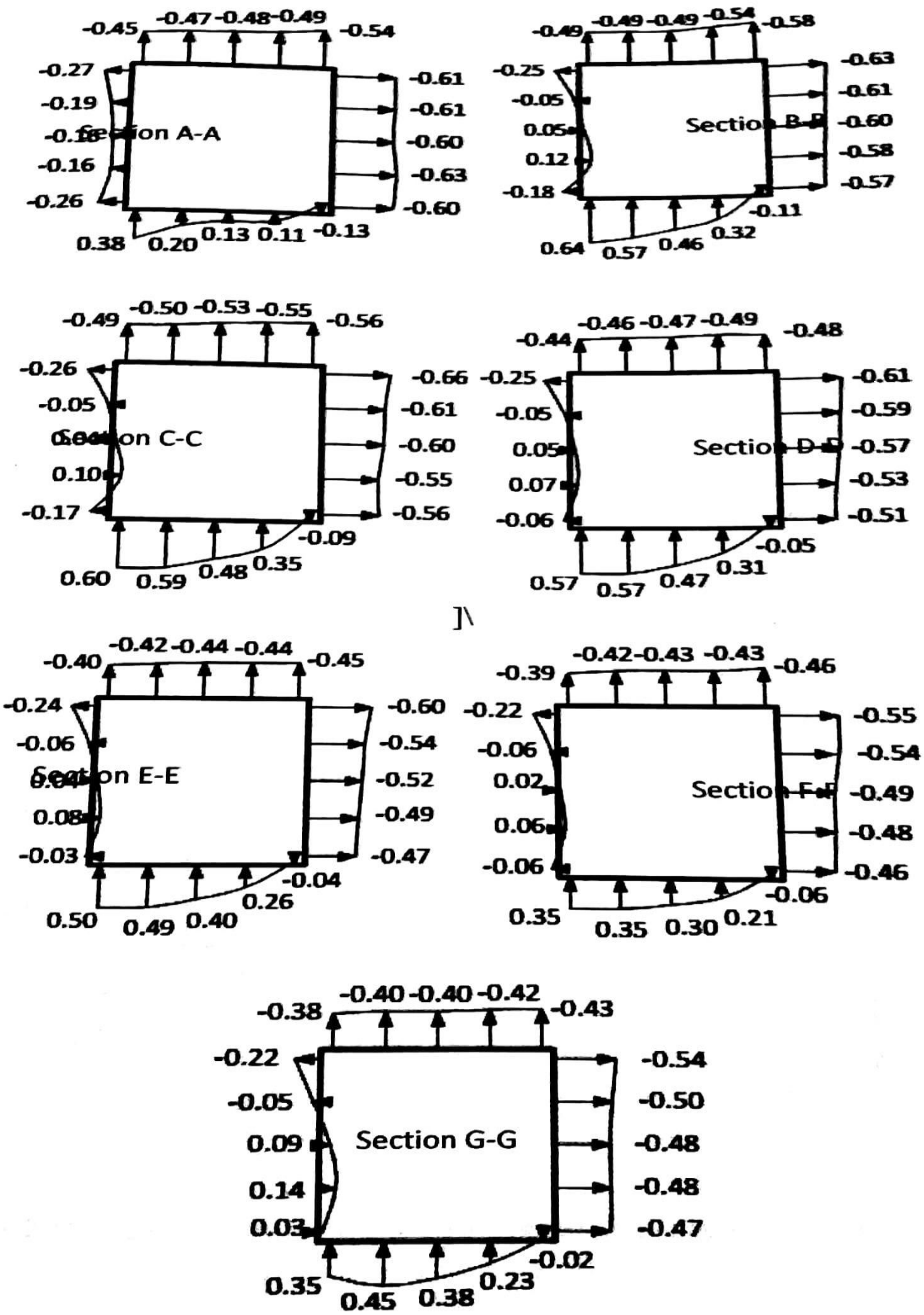


Fig 4.7 Cross-sectional variation of mean wind pressure on square shape at 60 degree wind incidence angle

CHAPTER 5

WIND RESPONSE ANALYSES

5.1 GENERAL

The purpose of study is to evaluate the position of tall buildings with square shapes under wind loads got from experimental measurements. The linear static method is used to analyze buildings using STAAD.PRO software. For various wind incidents the response of building frame is obtained with angles of 0 degree, 30 degree, 60 degree under isolated conditions.

5.2 DETAILS OF THE BUILDING

Building of square shaped is considered for wind response analysis. A G+17 storied building of plan area 20m X 20m and height 60 m is modeled using STAAD.PRO software. Building frame is consist of R.C.C beams, columns and slab. Table gives the details of element and building dimensions.

S. No	Particulars	Details
1.	Height of the Building	60 m
2.	Height of first storey	4.75 m
3.	Height of remaining storey	3.25 m
4.	No of Storey	G+17
5.	Size of beam	300mm X 600mm
6.	Size of Column	600mm X 600mm
7.	Thickness of slab	150mm
8.	Grade of concrete	M25
9.	Grade of steel reinforcement	Fe415
10.	Bracing System	ISA 200X200X25
10.	Live load on floor	4 kN/m^2
11.	Live load on roof	1.5 kN/m^2

Table 5.1 Description of frame element and building

5.3 RESONSE OF SQUARE SHAPE BUILDING WITHOUT BRACING SYSTEM

COLUMN A

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 3314.76 kN. For 30 degree, maximum axial force is equal to 3295.61 kN. And For 60 degree, maximum axial force is equal to 3525.71 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to -1097.45 kNm. For 30 degree, maximum moment is equal to -1042.11 kNm. And For 60 degree, maximum moment is equal to -1729.43 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 0 kNm. For 30 degree, maximum moment is equal to 1127.64 kNm. And For 60 degree, maximum moment is equal to 3121.175 kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 4.9718 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to 4.3128 cm & along the Y-direction is equal to 2.0614 cm. For 60 degree, displacement along the X direction is equal to 2.8543cm cm & along the Y-direction is equal to 4.6801 cm.

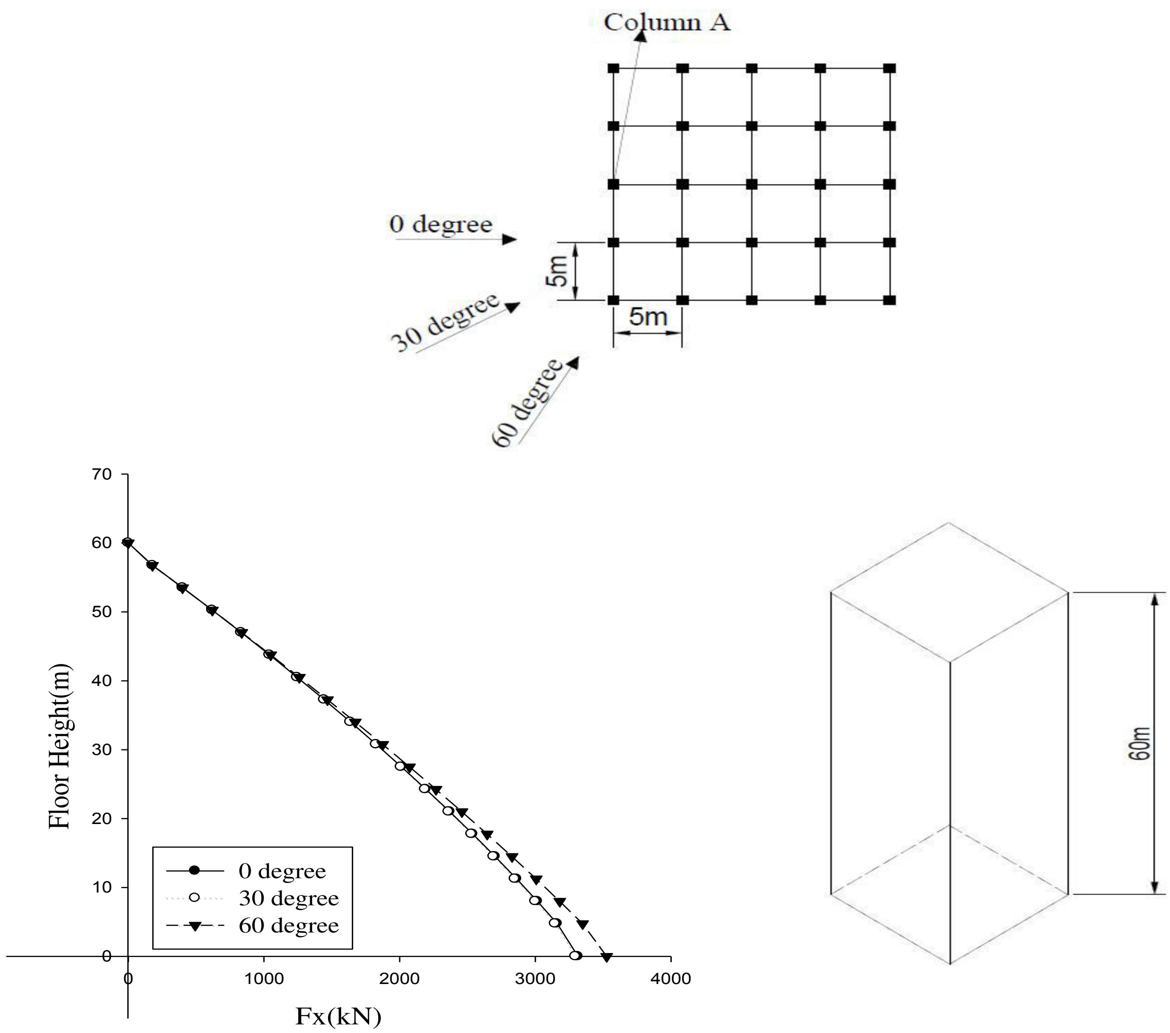


Fig 5.1 Effects of wind on axial force in column-A

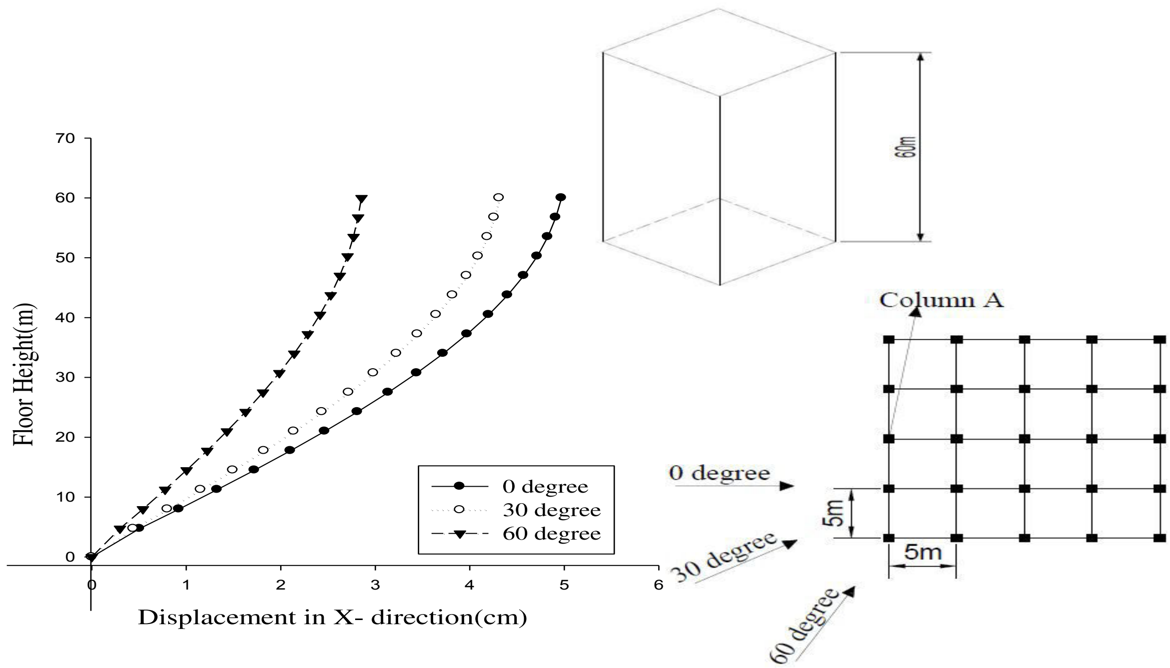


Fig 5.2 Effects of wind on displacement in x direction in column-A

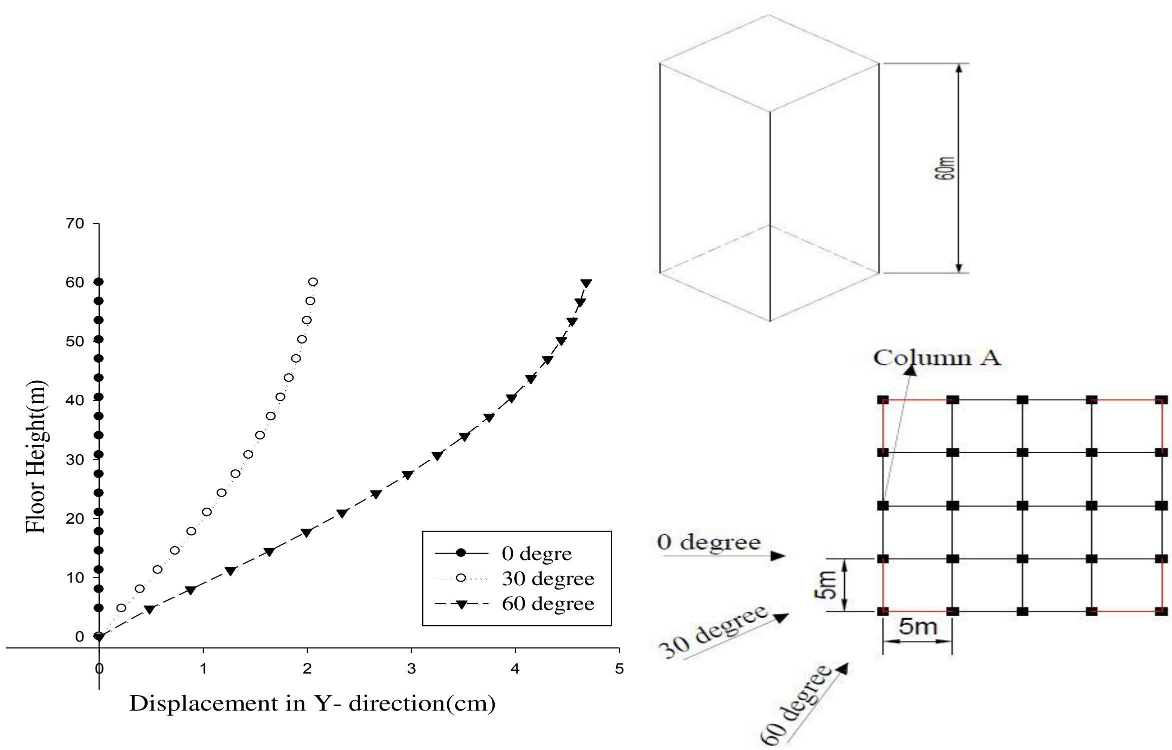


Fig 5.3 Effects of wind on displacement in y direction in column-A

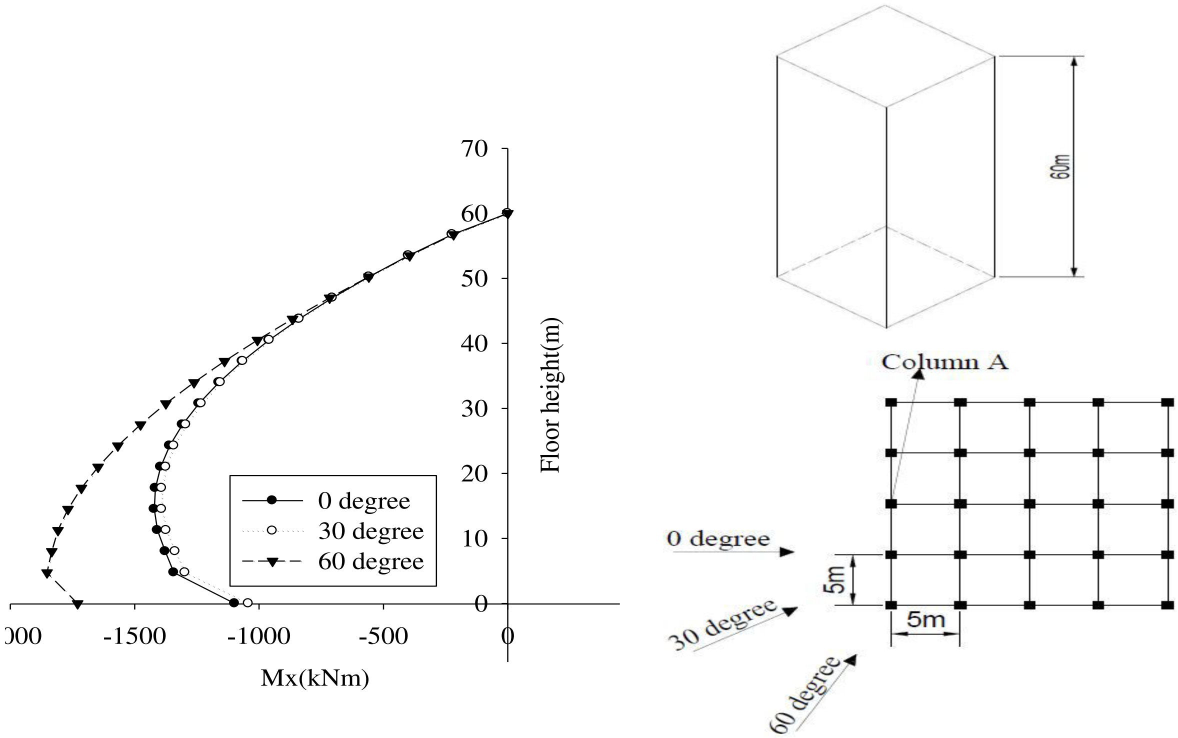


Fig 5.4 Effects of wind on moment M_x in column-A

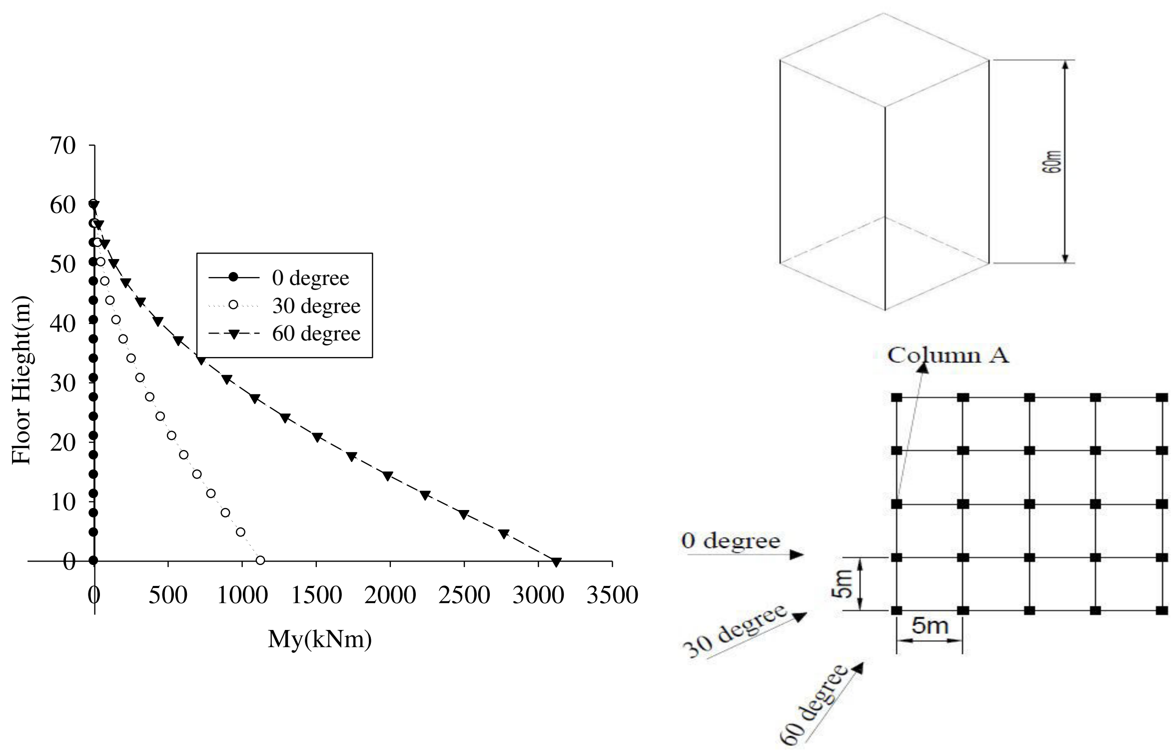


Fig 5.5 Effects of wind on moment M_y in column-A

COLUMN B

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 5404.77 kN. For 30 degree, maximum axial force is equal to 5404.74 kN. And For 60 degree, maximum axial force is equal to 5404.74 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 3029.305 kNm. For 30 degree, maximum moment is equal to 3142.74 kNm. And For 60 degree, maximum moment is equal to 1743.908 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 0 kNm. For 30 degree, maximum moment is equal to 1520.315 kNm. And For 60 degree, maximum moment is equal to 2844.405 kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 4.9718 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to 4.3128 cm & along the Y-direction is equal to 2.0614 cm. For 60 degree, displacement along the X direction is equal to 2.8543cm cm & along the Y-direction is equal to 4.6801 cm.

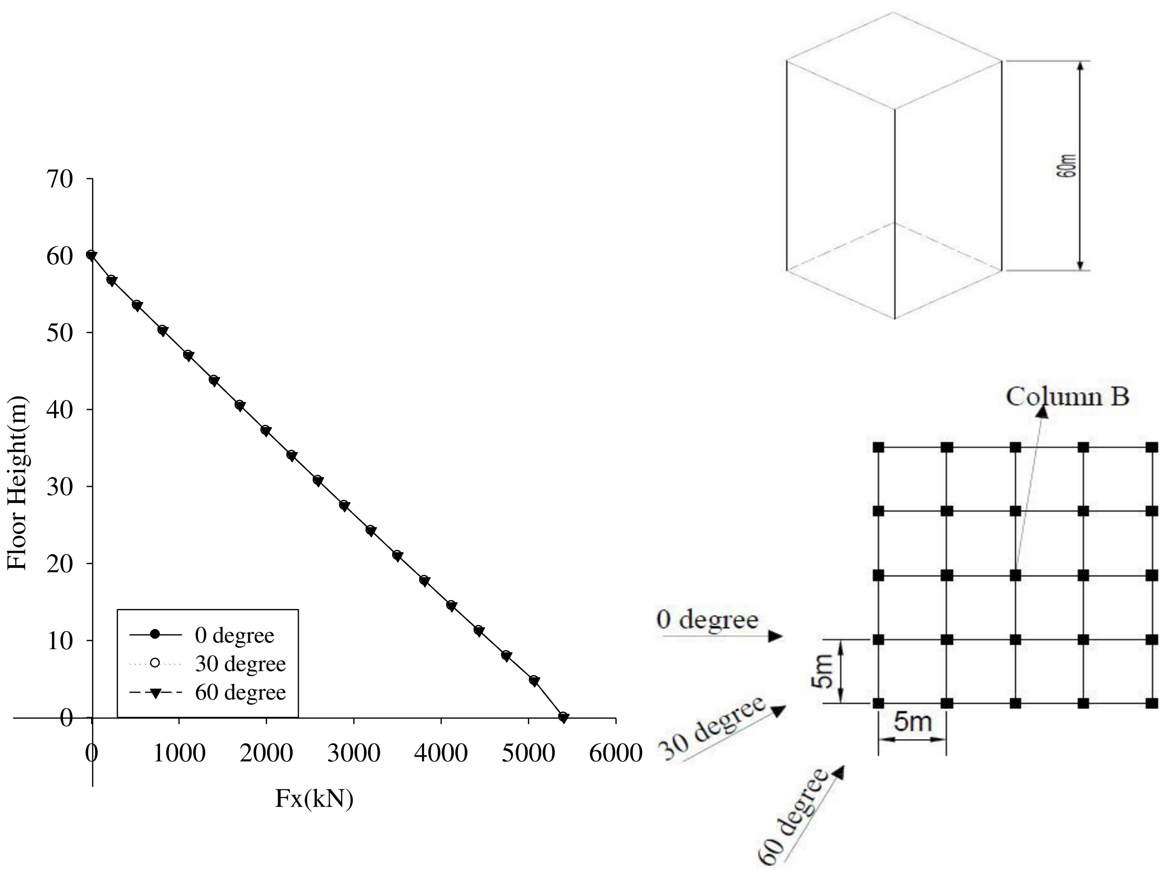


Fig 5.6 Effects of wind on axial force in column-B

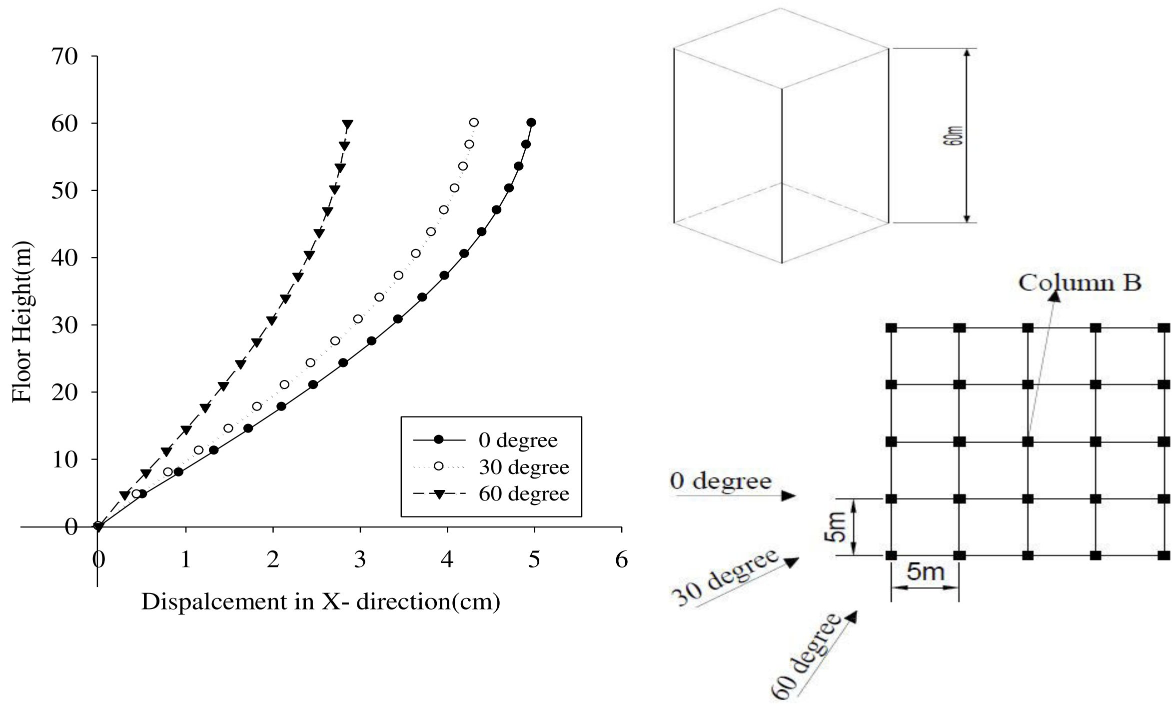


Fig 5.7 Effects of wind on displacement in X direction in column-B

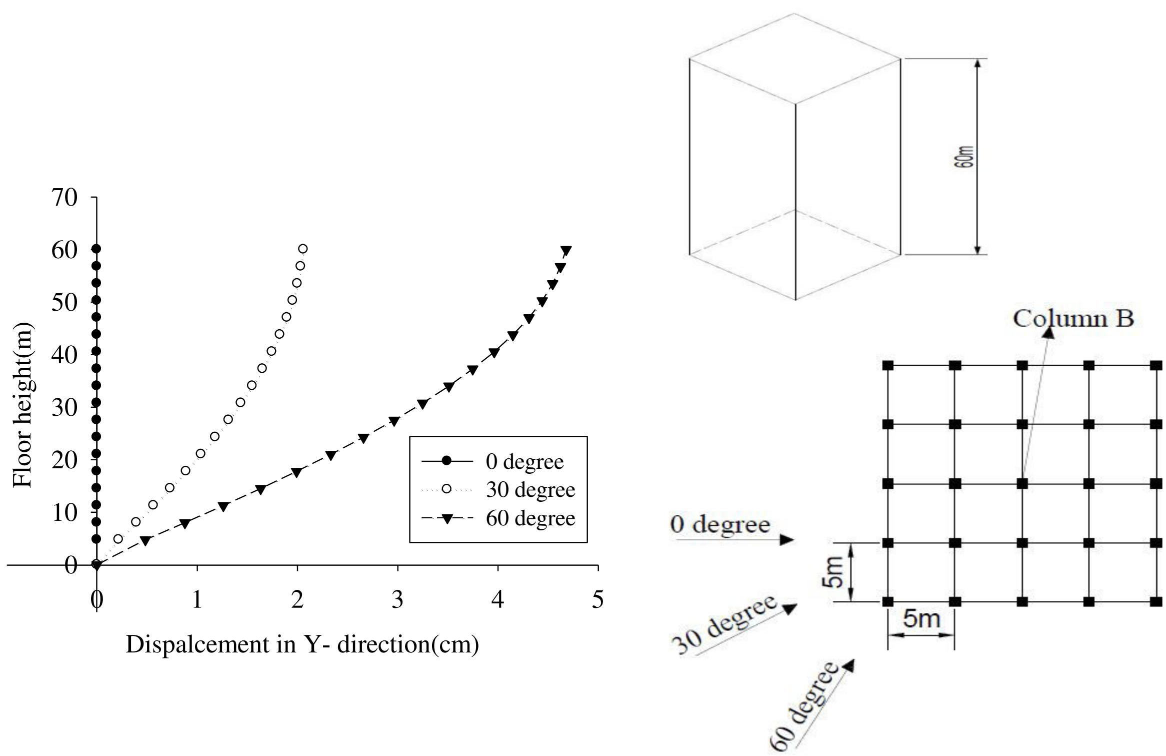


Fig 5.8 Effects of wind on displacement in Y direction in column-B

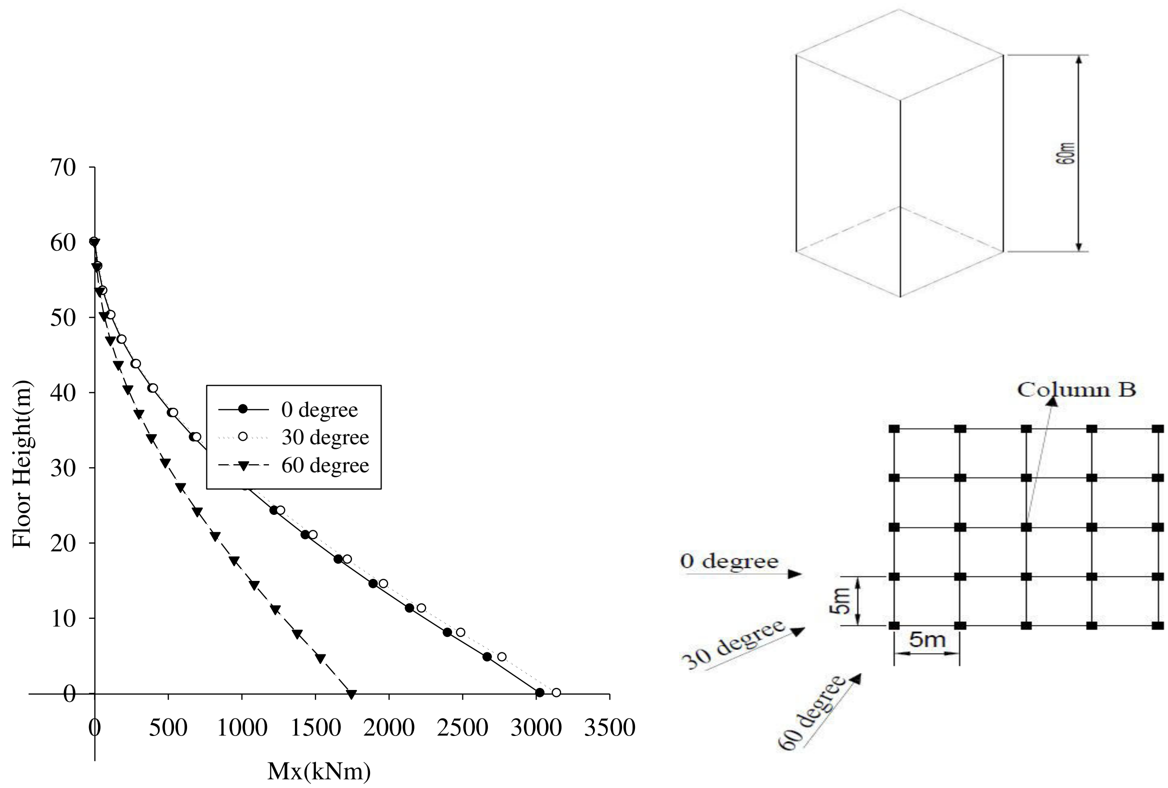


Fig 5.9 Effects of wind on moment M_x in column-B

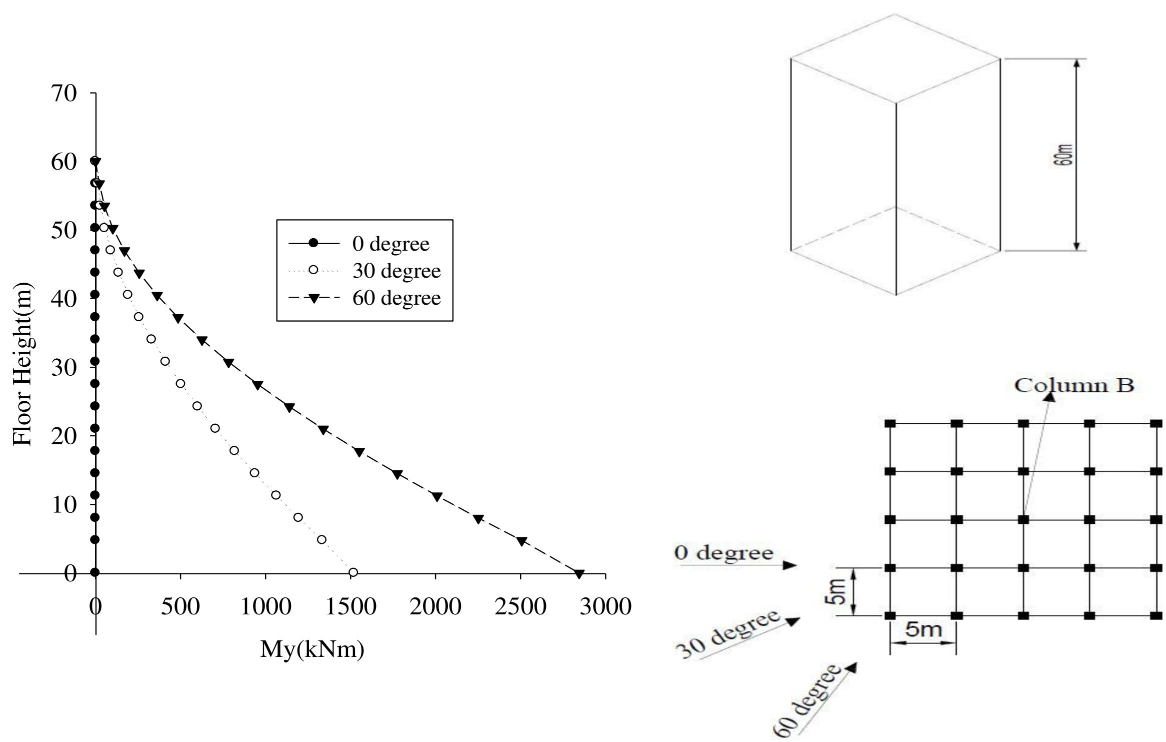


Fig 5.10 Effects of wind on moment M_y in column-B

COLUMN C

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 5014.4 kN. For 30 degree, maximum axial force is equal to 4985.3 kN. And For 60 degree, maximum axial force is equal to 4925.79 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 4249.825 kNm. For 30 degree, maximum moment is equal to 4527.22 kNm. And For 60 degree, maximum moment is equal to 2934.763 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to -1441.04 kNm. For 30 degree, maximum moment is equal to 93.17 kNm. And For 60 degree, maximum moment is equal to 1032.183 kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 4.9718 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to = 4.3128 cm & along the Y-direction is equal to 2.0614 cm. For 60 degree, displacement along the X direction is equal to 2.8543cm cm & along the Y-direction is equal to 4.6801 cm.

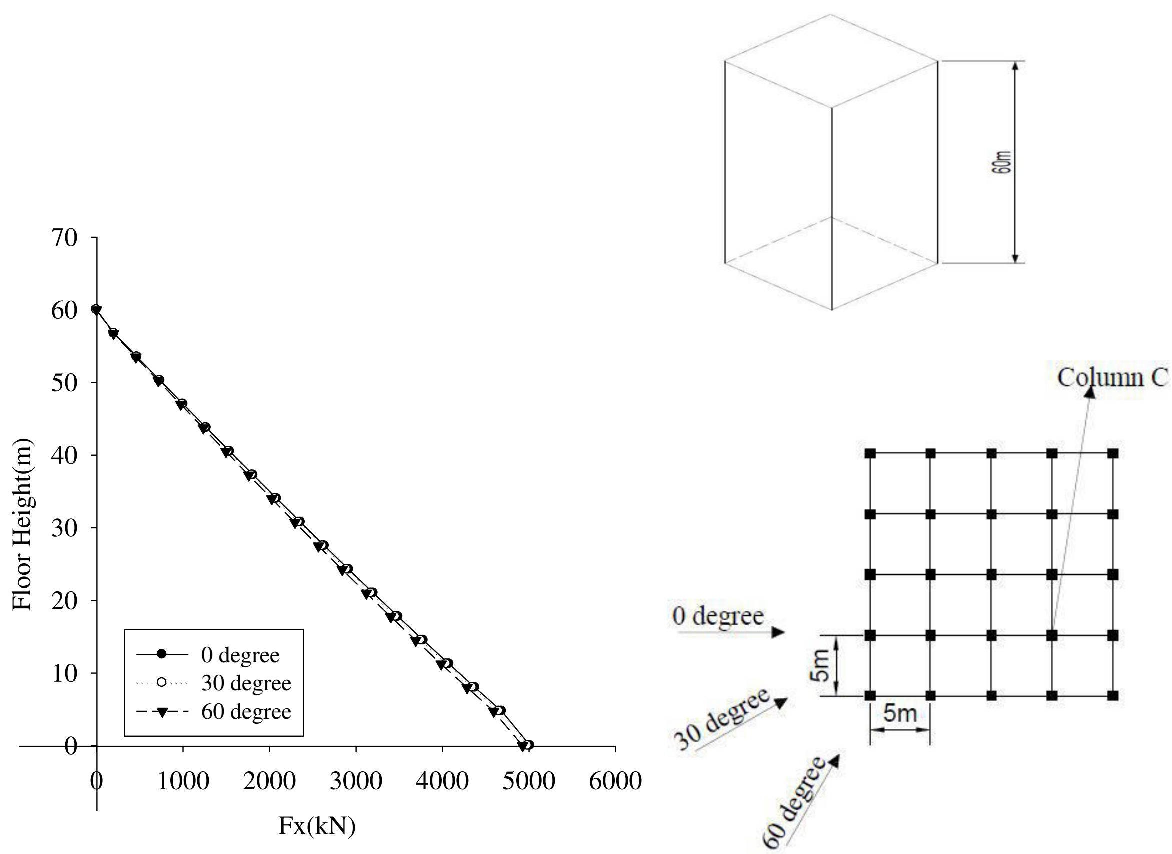


Fig 5.11 Effects of wind on axial force in column-C

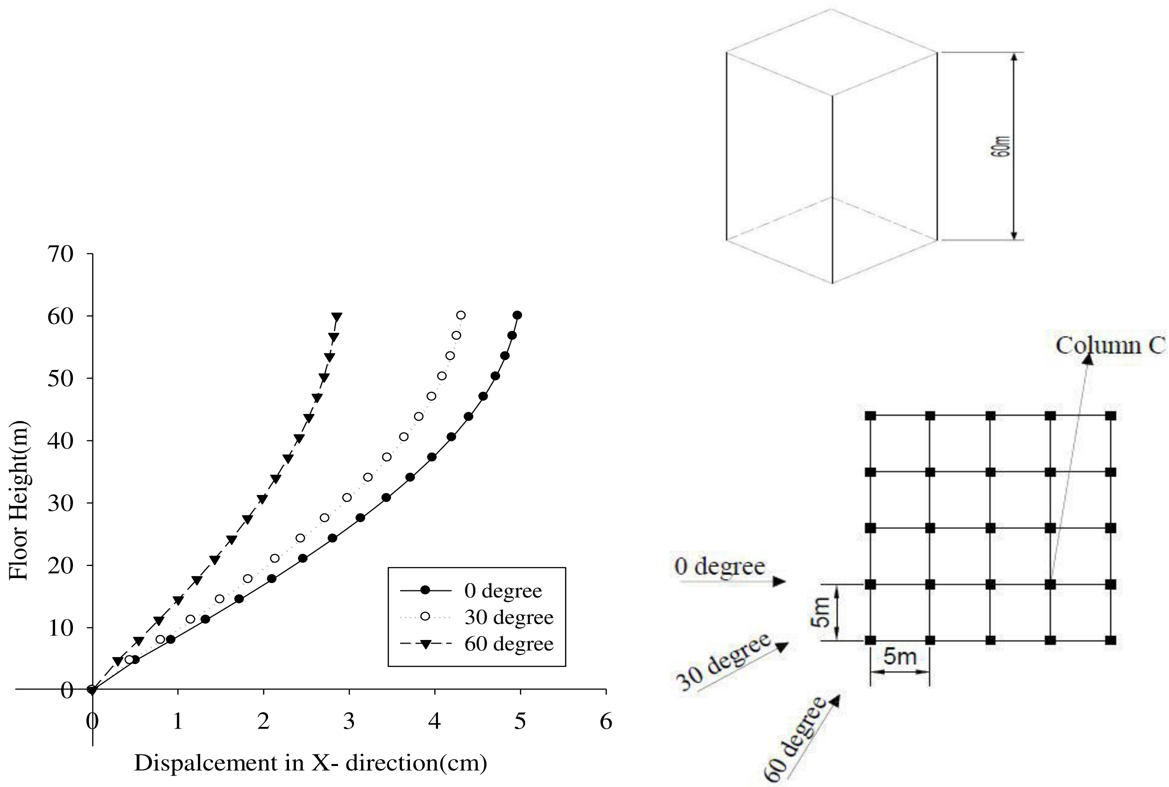


Fig 5.12 Effects of wind on displacement in x direction in column-C

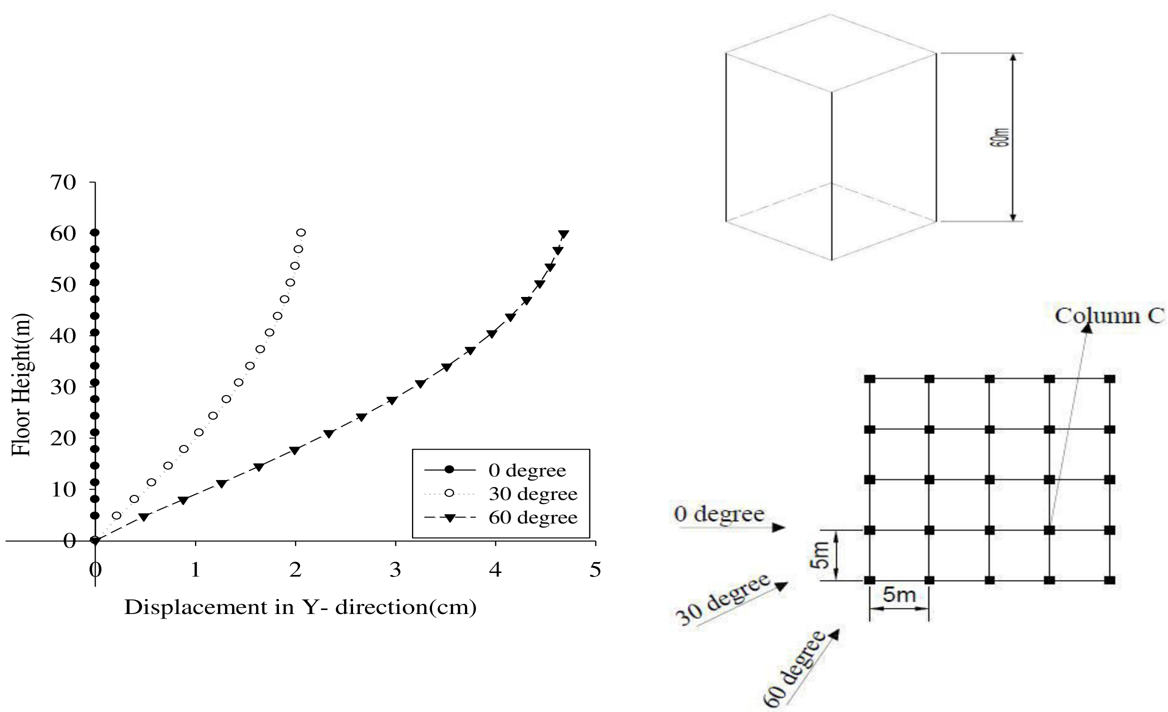


Fig 5.13 Effects of wind on displacement in y direction in column-C

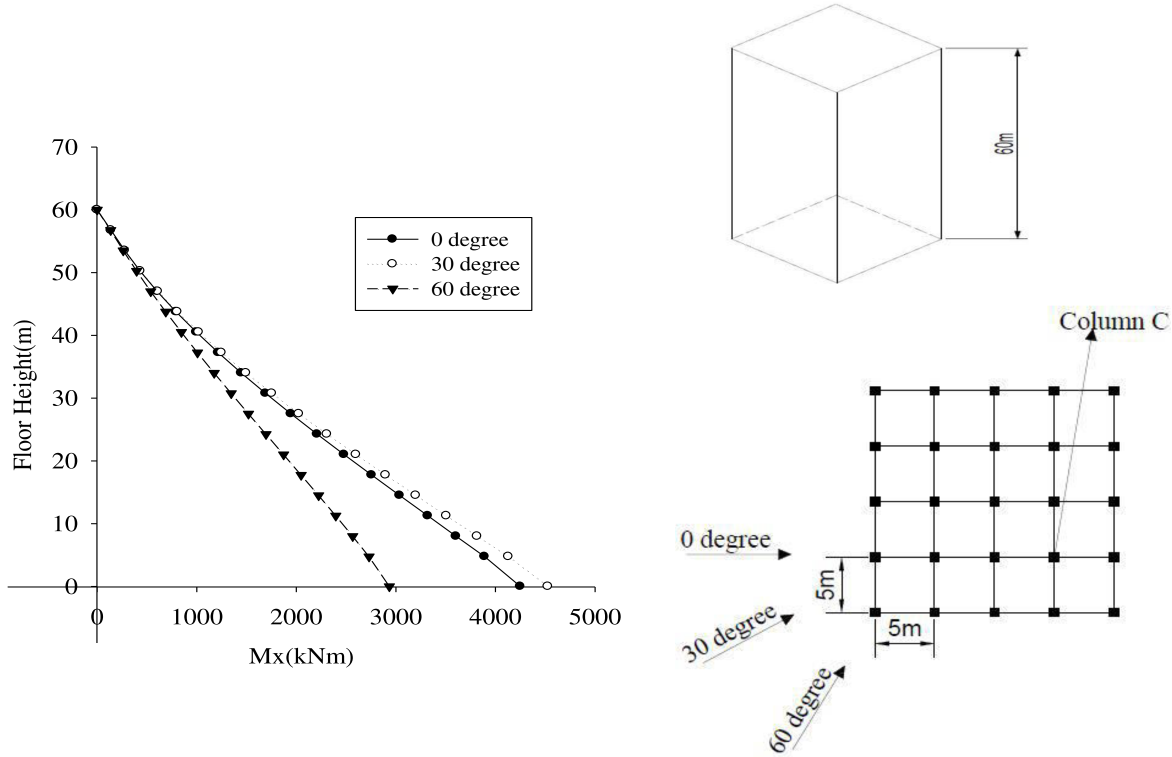


Fig 5.14 Effects of wind on moment M_x in column-C

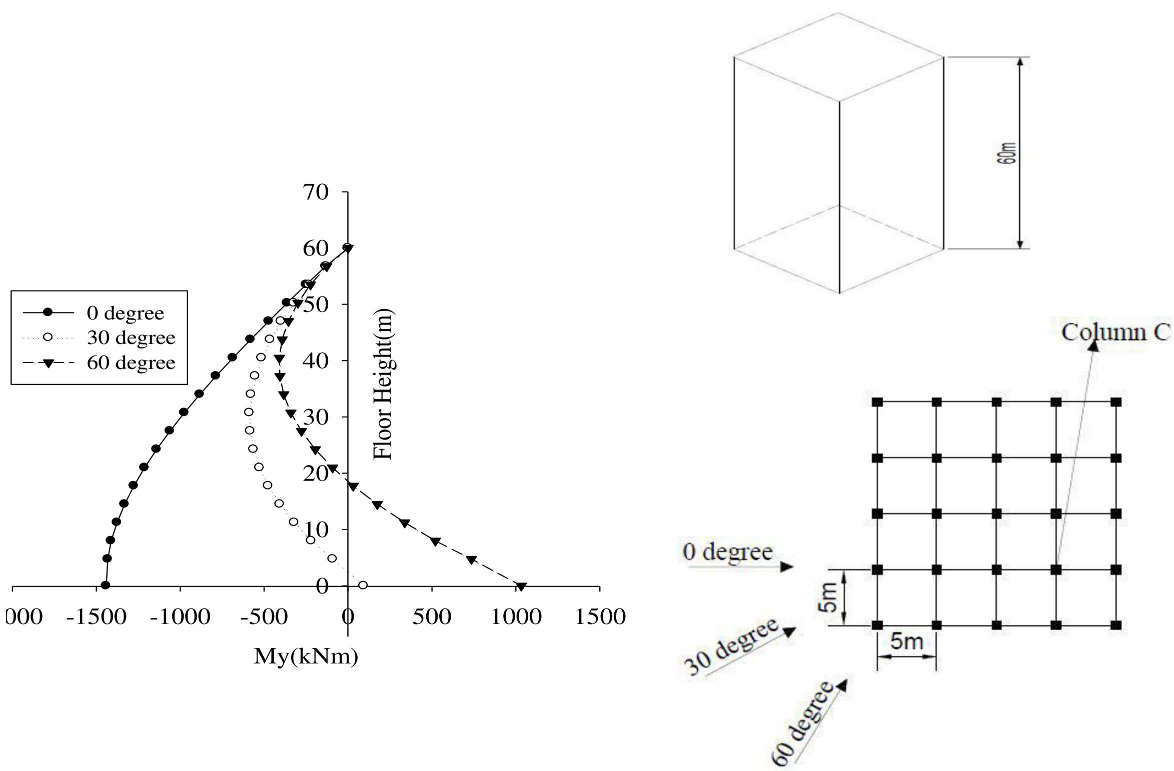


Fig 5.15 Effects of wind on Moment M_y in column-C

5.4 RESONSE OF SQUARE SHAPE BUILDING WITH BRACING SYSTEM

COLUMN A

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 3319.17 kN. For 30 degree, maximum axial force is equal to 3276.25 kN. And For 60 degree, maximum axial force is equal to 2138.81 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to -1716.53 kNm. For 30 degree, maximum moment is equal to -1631.95 kNm. And For 60 degree, maximum moment is equal to -1770.08 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 0 kNm. For 30 degree, maximum moment is equal to 1174.913 kNm. And For 60 degree, maximum moment is equal to 2875.585 kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 3.6753 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to 3.3252 cm & along the Y-direction is equal to 1.7613 cm. For 60 degree, displacement along the X direction is equal to 2.0263cm cm & along the Y-direction is equal to 3.3268 cm.

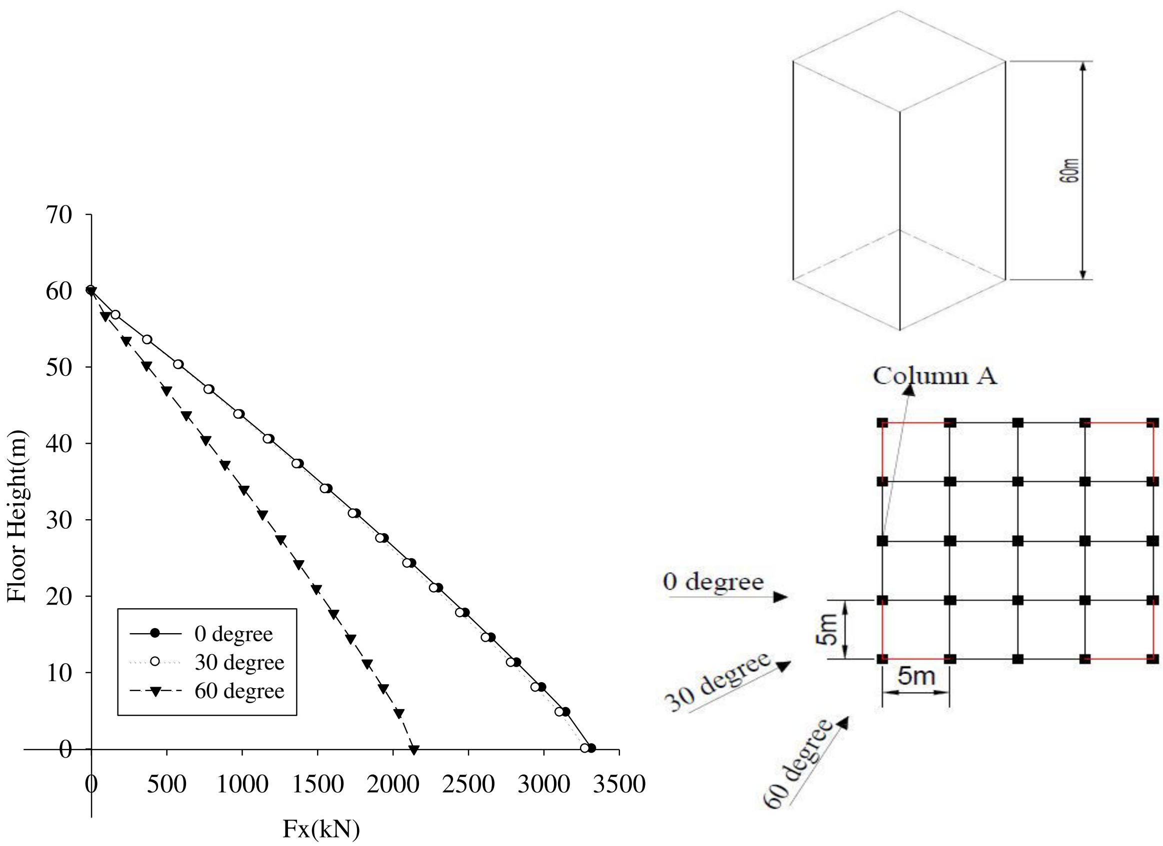


Fig 5.16 Effects of wind on axial force in column-A

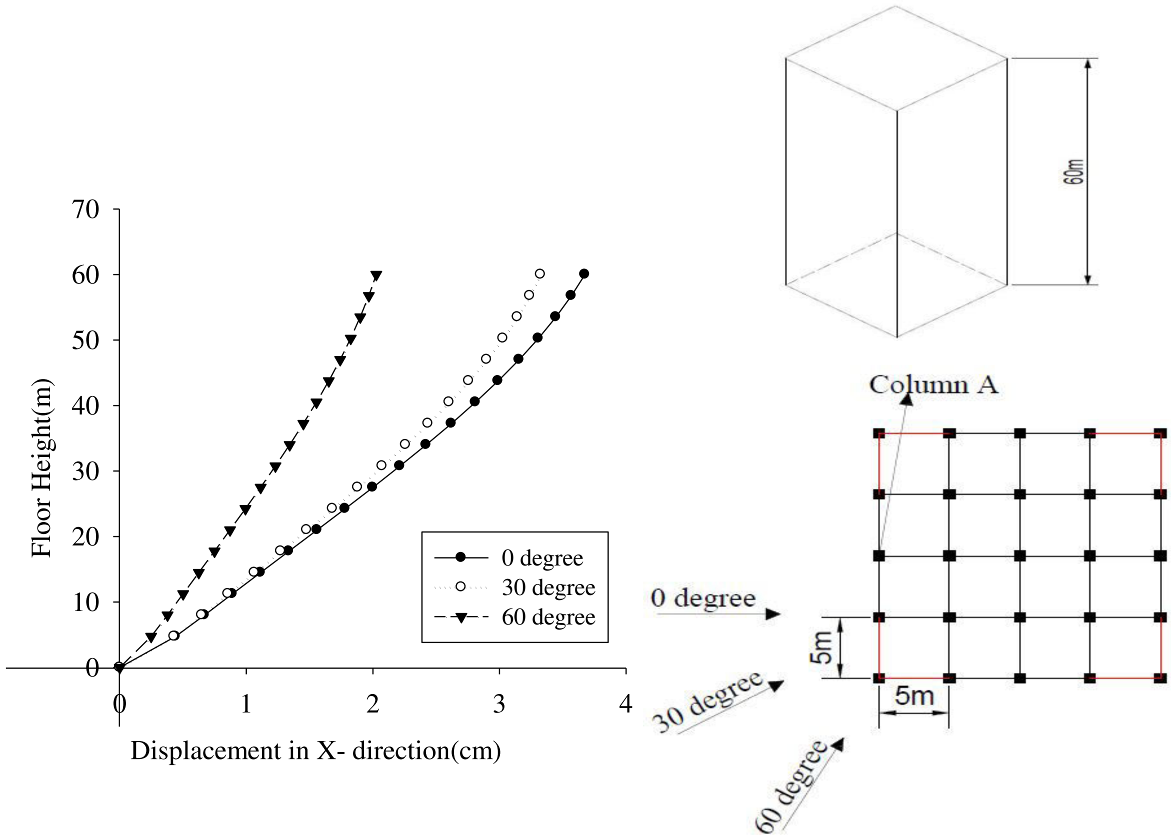


Fig 5.17 Effects of wind on displacement in x direction in column-A

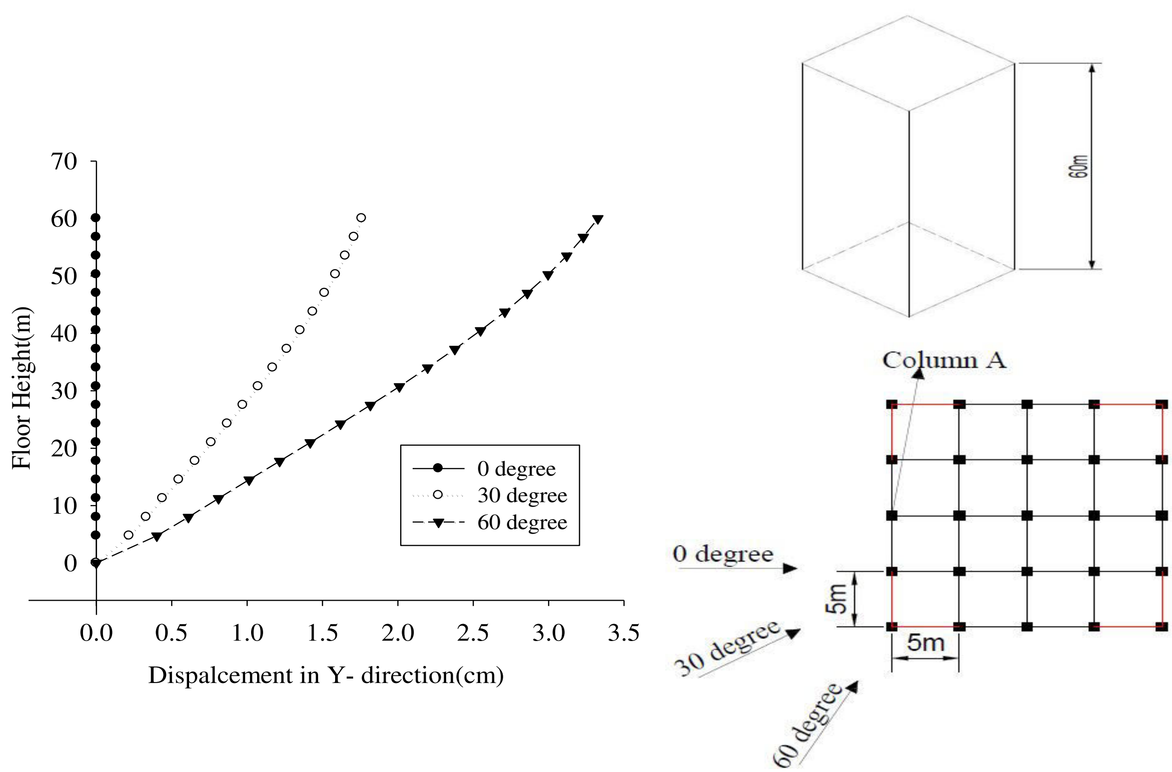


Fig 5.18 Effects of wind on displacement in y direction in column-A

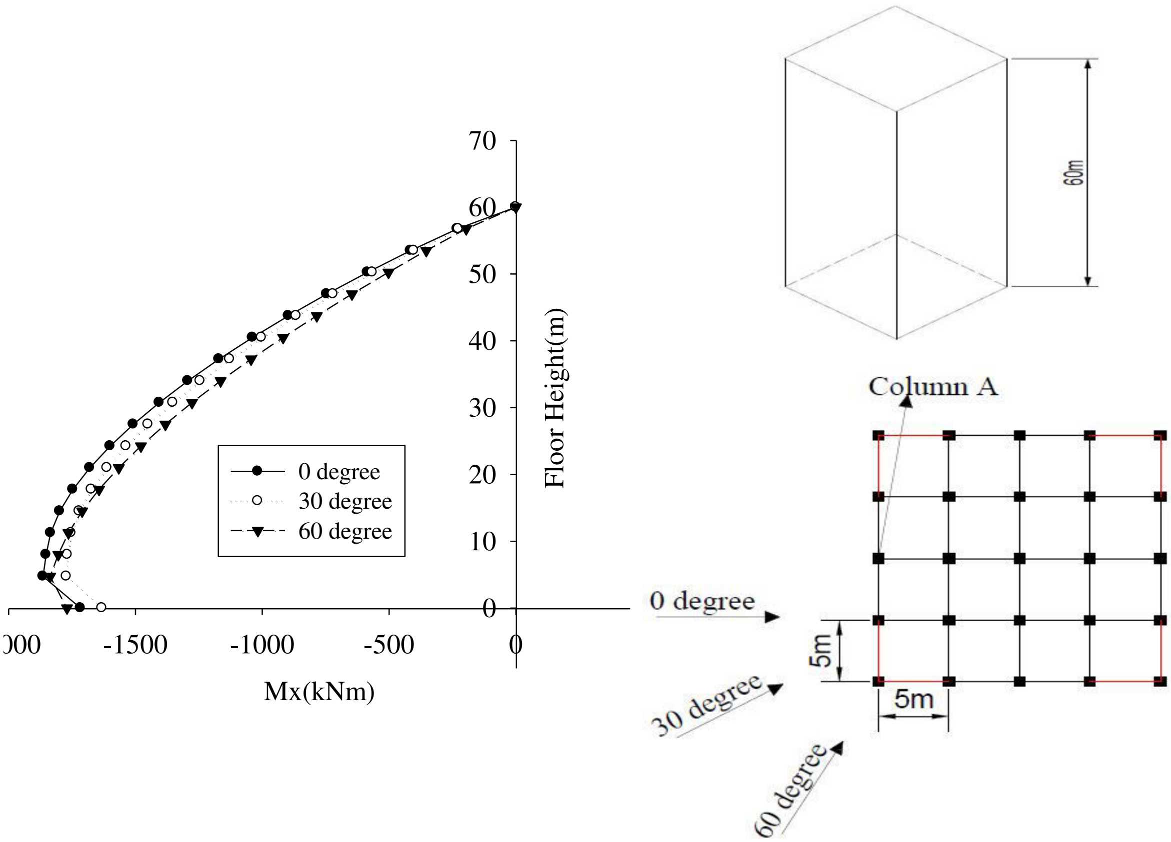


Fig 5.19 Effects of wind on moment M_x in column-A

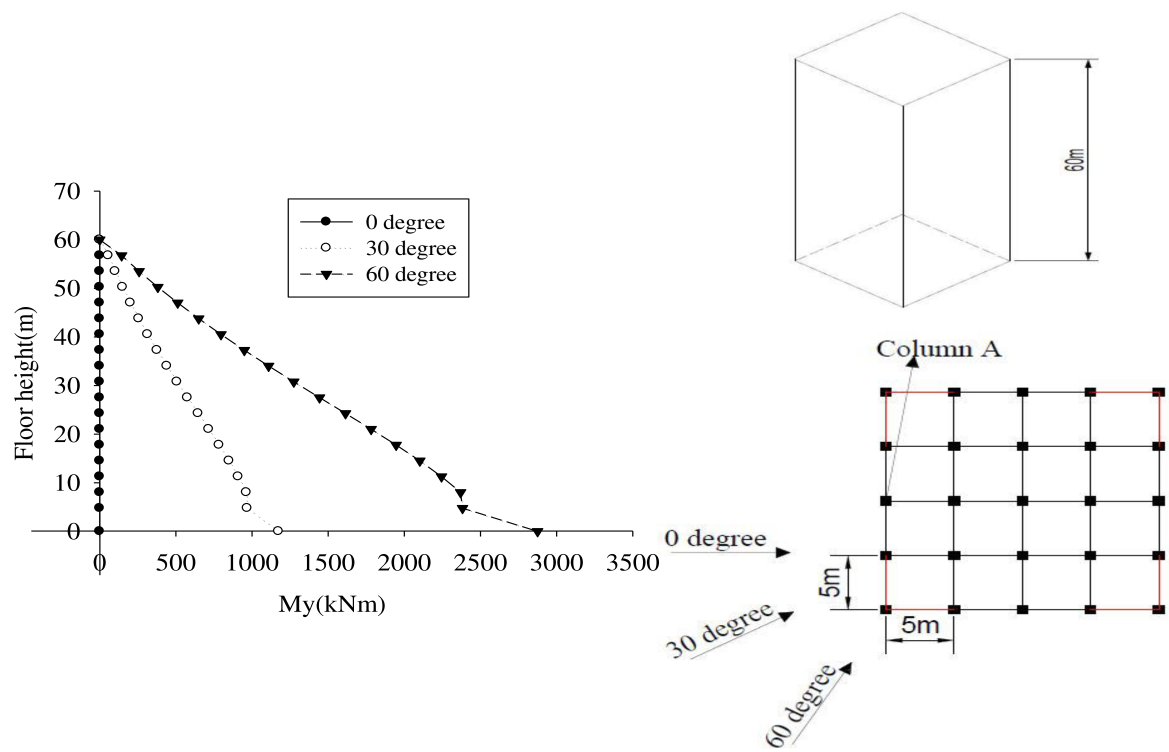


Fig 5.20 Effects of wind on Moment M_y in column-A

COLUMN B

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 5381.87 kN. For 30 degree, maximum axial force is equal to 5381.74 kN. And For 60 degree, maximum axial force is equal to 3887.9 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 2031.868 kNm. For 30 degree, maximum moment is equal to 2246.52 kNm. And For 60 degree, maximum moment is equal to 1250.37 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 0 kNm. For 30 degree, maximum moment is equal to 1096.32 kNm. And For 60 degree, maximum moment is equal to 2875.585 kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 3.6753 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to 3.3252 cm & along the Y-direction is equal to 1.7613 cm. For 60 degree, displacement along the X direction is equal to 2.0263cm cm & along the Y-direction is equal to 3.3268 cm.

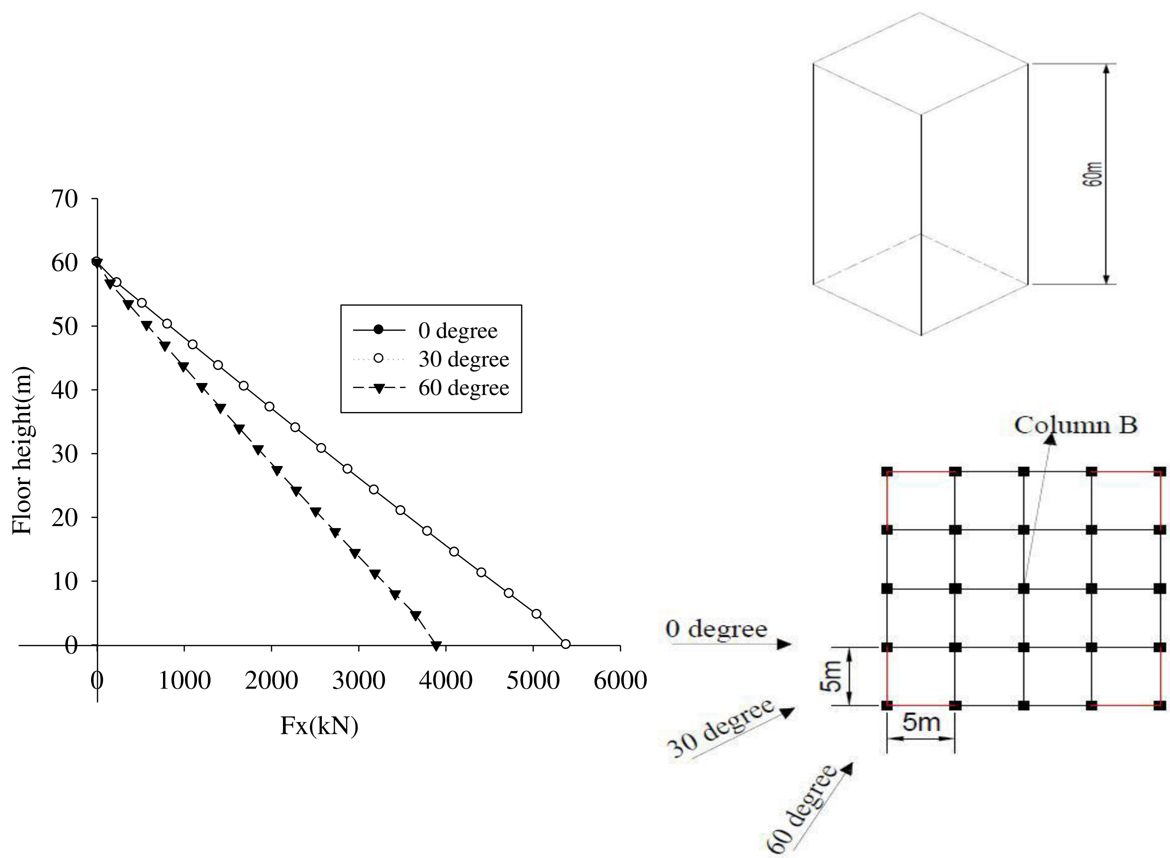


Fig 5.21 Effects of wind on axial force in column-B

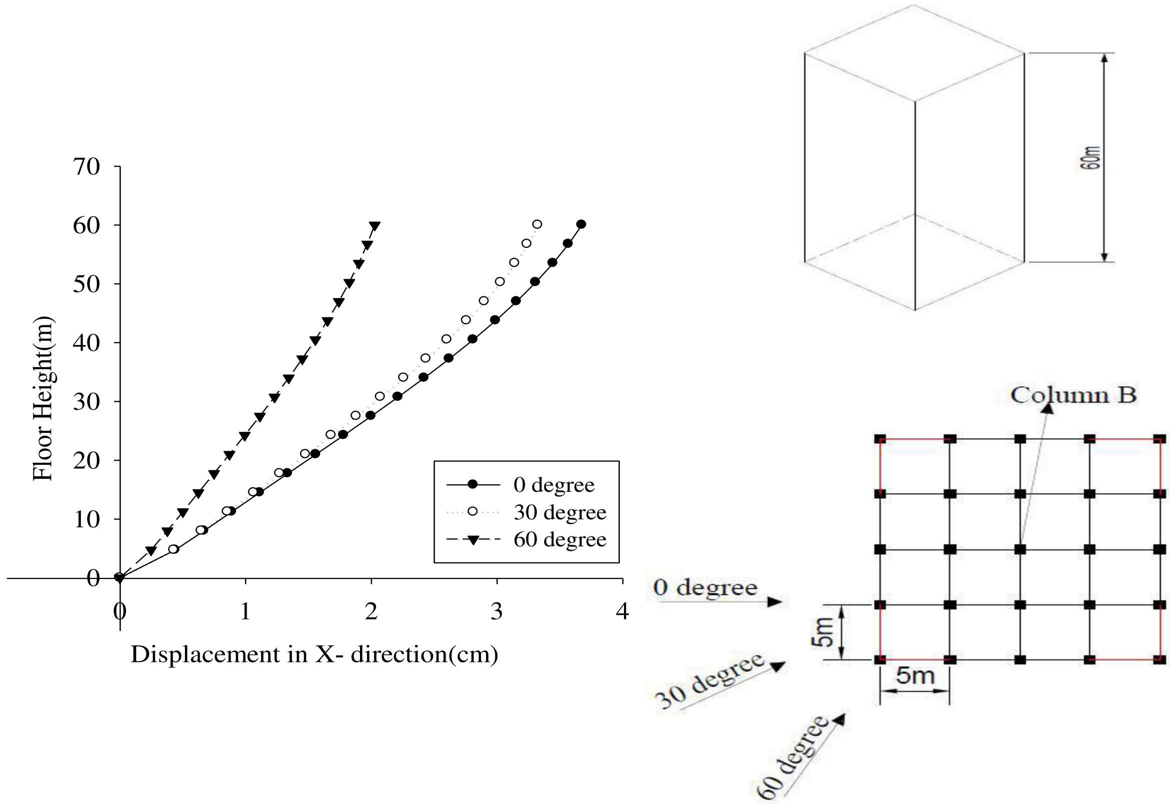


Fig 5.22 Effects of wind on displacement in x direction in column-B

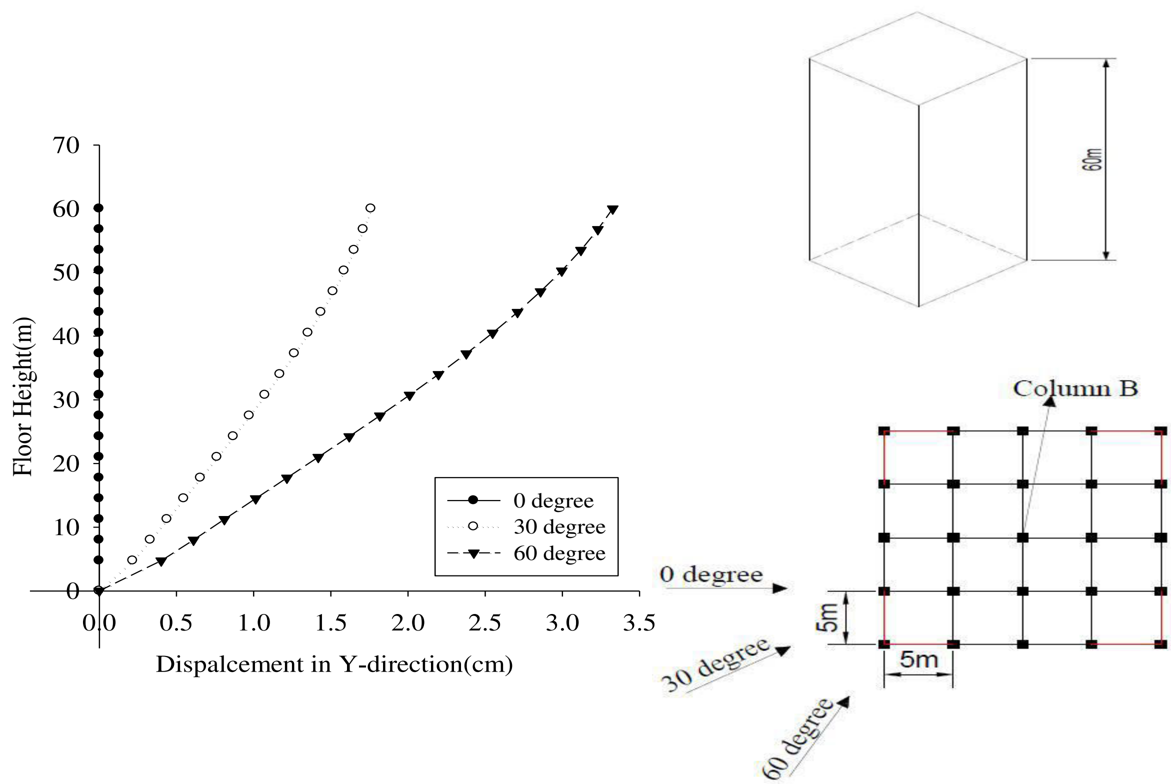


Fig 5.23 Effects of wind on displacement in y direction in column-B

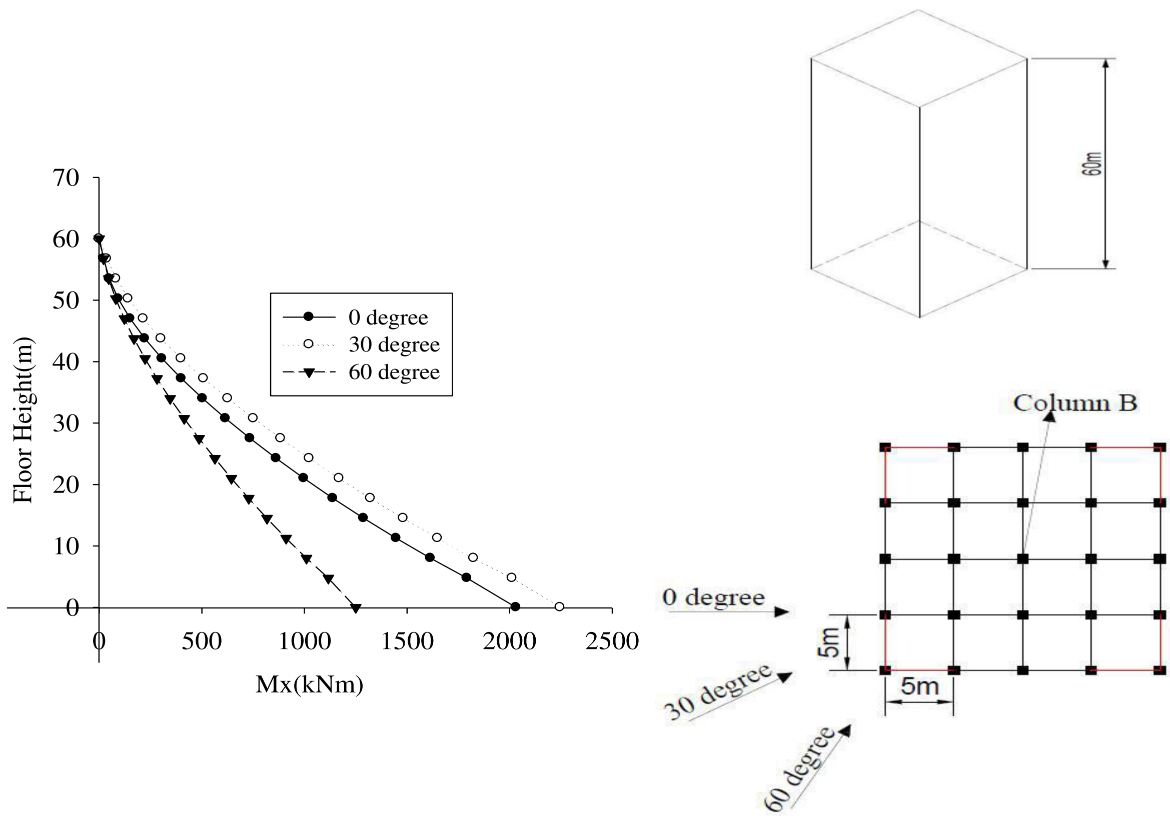


Fig 5.24 Effects of wind on moment M_x in column-B

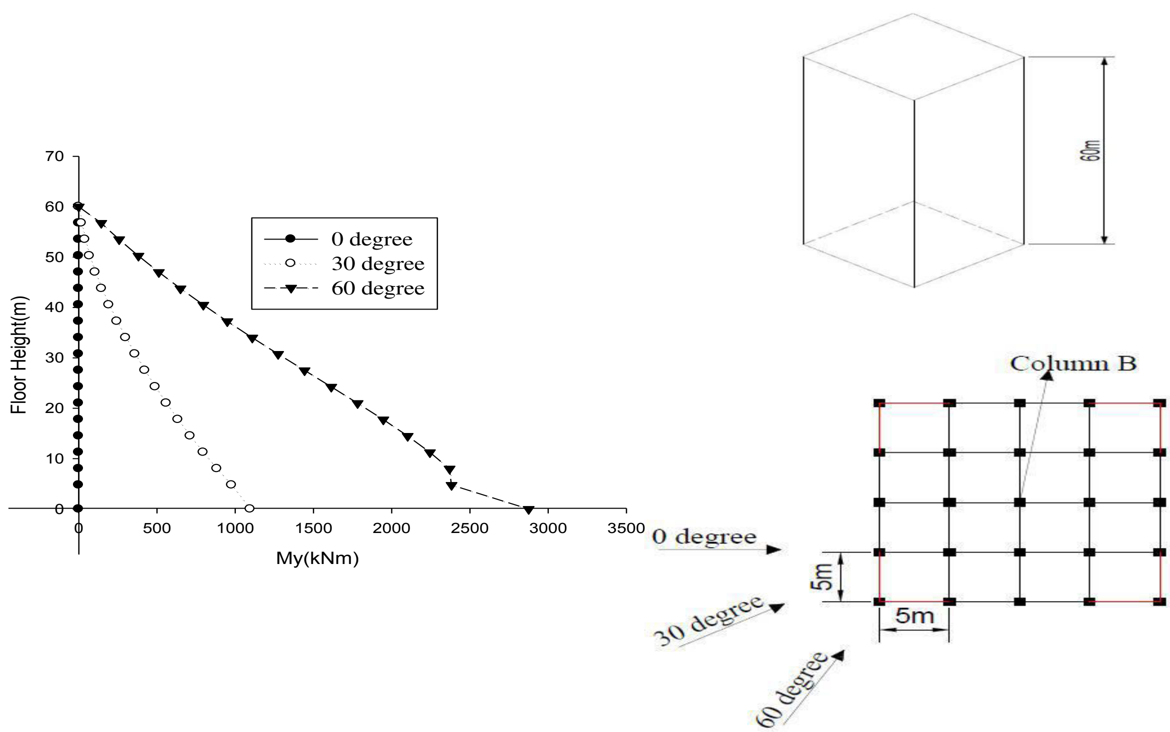


Fig 5.25 Effects of wind on Moment M_y in column-B

COLUMN C

Fx

For 0^0, 30^0,60^0 wind loading, Axial force decrease with increase in height. Maximum value of axial force found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of axial force on moving from top to bottom. For 0 degree, maximum axial force is at the bottom of the building which is equal to 4919.22 kN. For 30 degree, maximum axial force is equal to 4909.72 kN. And For 60 degree, maximum axial force is equal to 3426.9 kN.

M_x

For 0^0, 30^0,60^0 wind loading, moment M_x decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to 3231.483 kNm. For 30 degree, maximum moment is equal to 3291.37 kNm. And For 60 degree, maximum moment is equal to 2134.663 kNm.

M_y

For 0^0, 30^0,60^0 wind loading, moment M_y decrease with increase in height. Maximum value of moment found at the bottom of the building and minimum found at the top edge of the building. This is because of cumulative sum of moment on moving from top to bottom. For 0 degree, maximum moment is at the bottom of the building which is equal to -1861.52 kNm. For 30 degree, maximum moment is equal to -985.07 kNm. And For 60 degree, maximum moment is equal to 16.6575kNm.

Displacement

For 0^0, 30^0,60^0 wind loading, the storey displacement increases with increase in height. Minimum value of storey displacement found at the bottom of the building and maximum found at the top edge of the building. For 0 degree, displacement along the X direction is equal to 3.6753 cm & along the Y-direction is equal to 0 cm. For 30 degree, displacement along the X direction is equal to 3.3252 cm & along the Y-direction is equal to 1.7613 cm. For 60 degree, displacement along the X direction is equal to 2.0263cm cm & along the Y-direction is equal to 3.3268 cm.

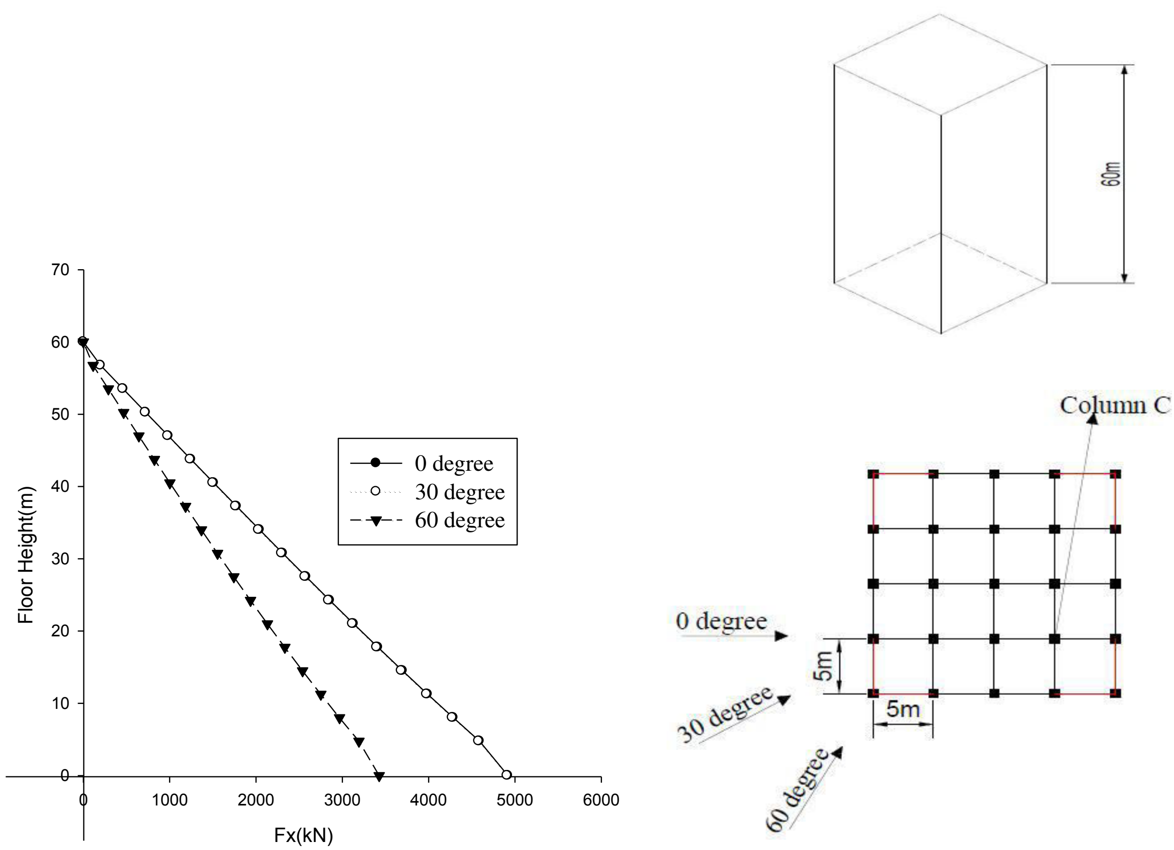


Fig 5.26 Effects of wind on axial force in column-C

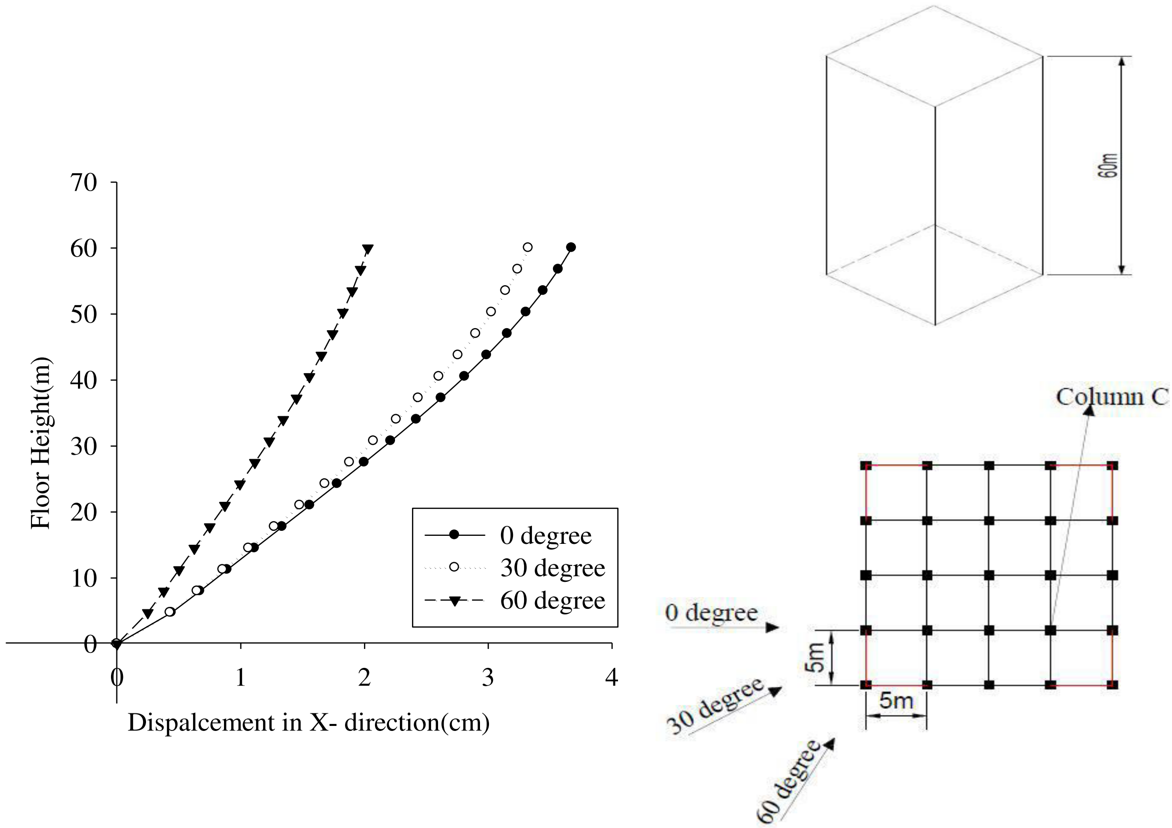


Fig 5.27 Effects of wind on displacement in x direction in column-C

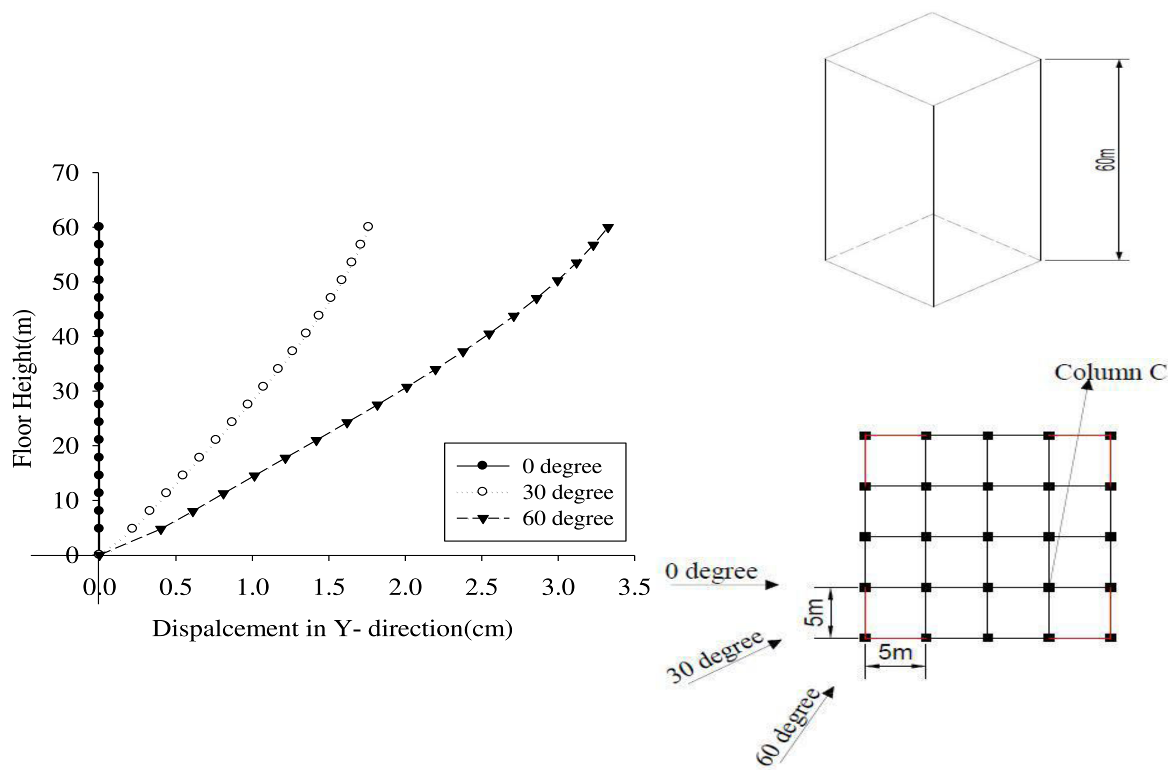
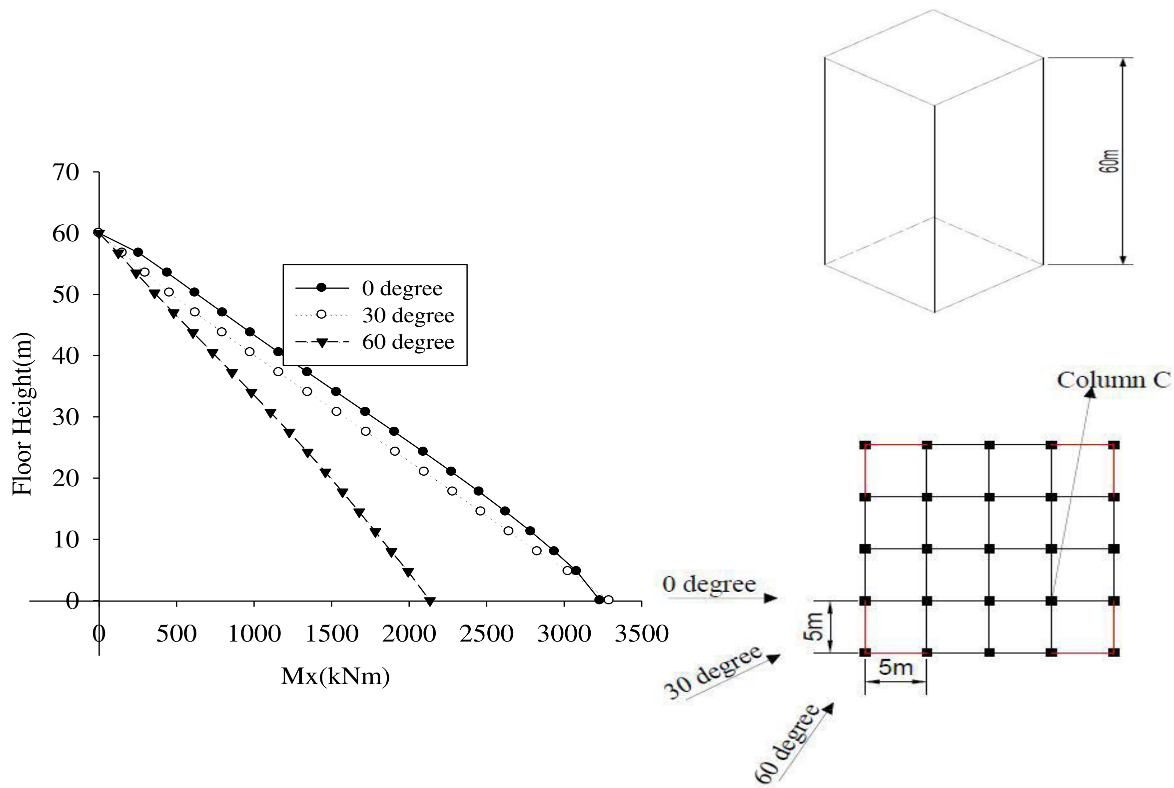


Fig 5.28 Effects of wind on displacement in y direction in column-C



0Fig 5.29 Effects of wind on moment M_x in column-C

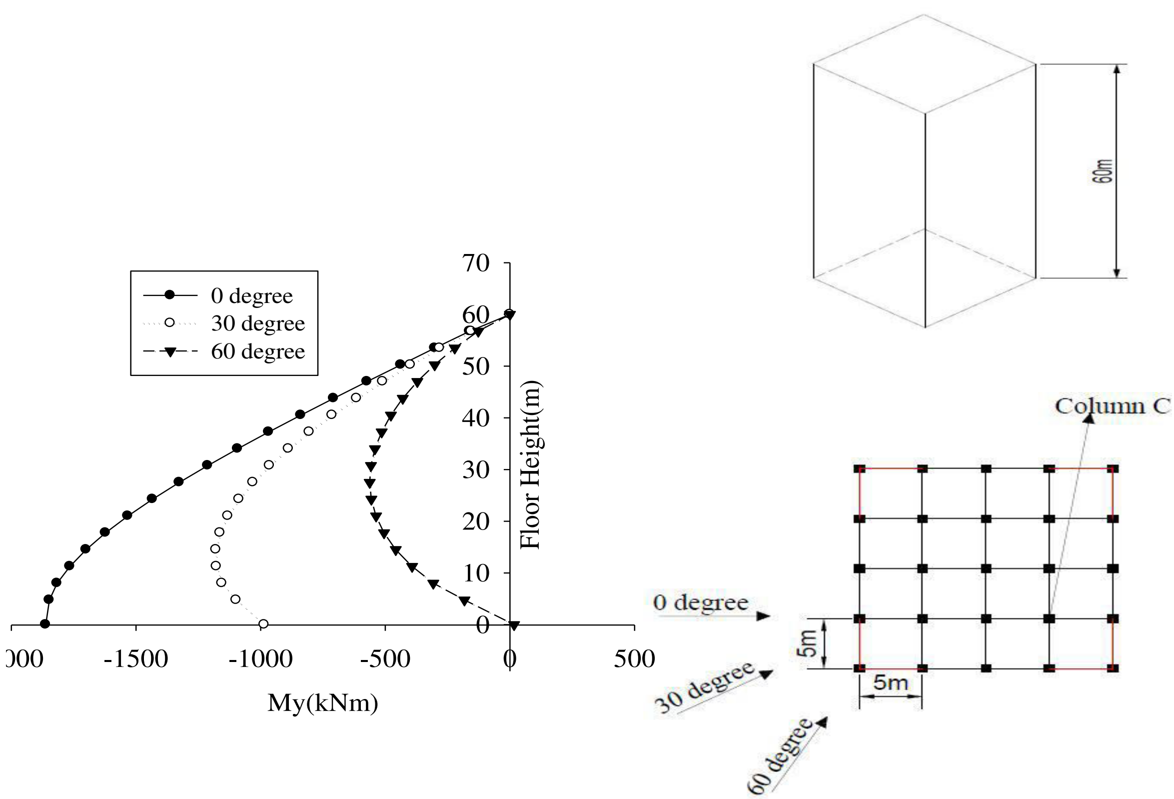


Fig 5.30 Effects of wind on moment M_y in column-C

CHAPTER 6

RESULT AND DISCUSSION

6.1 GENERAL

The purpose of study is to evaluate the position of tall buildings with square shapes under wind loads got from experimental measurements. For various wind incidents the response of building frame is obtained with angles of 0 degree, 30 degree, 60 degree under isolated conditions. And comparison of axial force, displacement along X and y direction, moment (M_x, M_y) at all wind incidence angle with or without bracing system in frame.

6.2 COMPARISON OF WIND RESPONSE

6.2.1 At 0 degree wind incidence in column A

In plot of axial force with height for column A, decreases with increase in height of the building. Axial force is found to be almost equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 0^0 winds loading.

In plot of displacement with height of building for column A, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 0^0 winds loading.

In plot of moment about x axis with height for column A, moment decreases with increase in height of building. And the moment has negative sign which shows the hogging moment developed in the column A. Moment is found to be zero at the top edge of the building in both cases subjected to 0^0 winds loading. But maximum moment does not induced in the column A, at the base of the building. It occurs at the above of the base of the building. In frame with bracing model, moment about x in column A is found to be more in comparison of frame without bracing.

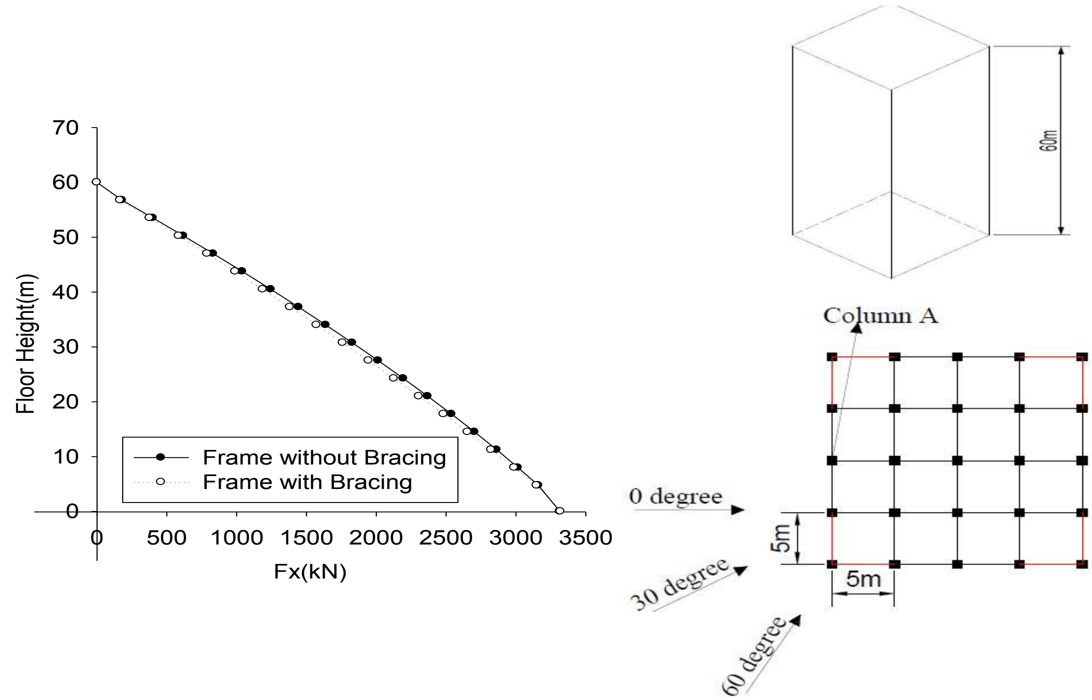


Fig 6.1 Comparison of axial force in column A at 0 degree wind incidence angle with and without bracing in frame

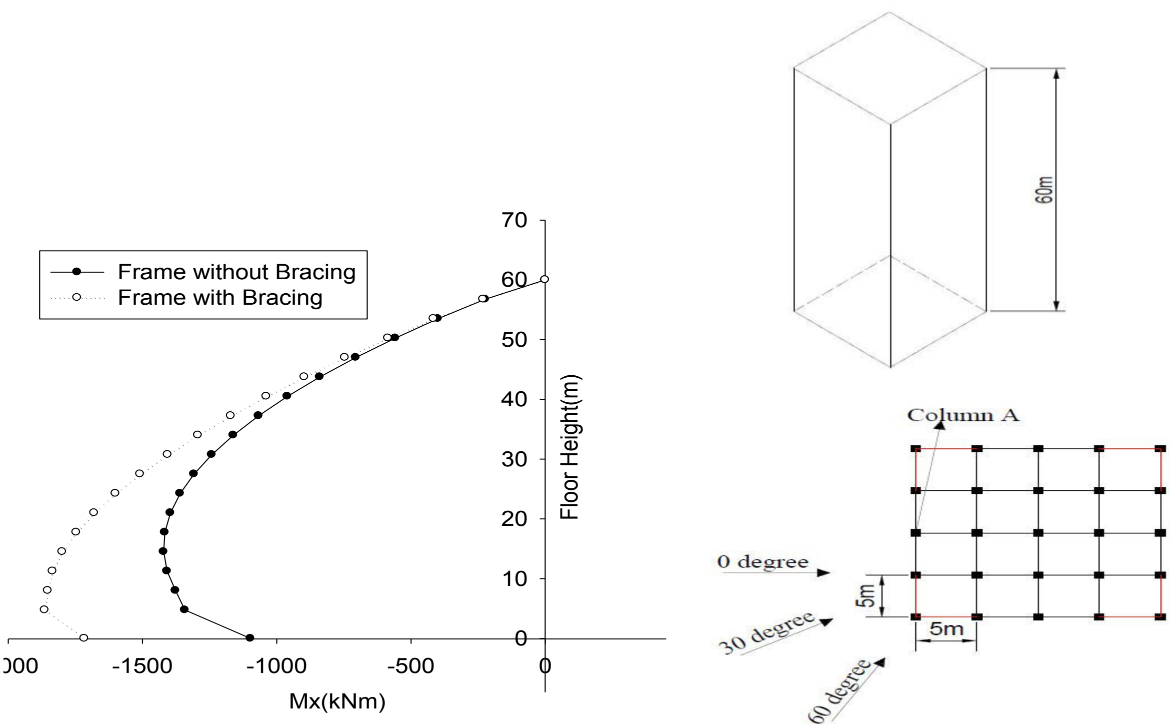


Fig 6.2 Comparison of moment M_x in column A at 0 degree wind incidence angle with and without bracing in frame

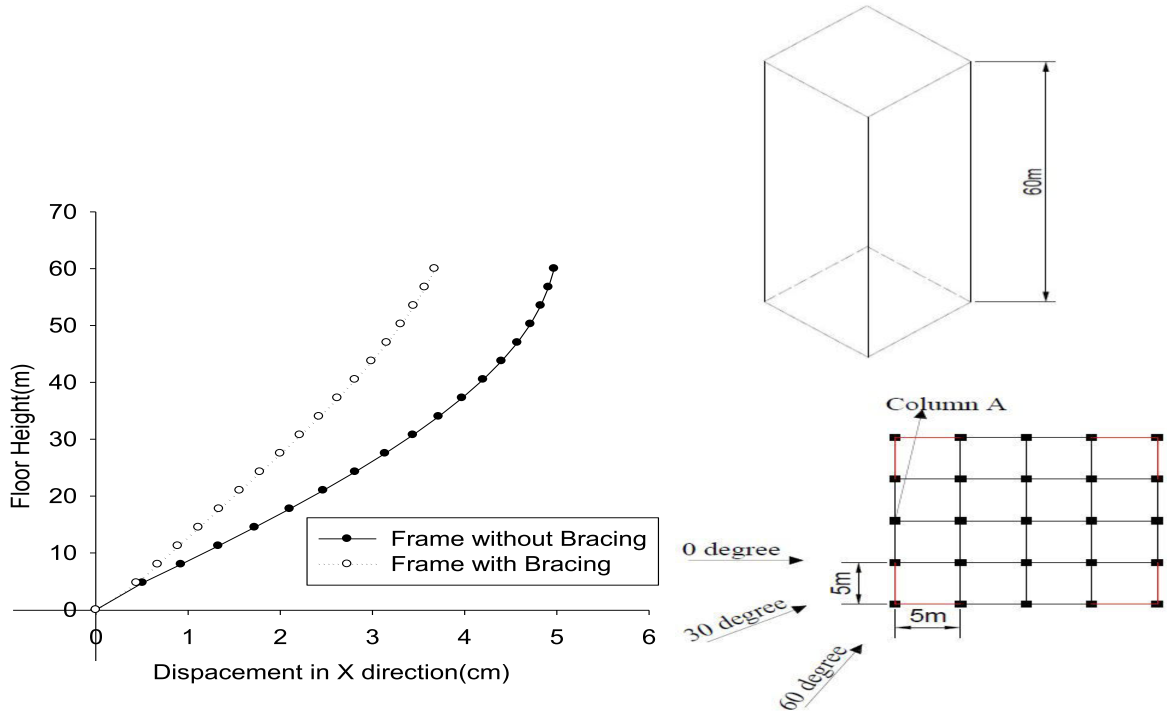


Fig 6.3 Comparison of displacement in X direction in column A at 0 degree wind incidence angle with and without bracing in frame

6.2.2 At 30 degree wind incidence in column A

In plot of axial force with height for column A, decreases with increase in height of the building. Axial force is found to be almost equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 30^0 winds loading.

In plot of displacement along x & y direction with height of building for column A, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 30^0 winds loading.

In plot of moment about x axis with height for column A, moment decreases with increase in height of building. And the moment has negative sign which shows the hogging moment developed in the column A. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. But maximum moment does not induced in the column A, at the base of the building. It occurs at the above of the base of the building. In frame with bracing model, moment about x in column A is found to be more in comparison of frame without bracing.

In plot of moment about y axis with height of building for column A, moment in column decreases with increase in height of the building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column A. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. Maximum moment about y axis in column A, is found to be at the base of the building. In frame with bracing model, moment about y in column A is found to be more in comparison of frame without bracing

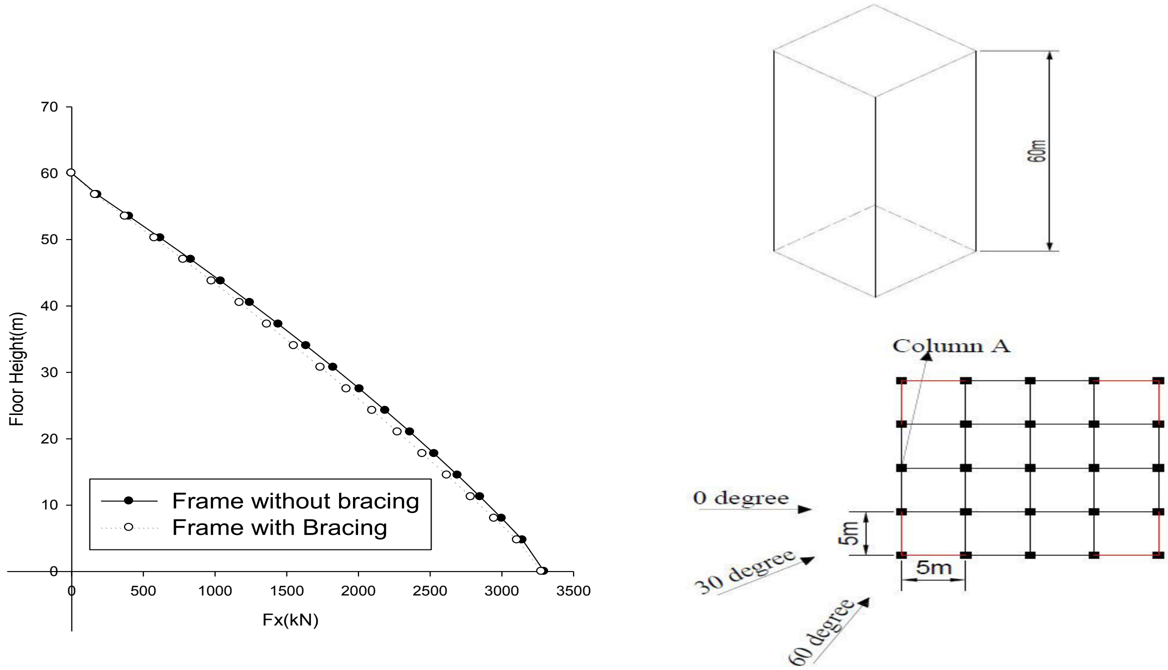


Fig 6.4 Comparison of axial force in column A at 30 degree wind incidence angle with and without bracing in frame

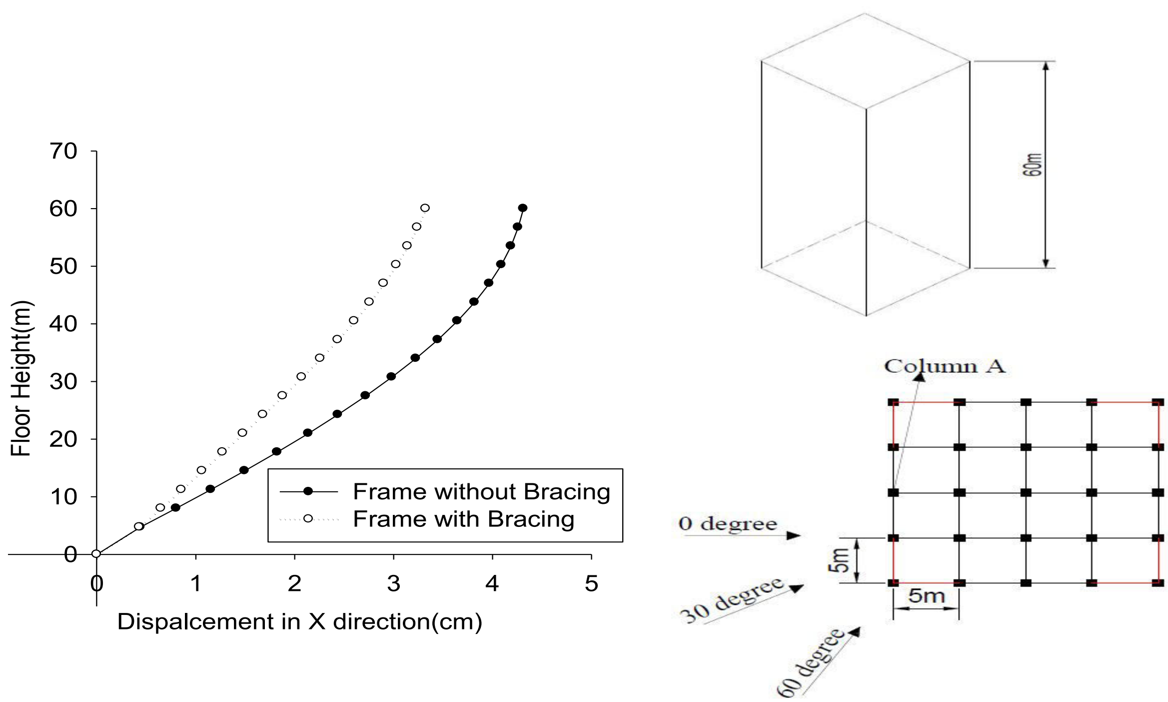


Fig 6.5 Comparison of displacement in x direction in column A at 30 degree wind incidence angle with and without bracing in frame

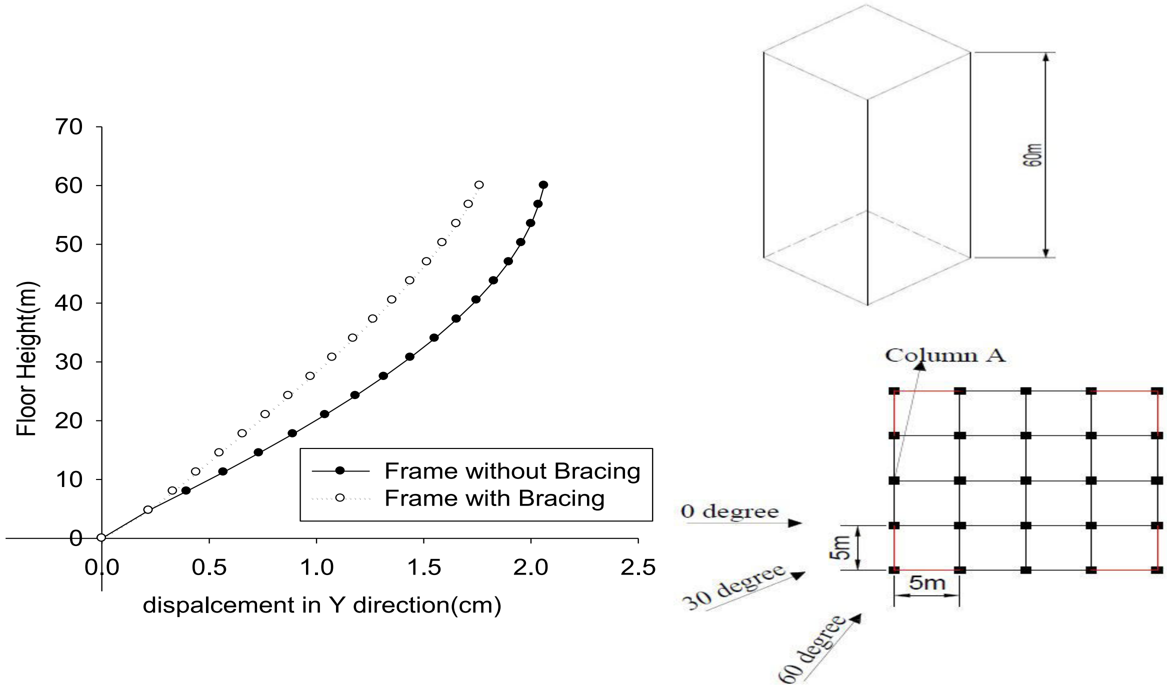


Fig 6.6 Comparison of displacement in Y direction in column A at 30 degree wind incidence angle with and without bracing in frame

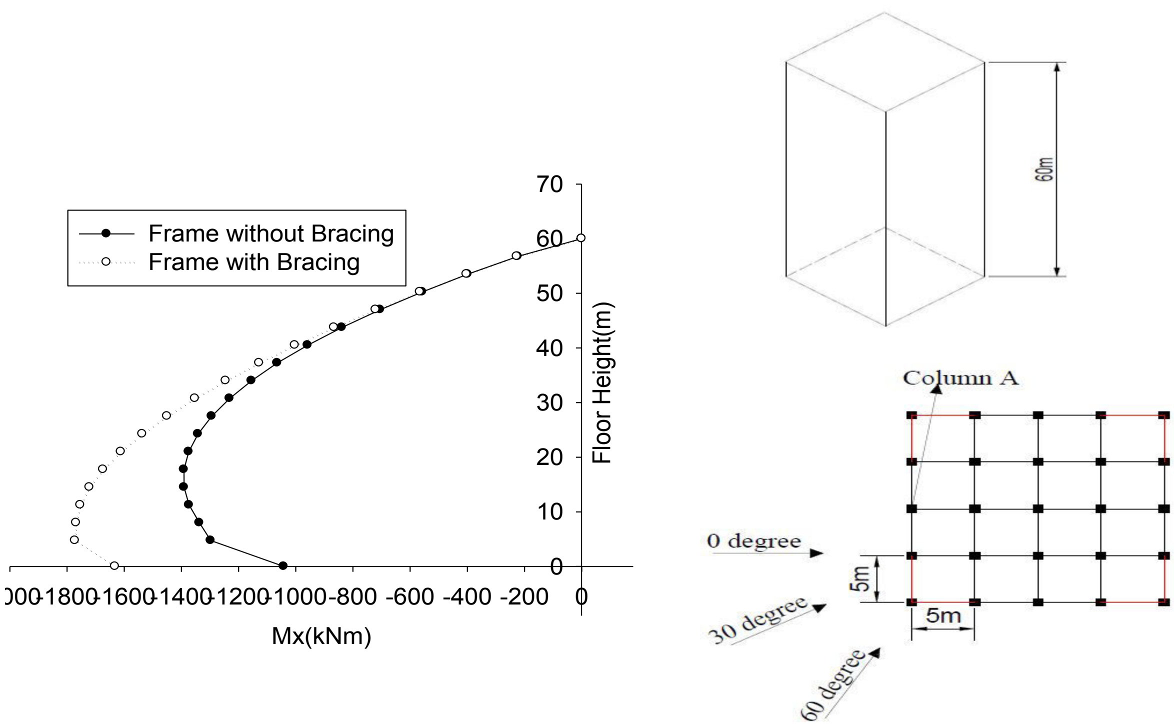


Fig 6.7 Comparison of moment M_x in column A at 30 degree wind incidence angle with and without bracing in frame

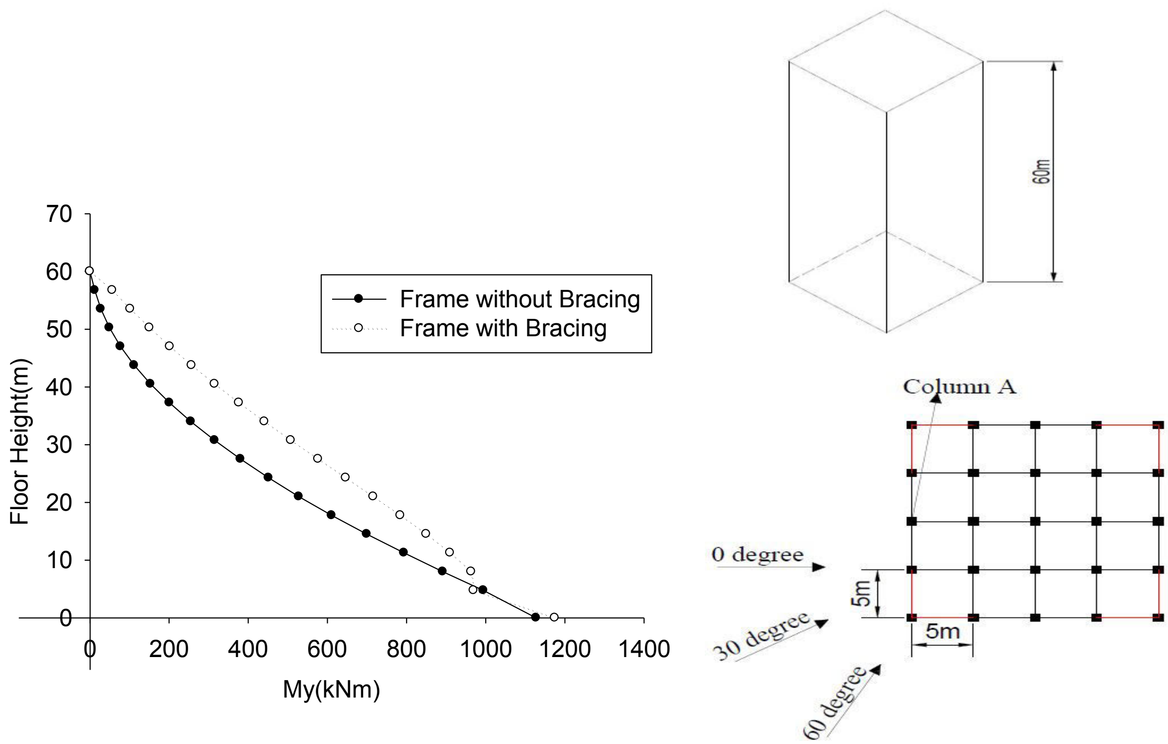


Fig 6.8 Comparison of moment M_y in column A at 30 degree wind incidence angle with and without bracing in frame

6.2.3 At 60 degree wind incidence in column A

In plot of axial force with height for column A, decreases with increase in height of the building. Axial force is found to be more in model frame without bracing in comparison to frame model with bracing, subjected to 60^0 winds loading. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 60^0 winds loading.

In plot of displacement along x & y direction with height of building for column A, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 60^0 winds loading.

In plot of moment about x axis with height for column A, moment decreases with increase in height of building. And the moment has negative sign which shows the hogging moment developed in the column A. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. But maximum moment does not induced in the column A, at the base of the building. It occurs at the above of the base of the building. In frame with bracing model, moment about x in column A is found to be almost equal of frame without bracing.

In plot of moment about y axis with height of building for column A, moment in column decreases with increase in height of the building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column A. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. Maximum moment about y axis in column A, is found to be at the base of the building. In frame with bracing model, moment about y in column A is found to be more in comparison of frame without bracing.

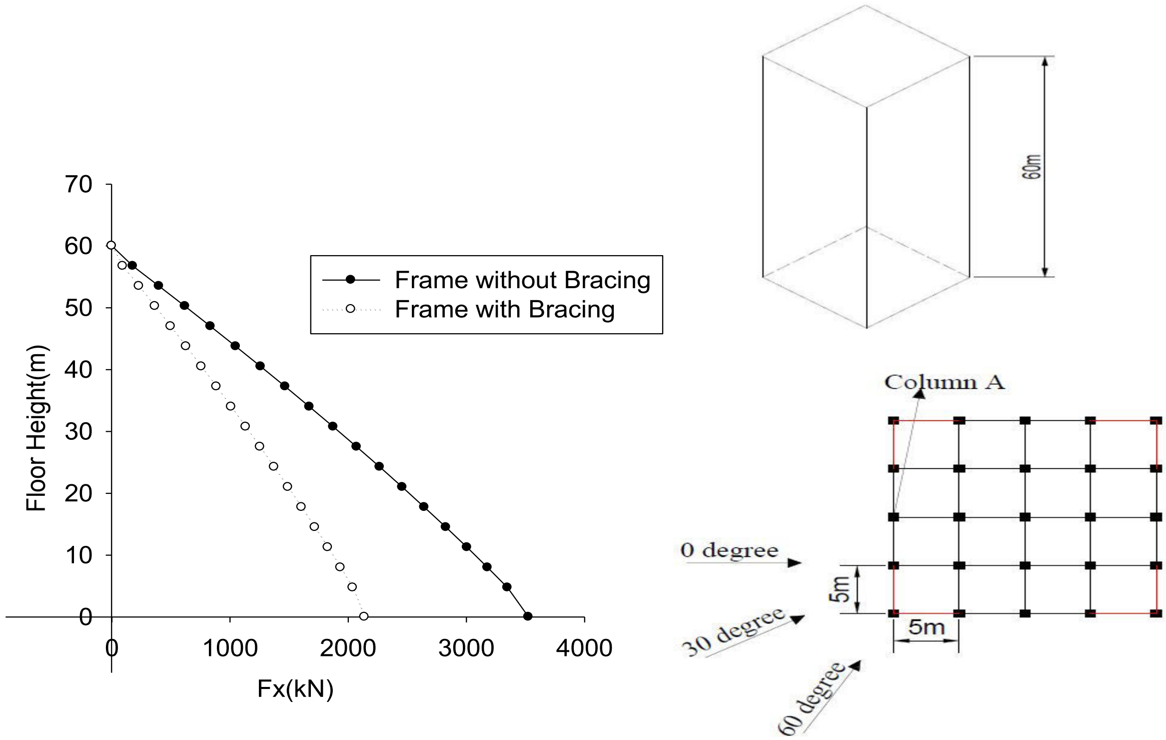


Fig 6.9 Comparison of axial force in column A at 60 degree wind incidence angle with and without bracing in frame

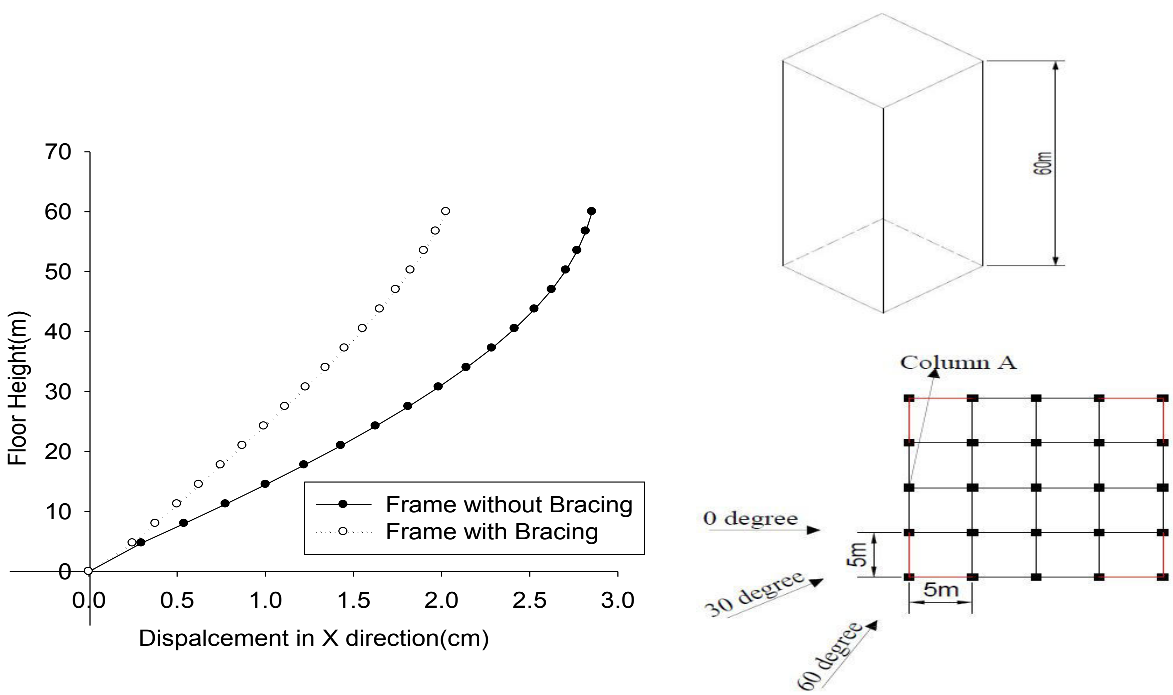


Fig 6.10 Comparison of displacement in X direction in column A at 60 degree wind incidence angle with and without bracing in frame

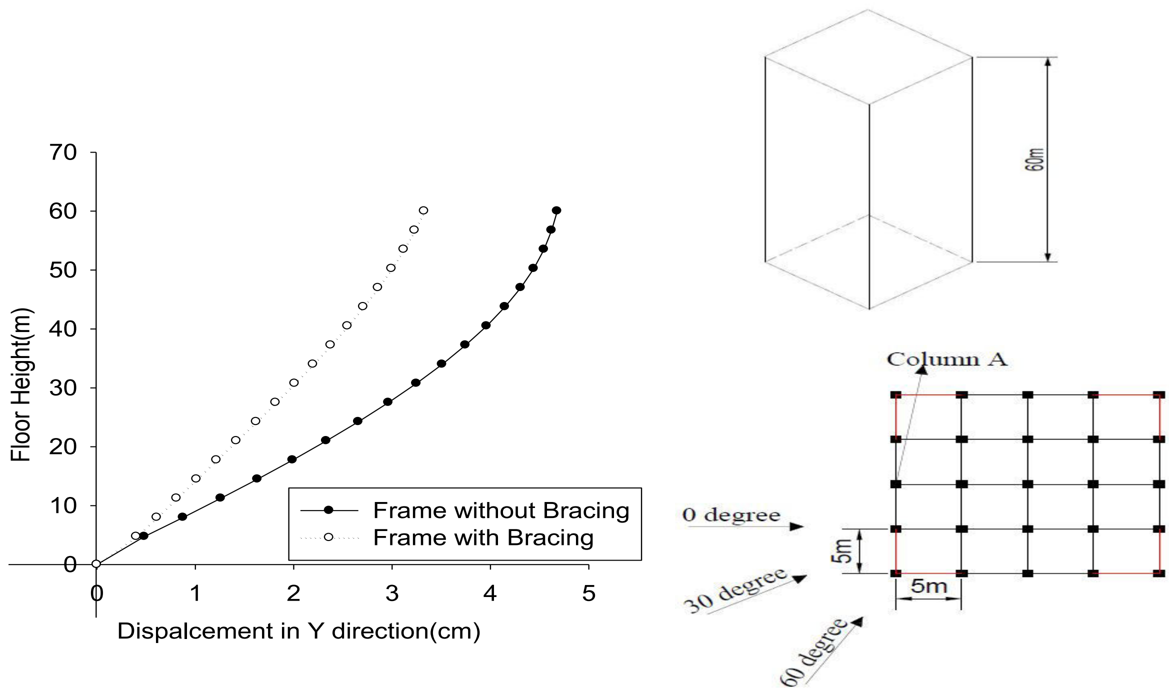


Fig 6.11 Comparison of displacement in Y direction in column A at 60 degree wind incidence angle with and without bracing in frame

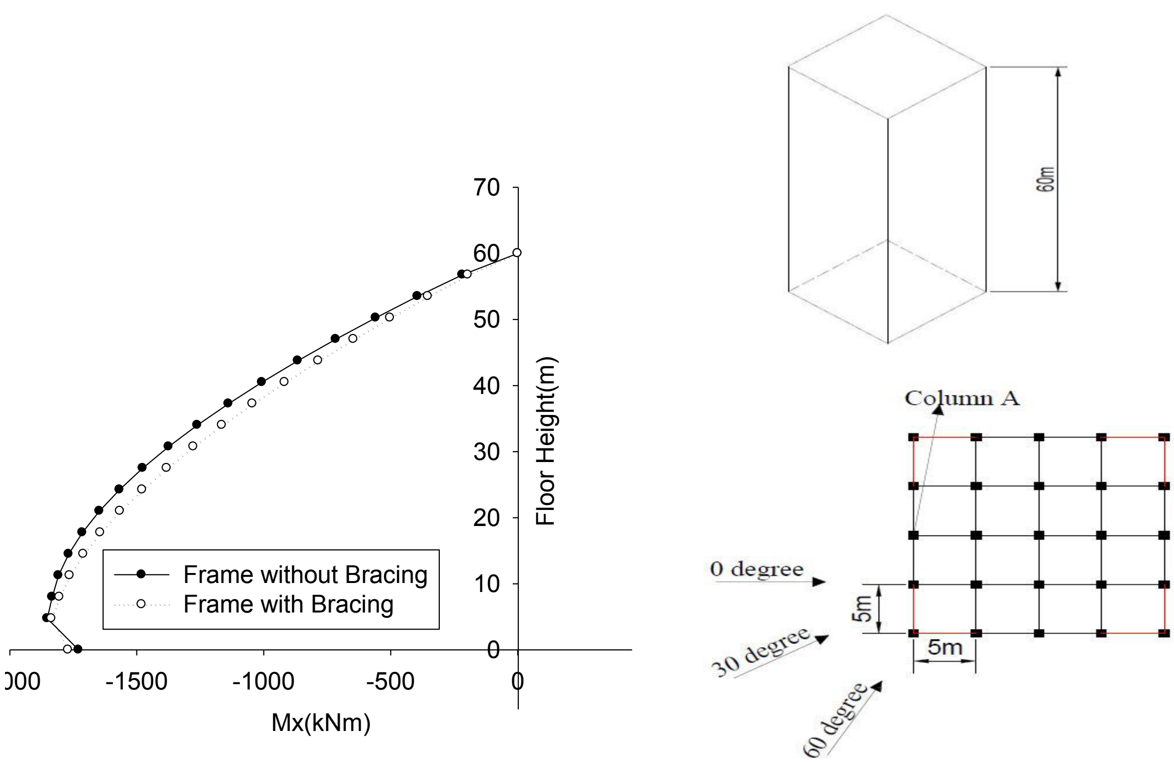


Fig 6.12 Comparison of moment M_x in column A at 60 degree wind incidence angle with and without bracing in frame

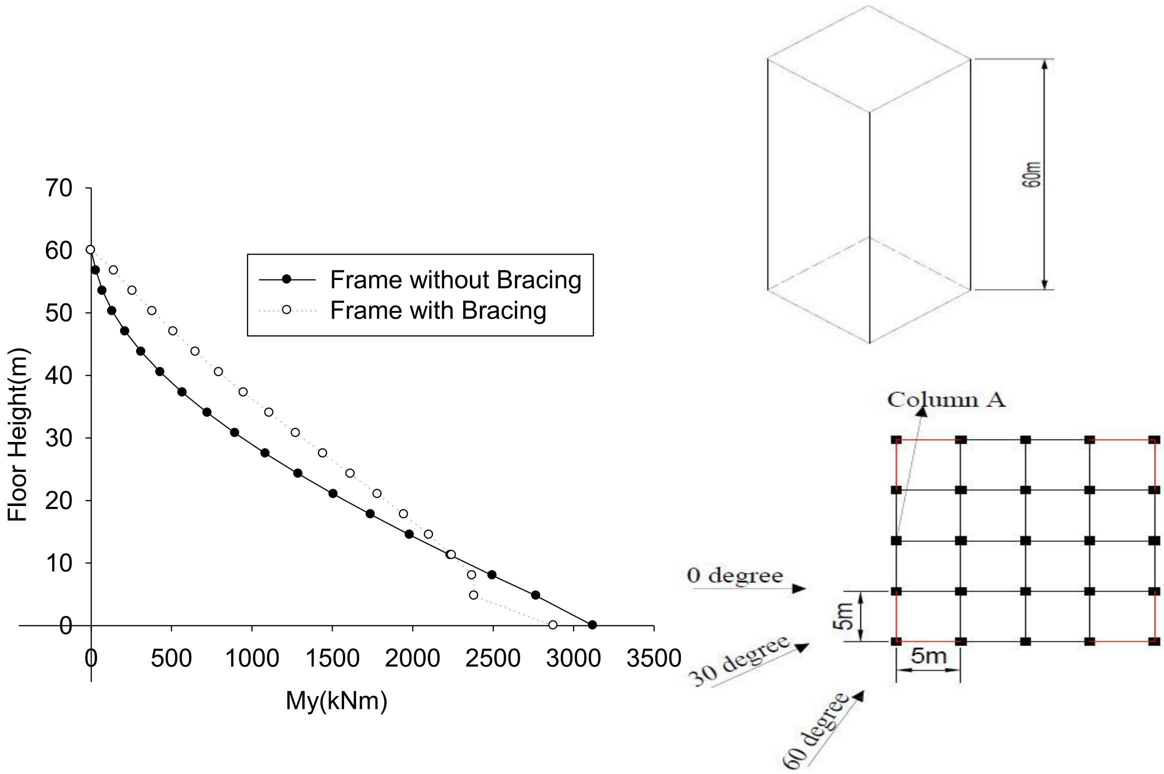


Fig 6.13 Comparison of moment M_y in column A at 60 degree wind incidence angle with and without bracing in frame

6.2.4 At 0 degree wind incidence in column B

In plot of axial force with height for column B, decreases with increase in height of the building. Axial force is found to be equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 0^0 winds loading.

In plot of displacement with height of building for column B, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 0^0 winds loading.

In plot of moment about x axis with height for column B, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column B. Moment is found to be zero at the top edge of the building in both cases subjected to 0^0 winds loading and maximum moment occurs at the base of the building in column B subjected to 0^0 winds loading. In frame with bracing model, moment about x in column B is found to be less in comparison of frame without bracing.

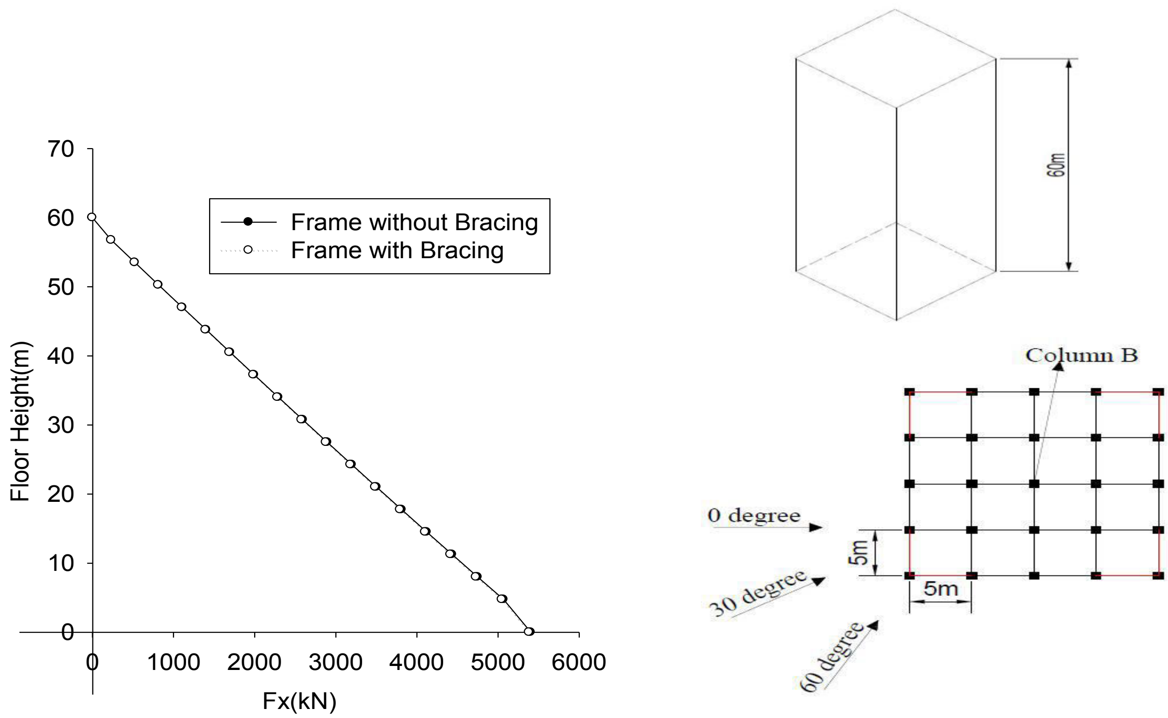


Fig 6.14 Comparison of axial force in column B at 0 degree wind incidence angle with and without bracing in frame

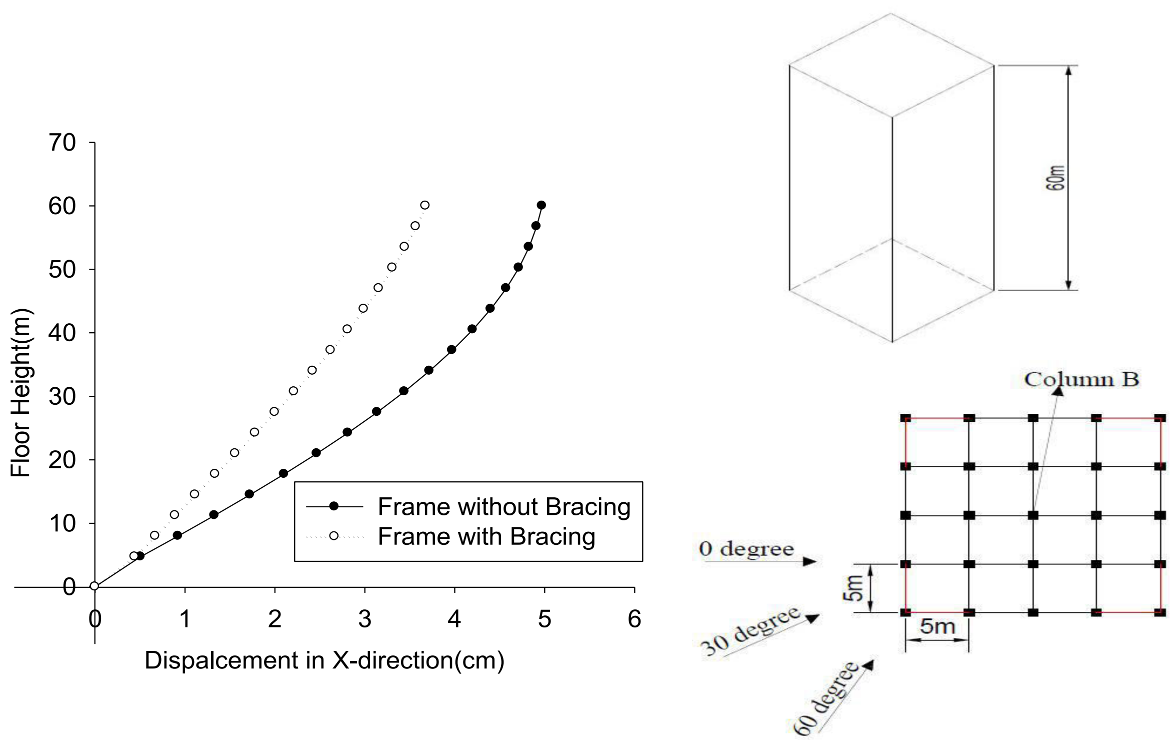


Fig 6.15 Comparison of displacement in X direction in column B at 0 degree wind incidence angle with and without bracing in frame

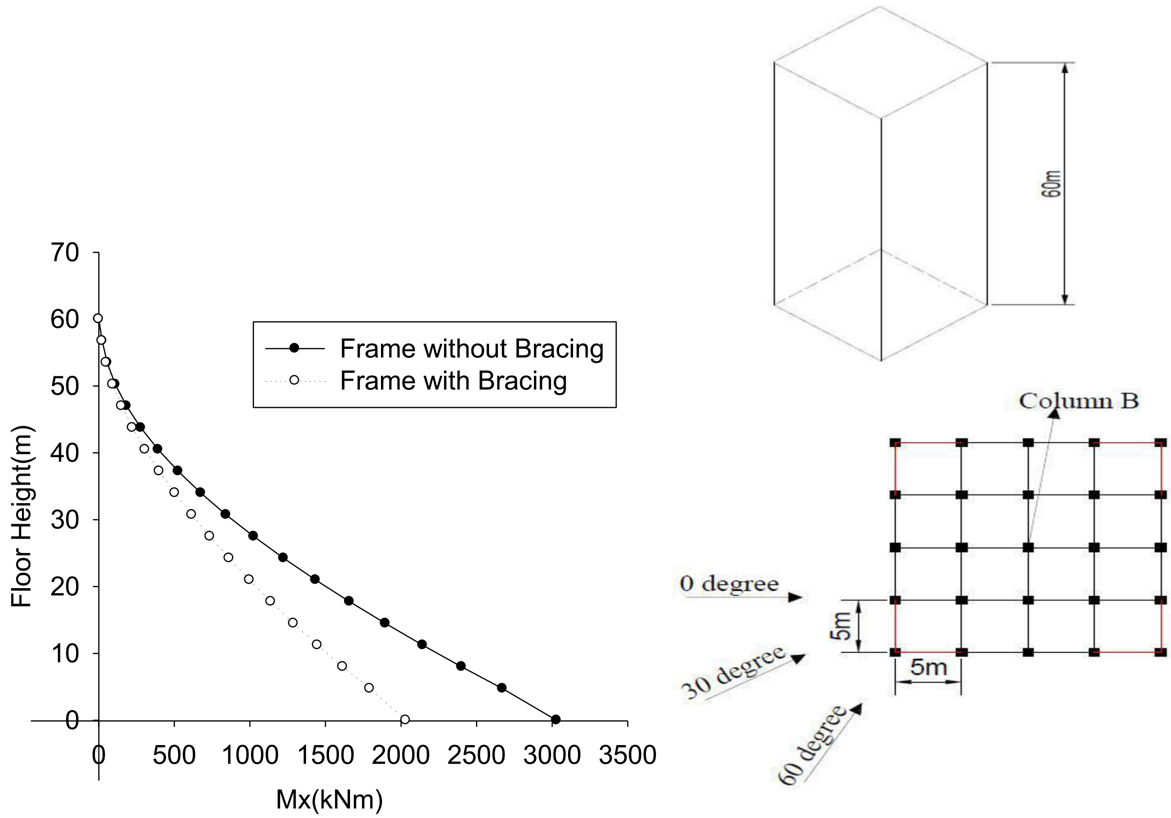


Fig 6.16 Comparison of moment M_x in column B at 0 degree wind incidence angle with and without bracing in frame

6.2.5 At 30 degree wind incidence in column B

In plot of axial force with height for column B, decreases with increase in height of the building. Axial force is found to be equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 30^0 winds loading.

In plot of displacement along x & y direction with height of building for column B, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 30^0 winds loading.

In plot of moment about x axis with height for column B, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column B. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. Maximum moment induced in the column B, at the base of the building. In frame with bracing model, moment about x in column B is found to be less in comparison of frame without bracing.

In plot of moment about y axis with height of building for column B, moment in column decreases with increase in height of the building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column B. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. Maximum moment about y axis in column B, is found to be at the base of the building. In frame with bracing model, moment about y in column B is found to be less in comparison of frame without bracing.

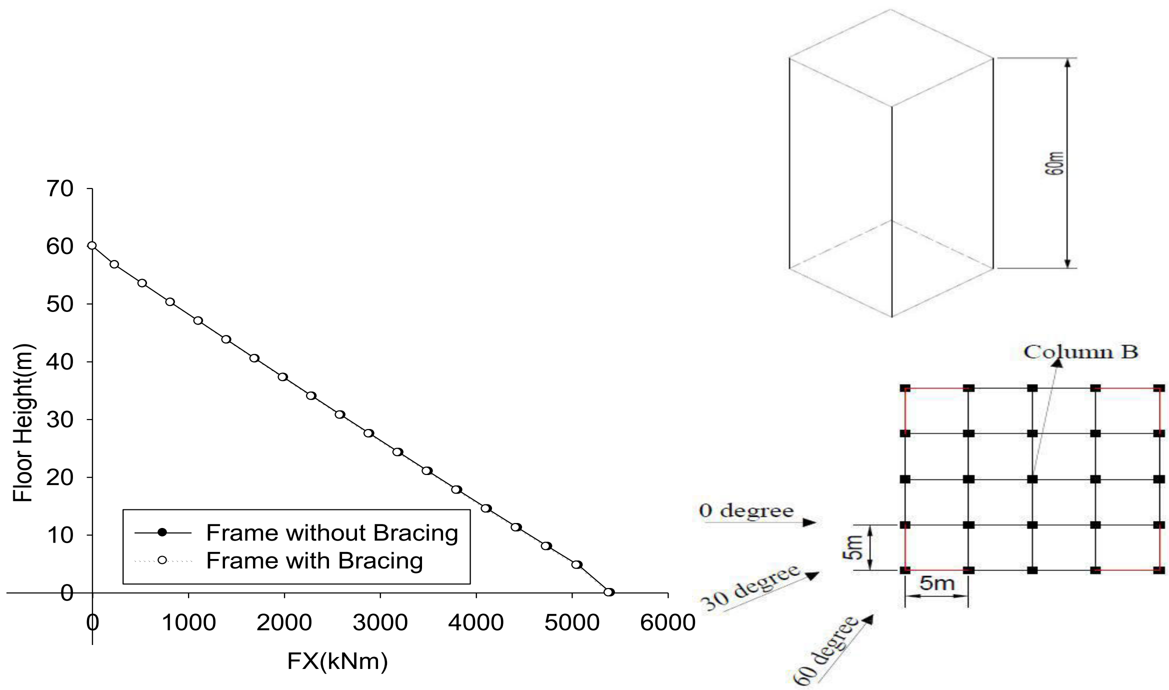


Fig 6.17 Comparison of axial force in column B at 30 degree wind incidence angle with and without bracing in frame

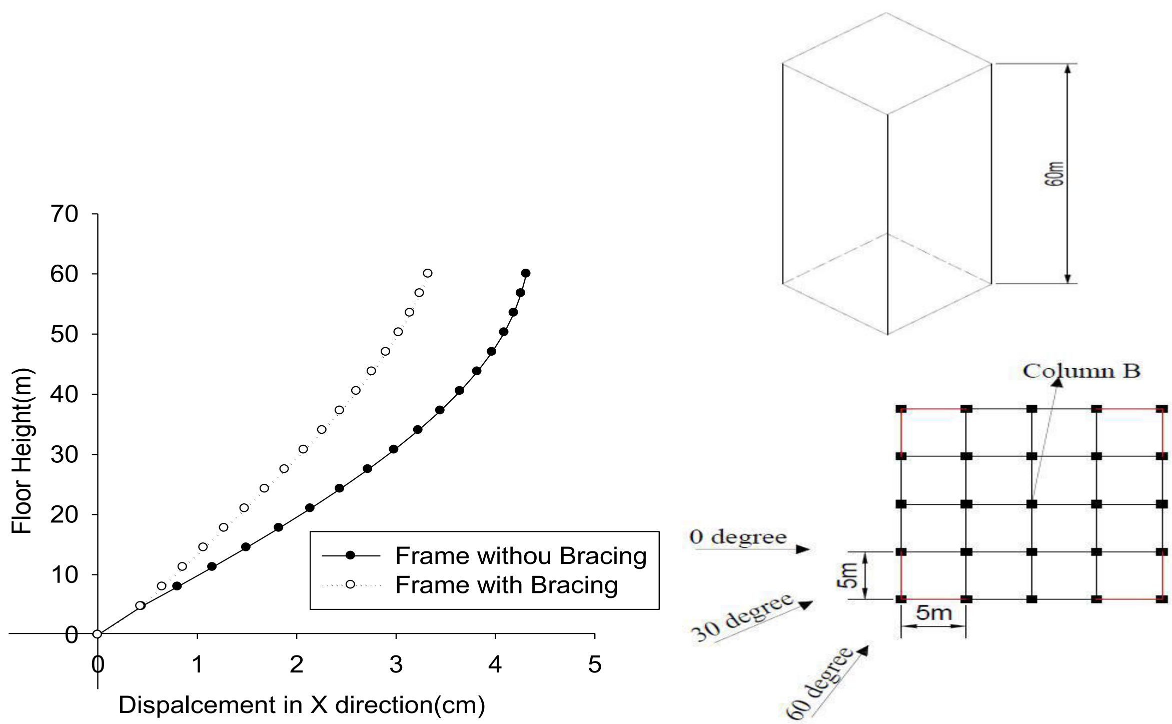


Fig 6.18 Comparison of displacement in X direction in column B at 30 degree wind incidence angle with and without bracing in frame

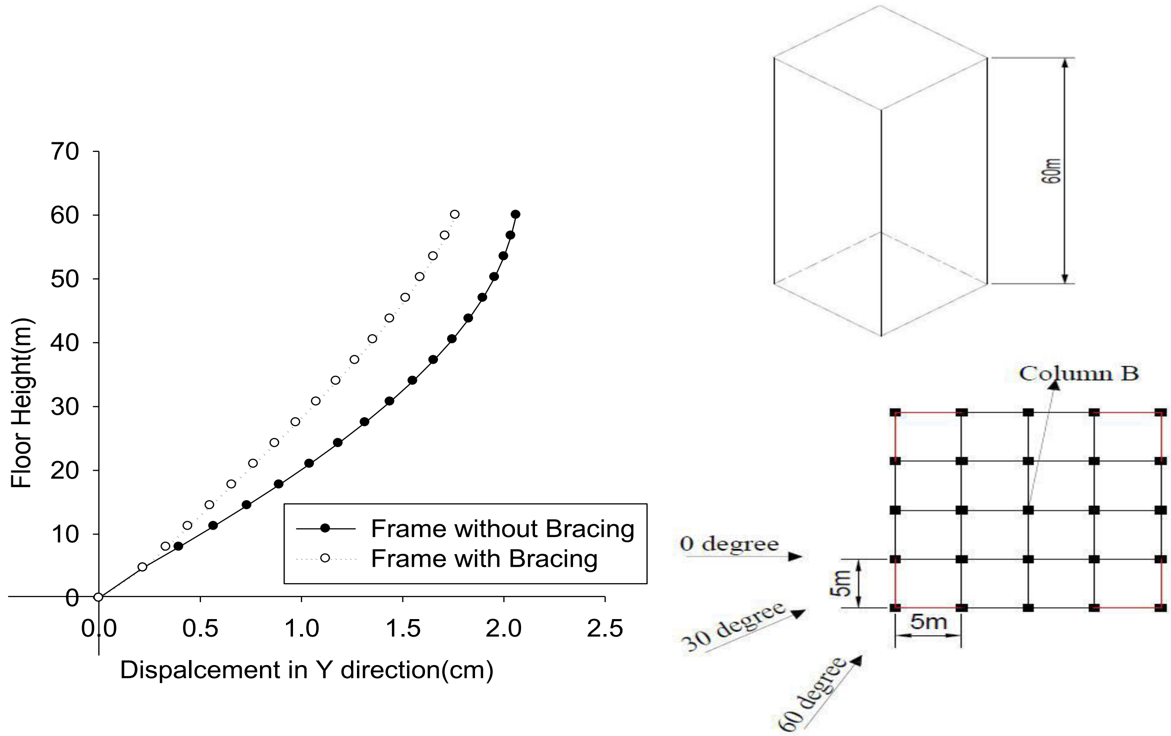


Fig 6.19 Comparison of displacement in Y direction in column B at 30 degree wind incidence angle with and without bracing in frame

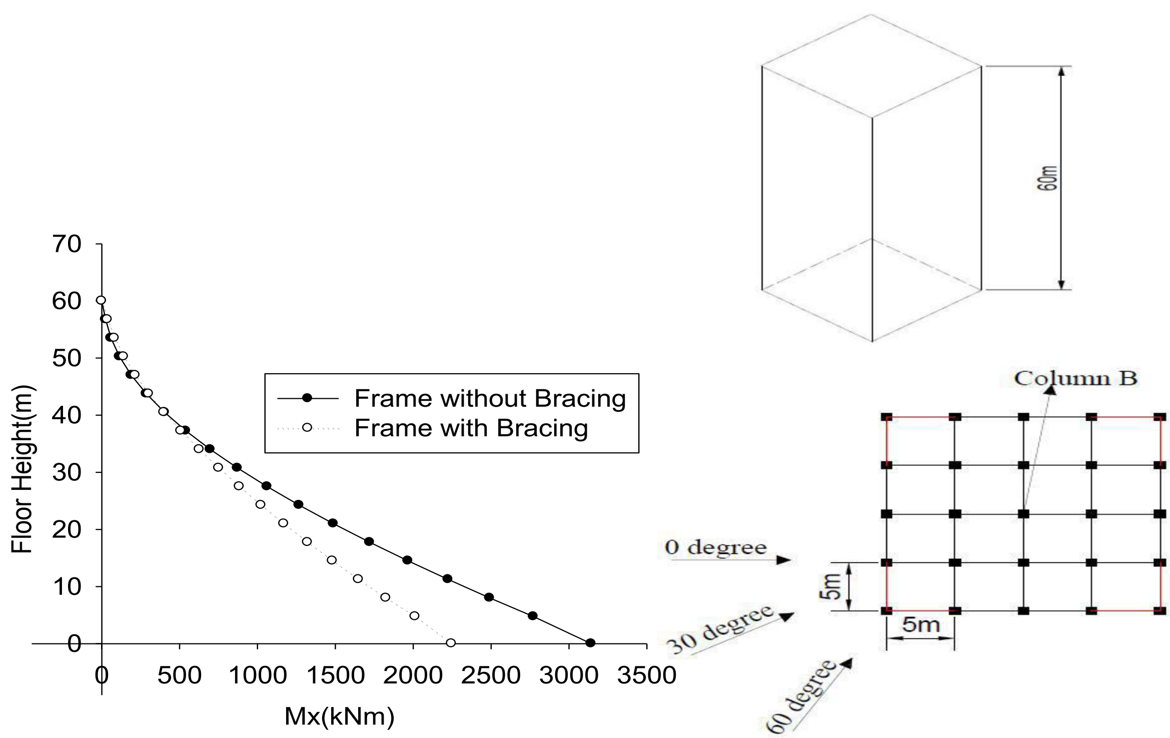


Fig 6.20 Comparison of moment M_x in column B at 30 degree wind incidence angle with and without bracing in frame

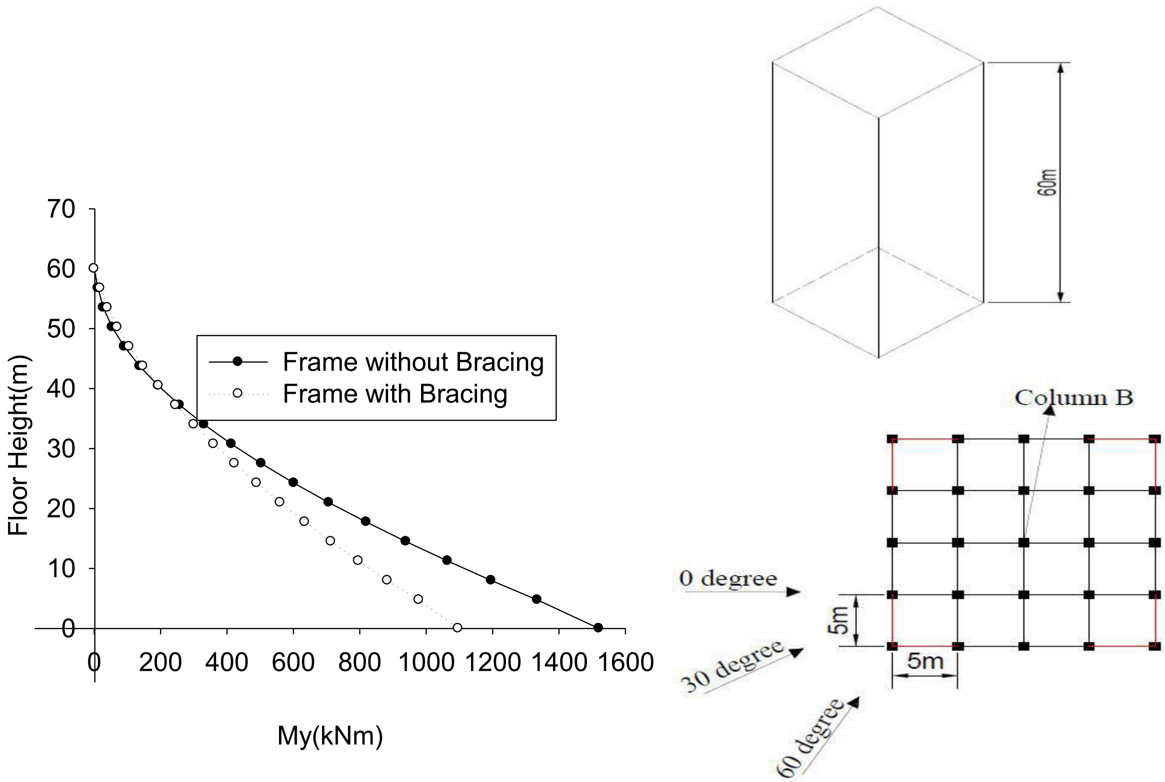


Fig 6.21 Comparison of moment M_y in column B at 30 degree wind incidence angle with and without bracing in frame

6.2.6 At 60 degree wind incidence in column B

In plot of axial force with height for column B, decreases with increase in height of the building. Axial force is found to be less in frame with bracing model in comparison to frame without bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 60^0 winds loading.

In plot of displacement along x & y direction with height of building for column B, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 60^0 winds loading.

In plot of moment about x axis with height for column B, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column B. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. Maximum moment induced in the column B, at the base of the building. In frame with bracing model, moment about x in column B is found to be less in comparison of frame without bracing.

In plot of moment about y axis with height of building for column B, moment in column decreases with increase in height of the building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column B. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. Maximum moment about y axis in column B, is found to be at the base of the building. In frame with bracing model, moment about y in column B is found to be more in comparison of frame without bracing.

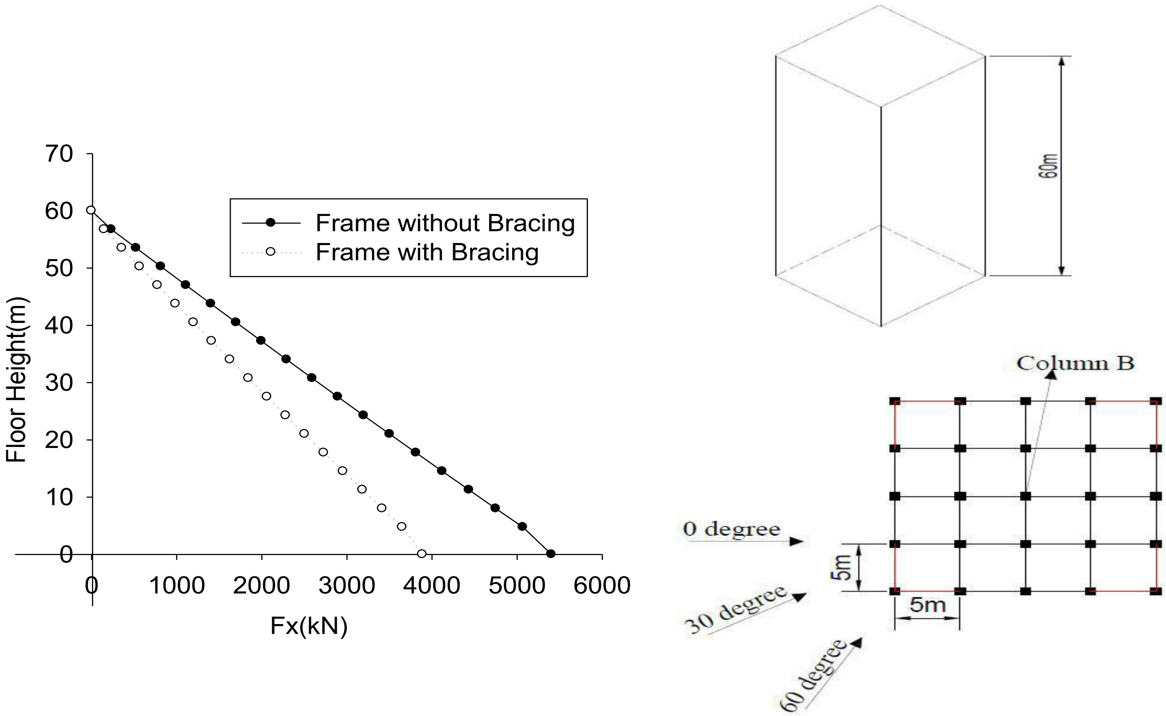


Fig 6.22 Comparison of axial force in column B at 60 degree wind incidence angle with and without bracing in frame

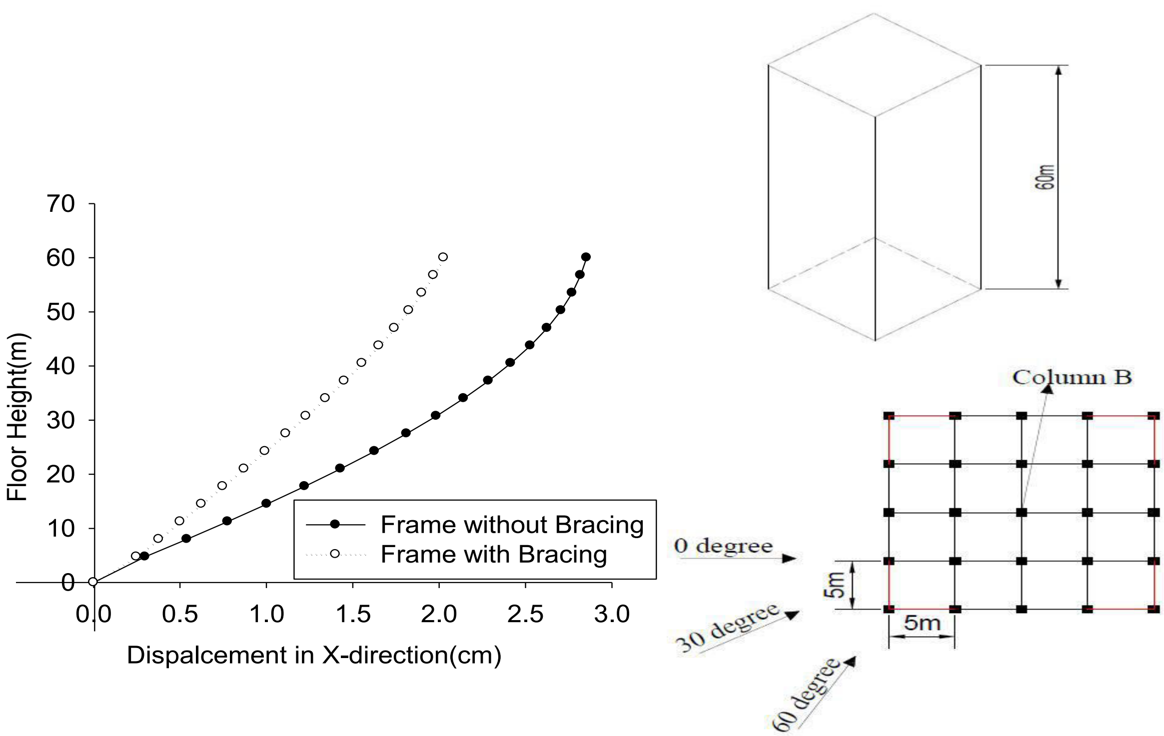


Fig 6.23 Comparison of displacement in X direction in column B at 60 degree wind incidence angle with and without bracing in frame

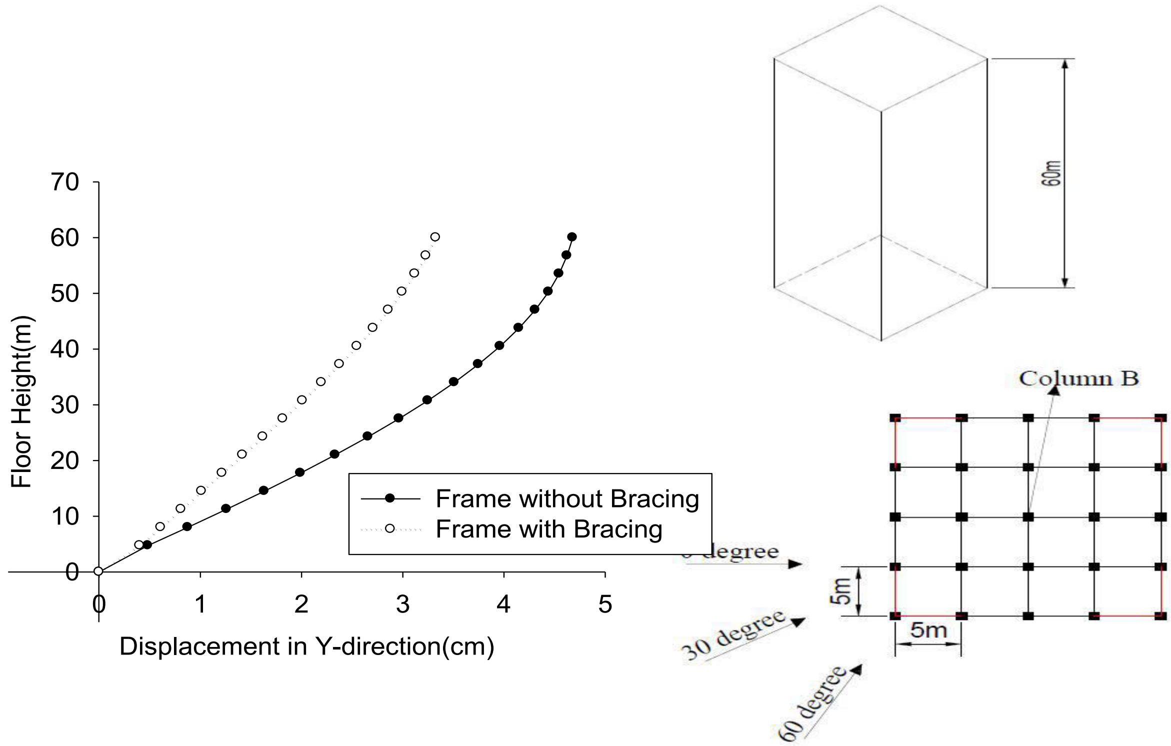


Fig 6.24 Comparison of displacement in Y direction in column B at 60 degree wind incidence angle with and without bracing in frame

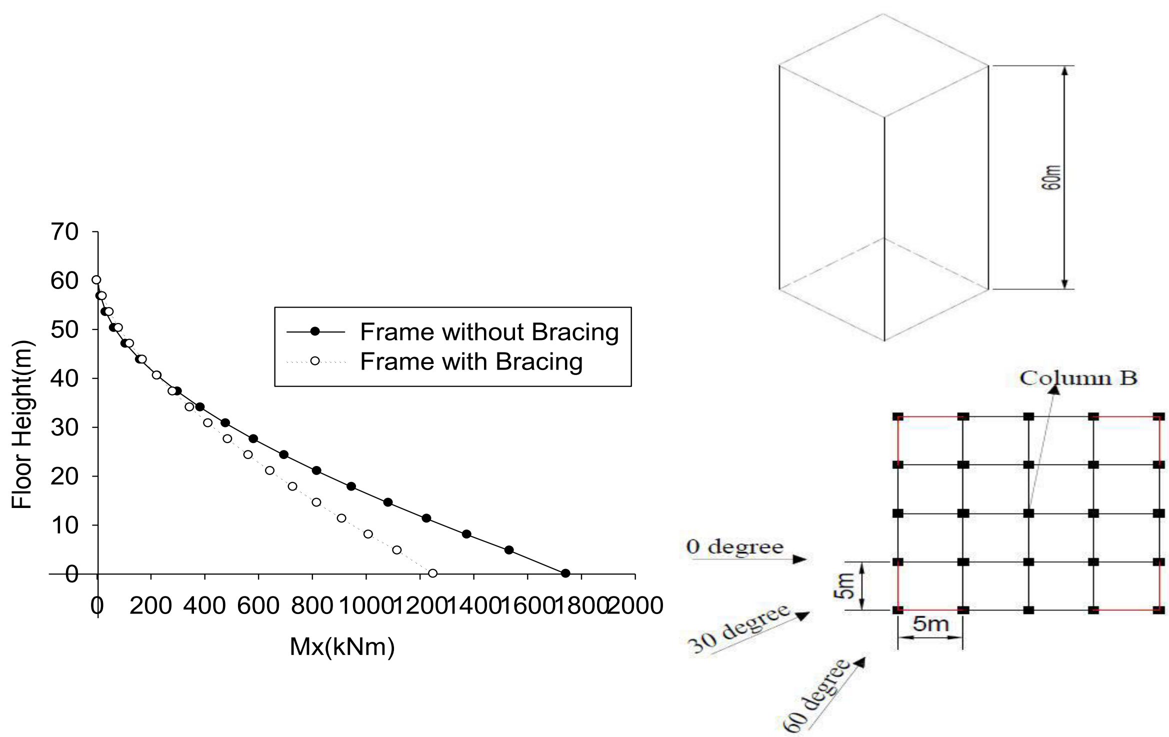


Fig 6.25 Comparison of moment M_x in column B at 60 degree wind incidence angle with and without bracing in frame

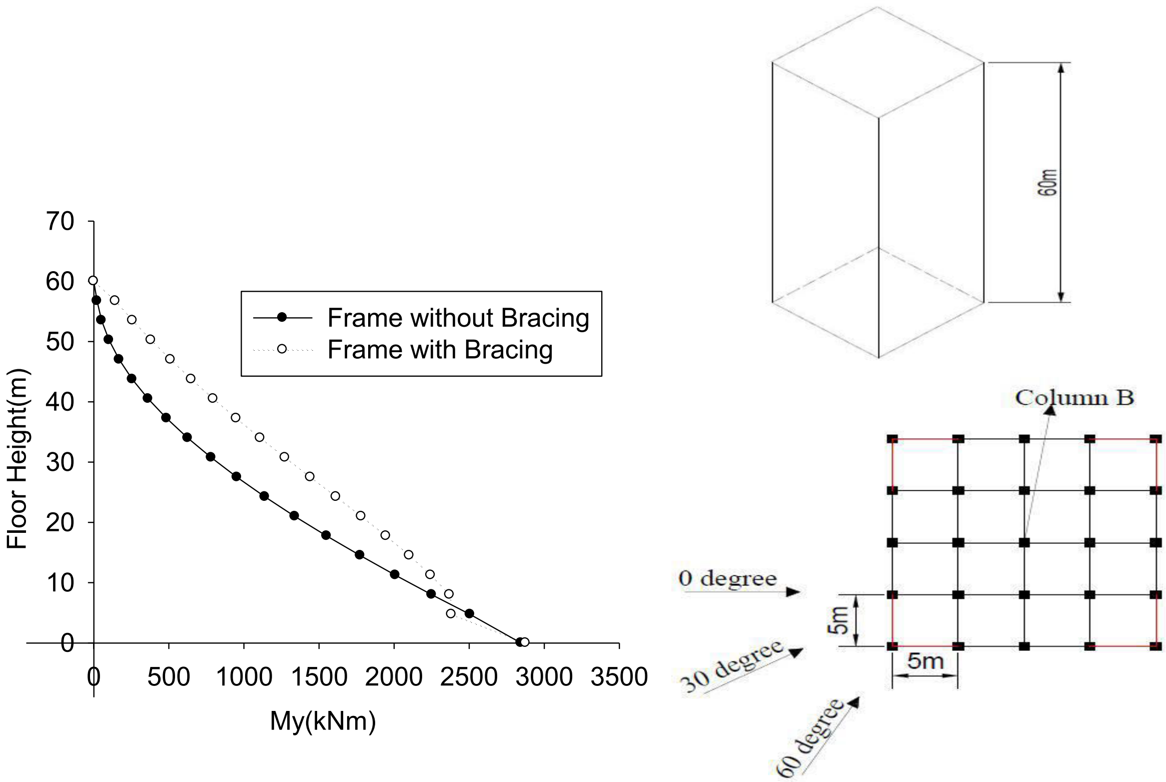


Fig 6.26 Comparison of moment M_y in column B at 60 degree wind incidence angle with and without bracing in frame

6.2.7 At 0 degree wind incidence in column C

In plot of axial force with height for column C, decreases with increase in height of the building. Axial force is found to be almost equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum, in both cases subjected to 0^0 winds loading.

In plot of displacement with height of building for column C, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 0^0 winds loading.

In plot of moment about x axis with height for column C, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 0^0 winds loading. Maximum moment induced in the column C, at the base of the building. In frame with bracing model, moment about x in column C is found to be less in comparison of frame without bracing up to 27m, but above this height of the building moment about x is found to be more in case of frame with bracing.

In plot of moment about y axis with height of building for column C, moment in column decreases with increase in height of the building. And the moment has negative sign which shows the hogging moment developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 0^0 winds loading. And maximum moment is found to be at the base of the building. In frame with bracing model, moment about y in column C is found to be more in comparison of frame without bracing.

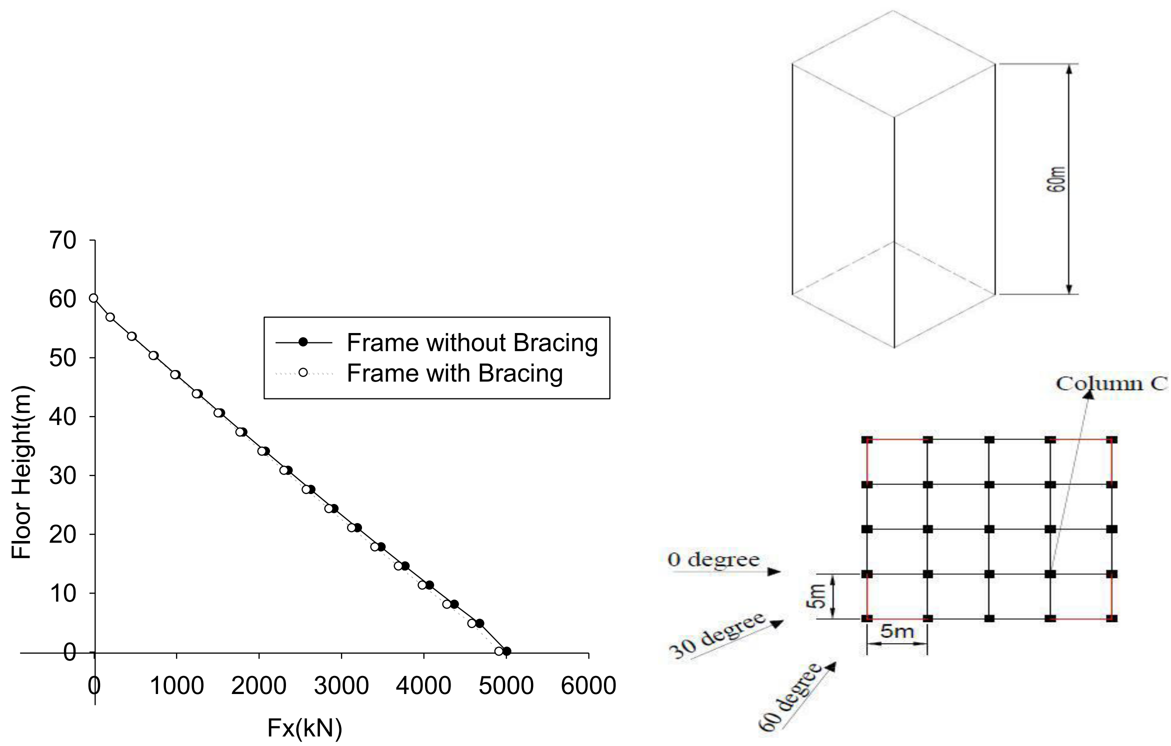


Fig 6.27 Comparison of axial force in column C at 0 degree wind incidence angle with and without bracing in frame

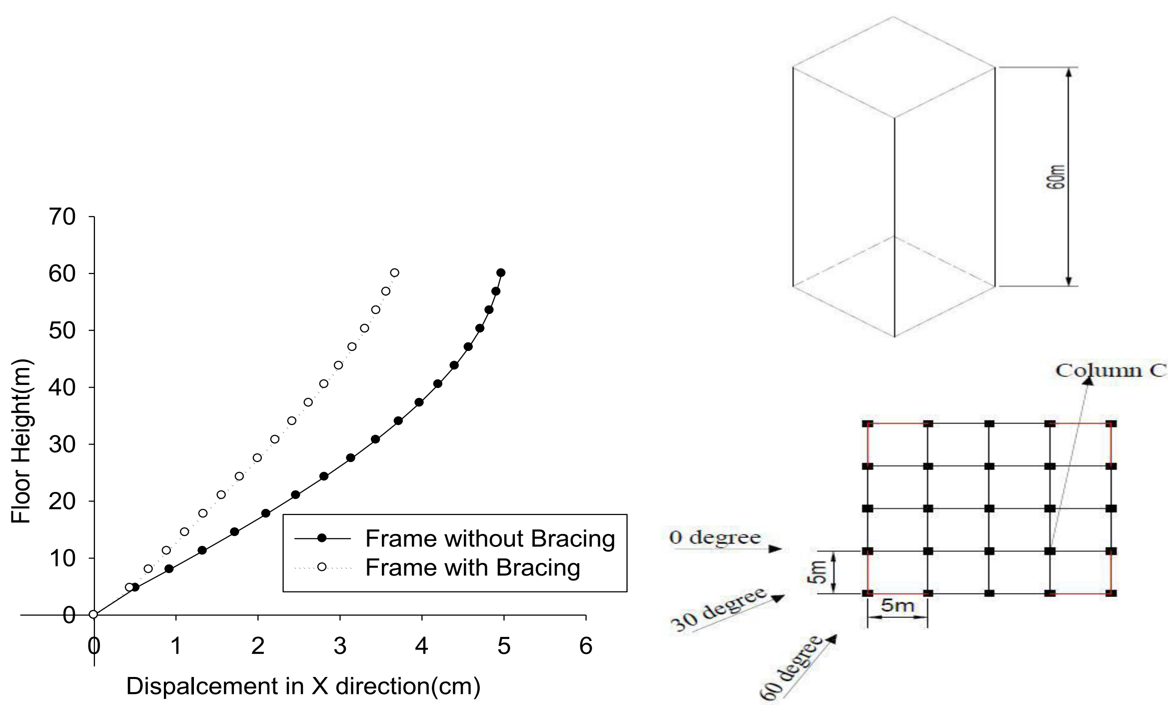


Fig 6.28 Comparison of displacement in X direction in column C at 0 degree wind incidence angle with and without bracing in frame

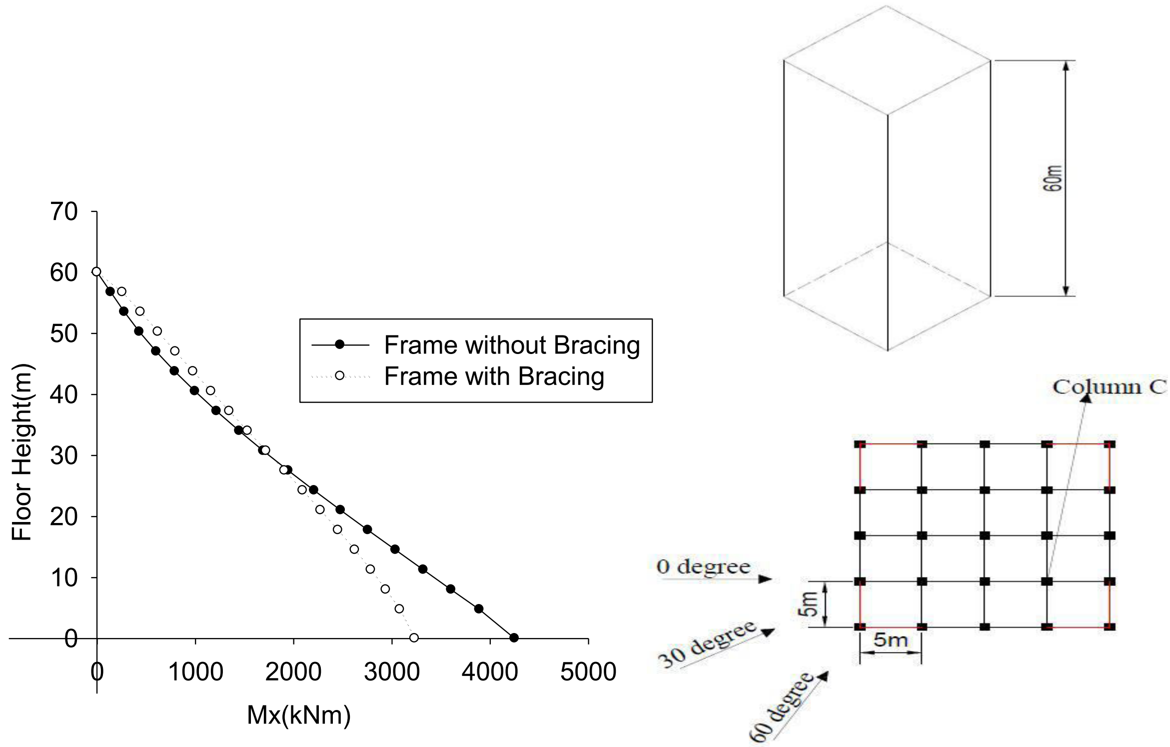


Fig 6.29 Comparison of moment M_x in column C at 0 degree wind incidence angle with and without bracing in frame

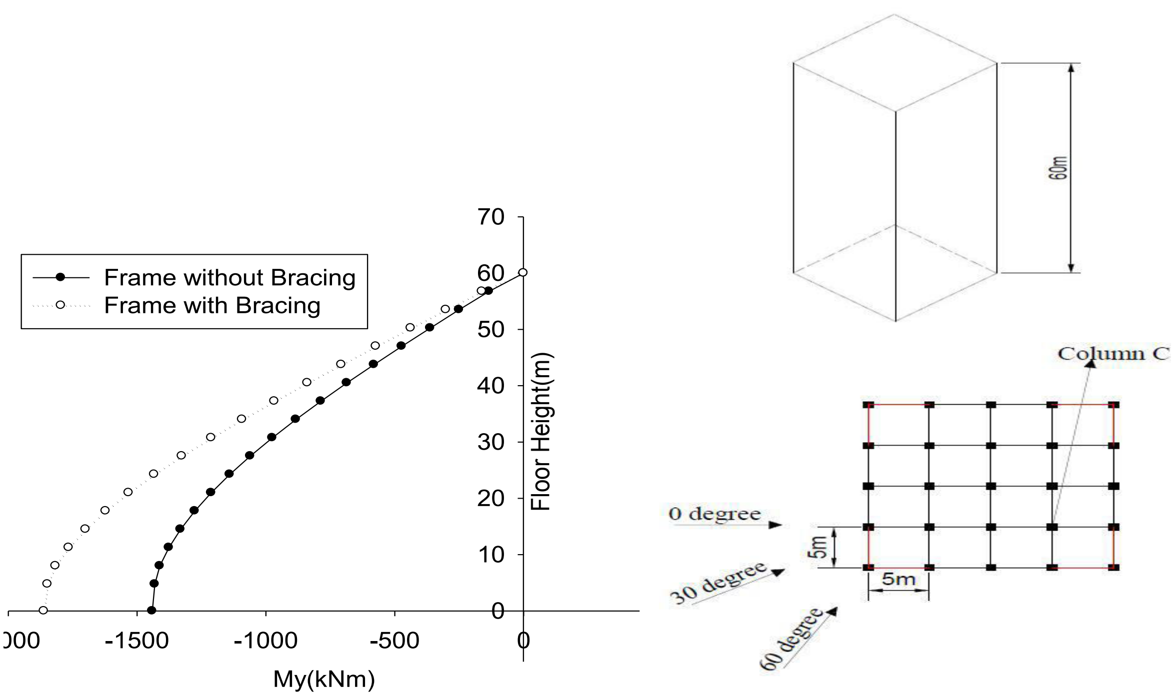


Fig 6.30 Comparison of moment M_y in column C at 0 degree wind incidence angle with and without bracing in frame

6.2.8 At 30 degree wind incidence in column C

In plot of axial force with height for column C, decreases with increase in height of the building. Axial force is found to be almost equal in both cases i.e. frame without bracing and frame with bracing. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 30^0 winds loading.

In plot of displacement along x & y direction with height of building for column C, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 30^0 winds loading.

In plot of moment about x axis with height for column C, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. Maximum moment about x axis in column C, is found to be at the base of the building. In frame with bracing model, moment about x in column C is found to be less in comparison of frame without bracing.

In plot of moment about y axis with height of building for column C, moment in column decreases with increase in height of the building. . And the moment has negative sign which shows the hogging moment developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 30^0 winds loading. But maximum moment about y axis in column C, is not found to be at the base of the building. In frame with bracing model, moment about y in column A is found to be more in comparison of frame without bracing.

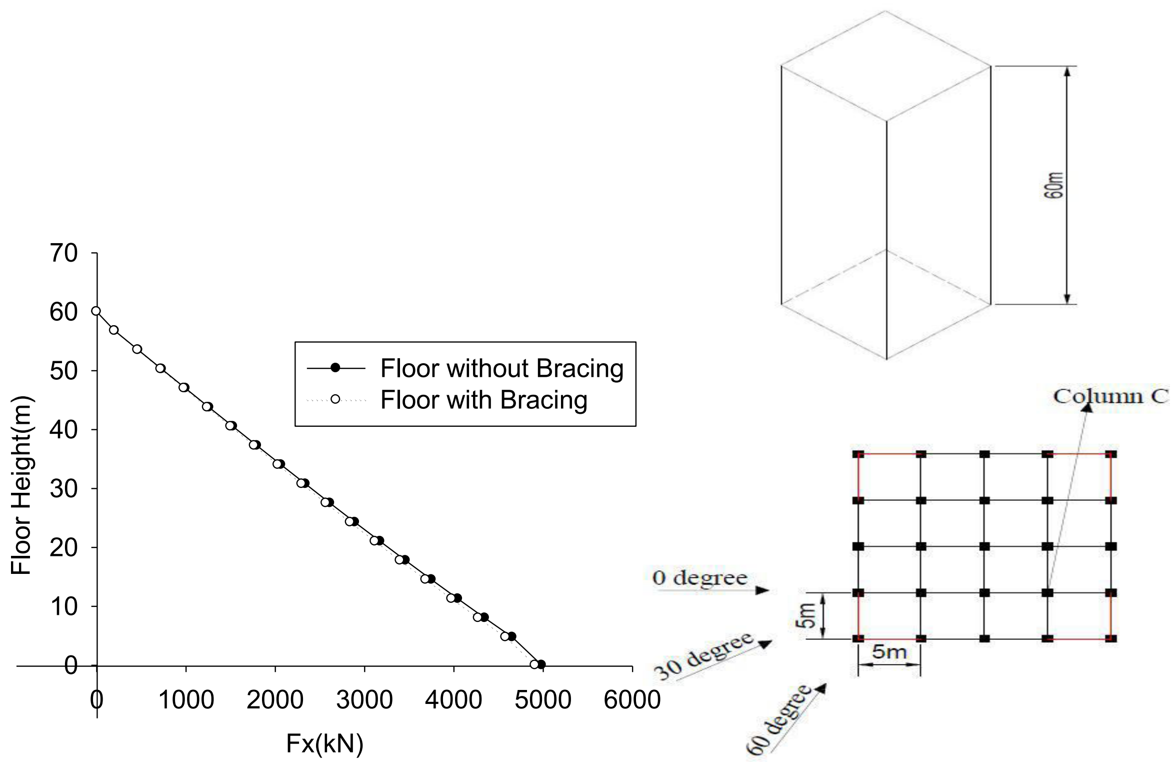


Fig 6.31 Comparison of axial force in column C at 30 degree wind incidence angle with and without bracing in frame

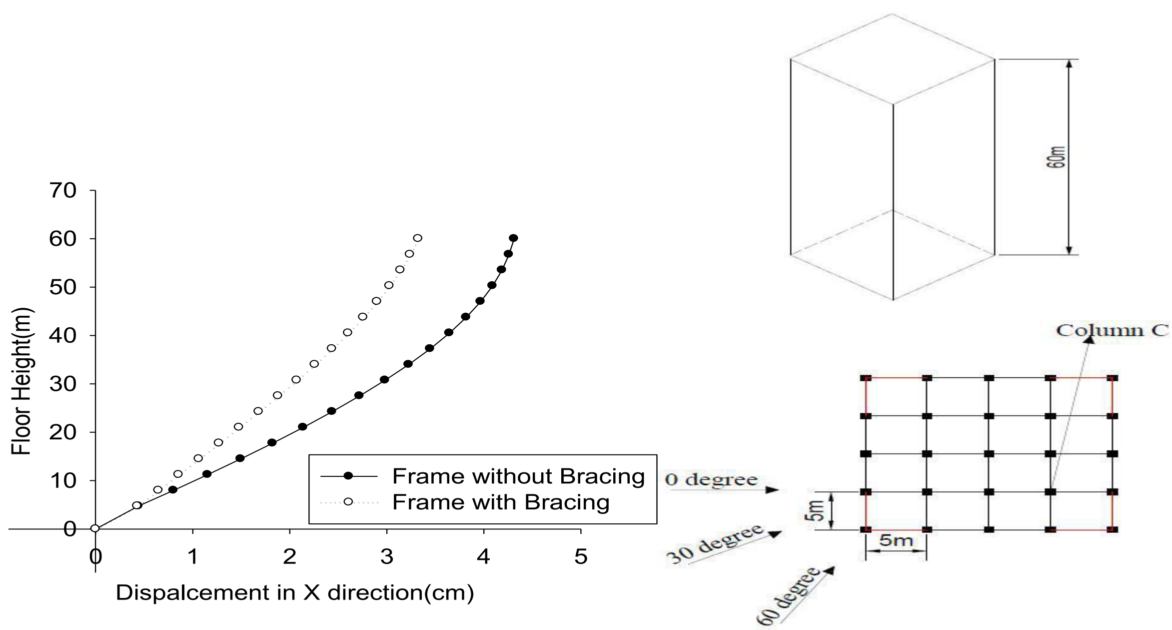


Fig 6.32 Comparison of displacement in X direction in column C at 30 degree wind incidence angle with and without bracing in frame

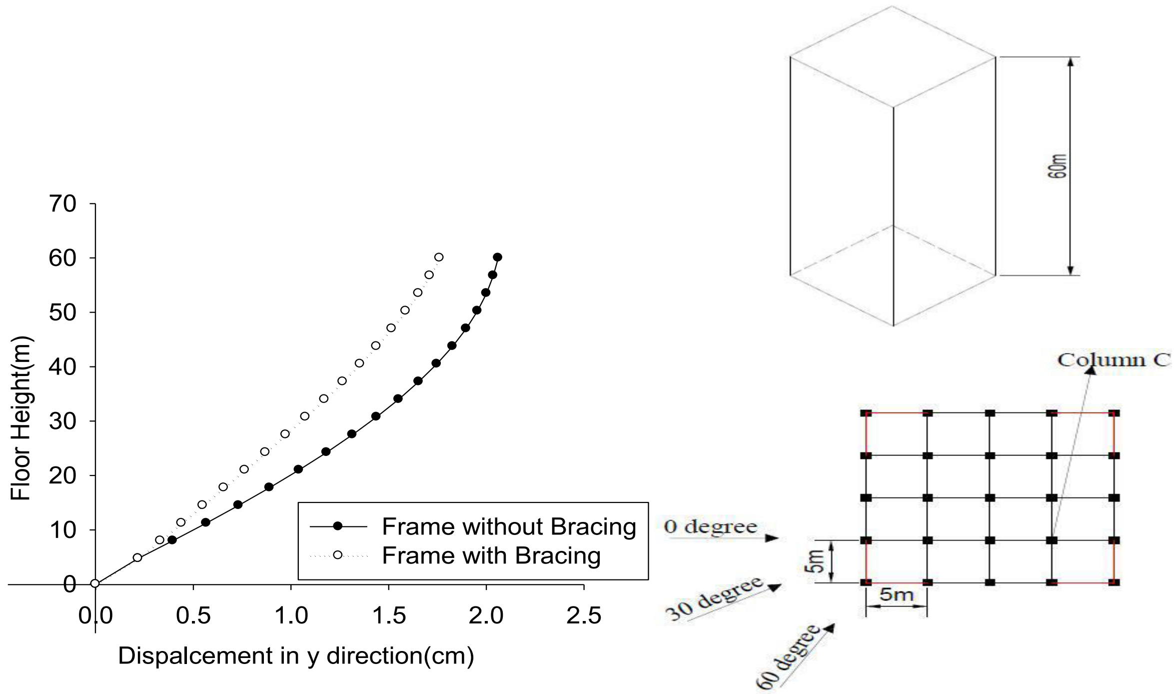


Fig 6.33 Comparison of displacement in Y direction in column C at 30 degree wind incidence angle with and without bracing in frame

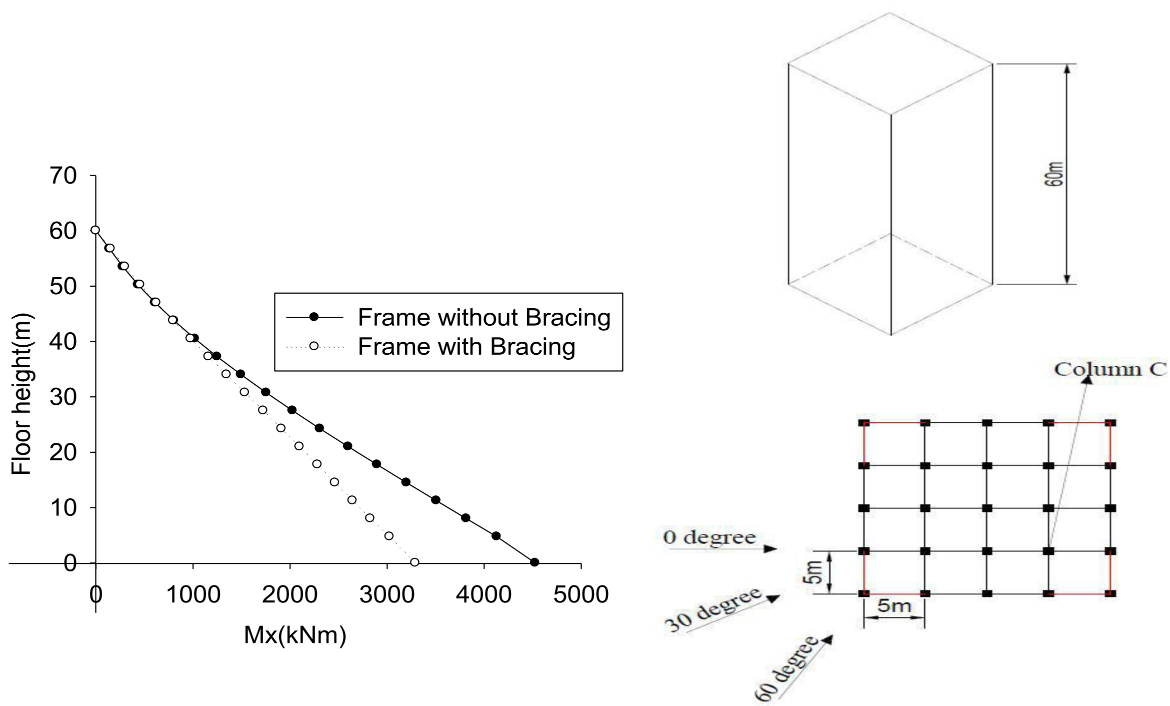


Fig 6.34 Comparison of moment M_x in column C at 30 degree wind incidence angle with and without bracing in frame

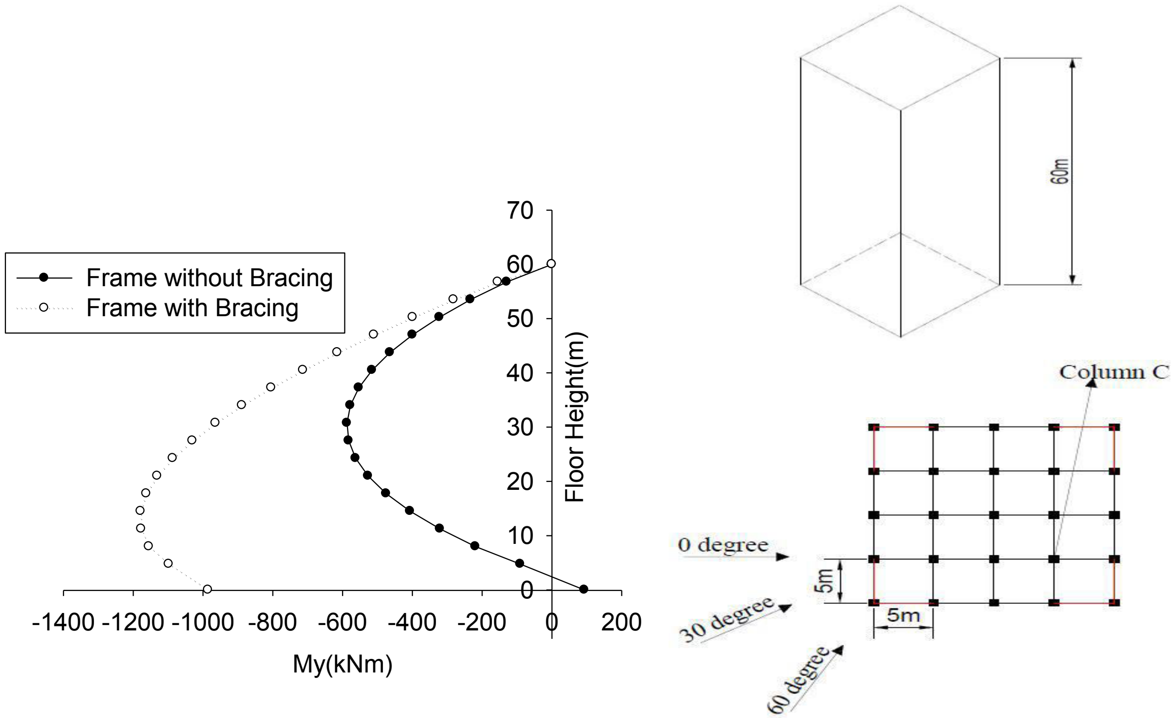


Fig 6.35 Comparison of moment M_y in column C at 30 degree wind incidence angle with and without bracing in frame

6.2.9 At 60 degree wind incidence in column C

In plot of axial force with height for column C, decreases with increase in height of the building. Axial force is found to be more in model frame without bracing in comparison to frame model with bracing, subjected to 60^0 winds loading. At the top edge of the building, axial force is found to be zero and at the bottom of the building, axial force is found to be maximum in both cases subjected to 60^0 winds loading.

In plot of displacement along x & y direction with height of building for column C, displacement of building increases with increase in height of the building. Displacement is found to be more in case of frame without bracing than in frame with bracing. At the top edge of the building, displacement is found to be maximum and at the bottom of the building, displacement is found to be zero in both cases subjected to 60^0 winds loading.

In plot of moment about x axis with height for column C, moment decreases with increase in height of building. And the moment has been plotted on the positive x axis which shows the sagging moment developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. Maximum moment about x axis in column C, is found to be at the base of the building. In frame with bracing model, moment about x in column C is found to be less in comparison of frame without bracing.

In plot of moment about y axis with height of building for column C, moment in column decreases with increase in height of the building. And the moment has been plotted on the positive and negative x axis which shows the sagging and hogging moments respectively, developed in the column C. Moment is found to be zero at the top edge of the building in both cases subjected to 60^0 winds loading. In frame model with bracing, hogging moment is developed in the column C from base to top of the building. And in frame model without bracing system, sagging moment is developed in the column C up to the height of 17.75m and thereafter, hogging moment is developed in the column C up to the top of the building

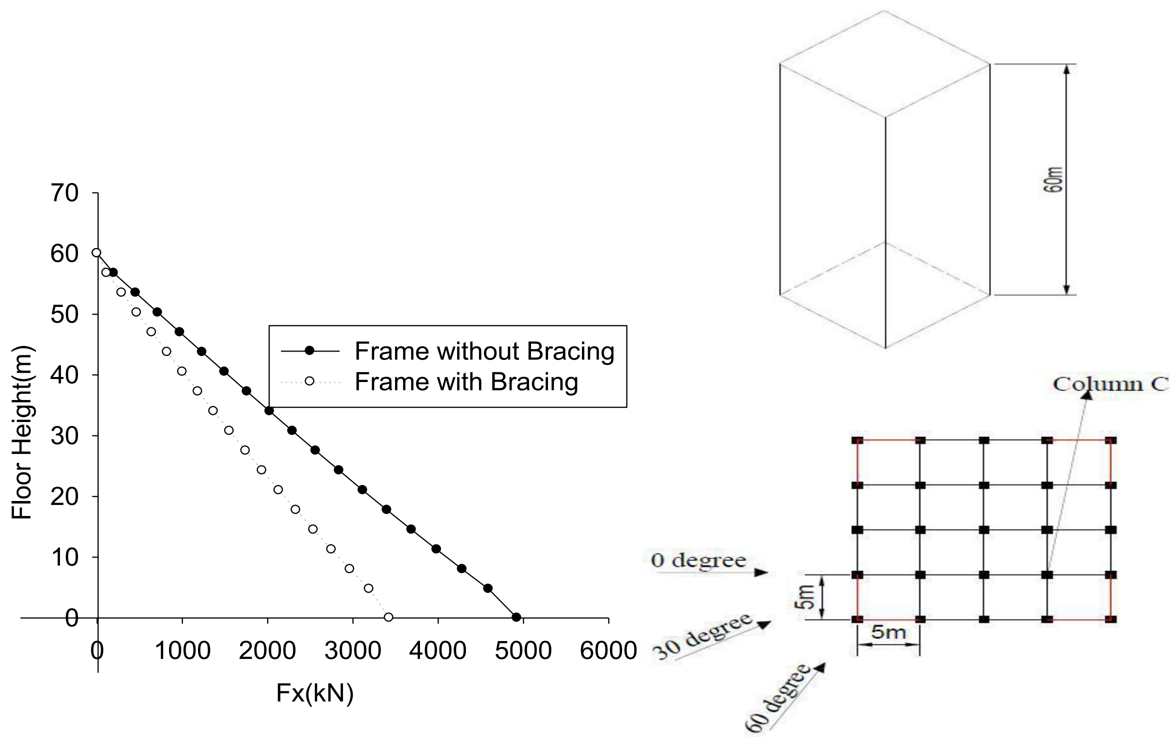


Fig 6.36 Comparison of axial force in column C at 60 degree wind incidence angle with and without bracing in frame

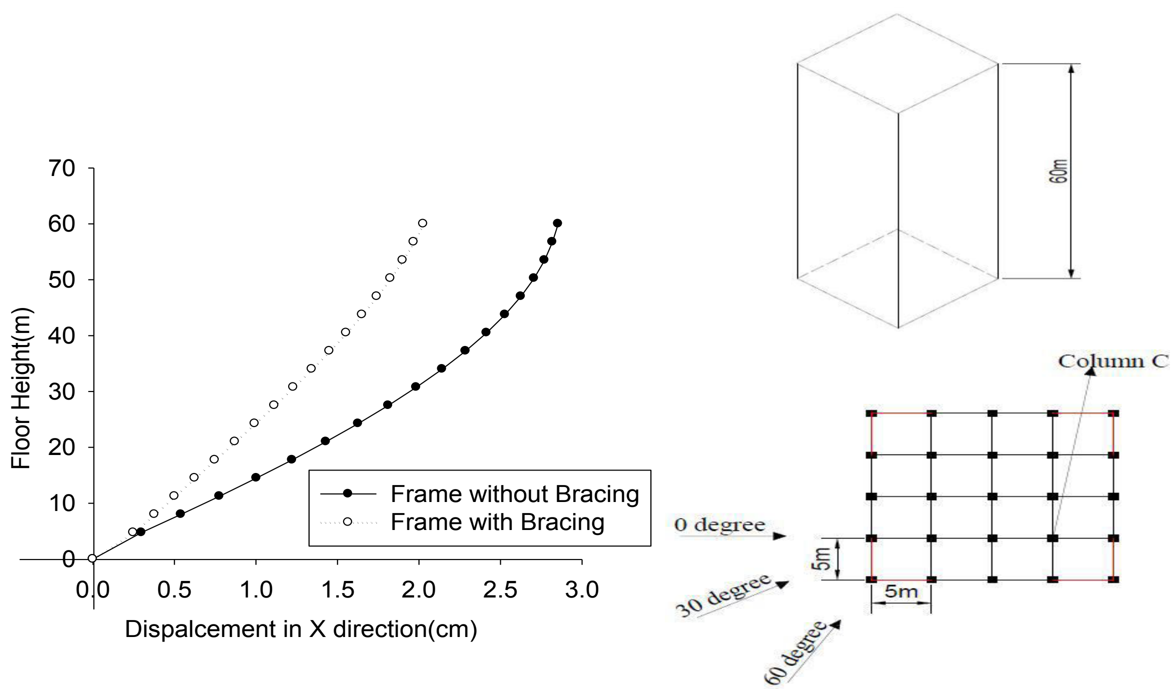


Fig 6.37 Comparison of displacement in X direction in column C at 60 degree wind incidence angle with and without bracing in frame

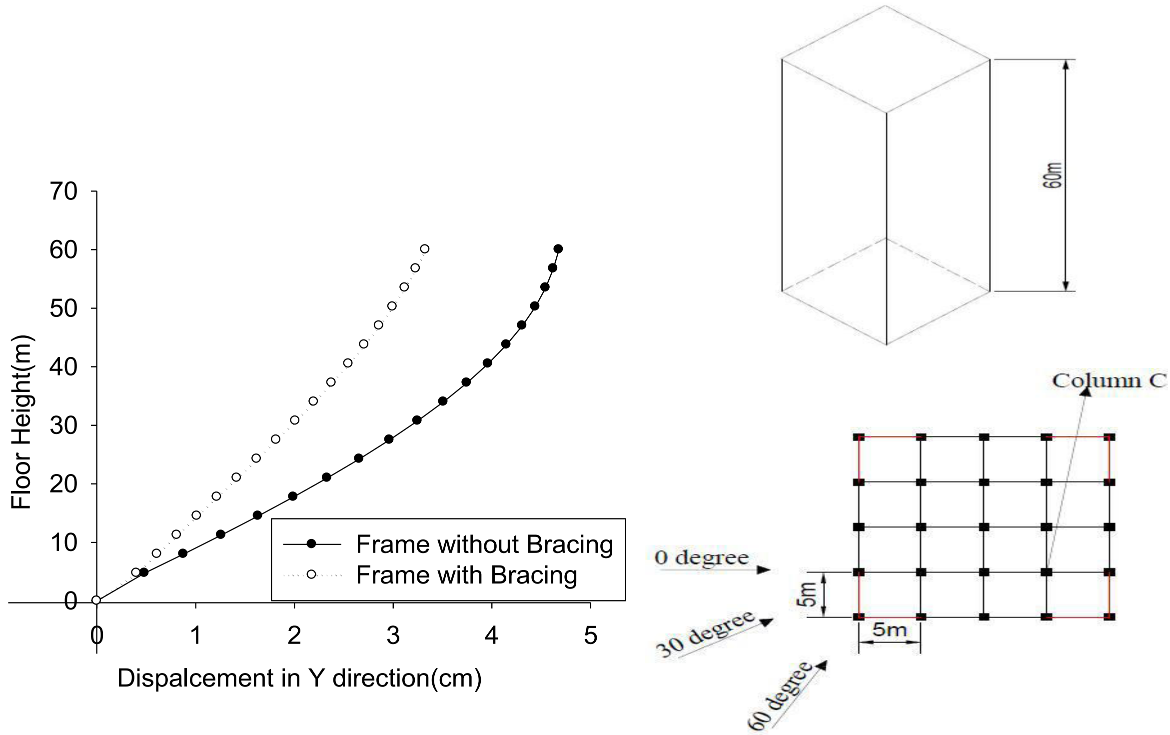


Fig 6.38 Comparison of displacement in Y direction in column C at 60 degree wind incidence angle with and without bracing in frame

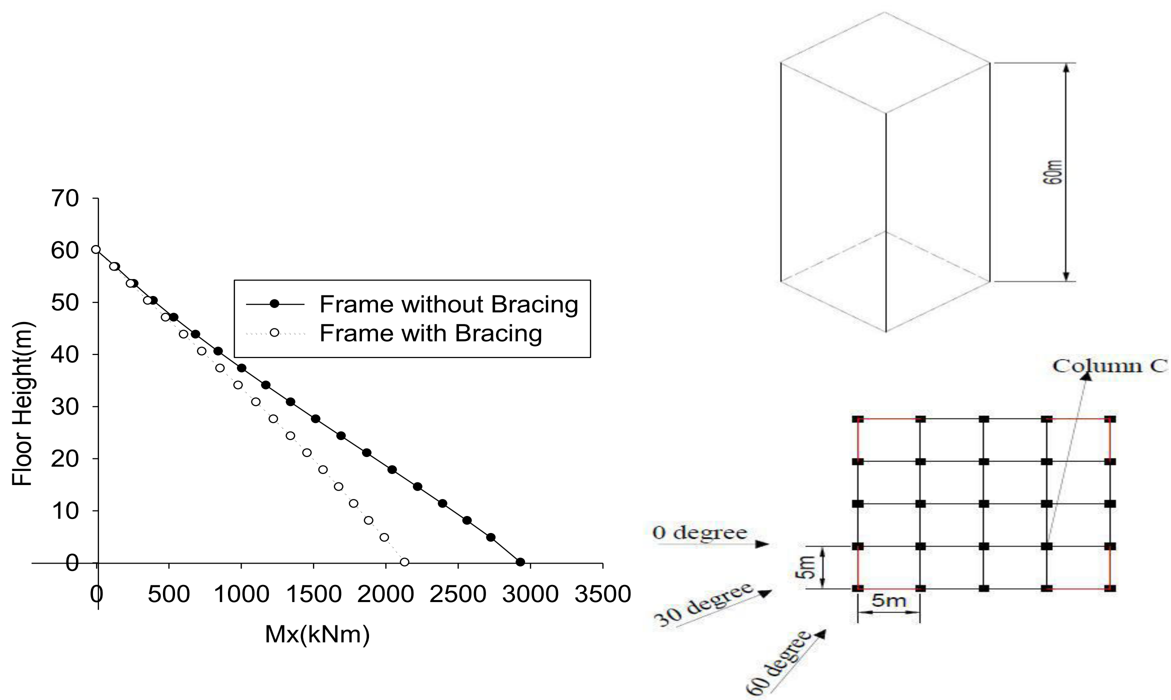


Fig 6.39 Comparison of moment M_x in column C at 60 degree wind incidence angle with and without bracing in frame

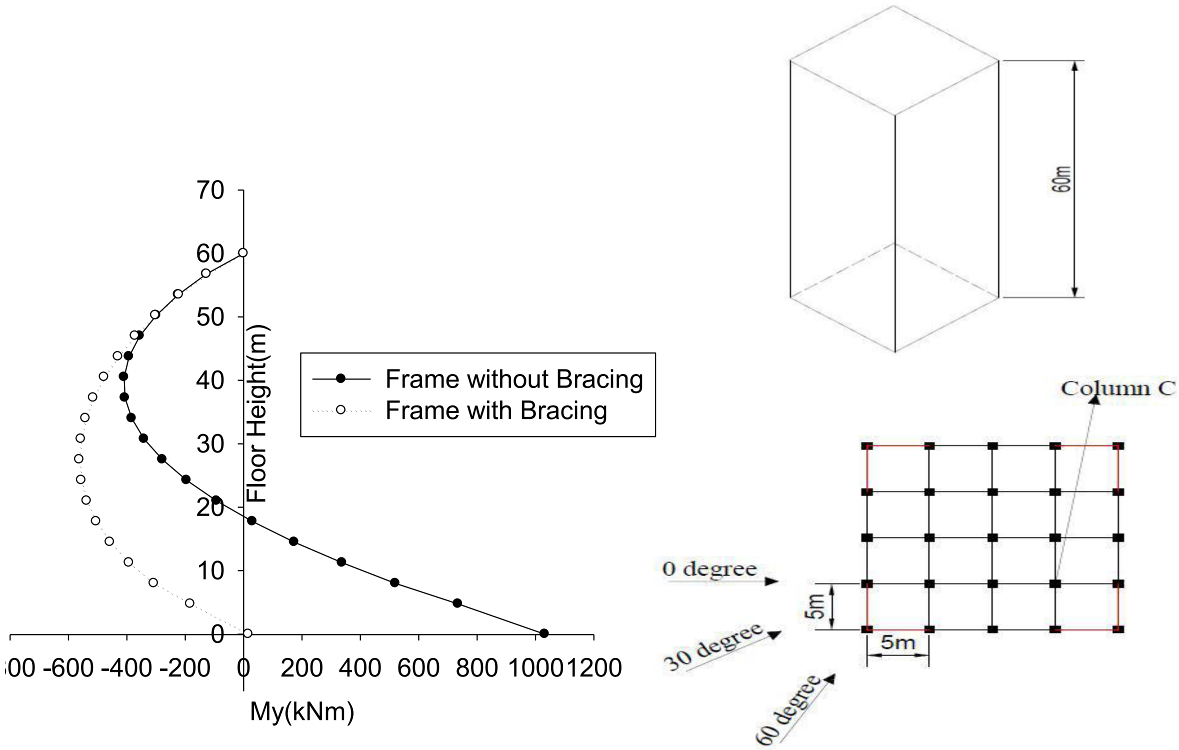


Fig 6.40 Comparison of moment M_y in column C at 60 degree wind incidence angle with and without bracing in frame

.

CHAPTER 7

CONCLUSION

7.1 GENERAL

The previous chapters of the thesis covers the response study of High Rise building under wind load with or without bracing system. In the experimental Study, models which is made up of Perspex sheet are used for pressure measurement. Response study is done to compute the response of square shape building under experimental wind loads.

7.2 EXPERIMENTAL STUDY-PRESSURE MEASUREMENT

1. At 0 degree wind angle, pressure occurs on the windward face and suction occurs on all remaining faces.

2. At windward face, positive wind pressure increases from bottom to top edge of the face due to increase in wind velocity with increase in height.

3. At the windward face positive pressure is maximum at the central line which decreases towards the edge.

4. Pressure reduces at the top near edge of windward face due to up-wash

5. On the side faces, suction reduces towards the leeward edge.

6. Uniform suction occurs on the leeward faces.

7. With changes in wind incidence angle, pressure value and suction value also changes on all faces.

7.2 WIND RESPONSE STUDY

1. Column B has been subjected to maximum axial force as compared to column A & C.

2. Axial force in column B is not effected by wind incidence angle.

3. At 30^0 wind angle, moment about x axis is maximum in all the columns A, B & C.

4. At 60^0 wind angle, moment about y axis is maximum in all the columns A, B & C.

5. Displacement along X direction is reduced by 29.00% by using steel bracing under 60 degree wind incidence loading.

6. Displacement along Y direction is reduced by 28.91% by using steel bracing under 60 degree wind incidence loading.

7. In column A, Axial force is found to be almost equal in both cases i.e. frame without bracing and frame with bracing and moment is increased by 56% by using steel bracing.

8. The axial force has reduced by 28.06% and 30% by using steel bracing in column B and column C respectively.

9. The moment has reduced by 32.955% and 27% by using steel bracing in column B and column C respectively.

REFERENCES

1. **Z.A. Siddiqi, Rashid Hameed, Usman Akmal**. "Comparison of Different Bracing Systems for Tall buildings, Pak. J. Engg. & Appl. Sci. Vol. 14, Jan., 2014(p.17-26)
2. **Himanshu Gaur , Ravindra Kumar Goliya**, "Correlating Stiffness and Shear Lag Behavior with Brace Configuration of Tall Truss Tube Buildings"
3. **Narasimha Murthy K, Darshan SK, Karthik AS, Santosh R, Shiva Kumar KS**, "Effective Study of Bracing Systems for Irregular Tall Steel Structures.
4. **G Navya , Pankaj Agarwal**, "Seismic Retrofitting of Structures by Steel Bracings"
5. **Abdul Karim, Srinivas B.N**, "A study on Outrigger System in a Tall R.C Structures Using Steel Bracing"
6. **Lekshmi Soman, Sreedevi Lekshmi**, "Comparative Study of Outrigger System with Braced Frame Core and Shear Core in High Rise Building."
7. **Adithya. M , Swathi rani K.S , Shruthi H K , Dr. Ramesh B.R ,** "Study On Effective Bracing Systems for High Rise Steel Structures" , *SSRG International Journal of Civil Engineering,* ISSN: 2348 – 8352, volume 2, Issue 2, February 2015, PP 19-22.
8. **IS: 875 (Part 1,2,3)-1987**, "Code of practice for design loads (other than earthquake) for building and structures, part 3 wind loads" 6th reprint, November 1998 Bureau of Indian Standards, New Delhi, India.
9. **Mendis, P. and Ngo, T.(2006),** "9/11 Five years on changes in tall building designs" Electronics Journal of Structural Engineering.
10. **Kwok, K.C.S., Wilheim, P.A and Wilkie, B.G. (1987),** " Effects of edge configuration on wind incidence response of tall buildings", Journal of Wind Engineering and Industrial Aerodynamics, 10, pp. 135-140.
11. **Kwok, K.C.S. (1988),** " Effects of building shape on wind-induced response of tall building", Journal of Wind Engineering and Industrial Aerodynamics, 10, pp. 135-140.

12. **Kumar, S. (2013),** " Effects of steps on Wind Loads on Tall Buildings", M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology, Roorkee, India.
13. **Kushal, T. (2013),** " Effects of Plan Shapes on the Response of Tall Buildings Under Wind Loads", M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology, Roorkee, India.
14. **Mendis, P. and Ngo, T.(2007),** " Wind loading on Tall Buildings", EJSE special issue: Loading on Structures, pp. 41-54.
15. **MS EXCEL 2007:** Spreadsheet for STAAD-PRO editor files and calculations.
16. **SIGMA PLOT 11.**0: The premier graphing application with statistical analysis features.
17. **STAAD-PRO V8i:** 3-D Structural Analysis and Design Software.