Analysis of outrigger numbers and locations with different bracing system

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Abstract : This paper presents a simple method of analysis for preliminary design of outrigger braced high rise shear walls subjected to three kinds of (Uniform,parabolic,Triangular)horizontal loading. A MATLAB programme written for analysis of 87 mtr High-rise building. Also, Optimal locations of outrigger with different bracing system are founded. Beside, Graphical method presented based on horizontal and vertical member stiffness of members of structures for finding out optimum location of outrigger.

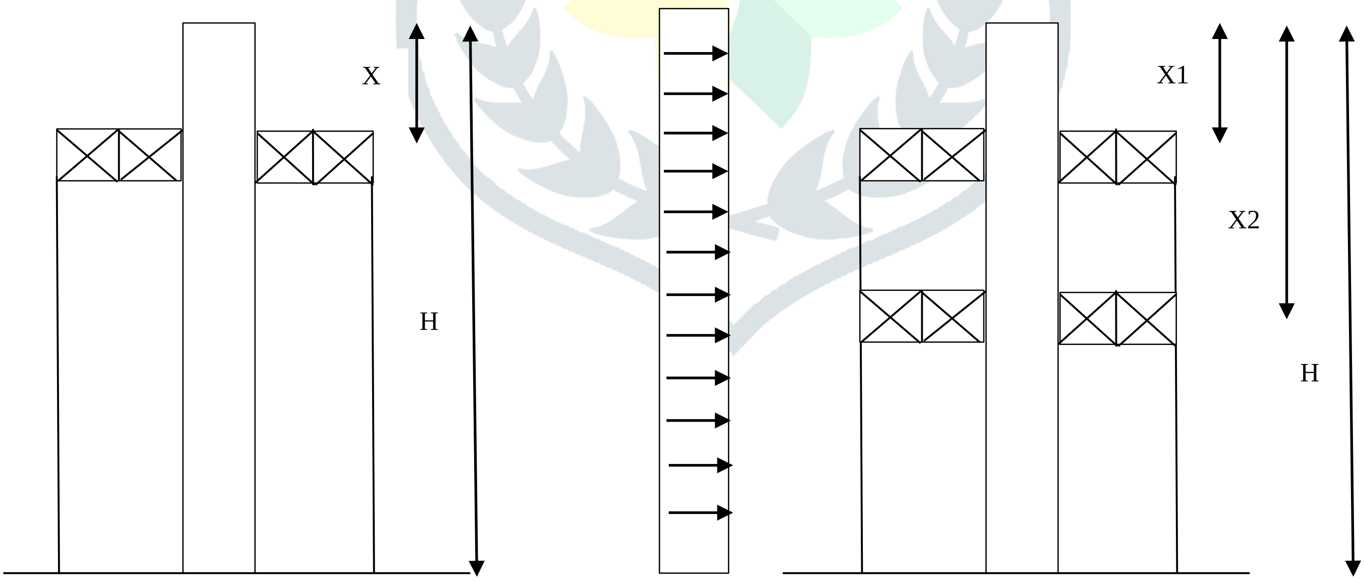
Keywords – High rise building , Outrigger system , Lateral Loading , Bracing

1. INTRODUCTION

An outrigger braced high-rise structure consists of a reinforced concrete or braced steel frame main core connected to the exterior columns by flexurally stiff horizontal cantilevers . Outrigger systems represent a very efficient structural system because the outriggers can reduce top deflection and core base moment.

The basic structural response of the system is quite simple. When subjected to lateral loads, the column restrained outriggers resist the rotation of the core, causing the lateral deflections and moments in the core to be smaller than if the freestanding core alone resisted the loading. The external moment is now resisted not only by bending of the core alone but also by the axial tension and compression of the exterior columns connected to the outriggers. As a result, the effective depth of the structure for resisting bending is increased when the core flexes as a vertical cantilever, by the development of tension in the windward columns and by compression in the leeward columns.

In addition to those columns located at the ends of the outriggers, it is usual to also mobilize other peripheral columns to assist in restraining the rotation of outriggers. This is achieved by tying the exterior columns with a one- or two-story-deep wall



a) one outrigger

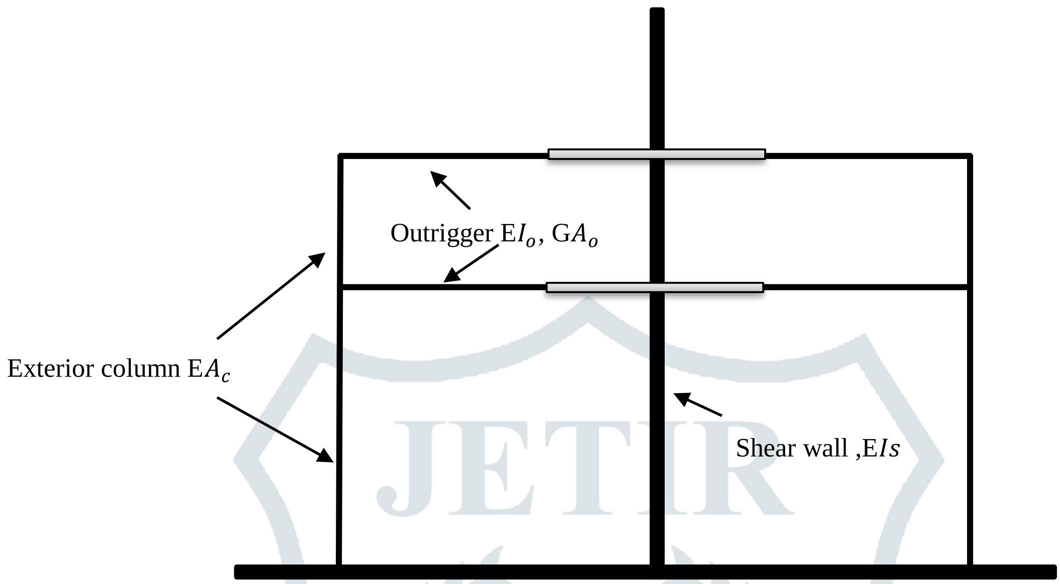
b) Two outrigger

commonly referred to as a “belt truss” around the building.

Belts can improve lateral system efficiency. For towers with outriggers engaging individual mega column, belts can direct more gravity load to the mega columns to minimize net uplift, reinforcement or the column splices required to resist tension and stiffness reduction associated with concrete in net tension.

For towers with external tube systems – closely spaced perimeter columns linked by spandrel beams– belts reduce the shear lags effect of the external tube, more effectively engage axial stiffness contributions of multiple columns, and more evenly distribute across multiple columns the large vertical forces applied by outriggers.

For both mega column and tube buildings, belts can further enhance overall building stiffness through virtual or indirect outrigger behavior provided by high in-plane shear stiffness , as well as increasing tower torsional stiffness.



Analytical Model

2. THEORY ON THE OPTIMIZATION OF THE OUTRIGGERS IN A SIMPLIFIED MODEL

2.1 Assumption for analysis

1)the Structure is Linear elastic;
2)only axial force induced in columns;
3)the outriggers are rigidly attach to the foundation;
4)the sectional properties of core , columns,and outriggers are uniform throughout their height;
5)the core is rigidly attach to the foundation
6)the belt truss is infinitely rigid and wraps around the perimeter columns.
7)stiffness provided by the typical floor slab connecting the core and the perimeter columns is ignored

2.2 Solution for Outrigger Braced structure

The compabability equation for rotation at the interface of one outrigger and core on the center line of the outriggers can simply be stated as,

$$\theta_t = \theta_r$$

$$\frac{w(H^3\text{-}X^3\ )}{6EI_t} + \frac{wx}{GA_t\dot{\alpha}} = \frac{M_r}{hGA_t\dot{\alpha}^2} + \frac{M_r b}{24EI_o\dot{\alpha}^2} + \frac{M_r}{hGA_o\dot{\alpha}^2} + \frac{M_r(H-X)}{EI_c}$$

$S_H=(1/\dot{\alpha}^2)(\frac{b}{24E_S I_0}+\frac{1}{2hGA_0})$ Flexibility value of Horizontal Member(Due to Outrigger)

$S_v= \frac{H}{E_c I_w}+\frac{H}{E_c I_c}$ Flexibility value of Vertical Member(Due to shear wall and Mega column)

$$K=\begin{bmatrix} \omega+1-\varepsilon_1 & 1-\varepsilon_2 & \dots 1-\varepsilon_n \\ 1-\varepsilon_2 & \omega+1-\varepsilon_2 & \dots 1-\varepsilon_n \\ 1-\varepsilon_3 & 1-\varepsilon_3 & \dots \omega+1-\varepsilon_n \end{bmatrix}$$

Where, $\omega = \frac{S_H}{S_V}$ ε=X/H

$E_c I_c = 2 E_c A_c l^2$

$\dot{\alpha} = \frac{l}{b}$

Where, $M_i = K^{-1}$B

$M_B = \frac{WH^2}{2} - \sum_{i=1}^{n} M_i$

$\Delta = \frac{WH^4}{8EI} - \frac{1}{2EI} \sum_{i=1}^{n} M_i \, (H^2 - X^2)$

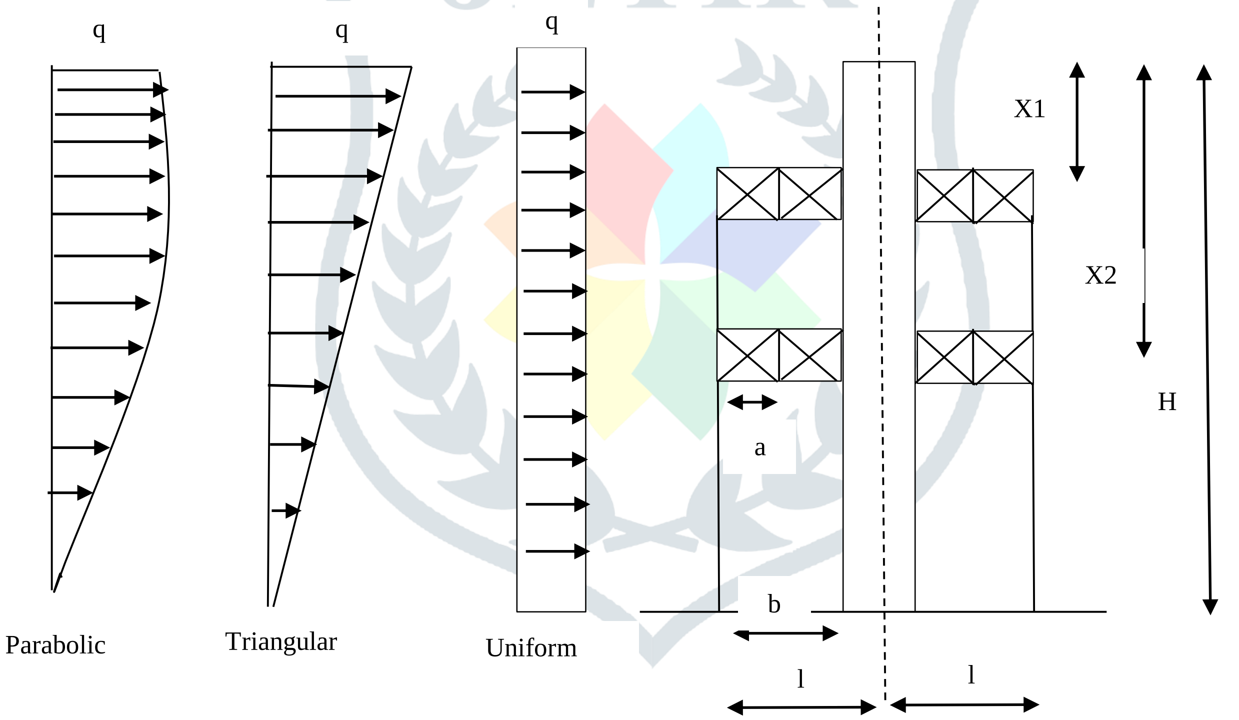
- Constraints

1) $\Delta_T \leq \Delta_{limit} = \frac{H}{500}$

2) x$\leq (H - 3X strorey\ height)/H$

3) $\frac{P}{P(capacity)} - 1 < 0$

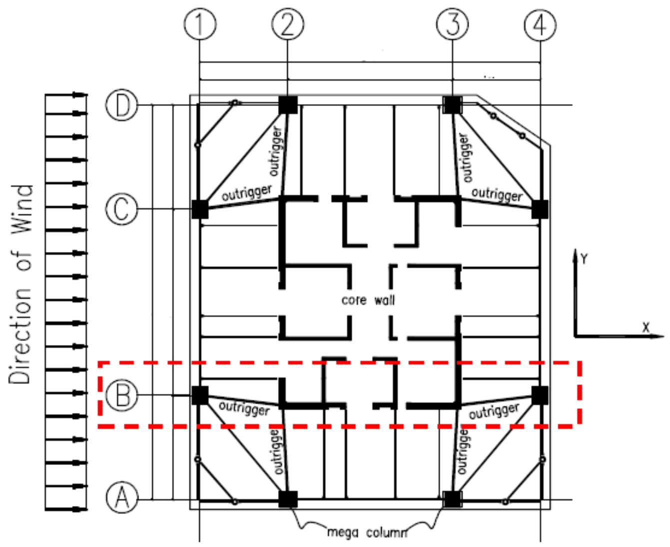
2.3 Flowchart for Optimization

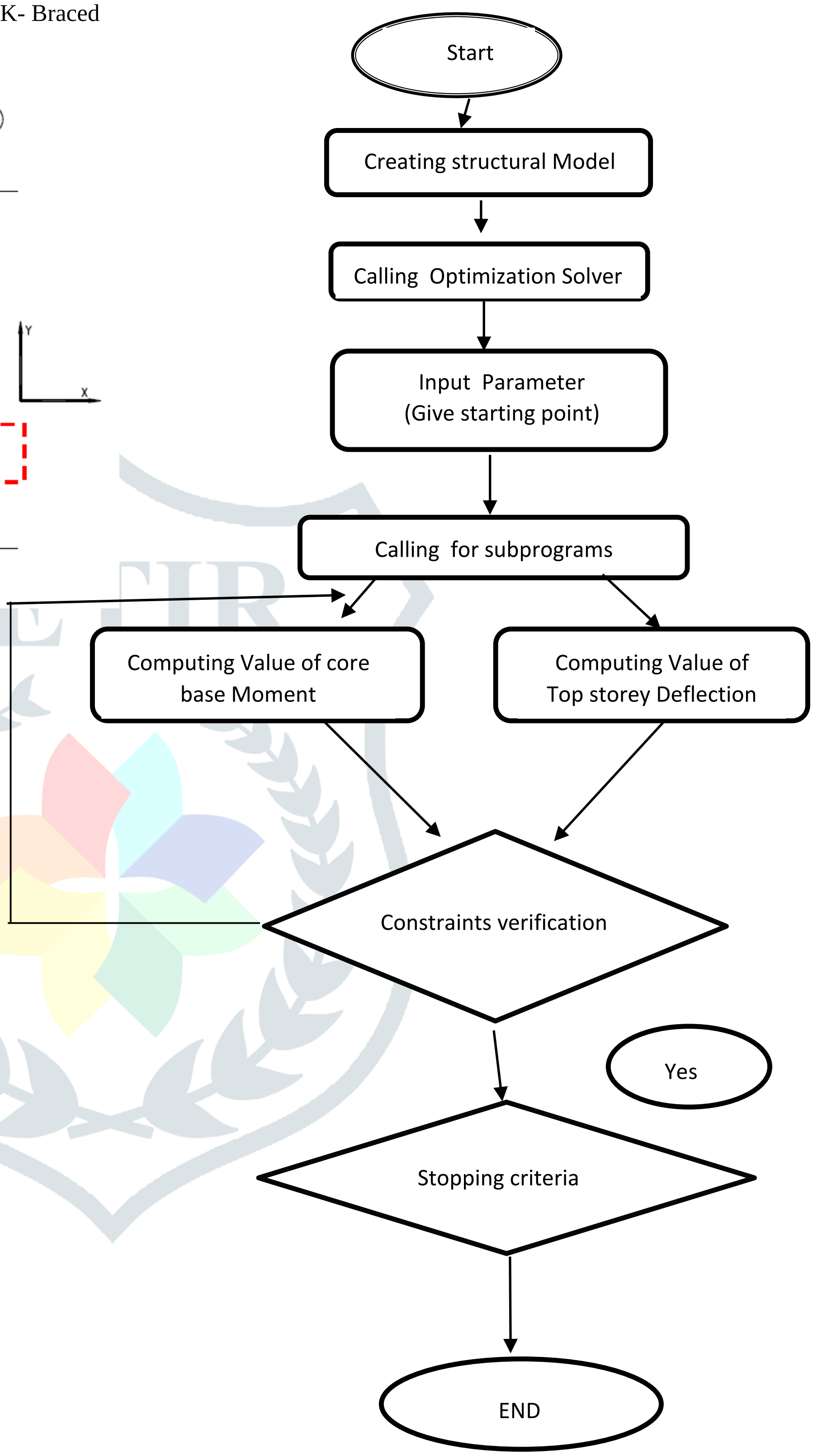


3. CASE STUDY

- Building Height of 87m,29 stories, floor to floor height of 3.0 m
- Horizontal floor Dimesions = 45x27m
- Core wall length = 9m
- Cross section area of Mega column = $3.12\text{x}10^{-2} m^2$
- Modulus of elasticity of Concrete = $4\text{x}10^{7}$kN/m^2
- Modulus of elasticity of steel = $2.1\text{x}10^{8}$ kN/m^2
- Top and bottom cords cross sectional area of outriggers -A_b= $1.78\text{x}10^{-2} m^2$
- Area of diagonal of outrigger system-A_d= $9.276\text{x}10^{-3} m^2$
- Building is subjected to uniformly Distributed lateral wind load = 1.6kN/m^2
- Load pattern used-1)Uniformly distributed 2)Triangular loading 3)Parabolic loading

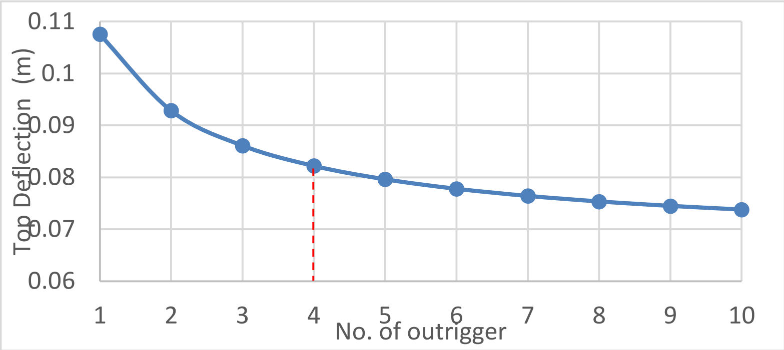
- Outrigger height-3m
- Type of bracing used- X Braced , N-Braced ,K- Braced

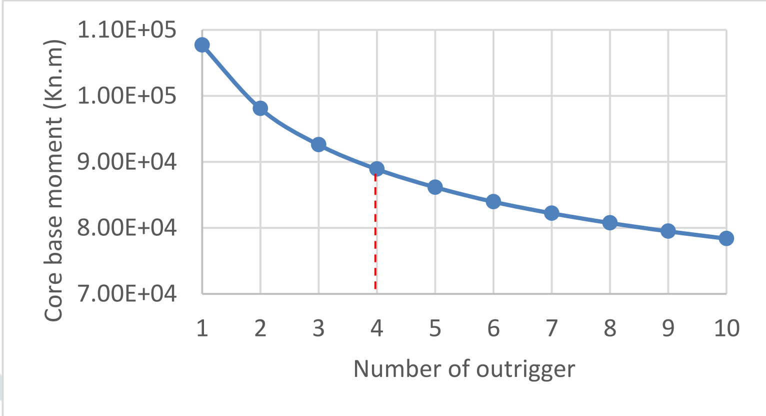


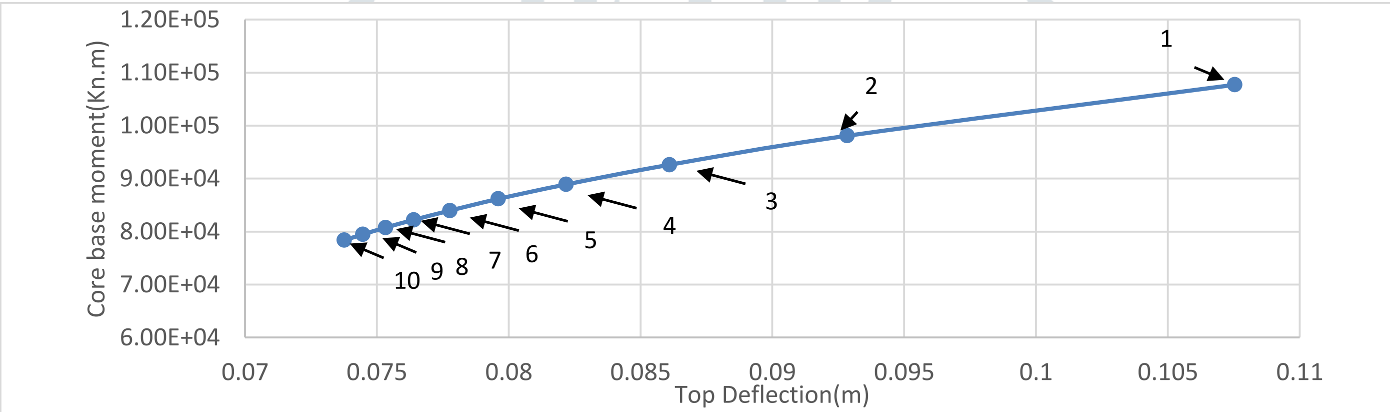


FLOW CHART

4.RESULTS ANALYSIS OF OPTIMIZATION DESIGN

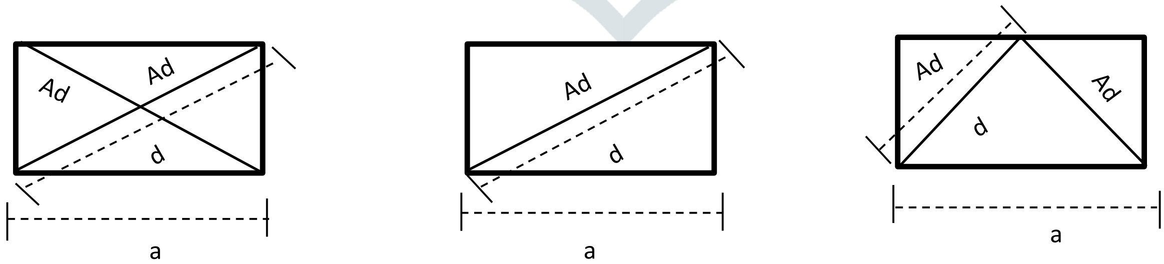






So, 4 number of outrigger is optimum for tall structures.

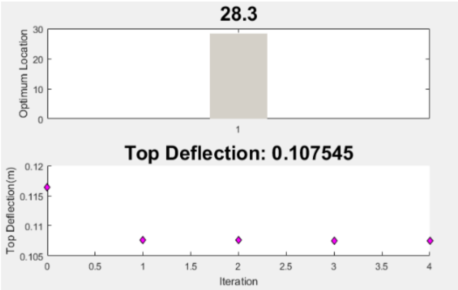
4.2 Different bracing system



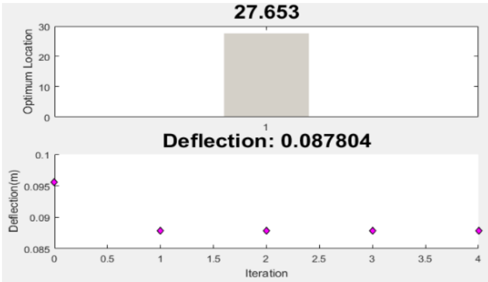
4.3 Results of different bracing system with different wind loading condition

4.3.1 Results of optimum location of one outrigger

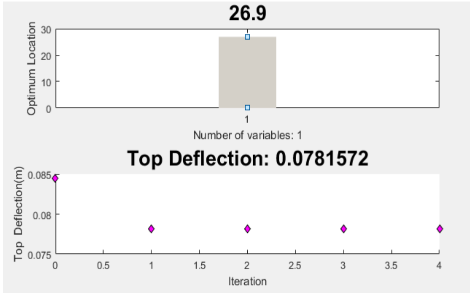
4.3.1.A For X type of bracing



Uniform wind loading

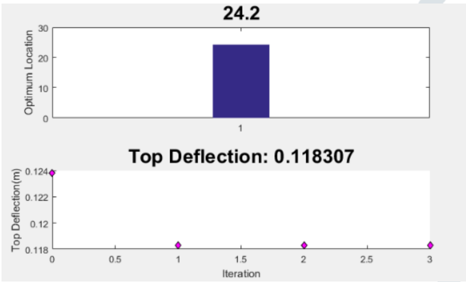


Parabolic wind loading

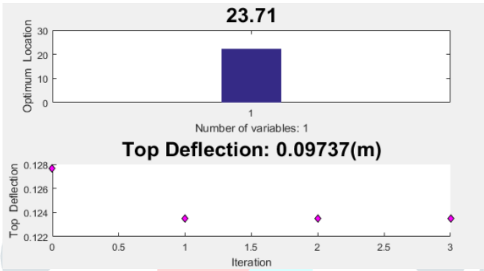


Triangular wind loading

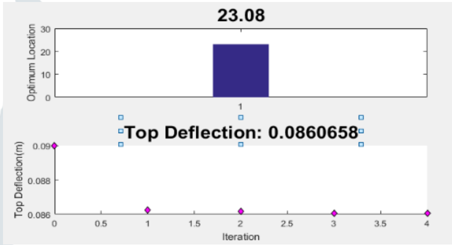
4.3.1.B For N type of bracing



Uniform wind loading

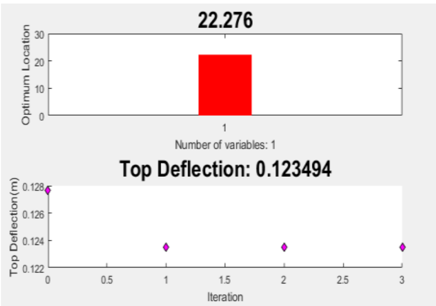


Parabolic wind loading

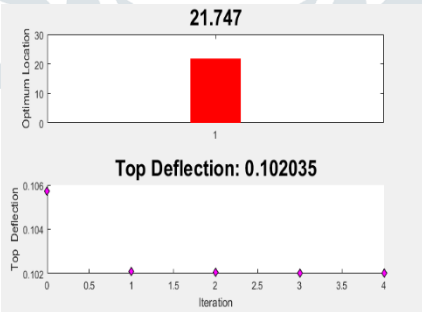


Parabolic wind loading

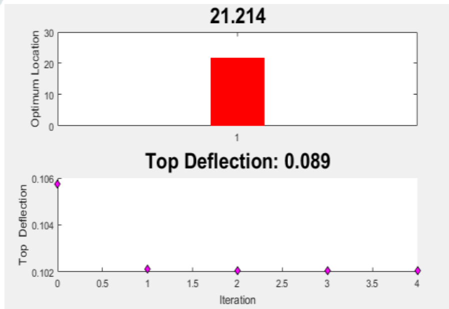
4.3.1.B For K type of bracing



Uniform wind loading

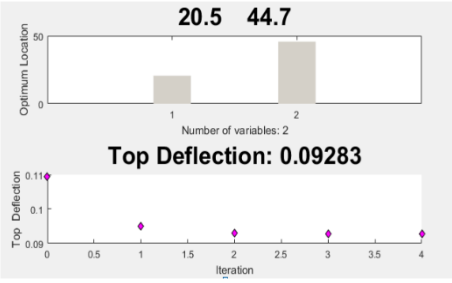


Parabolic wind loading

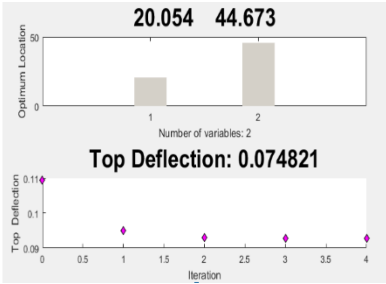


Triangular wind loading

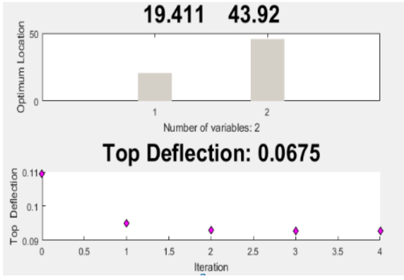
4.3.2 Results of optimum location of Two outrigger
4.3.2.A For X type of bracing



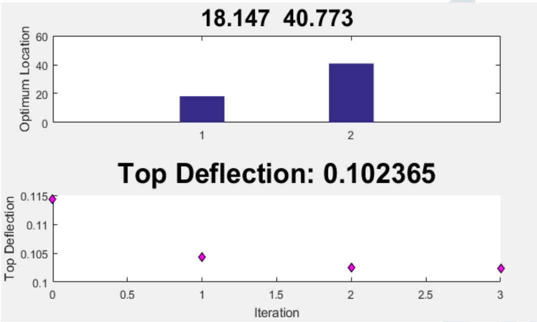
Uniform wind loading



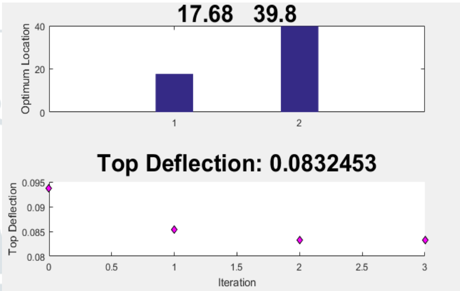
Parabolic wind loading



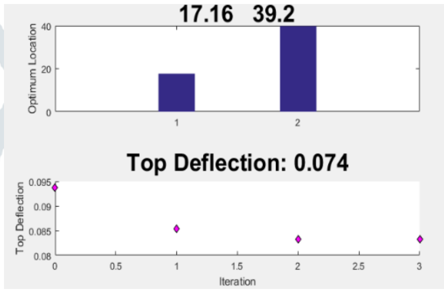
Triangular wind loading



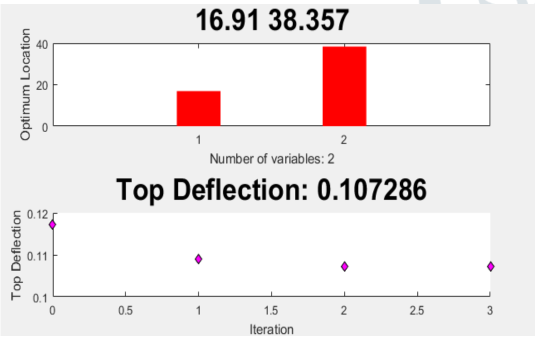
Uniform wind loading



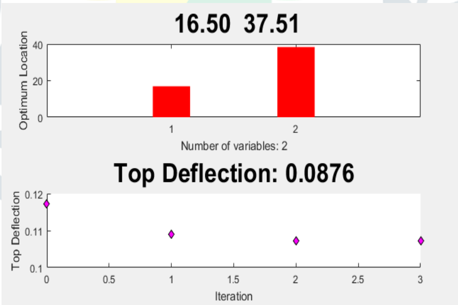
Parabolic wind loading



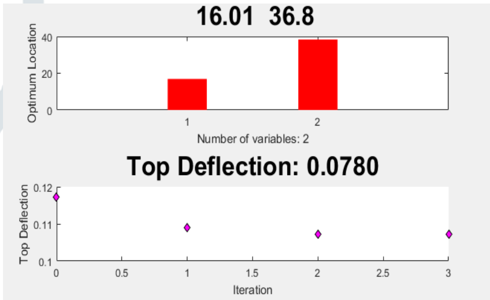
Triangular wind loading



Uniform wind loading



Parabolic wind loading



Triangular wind loading

5.GRAPHICAL METHOD FOR FINDOUT OPTIMUM LOCATION OF OUTRIGGER

- $Y=\frac{wH^4}{8EI_s}-\frac{M_a(H^2-x^2)}{2EI_s}-\frac{M_x(H^2-x^2)}{2EI_s}$

  The reduction in the deflection due to restraining moments is represented by the last two terms in the equation

Where, $M_a=\{\frac{wH^3}{6EI_sS_v}\}\{\frac{-x^4+x^3+xa^3-\omega a^3-a^3+\omega}{x-x^2-a+xa-a\omega+2\omega-\omega x+\omega^2}\}$

$M_x=\{\frac{wH^3}{6EI_sS_v}\}\{\frac{x+ax^3+x^3+xa^3-\omega a^3+a^3+\omega-a}{x-x^2-a+xa-a\omega+2\omega-\omega x+\omega^2}\}$

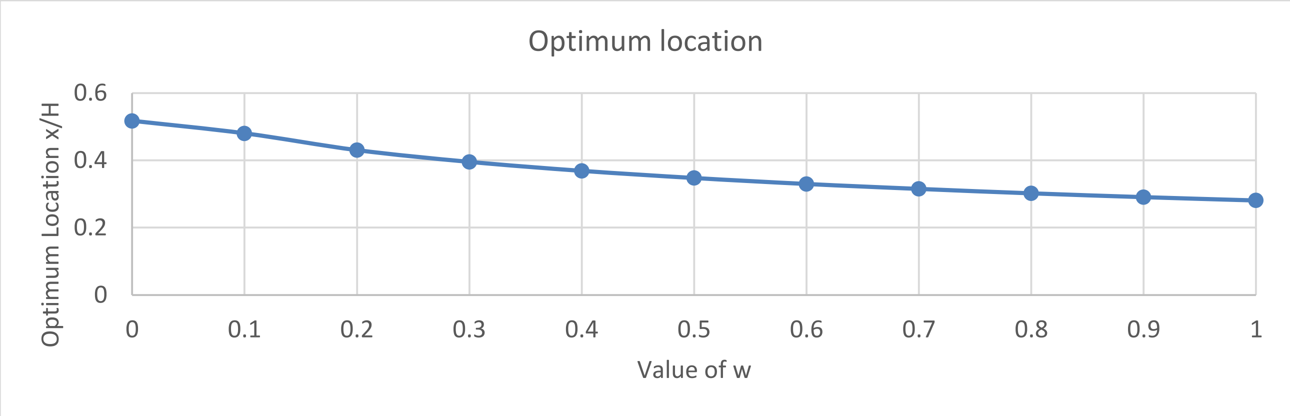
where, $\omega=\frac{S_H}{S_V}$ (Dimensional less parameter)

x=x/H (Dimensional less parameter)
a=a/H (Dimensional less parameter)
This reduction is maximized by differentiating it w.r.t. X,setting it equal to zero and solving for x

$\frac{dy}{dx}$ {[(1-a^2){w(1-a^3)+(1-x)(x- a^3)}+(1- x^2){w(1- x^3)-(1-a) (1-x^3)}]/{w^2+w(2-a-x)+(1-x)(x-a)}]=0

Above Equation allows a graphical representation of the optimum location of the second outrigger as a function of two dimensionless parameters, w and *a*/*H*.

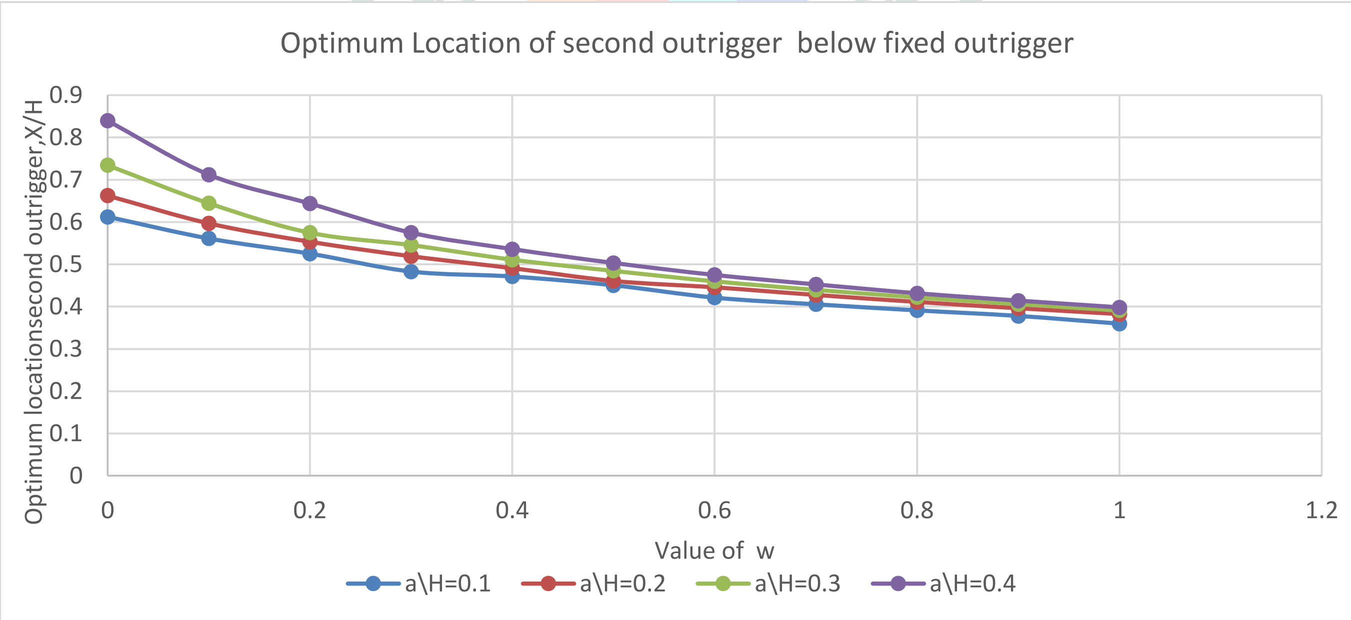
❖ Optimum location of one outrigger



$\omega = \frac{S_H}{S_V}$ (Dimensional less parameter) 0<W<1
x=x/H (Dimensional less parameter)

- By knowing stiffness ratio of (ω) ,from graph foundout optimum location of one outrigger .

❖ Optimum location of two outrigger



- If one outrigger at 0.1H from top and by knowing ratio(ω) of horizontal and vertical member's stiffness ratio, from graph finding out second outrigger's location.

6.CONCLUSION

The conclusions of this study can be summarized as follows:

1.For Tall buildings 2-3 outrigger is optimal number for reduction of lateral drift.
2.Three types of wind loading is applied and optimum location is found for same, parabolic wind loading give intermediate result between uniform and triangular wind loading.

3. Also analysis of building with different bracing system is done and find that as racking shear stiffness increase optimum location is going downward.
4. Graphical method introduced based on vertical and horizontal member's stiffness for finding out optimum location of outrigger system.
5. Various schemes can be obtained via algorithm,this makes it easy for designers and clients to assess the relative performance of structural systems with different numbers of outriggers at different locations.

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