# Wind analysis of tall structures with dampers by soft computing technique

*Introduction, model parameters, dampers, analysis results*

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***Abstract*—In this paper we have made an effort to bring out the effect of a damper which is installed to reduce the deflection of the building under wind forces. However the analysis is made by using static loads it is still a discussion topic for a structural engineer for either to analyze a structure statically or dynamically. The paper consists of an innovative type of damper called jack damping system which is yet not in practice but it is way more effective and efficient that the other type of damping system.**

***Index Terms*— wind induced forces, model parameters, jack damping system, axial force, base shear, moment, deflection.**

## I. Introduction

The simple wind analysis is done on an ideal structure by providing a moving mass at the face of the structure. The question is optimizing its weight and height for its maximum efficiency of the damping system. We can express a weight and height as a function of wind velocity and decide an optimum weight and height for a type of wind. But the sway of the structure and oscillation will not only depend upon a weight and mass of the structure but also the stiffness of the structure. In our thesis the structure has stiffness similar along it's both the axis, Axis X and Y but it linearly reduced along its height.

We can either achieve the height by keeping the mass constant or we can achieve a mass by keeping the height as constant. Initially we will take a random weight and see the effective height and in second state we will keep the height constant and vary the mass. In the beginning we have installed a Active mass damper or pendulum damping system, where it is expected to control the oscillation of the structure. But since we are dealing with static analysis, we have not seen any good results in deflection. But if the mass exceeds beyond 7000Kn we have encountered an excessive deformation. Hence instead of decreasing the sway the structural system has intended to increase in the limit with respect to weight. Hence we can install a new type of damping system called a cable jack damping system.

## II. Types of anchoring system

In this type of anchoring system we have two sub types of anchoring system. They are.

I. Parallel Anchoring System.
II. Diagonal Anchoring system.

### I. PARALLEL ANCHORING SYSTEM

This is one of the easiest ways of dissipating the energy of a structure. The active mass damping system is efficient in arresting the oscillation of the building but due to exceeding mass, the structure will be of system equipped with huge members to hold that mass in position. And the structural natural period comes into picture. But in Cable jack anchoring system it is not so, I.e. one can have a control over a jacking force which interns helps to monitor the deflection or sway in a controlled manner. For any structure if one has a control over the loading on a structure then he can overcome any type of possible problems which may arrive due to any type of accidental loading in the future. Some of the important working principles of this system are.

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I. Initially two corners of the structure of opposite face of wind impact are anchored to high tensile cables.
II. These cables run parallel following corners of the structural system.
III. They are then passed over a pulley, on a face of wind direction.
IV. Then they are brought down to a controlling system where a pull can be applied in a controlled manner depending on the wind velocity.
V. In this type of damping system the maximum restricted pull on a structure can be calculated by sway restriction of a structure.
VI. Then a maximum pull which can be applied on a cable is calculated.
VII. So when the wind velocity is less the axial pull will be just sufficient to stabilize the structure avoiding the excessive sway, i.e. minimum.

VIII. Even though there is a limiting sway allowance as per Indian standard which is H/500, we will make sure to make the sway zero for safety.
IX. Now in no wind cases, there will be no pull hence the building will not sway.
X. The main reason to control the axial pull is to ensure that the building will not sway in the negative direction when there is no wind.

## III. MODEL PARAMETERS

The modeling is done in STADD PRO V8i using coordinating system. The further in detail properties of model is shown below.

## IV. GEOMETRIC PARAMETERS

The geometry of the structure consists of an ideal plan of square in size consisting of 16 columns and corresponding beams of sizes 250 x 250 in size.

## V. LOADING PARAMETERS

In the first type of cable jack damping system we have to provide a cable along the path shown in below figure. The corners of the building is marked alphabetically A, B, C & D. The red line indicates the path followed by the cables. The salient features and the force transformation of the cable are discussed below briefly. The jacking system consists of two stages to control the deflection of the building in one axis. They are as follows.
Initially the structural engineer has to determine that how the software works for good of the structural system and then and then only he can analyze the structural system. He has many ways to determine the software check, but a good structural engineer will either compare a analysis results for a small frame or grid with manual method or determine the forces obtained ins within the range by experience.

I. Primary jack damping system.
II. Secondary jack damping system.

The stages of jacking system have divided into two as such to avoid the excessive deflections. The brief discussion will be made of respective damping system in following sections.

## I. PRIMARY JACK DAMING SYSTEM

In this system a top storey deflection is controlled by two cables as shown in figure. This is a primary stage because the cables require a larger jacking force compared to that of the secondary jacking force. The efficiency of the jacking system is inversely proportional to the primary jacking force. As the building height increases the jacking force required will also increase to bring it to minimum deformation state and intern the secondary deflection will also increase and so as the secondary jacking force.

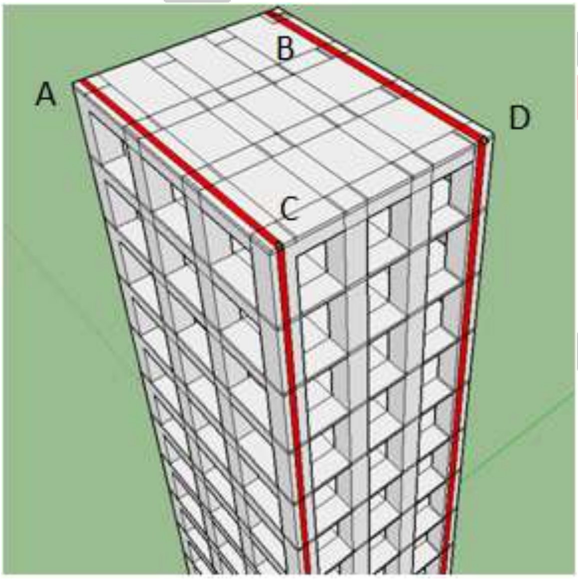


**Fig 1 Cable path (primary)**

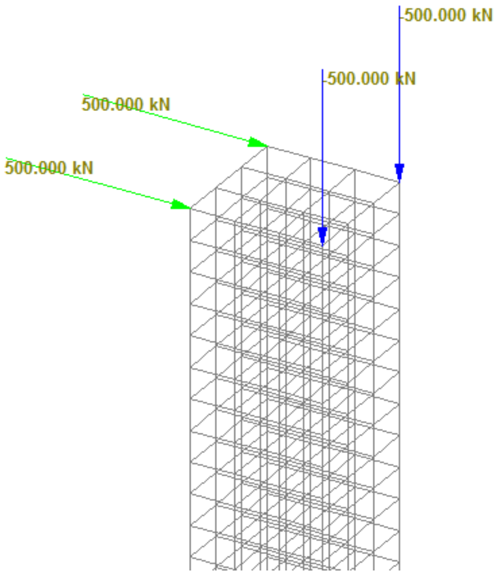


**Fig 2 Loads due to cables**

- In the above figure one can observe clearly the path of red line which indicates the line of cable.
- At the point A and B the cable is clamped at the center of the column, hence those nodal force caused due to the jacking force of cable can be replaced by the pint force shown in the green color which is horizontal.
- Then at the point C and D we can observe the green colored circular pulley.
- This pulley is assumed to be friction less, located at the center of the column and hence when a force is applied on a cable the structure is dragged vertically down.
- This force can be replaced by the vertical nodal force indicated in blue color as shown in figure.

- Since the pulley is assumed to be completely frictionless and by the principle of super positioning, the force at the jacking will be same at points A, B and C, D.
- Since there are three different kinds of jacking system, they will be discussed in the separate sections.

**TRIALS**

In this analysis we will carry out series of experiments in which we will note down the deflection caused due to the change in the axial pull of the cables. As we know the axial pull effect is observed on the structure is most effected at the top stories and least effected at the bottom storey. But the central storey will also deflect in the direction of wind and also in the negative direction. After optimizing the axial pull on a structure we can confirm its effect on the structure where the deflection is very least and the chosen Load case has not become maximum load case for any members. This is a crucial property which we need to observe.

| Cable jack damping system (Parallel system) | | |
|---|---|---|
| Trial No | Axial pull in Kn | Deflection Curve |
| 1 | 100 | -2.856 |
| 2 | 200 | -2.429 |
| 3 | 300 | -2.002 |
| 4 | 400 | -1.574 |
| 5 | 500 | -1.147 |
| 6 | 600 | -0.72 |
| 7 | 700 | -0.293 |
| 8 | 800 | 0.134 |
| 9 | 900 | 0.561 |
| 10 | 1000 | 0.988 |

**Table 1 Tabulated trial results of parallel jack damping.**

The above results are tabulated based on the results we achieved by the software. The graph is plotted for the tabulated result. In the trial and error method we went on increasing the axial load by 100Kn but if we require a even more accurate linear relationship we can go for finer intervals like 50Kn and 10Kn. But since we are not dealing with any of the property of slopes or a angle of line and also we just need the load at the point of maximum deflection we will go for a rough intervals of 100Kn.

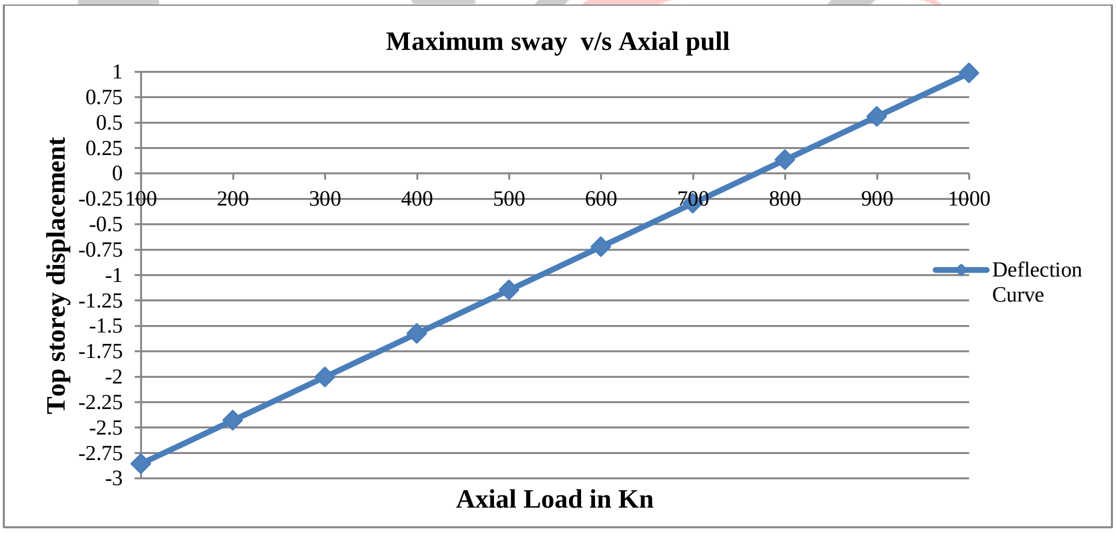


**Fig 3 Graph showing relation between maximum sway and axial pull**

In the above graph we can observe the deflection change of the outer most columns with respect to cable jacking force. Some of the salient features of the graph are explained below.

- The deformation of the structure decreased as the cable jacking force is increased.
- The linear variation can be seen in the graph and we can observe the point where the deflection has reached Zero.
- This axial pull will be the maximum primary axial pull on a cable to control deflection.
- By linear interpolation or similar triangle rule we can achieve a force at which there will be no deflection and it is 768.613Kn.
- By keeping this force constant we can decide necessary secondary force at which we can decide a secondary force.

## II. SECONDARY JACK DAMING SYSTEM

In this type of jacking system the deflection due to a primary jacking system is arrested by the secondary jacking system. As we can observe that the structure is deformed in the direction of wind we can overcome this deformation by providing the secondary anchoring cable system. We can observe a lot of changes in the structural system that the deformation caused due to the secondary jack damping system are less. The salient features of this method are provided below.

- The green path shows the path followed by the secondary cable jack damping system.
- The point of jacking will be at the central height of the opposite face where the Secondary jacking system is installed.
- The anchorage of the cable is done as same as that of primary jacking system except that the pulley is absent.
- The forces excreted due to jacking of the cables can be replaced by the point load pulling the node downwards.
- This force can be replaced by the vertical force on the node as shown in figure.
- The maximum deflection observed is 0.599m on the opposite face of the wind in between the columns of 866 and 826.
- The axial force indicated in blue color is applied at central height of the structure.

### TRIALS

In this analysis we will carry out the same iterations as that of the previous damping system. The Load incremental is 100kn and the results are tabulated by taking the outmost columns deflection as reference. Since the mode shapes showing the deflection have yielded two critical columns. For reference we will consider two deflections. The results are tabulated in below tabular column. There is a deflection in the direction of the wind, in both the positive and negative direction. The salient features of the results are tabulated below.

As that of previous system we cannot compare the results for a single critical deflection value, because the structure has yielded two consecutive results, in which both of them are maximum. Hence by plotting the results in graph we can minimize or maximize the secondary axial pull of cable and bring to a value in such a way that it will not maximize the sway of the structure.

| **Cable jack damping system (Parallel system)** | | | |
|---|---|---|---|
| Trial No | Axial pull in Kn | Deflection Curve 1 | Deflection Curve 2 |
| 1 | 100 | 0.191 | -0.446 |
| 2 | 200 | 0.383 | -0.301 |
| 3 | 300 | 0.574 | -0.156 |
| 4 | 400 | 0.765 | -0.011 |
| 5 | 500 | 0.957 | 0.133 |
| 6 | 600 | 1.148 | 0.278 |
| 7 | 700 | 1.339 | 0.423 |

**Table 2 Tabulated trial results of parallel jack damping.**

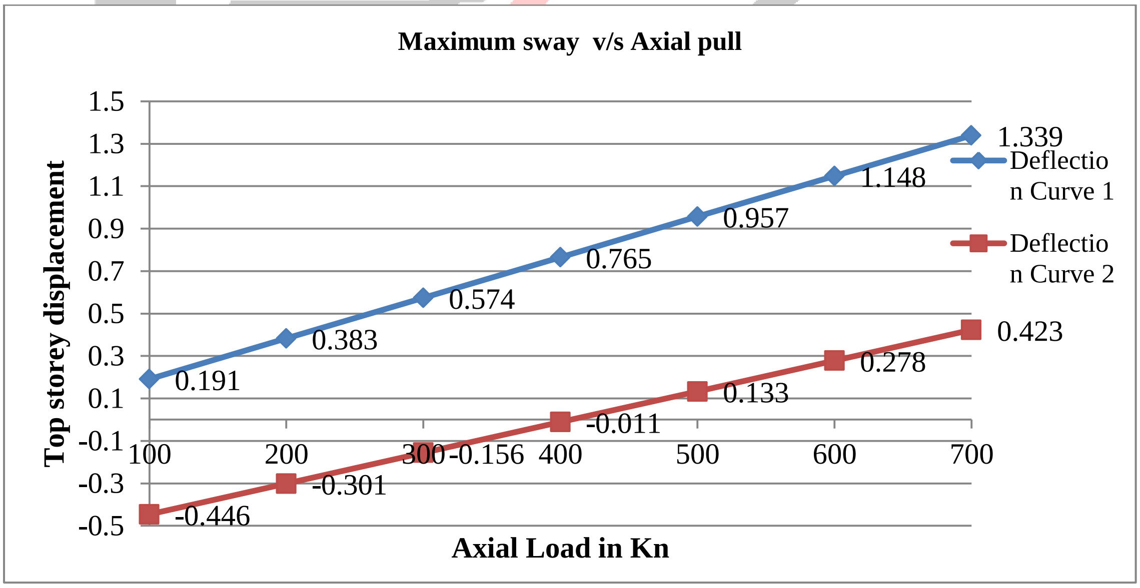


**Fig. 4 Graph showing the relation of both jacking system**

The above graph has shown some of the important behavior of the structural system. They are.

- In the graph the blue deflection curve indicates the deflection curve 1 and the red indicates the deflection curve 2.
- The blue graph is due to the primary jacking system and the red is due to the secondary jacking system.

- The secondary ultimate jacking force must be of such a way that it will not contribute to a primary deflection.
- However it is unavoidable to make a secondary jacking unaffecting the primary one.
- Now we have to keep in mind that the jacking force in secondary jack must reduce the deflection in mid height and must also not contribute to the primary deflection.
- In the graph along x axis we have got axial pull, this we have to choose in such a Way that neither both of the y axis values are maximum.
- If we choose to minimize the secondary deflection by increasing the secondary jacking force we will definitely increase the primary deflection.
- Hence we can choose somewhere in between those jacking force for effectiveness.
- In the graph by observation an axial pull, we can decide that both the deflection curve of the graph has not converged at any point.
- They went on diverging, which means as the axial pull on the secondary cable has increased the deformation in the primary point and the secondary point has went on yielding eccentrically.
- The displacement at the tip of the structure and the displacement at the mid height of the structure are related in the presence of lateral load at the top.
- Now we have to fix a pull required for ourselves as to bring down the deflection approximately.
- Let's restrict the displacement of mid storey to 0.36m and top storey to 0.275m and an axial pull to 150Kn.
- Generally there exist more deformation in the case of cantilever structure and in propped cantilever we will have more deformation at center.
- The reason for this displacement restriction is that because at the top storey we need to arrest more displacements and we cannot take any chances though.

## VI. EFFECTIVE HEIGHT FOR DAMPER INSTALLATION

Now we came to conclusion that the deflection is controlled by installing the cables at the top storey and the mid storey. Now we need to check either the installation height has any effect over the dampers efficiency. If it has we will check for the efficient height of damper installation, however since it has to be at a slab level, we will make sure to install it in the slab levels itself. This process is done on the following ways.

- Initially we have to keep the height of any one of the dampers height as a constant.
- Now the height of another damper is varied to determine the deflection change in the structure.
- The graph is plotted with the height and the deflection change in the system.
- The analysis is done by keeping the secondary damper in the position and moving the primary damper down by a storey height per trials.
- The deflection has reduced in the top primary point for first trial from 0.360m to 0.184m and at a mid storey it has increased from 0.275m to 0.388m.
- In the third experiment we will bring down the damper by one storey again.
- We have observed that the primary deflection has increased from 0.184m to 0.082m and secondary has reduced from 0.388 to 0.403.
- Hence we can conclude that if the jacking point is reduced in height the secondary deflection will reduce due to the reason that the damper will go near the secondary point, but the primary deflection will increase due to the increase in distance from the primary point.
- Since the damper is installed by observing the deflected shapes as mentioned in section 5.1.8 we will not have to worry about the effectiveness by varying the height of the damper installation.

Hence concluding the above section it is time to discuss in brief the effect of the dampers in the column behavior.

## VII. SOFTWARE RESULTS

Same as that of the conventional system we will be comparing the results of the column with an axial force, Shear force, Bending moment and deflection.

### I. AXIAL FORCE

The behavior of the structure has completely changed and the structure no longer represents the conventional system. Some important observations made will be tabulated below. All these points will explain how the graph differs from the conventional system.

- If we take a look on a graphs the axial load on a columns have been reduced to a greater extent that of fig 4.11
- Column 1 had a grater axial force in the previous system than that of column6 from the beginning till top, but in this system we can make out that in the beginning the column axial force is same but as the height increases the axial force line6 exceeds axial force line 1.
- The column 1 and 6 are peripheral columns and when the wind load acts on a structure the column 1 is a opposite faced column and the building deforms towards the outer face and it is obvious to expect greater axial force on outer columns.
- But in case of parallel damping system we will arrest the deflection by damper and intern the axial force hence we need to assume that the damper installation on corner column I.e. the cable pass right over column no 6 making it to take more axial load than that of column 1.

The column 6 axial line almost resembles a straight line, but other lines are of curve in shape for conventional system but in parallel damping system we can expect column 6 and 2 to follow a linear relation.

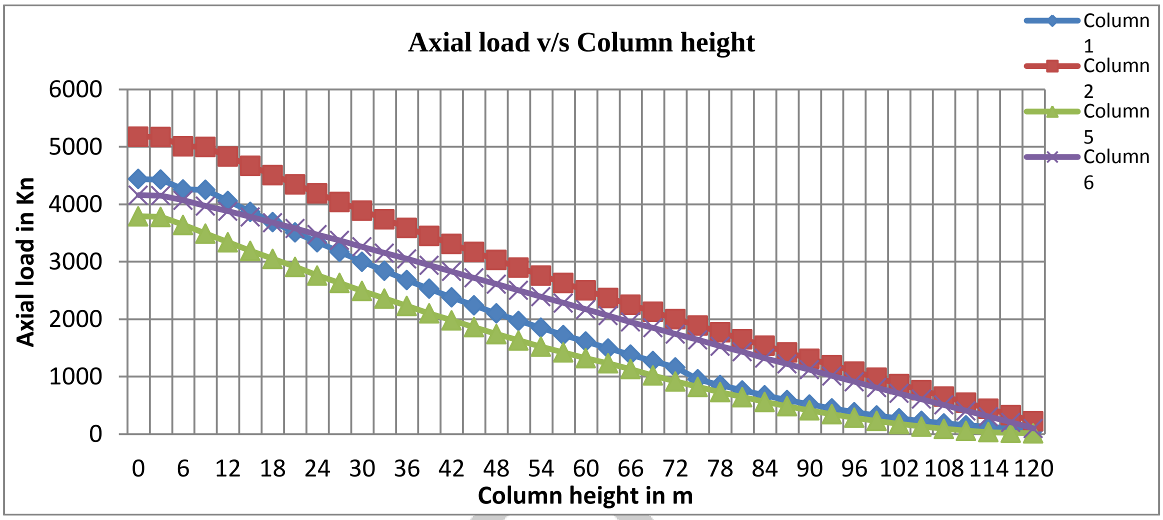


**Fig. 4 Graph showing the relation of both jacking system**

## II. BENDING MOMENT

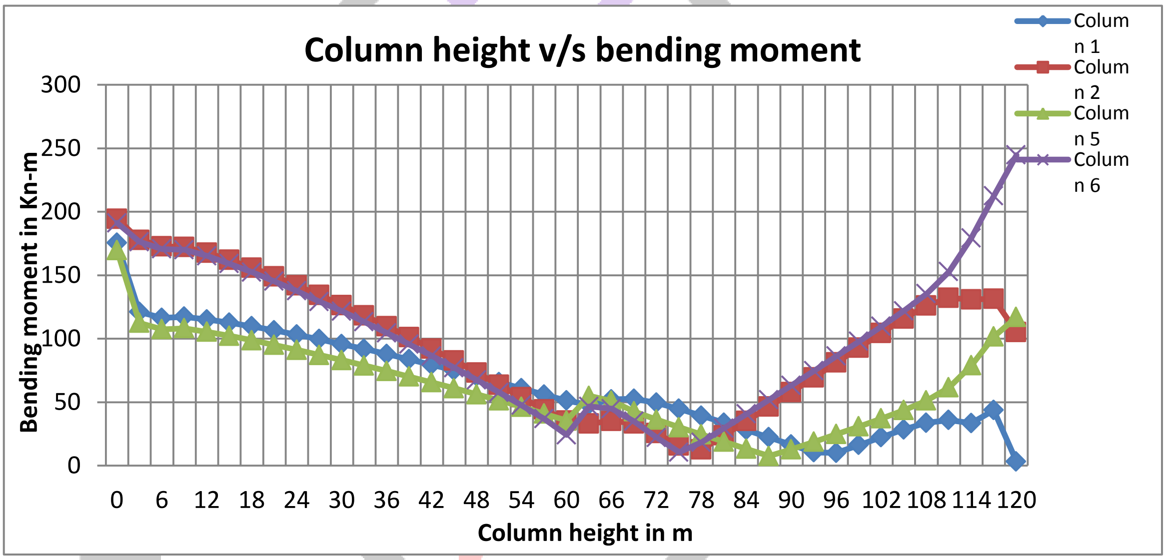


**Fig. 5 Graph showing the relation of bending moment**

- The bending moment of the structure has reduced which means the overturning moment is less now.
- In the graph we can see the variation of bending moment, none of the column follows any definite patterns.
- At the center of the curve we can see the small rise of the moment curve; this is due to the face that when a damper is installed the opposite face of the structural system at mod height will have a tension.
- In a figure 4.12 we can observe that the moment curve of the column 1 and 2 is almost similar, and 5,6 are also similar, but if we take a look at a moment diagram the column 6 and column 2 has similarities.
- The column no 6 shows a clear and a critical moment of the structure since the cables are so connected to the column.
- The results obtained in software prove to be only symmetric along one axis hence we need to consider the analysis of other 4 columns also.

## III. DISPLACEMENT

The displacement of the structure is one of the important criteria to be taken care of because it is the criteria which make the structure unstable and affect the comfort of the occupants.

- The deflection of the structure has reduced from 3.2meters to 0.3m at top of the structure.
- And all it takes is a simple cable jacking system and a pulley.
- We can see a second mode shape of the structure as same as that of the above deflection curve and if we make the damping system in such a way that the second mode shapes of the structure will be its first mode shapes.
- The difference of the deflection curves has a difference in the above graph which can be observed, but in conventional system it is not.

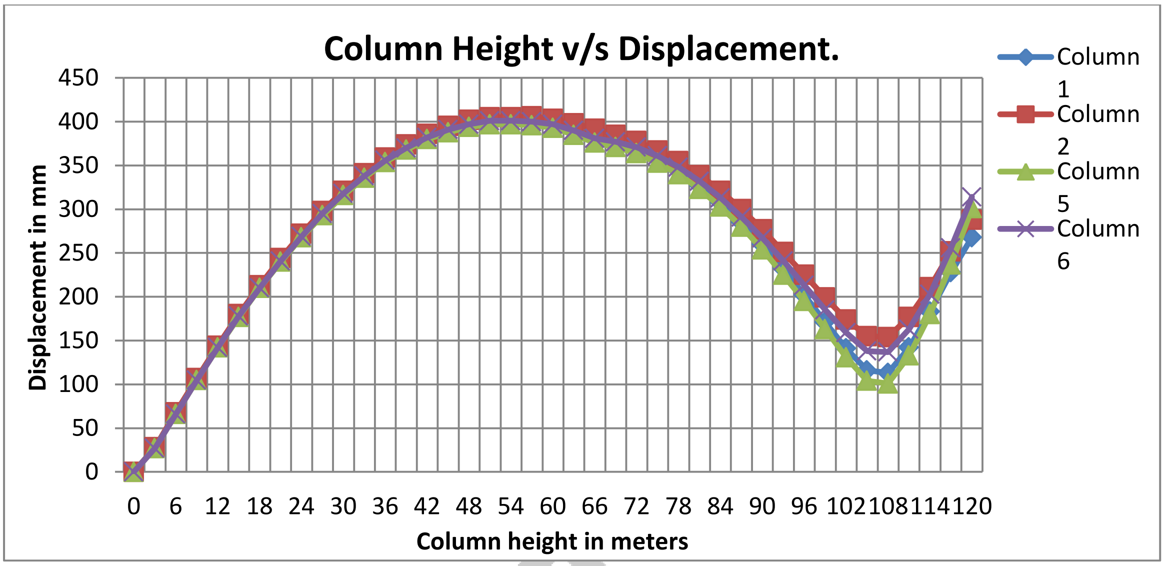


**Fig. 6 Graph showing the relation of deflection**

### III. ACKNOWLEDGMENT

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