Analysis of multistoried R.C.C Frame by using composite (steel) bracing for earthquake and gravity loading

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***Abstract*: Due to Industrial revolution, availability of jobs and facilities, population from rural area is migrating towards cities. Because of this metro cities are very thickly populated. Availability of land goes on decreasing and land cost also increases. To overcome this problem the use of multistoried buildings is must. But such provisions increases self weight and live load along with earthquake forces. With increase in height stress, strain, deformation and displacement in the structure increase which ultimately increases the cost of construction due to increased cross-sections of the elements. Multi-storey buildings are designed to carry gravity loads as well as earthquake loads and their combinations. I.S. codes providing these loading combinations for which structure need to be analyze and design. The analysis is aimed at finding the internal forces in component of structures and to find displacements developed in the structure leading to the development of strains. Structure must be safe from both strength viewpoint and serviceability as well. While vertical forces are most significant, the primary problem for most structures is force in the horizontal or lateral direction, which tends to subject buildings to large horizontal distortion. Therefore, most buildings are designed with lateral-force-resisting systems to resist the effects of earthquake forces. Bare frames are found to be more flexible and have large section requirement to with stand forces induced. The same can be minimizing by making structure more rigid. In this volume, use of bracing to increase the stiffness of structure has been resorted to on the basis of previous work done on.The cross-type, diagonal- type concrete bracing separately. The cross- type, diagonal- type of bracing system has been used. A number of structures with same height and width with and without braces have been analyzed. The responses of braced frames of different configurations have been compared with each other and the same also have been compared with unbraced frame. For all type of structures which are serving more economy for particular type, it was found that the lateral displacements are well within the acceptable limit as per IS 1893:2002.**

***Keywords*: Analysis of G+12,G+14,G+18building ,study of various forces of building like axial force ,shear force bending moment, study of displacement of building by using cross and diagonal bracing , comparison of displacement for cross and diagonal bracing etc**

I) INTRODUCTION

Importance of Multistoried Building The tallness of a building is relative and cannot be defined in absolute terms either in relation to height or the number of stories. But, from a structural engineer's point of view the tall building or multi-storied building can be defined as one that, by virtue of its height, is affected by lateral forces due to wind or earthquake or both to an extent that they play an important role in the structural design. Tall structures have fascinated mankind from the beginning of civilization. The Egyptian Pyramids, one among the seven wonders of world, constructed in 2600 B.C. are among such ancient tall structures. Such structures were constructed for defense and to show pride of the population in their civilization.

The development of the high-rise building has followed the growth of the city closely. The process of urbanization that started with the age of industrialization is still in progress in developing countries like India. Industrialization causes migration of people to urban centers where job opportunities are significant. The land available for buildings to accommodate this migration is becoming scarce, resulting in rapid increase in the cost of land. Thus, developers have looked to the sky to make their profits. The result is multistoried buildings, as they provide a large floor area in a relatively small area of land in urban centers.

Analysis of Multi-story Building Subjected to Various Loads

The analysis is aimed at finding the internal forces in component of structures and to find displacements developed in the structure leading to development of strains. Structure must be safe from both strength view point and serviceability as well. Bare frames are found to be more flexible and have large section requirement to with stand forces induced. The same can be minimizing by making structure more rigid. In this volume use of bracing to increase the stiffness of structure. The cross type of bracing system has been used. A number of structures with different heights and widths with and without braces have been analyzed. The responses of braced frames of different types have been compared with each other and the same also have been compared with unbraced frame

Frames were considered as fully braced frames in preceding discussion, however, partially braced frames also have been analyzed and optimum locations of braces have been found. Behaviours of fully braced frames with the partially braced frames also were studied. With this view all parameters in dimensionless form, to include geometry of frame, axial forces, shear forces; bending moments, displacements, location of bracing etc have been used

Loads on Buildings

There are different types of loads are acting on the building but basically there are two types of loads, which a structure must support.

1. **Gravity load:** These act vertically downward and can be further divided into 'Dead Load' and 'Live Load'. Dead load consists of the weight of the structure itself including the frame, walls, plaster, flooring, waterproofing, fixed furniture etc. Live load constitutes the transient loads such as the weight of people, movable furniture, furnishings, domestic equipment etc.

2. **Lateral loads:** These act horizontally on the building. The most common lateral loads are wind load and earthquake load. These are occasional loads and may act in any direction.

Type of bracing

A) Diagonal bracing

B) Cross bracing

C) Zip type of bracing

D) K type of bracing

E) V Type of bracing

II) METHOD OF EARTHQUAKE ANALYSIS

Earthquake analysis of building is required to know how the building is going to behave at the time of earthquake. This can be done either by dynamic or simple equivalent static analysis. Static analysis does not give us clear idea of how the structure is going to behave during earthquake but gives approximate forces and displacements. Dynamic analysis gives somewhat accurate results. This method requires large amount of computational work. Moreover, to carry out this analysis ground motion data is required.

Following are the method of analysis.

As per IS: 1893-2002, method

Equivalent static method

In this method, certain amount of constant lateral acceleration is assumed to be acting on the building. Hence, the determination of total lateral force on the structure is simply product of seismic weight of the respective building and the ratio of the selected lateral acceleration due to the gravity.

1) INTRODUCTION

The structural analysis is a mathematical algorithm process; from a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. To perform an accurate analysis it is important to determine the information regarding the structural loads, geometry, support conditions, and materials properties. Commercial computer software for structural analysis typically uses matrix finite-element analysis, which can be further classified into two main approaches: the displacement or stiffness method and the force or flexibility method. To perform an accurate analysis a structural engineer must know about structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared with criterion that indicates the conditions of failure. Advanced structural analysis software also examines stability.

There are three approaches to the analysis:

- The mechanics of materials approach (also known as strength of materials),
- The elasticity theory approach (which is actually a special case of the more general field of continuum mechanics),
- The finite element approach.

The first two make use of analytical formulations which apply mostly to simple linear elastic models, lead to closed-form solutions, and can often be solved by hand. The finite element approach is actually a numerical method for solving differential equations generated by theories of mechanics such as elasticity theory and strength of materials. However, the finite-element analysis packages, give more accurate results compared with approximate methods, but they involve significant computational efforts. Hence are preferred for complex structures.

EQUIVALENT STATIC ANALYSIS FOR EVALUATION OF LATERAL LOADS AS PER IS-1893 (PART-I): 2002

For the purpose of determining seismic force, the country is classified into four seismic zones, which are presented in Figure 1, of I.S. 1893 (Part-I): 2002 [10].

The total design lateral force (design seismic base shear) along any principal direction shall be calculated by using following expression

$$V_B = A_h \cdot W \qquad \text{(Eq. 3.3 a)}$$

Where,

V_B = design seismic base shear

A_h = design horizontal seismic coefficient for structure as explained in clause no. 2.3.4.1

W =seismic weight of building as explained in clause no. 2.3.4.2

Design Horizontal Seismic Coefficient (A_h)

Steps for computation of Design horizontal seismic coefficient (A_h) are as follows.

1. Calculation of approximate natural period of vibration (T_a)

The approximate fundamental natural period of vibration in seconds for moment resisting frame buildings without brick infill panels can be estimated by using following expression.

For RC frame buildings

$$T_a = 0.075\, h^{0.75} \qquad \text{(Eq. 3.3 b)}$$

For Steel frame buildings

$$T_a = 0.085\, h^{0.75} \qquad \text{(Eq. 3.3 c)}$$

And the approximate fundamental natural period of vibration in seconds for other types of buildings including moment resisting building with infill can be estimated as

For other buildings

$$T_a = \frac{0.9\,h}{\sqrt{d}} \qquad \text{(Eq. 3.3 d)}$$

Where, h = Height of building in meters. This excludes the basement storey's where basement walls are connected with ground floor deck or fitted with building columns; however, it includes the basement when they are not connected.

d = base dimension of the building at the plinth level in meters along considered direction of the lateral force.

Determination of zone factor (Z)

It is a factor used to obtain the design acceleration spectrum depending upon perceived seismic hazard in the zone in which structure is located. The basic zone factors included in I.S. code are reasonable estimate of peak ground acceleration. Zone factor given in Table 2 of I.S. 1893: 2002[10] shows the values of zone factor depending upon the seismic intensity.

Determination of importance factor (I_m)

Seismic design philosophy assumes that a structure may undergo some damage during severe shaking. However critical and important facilities must respond better during an earthquake than an ordinary structure. Importance factor is meant to account for this by increasing the design force level for critical and important structures. Importance factor depends upon functional use of structures; characterized by hazardous consequences of its failure, post earthquake functional needs, historical value or economic importance. The importance factor is given in Table no.6 of I.S. 1893 (part I): 2002[10] depending on the importance of structure.

Determination of response reduction factor (R)

The structure is allowed to be damaged in case of severe shaking. Hence the structure is designed for seismic force much less than what is expected under ground shaking if structure were to remain linearly elastic.

The Response reduction factor depends upon the perceived seismic damage performance of the structure characterized by ductile and brittle deformations. However, the ratio (I/R) shall not be greater than 1.0. The values of R for buildings are given in Table 7 of I.S. 1893 (Part I): 2002[10] depending on the type of structure.

Determination of average response acceleration coefficient (S_a/g)

Average response acceleration for Rock and soil sites as given in Figure 2 of I.S. 1893 (Part I): 2002[10] based on appropriate natural periods and damping of structure. These curves represent free field ground motion. Here, Figure 2 shows proposed 5% spectra for different soil sites and Table 3 of the I.S. gives multiplying factors for obtaining spectral values for various other damping.

Calculation of design horizontal seismic coefficient (A_h)

The design horizontal seismic coefficient for a structure shall be determined by the following expression.

$$A_h = \frac{Z}{2} \cdot \frac{I_m}{R} \cdot \frac{S_a}{g}$$

Percentage of imposed load is 25% and above 3.0 kN/m^2 it is 50%.

Distribution of Seismic Forces

Lateral load distribution with building height depends on the natural periods, mode shapes of the building, and shape of design spectrum. In low and medium rise buildings, fundamental period dominates the response and fundamental mode shape is close to a straight line (with regular distribution of mass and stiffness). For tall buildings, contribution of higher modes can be significant even though the first mode may still contribute the maximum response. The base shear shall be distributed along the height of building by using following expression.

$$Q_i = V_B \cdot \frac{W_i\, h_i^2}{\sum_{j=1}^{n} W_i\, h_i^2} \qquad \text{(Eq. 3.3 f)}$$

Where,

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base, and

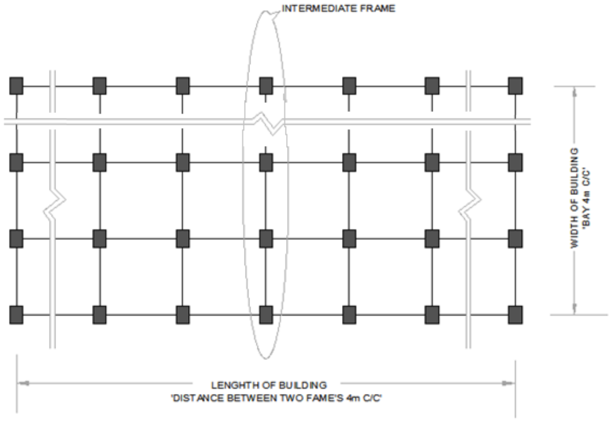
n = Number of storey in the building, the number of levels at which the masses are Located

II) PROBLEM DEFINATION

Plane frame is one in which all the members and applied forces lie in same plane. The joints between members are generally rigid. The stress resultants are axial force, bending moment and corresponding shear force. As plane frames were used for the project, so linear elastic plane frame analysis is performed for the different models of the building using STAAD III analysis [37] package. The frame members are modeled with rigid end zones. Equivalent static analysis is performed on the models of the building considered in this study. These are briefly described in 3.1 above.

Structural Response

If the base of the structure is suddenly moved, as in a seismic event, the upper part of the structure will not respond instantaneously, but will lag because of the inertial resistance and flexibility of the structure. The resulting stresses and distortions in the building are the same as if the base of the structure were to remain stationary while time-varying inertia forces are applied to the upper part of the building. Generally, the inertia forces generated by the horizontal components of ground motion require greater consideration for seismic design since adequate resistance to vertical seismic loads is usually provided by the member capacities required for gravity load design. These forces are called inertia forces i.e., F = ma. In the equivalent static analysis procedure, the inertia forces are represented by equivalent static forces.



Plan of the building

The model data of building

Structure	OMRF
No. of stories	G + 12, G + 16, G + 18,
Storey height	3.00 m
Type of building use	Residential
Foundation type	isolated footing
Seismic zone	IV
Material Properties	
Young's modulus of M20 concrete, E	22.36 x 10 6 kN/m2
Grade of concrete	M20
Grade of steel	Fe 415
Density of reinforced concrete	25 kN/m3
Modulus of elasticity of brick masonry	3.50 x 10 6 kN/m2
Density of brick masonry	19.20 kN/m3
Member Properties	
Thickness of slab	0.125 m.
Beam size	0.23 x 0.30 m.
Column size	0.23 x 0.60 m.
Thickness of wall	0.23 m.

Dead Load Intensities

Floor finishes	1.0 kN/m2
Live Load Intensities	
Roof and Floor	3.0 kN/m 2

Earthquake LL on slab as per Cl. 7.3.1 and 7.3.2 of IS 1893(part 1)2002

Floor 0.25 x 3.0 =	0.75kN/m 2
Seismic Zone	IV
Zone factor, Z	0.24
Importance factor, I	1.00
Response reduction factor, R	3.00

The load cases considered in the seismic analysis are as per IS 1893 – 2002

Table No. 3.1 Models used for analysis.

Model	**Frame Type**	**Structure variation**	**Bay variation**	**Beam depth variation**
I	Bare Frame	G+12 , G+14 G+18	3 bay	230x600mm
II	''cross braced, Frame	G+12 , G+14 G+18	3 bay	230x600mm
III	Diagonal braced frame	G+12 , G+14 G+18	3 bay	230x600mm

LOAD COMBINATION

In the limit state design of reinforced concrete structures, following load combinations shall be accounted as per I.S. 1893 (Part I) – 2002[10]. Where the terms D.L., I.L., and E.L. stand for the response quantities due to dead load, imposed load and designated earthquake load respectively.

Combinations for limit state of collapse	**Combinations for limit state of serviceability**
1.5 (DL + LL) 1.2 (DL + LL ± EQ) 1.5 (DL ± EQ) 0.9 DL ± 1.5 EQ	1) (DL+0.8LL+0.8EQ) 2) (DL + LL) 3) (DL + EQ)

III) RESULT AND DICUSSION

BARE FRAME:

A bare frame is a frame without bracing the response of bare frame of different type have been compared with braced frame frames with various H/W ratios and member section and various type of structure like (G+12) (G+14) (G+18)were tried as fallow

a) Bare frame with variation in floors, like (G+12) (G+14) (G+18) and find out the displacement ,axial force ,bending moment ,shear force for earthquake loading

b) Braced frame (diagonal bracing) with variation in floors like (G+12) (G+14) (G+18) and find out the displacement ,axial force ,bending moment ,shear force for earthquake loading compare with bare frame

c) Braced frame (cross bracing) with variation in floors, like (G+12) (G+14) (G+18) and find out the displacement ,axial force ,bending moment ,shear force for earthquake loading compare With bare frame

d) Study the various frame s to find out optimum location of bracing and compare the results of bare frame , cross bracing ,diagonal bracing

Following six cases we will studied
Braced Frame (case1)

A braced frame is defined as "a frame in which all resistance to lateral force, sway and frame instability is provided by a specially designed resisting system". The resistance of tall buildings to lateral loads as well as to earthquakes is the main determinant in the formulation of structural systems that evolve by the using bracings.

The structure level strengthening includes the options like adding of shear wall, infill walls or full level and bay bracing that is fully braced frames. The member level strengthening approach is to upgrade the strength of the member, which is seismically deficient. This approach is more cost effective as compared to structure level strengthening which is followed in the report. Frames with lateral resisting elements here particularly for brace system, provide lateral stability to the overall framework. Bracing has been used to stabilize laterally the majority of tallest building structure as well as one of the major retrofit measures which improve the seismic performance of the frame by increasing its lateral stiffness and capacity. The required member sizes for the beams and columns in such a frame are often governed by gravity loads. It is therefore possible in the initial stage of design to treat the frame and the bracing as two separate load carrying systems. It has following advantages.

- It assures that the system has the required lateral resistance needed to ensure good seismic performance.

It is able to produce a laterally very stiff structure using minimum additional material which makes it an economical structural form for any height of buildings.

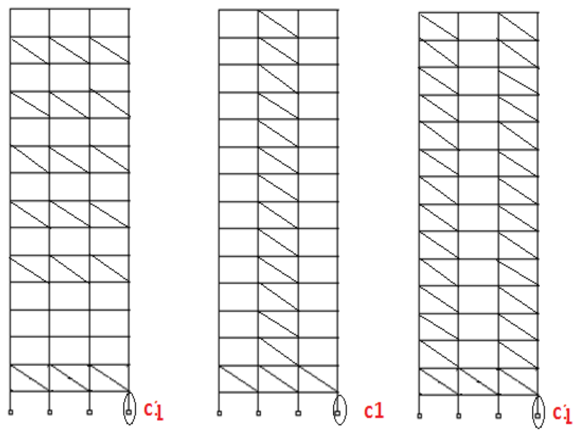
For braced frames with 600 mm beam depth is considered. As regards this project following frame was tried for Cross Braces and Diagonal Braces:

- Width of structure - Number of bays was tried as 3
- Height of structure - The structure considered was - G+12,G +14,G+18

Fully braced frames are more rigid. But from economy point of view arbitrarily braced ones have least forces induced in the structure and at the same time produce maximum displacement within prescribed limits. The efficiency of a structure to resist lateral forces depends on the location of the bracing system employed. Hence it was decided to try bay wise and level wise bracing positions and optimum combination of the same i.e. partially braced structure what is called "braced frames with outriggers" was studied, and consequently the cell wise bracing patterns were analyzed and the response of such frames was compared with bare frames.

Outrigger i.e. partially Braced Frame (case2)

A braced frame with outrigger is shown in Figure the structure comprises of a frame with central bay braced clubbed with a system of two equal length outriggers. Such outriggers show more stiffening effect for overall structure. The induced compression and tension forces in the columns create a large resisting moment to applied horizontal loading. The frame with combination i.e. outer bay braced throughout for G+12, G+ 14, G+ 18 storied structures with 600 mm beam depth structure was used. For other cases economy is tabulated below. The pattern of bracing with common bays and level variation which gives an optimum result is shown



Bay wise and Level wise Braced Frame (case3)

The main function of bracing system is to resist lateral forces. Building frame systems can be separated from optimally braced frame structures as shown in**,** there is clear separation of functions in which the gravity loads are resisted by second assembly and horizontal loads are resisted by the braced assembly. The efficiency of a building to resist lateral forces depends on the bracing pattern employed. However, the type of bracing pattern used and its location are usually dictated by architectural, functional and structural considerations. Hence it is decided to use two kinds of stiffening effects

a) Bay wise bracing

b) Level wise bracing

Assuming that, the interacting forces between the truss frame and moment frame as shown in below enhance the combined moment-truss frame stiffness to a level larger than the summation of individual moment frame and truss stiffness. The same is applicable to level wise bracing, since for a column in a braced frame it is assumed that columns are restricted at their ends from horizontal displacements and therefore are only subjected to end moments and axial loads as transferred from the frame. It is worth to assume that the frame, possibly by means of a bracing system, satisfies global stability check hence hoping to get more economy as compared to bare frame.

a) Bay wise Braced Frame

For this part following frame was tried. A typical frame of this type is shown in Figure 4.3(a). In this part trials were carried out to decide optimum location of braces considering specific bays as fully braced for cross Braces and diagonal Braces.

- Width of structure - Number of bays tried was as 3
- Height of structure - The structure considered was a G+12, G+14, G+18 storied structure.

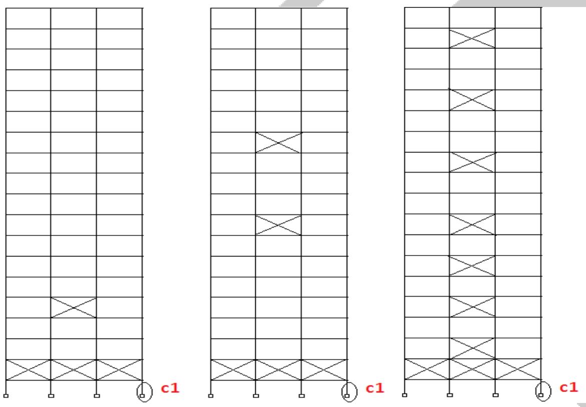
b) Level wise Braced Frame

For this part following frame was tried. A typical frame of this type is shown in this part trials were carried out to decide optimum location of braces considering specific levels as fully braced for cross Braces and diagonal Braces.

- The structure considered was a 3 bay
- Height of structure - The structure considered was G+12,G+14,G+18 storied structure

Partially Braced Frame for the Combination of Specific Bays and Levels (case4)

In a structure placing the braces bay wise and level wise share the algorithm which allows for combining them evolving a "braced frame with outrigger" i.e. a partially braced frame with regard to the project, results the new logic for combination of above two scenarios. A typical frame of this type is shown in partially braced frames having combination of above two types i.e. bay wise and level wise braced frames shall be analyzed to study and compare the response of such frames. In this dissertation work on 3 Bay G+12,G+14 G+ 18 storied structures with 600 mm beam depth structure was used



Optimum bay wise and level wise location for bracings (case5)

Fully braced frames described previously, when analyzed, exhibit the values of forces and displacements which are changing with the variation of number of parameters. However it was noticed that the frames underwent a very small lateral displacement than was permissible when they were fully braced. It is but obvious that, when such frames were partially braced i.e. braced all along the height in a particular or a combination of number of bays which is less than total numbers of bays for the frame, will produce a larger displacement. Similar thing will happen when braced all along the level or a combination of number of levels concerned, within allowable limit. Hence it was decided to find out such possibility of developing a particular pattern for partially braced frames, which would produce smaller forces for worst load combinations. It says that the bracing pattern tried should be always satisfied strength as well as serviceability criterion.

Partially braced-cell wise Braced Frames (case6)

After finding optimum bay wise and level wise braced frames it was further extended to partially braced and cell wise braced frames hoping to get more economy. It allows us to move towards next logic to develop which leads to the economy by taking number of trials. These analyses were further tried in the 3 bay G+12, G+ 14, G+ 18 storied structures with 600 mm beam depth structure was used.

PARAMETRIC STUDY

A structural system is a set of quantities, some of which are viewed as variables during the design process. Those quantities defining a structural system that are fixed during the design are pre-assigned parameters. Those quantities that are not pre-assigned are the design variables. The pre-assigned parameters together with the design variables completely describe a design. All above frames were analyzed to study their response as revealed by the variation in the following parameters chosen.

Internal forces

Forces induced viz. axial force, shear force and bending moment in a particular column segment (C1) as shown in were considered for this purpose. The segment so chosen is the worst loaded segment in case of a bare frame. In order to facilitate the direct comparison between unbraced and fully or partially braced frames the latter have been analyzed for the same geometry of mutually perpendicular/orthogonal members for the same loading combination for which the bare frame yielded the maximum design force in the members so selected. However once the design forces were evaluated for fully or partially braced structures all individual segments were redesigned and the minimum required cross sections and steel percentage was calculated. Ultimately cost comparison was carried out.

- Lateral Displacement
- Shear force
- Bending moment
- Axial force

Lateral Displacement

The earthquake ground motion may generate the very large inertia force which causes the large displacement. Being basic parameter in tall structure it is necessary to keep the displacement within the permissible limit to study the variation in lateral displacement by providing the cross and diagonal bracing

The lateral displacement of un braced building for the cases of dead load and live load combination for seismic analysis in x direction. The lateral displacement is observed in the three type of buildings to check the effect of height on displacement, in building like (G+12),(G+14),(G+18) at three level i.e. at Top, Middle, Bottom level, etc

Provided that for any structure with T ≤ 0.1s, the value of A_h will not be taken less than Z/2 whatever the value of I_m /R.

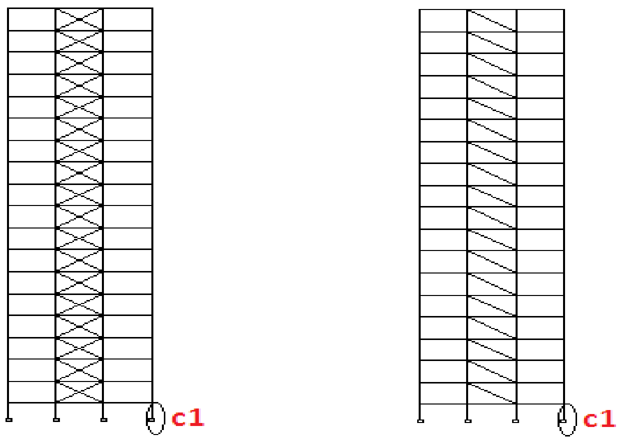
Seismic Weight of Building

Seismic weight of each floor is its full dead load plus appropriate amount of imposed load. While computing seismic weight of each floor, the weight of columns and walls shall be equally distributed to the floors above and below the storey. Any weight supported in between storey shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

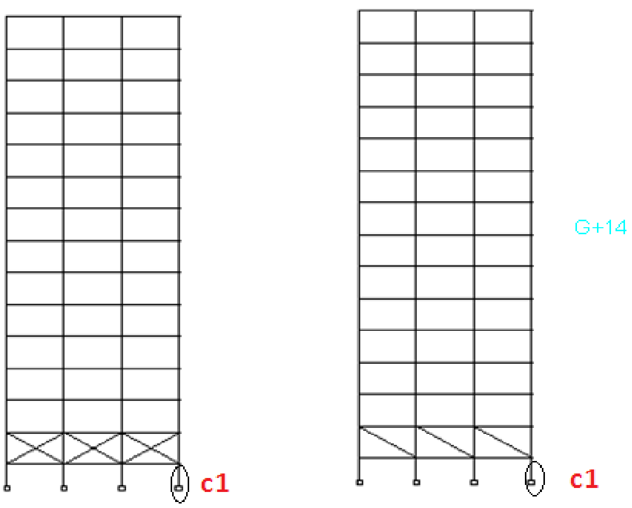
The percentage of Imposed load to be considered in seismic weight calculations is given in Table 8 of I.S. 1893 (2002) [10]. As uniformly distributed imposed load up to 3.0 kN/m^2

BAYWISE OPTIMIZATION OF BRACINGS

As discussed earlier for bay wise optimization, number of combinations were tried and the parameters such as bending moment, shear force and axial force in the same member located as worst loaded member in bare frame was studied as shown in Alternative bracing patterns were tried for 3 bay G+12, G+ 14, G+ 18 storied structures with 600 mm beam depth structure was used.

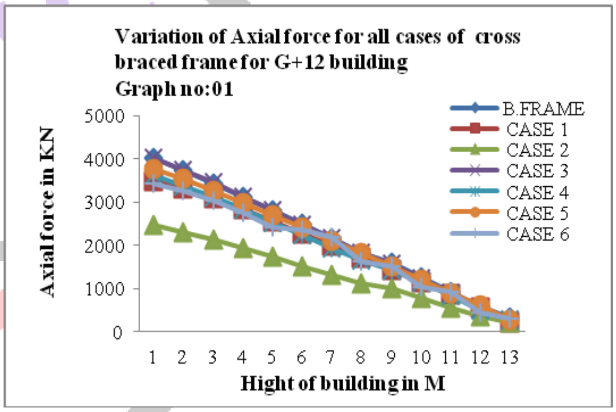


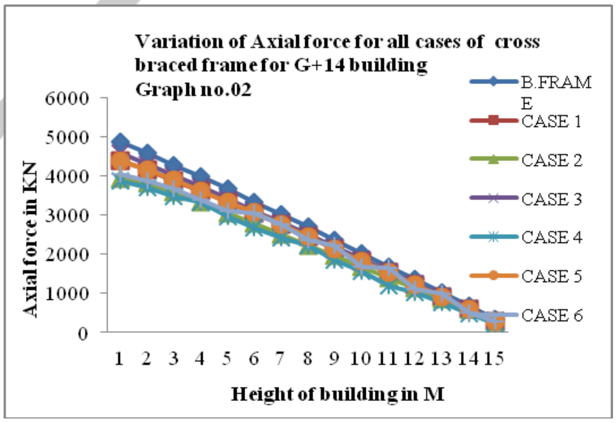
Frames used for Bay wise optimization showing specific member i.e. 'C1' used for analysis.

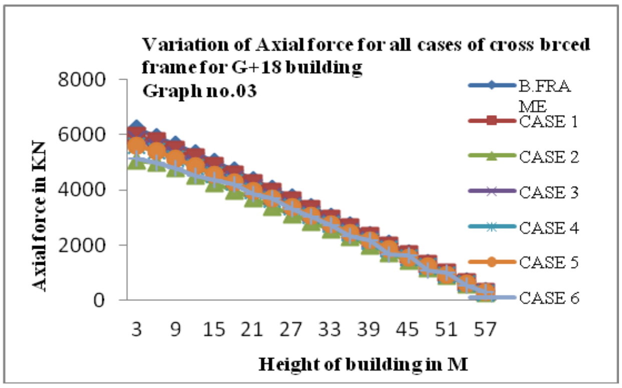


Variation Of Axial Force In Member 'C1' With Variation In Bracing Position:

Please refer table TL-1,2,3 and graph GL-1,2,3, which shows the values of ratio of axial force (Ra) along with natural logarithm of reference number 'N' as dimensionless parameter and the graph GL-1,2,3 shows the variation of dimensionless parameter Ra for all cases of levels braced for 3 bay G+12, G+ 14, G+ 18 storied structures with 600 mm beam depth structure was used. Which is denoted as C1 as shown in? The value of axial force in member C1 of bare frame is chosen as reference value appearing in the denominator of ratio Ra. Ratio Ra for fully braced frame is found .Due to the provision of bracing in the structure; the values of axial forces are well below the limit of fully braced. Structure. The graph show the increment in the values of ratios of Ra, but when looked for separate cases, such as for one level braced the graph linearly decreases as bracing location move to upper levels. At the same time for other cases of braced frames, the graph suddenly increases and decreases within a short range of abscissa leaning to the decreasing values of the ratios of axial force, indicating that for level bracing, as bracing level position move to the upper levels the value of Ra reduces, but not securing the optimum economy.

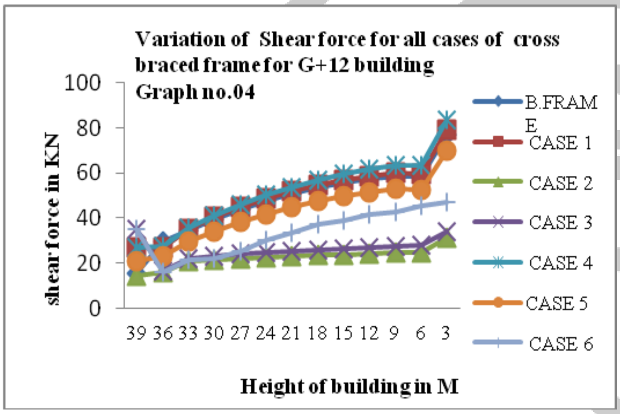


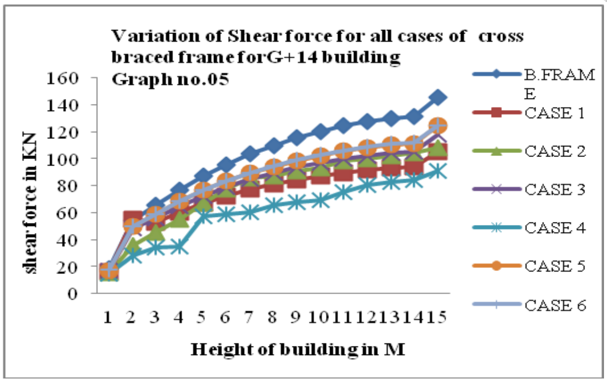


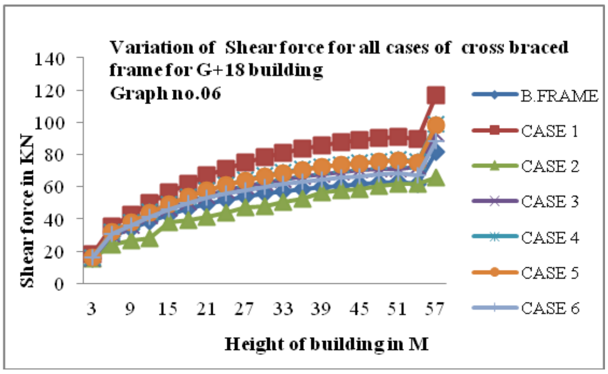


Variation Of Shear Force In Member 'C1' With Variation In Bracing Position:

Please refer table TB-4, 5, 6 and graph GB-4, 5, 6 which shows the values of ratio of shear force along with Natural logarithm of reference number 'N' as dimensionless parameter for 3 bay (G+12) (G+14) (G+18) structure and the graph GB-4, 5, 6 shows the variation for all cases of bays braced for member . The value of shear force in member C1 of bare frame is chosen as reference value appearing in the denominator of ratio Rs. Ratio Rs for fully braced frame. Due to the provision of bracing in the structure, the shear forces increase for some cases as seen in the graph which cross that of fully braced frame but for other cases they decrease

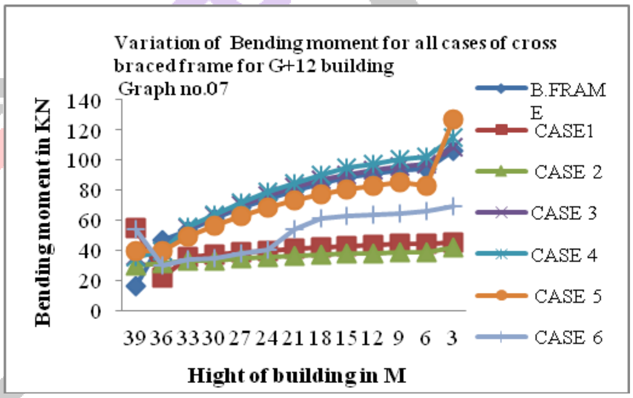


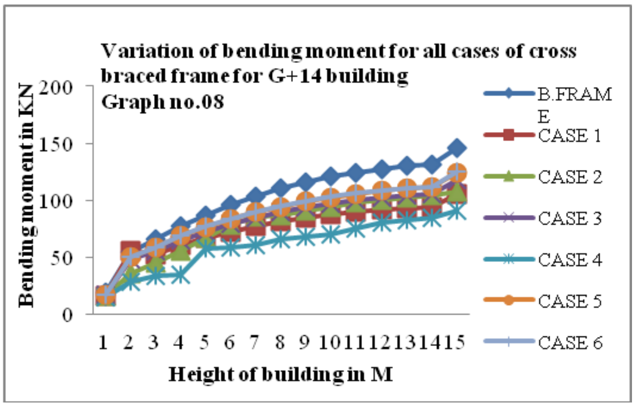


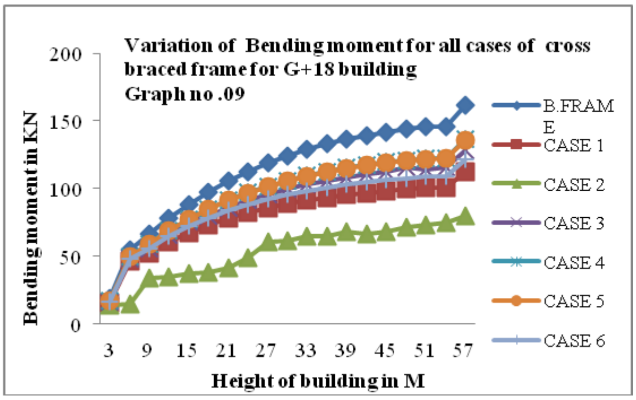


Variation Of Bending Moment In Member 'C1' With Variation In Bracing Position:

Please refer table TB-7, 8, 9 and graph GB-7, 8 ,9which shows the values of ratio of bending moment (Rm) along with natural logarithm of reference number 'N' as dimensionless parameter for 3 bay (G+12) (G+14) (G+18) structure and the graph GB-7,8,9 shows the variation of Rm for all cases of bays braced for member. The value of bending moment in member C1 of bare frame is chosen as reference value appearing in the denominator of ratio Rm. Ratio Rm for fully braced frame. The graph reveals that the bending moment in bare frame is more than fully braced frames which appears the upper limit which is an upper limit for other graphs. Due to the provision of bracings in the structure, the bending moments decrease for all cases of bays braced but as we move to the increased number of bays braced at a time the value further reduces.







Interpretation:
Graphs GB-1,2,3 GB-4,5,6 and GB-7,8,9 show the variation of axial force, shear force and bending moment. The bracing pattern changes. Tables TB-1,2,3 TB-4,5,6 and TB-7,8,9 list the values of dimensionless parameter Ra, Rs and Rm for various bracing patterns. Overall, these graphs GB-1, GB-2 and GB-3 show the sharp undulations between minimum and maximum value of the parameter. In the graphs just for the sake of convenience as well as with a view to distinguish the same from the rest of data the dimensionless parameters obtained in case of bare frame and a fully braced one the same value has been considered as the constant ordinate for each abscissa viz. ln(N). Obviously every graph shows two lines parallel to the x-axis. If these are considered as the upper and the lower limits as may be appropriate to a particular dimensionless parameter one finds that many a times in case of partially braced frames the dimensionless parameters observed exceeds the upper limits and is less than the lower limit so considered. However a number of cases may be found common to all of them as shown in these are most optimum cases as far as force levels are concerned. Shows the variation of Rm for all cases of bays braced for member number 06 which is denoted as C1 as shown in Figure. The value of bending moment in member C1 of bare frame is chosen as reference value appearing in the denominator of ratio Rm. Ratio Rm for fully braced frame is found. The graph reveals that the bending moment in bare frame is more than fully braced frames which appears the upper limit which is an upper limit for other graphs. Due to the provision of bracings in the structure, the bending moments decrease for all cases of bays braced but as we move to the increased number of bays braced at a time the value further reduces.

VARIATION OF DISPLACEMENT IN STRUCTURE
Both gravity loads as well as earthquake forces do produce sway in structures. Hence it is important to study the variation of lateral displacement in the analyzed structures. Obviously, it depends on the height of structure, number of bays, variation of column cross sections, stiffness of beam, type of frame whether braced or unbraced, position of bracing etc. As per I.S. 1893:2002[10] maximum permissible relative lateral drift in the structure is 0.004H, where H is height of the structure from base. Hence to insure the serviceability criterion, considering the lowest point as base of structure and highest point as top of the structure maximum relative drift is found and simultaneously compared with the permissible one as well as with other analyzed structures such as fully braced, partially braced and cell wise braced structures.

To compare the variation of lateral displacement between bare frame, fully braced frame and optimally bay wise and level wise braced frame a leftmost column of entire structure is considered. The graph is plotted for the optimum sizes of bare frames, only in quest of the view over the variation concerning the lateral displacement due to the provision of bracing. The extent of lateral displacement is considered at the top of each column of respective stories along the whole structure. The same concept is adopted for the comparisons of bare frame, fully braced frame, optimally partially braced frame – either partially bay wise or level wise braced, and cell wise braced frame particularly for 3 bay G+12,G+14,G+18 structure. By means of these we want to study the actual performance of the structure under the given different configurations of bracing. Such as we studied the structures braced - particular bay wise and level wise throughout, outrigger and cell wise combinations. Among all of these structures which will give displacement within prescribed limit along with economy are accepted because such structures have maximum relative drift as compared to fully braced frame but within permissible/allowable one and at the same time yields saving by reducing the forces. The entire graph shows the linear variation of displacement and it is easier to compare the different bracing pattern under considered loading. On abscissa height from base and on normal the displacement is plotted. As discussed earlier that the fully braced structure is very stiff and in the graph also it depicts that always fully braced structure is giving less displacement as compared to any other bracing pattern employed and the bare frame is one in which the maximum displacement is expected. The displacement properties are studied and compared as shown in graph below.

Comparison of variation of lateral displacement along height of structure
Table TD-22, 23, 24 and Graph GD-22, 23, 24 shows, the variation of lateral displacement along the height of structure for 600 mm beam depth considered for 3 bay G+12, G+14, and G+ 18. Structure – bare frame, fully braced frame and optimally bay wise and level wise braced frame.
The largest permissible drift as per IS-1893:2002[10] is 0.004H which is 153.76 mm ,179.2mm and 230.4mm for G+12,G+14,G+18 structure irrespective to bay. It is seen from the table that the variation of lateral displacement is almost linear. For bare frames the lateral drift is well within the permissible one, but it is increasing as moving towards the top most point of the structure. Also the lateral displacements for fully braced frames are getting substantially reduced as compared with bare frame, but these are uneconomical structures from saving point of view.

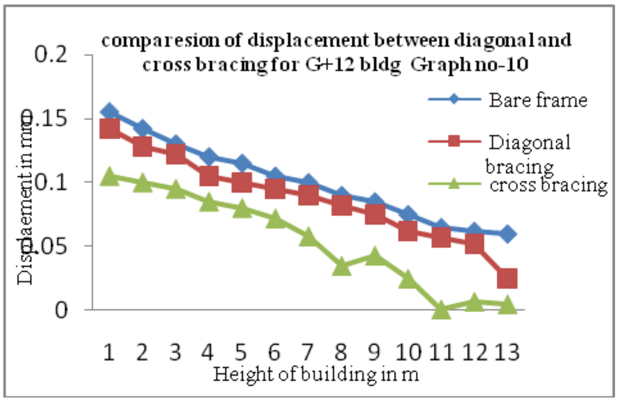


TABLE NO:-Comparison of displacement for cross and diagonal braced frame for G+12 building
Comparison in bare and cross bracing here

Case 1-Diagonal bracing
Case 2 Cross bracing

LEVEL	HEIGHT	B.FRAME	CASE 1	CASE 2
324	39	0.625	0.325	0.255
300	36	0.525	0.31	0.225
276	33	0.495	0.295	0.192
252	30	0.435	0.265	0.155
228	27	0.425	0.255	0.135
36	24	0.378	0.175	0.095
60	21	0.365	0.155	0.085
84	18	0.351	0.125	0.035
204	15	0.295	0.095	0.043
108	12	0.262	0.085	0.025
180	9	0.211	0.065	0.001
132	6	0.175	0.055	0.007
156	3	0.129	0.025	0.005

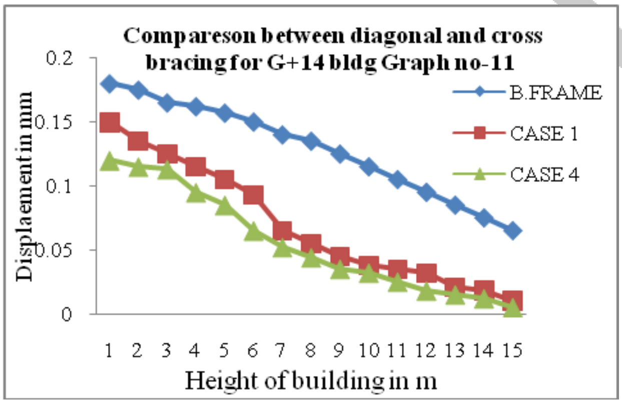


TABLE NO:-Variation of a displacement for a diagonal and cross braced for G+14 building

LEVEL	HEIGHT	B.FRAME	CASE 1	CASE 2
50	45	0.755	0.355	0.215
112	42	0.585	0.245	0.135
174	39	0.555	0.242	0.113
236	36	0.525	0.185	0.095
298	33	0.485	0.145	0.085
360	30	0.438	0.093	0.065
422	27	0.393	0.052	0.052
484	24	0.346	0.048	0.044
546	21	0.298	0.039	0.043
608	18	0.255	0.038	0.047
670	15	0.202	0.035	0.035
732	12	0.155	0.032	0.049
794	9	0.109	0.021	0.046
856	6	0.066	0.018	0.031
918	3	0.026	0.005	0.042

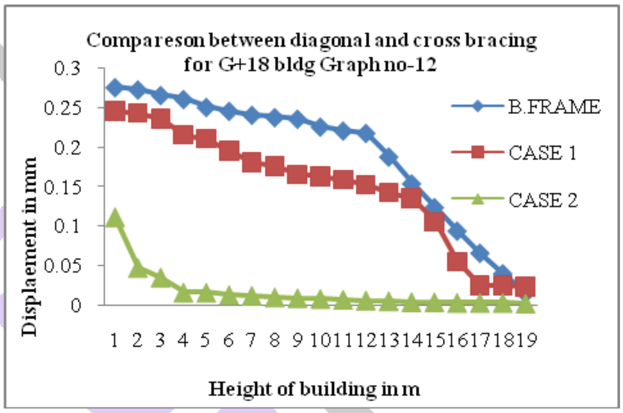


TABLE NO:- Variation of displacement for diagonal and cross braced frame for G+18 building

LEVEL	HEIGHT	B.FRAME	CASE 1	CASE 2
468	57	0.527	0.371	0.211
444	54	0.506	0.367	0.046
396	51	0.485	0.366	0.034
372	48	0.461	0.358	0.015
348	45	0.434	0.352	0.015
324	42	0.406	0.343	0.012
420	39	0.376	0.333	0.011
300	36	0.345	0.323	0.009
276	33	0.314	0.309	0.008
252	30	0.285	0.265	0.007
36	27	0.249	0.225	0.006
228	24	0.217	0.195	0.005
204	21	0.187	0.182	0.004
180	18	0.153	0.145	0.003
156	15	0.123	0.115	0.003
132	12	0.093	0.055	0.002
108	9	0.065	0.025	0.002
84	6	0.039	0.025	0.002
60	3	0.014	0.023	0.001

As discussed earlier it is proved that optimally braced frames are stiff, strong, and an economical structural system. Fully braced frames are very conservative in so far as lateral drift is concerned but uneconomical and at the same time optimally braced one have least forces induced in the structure and produce maximum displacement within prescribed limit.

Similarly, Table TD-22,23,24 and Graph GD-22,23,24 shows the variation of lateral displacement along the height of structure for 600 mm beam depth considered for 3 bay G+12, G+14, and G+ 18. Structure – bare frame, fully braced frame, frame with outrigger and cell wise braced frame.

The graph shows the similar variation as discussed earlier but the lateral displacement for optimally cross and diagonal braced frame is less than that of bare frame but well within the permissible limit. In lateral displacement 43.12% decrement is found in the tall structure (G+18) braced frame as compared to bare frame. Similarly for partially braced frame this amount is getting reduced by one third as compared to bare frame. Hence it is proved that for cell wise braced frame though the bare frame, but is well within the acceptable limit. It is advantageous to adopt such optimally cell wise braced frame to increase the economy.

IV) CONCLUSIONS

- For the bare frame the average aspect ratio of column is nearly two and for fully braced frame the aspect ratio of column reduces to a value slight above one and hence axial force is reduced.
- Bending moment in column is substantially reduced as compared to bare frame.
- Braces are found to carry large axial forces as compared with shear forces and bending moments, which are insignificantly small.
- Braces just facilitate a smooth stress transfer across the width of the structure simultaneously increasing the rigidity substantially.
- Lateral displacement in such frame is tremendously reduced as compared to bare frame of the same geometry, which is already within the permissible limit.

Table no:-Comparison between bare and cross bracing for displacement

Sr no	Type of building	Floor level	Load combination	Displacement in member		
				Bare frame	Cross bracing	% Reduction
1)	G+12	Bottom	1.5(DL+LL)	0.155	0.105	15.86
		Middle		0.100	0.058	54.71
		Top		0.060	0.005	55.58
2)	G+14	Bottom	1.5(DL+LL)	0.180	0.100	14.29
		Middle		0.135	0.044	52.95
		Top		0.065	0.005	48.75
3)	G+18	Bottom	1.5(DL+LL)	0.275	0.110	7.53
		Middle		0.225	0.007	62.63
		Top		0.014	0.007	51.98

- For 3Bay G+12,G+14,G+18 structures, symmetrically braced along given number of bays with cross type bracing, are nearly found to be economical with diagonal type bracing.
- Bending moment is getting reduced for worst loaded column and axial force in such column segments is increased. Hence the substantial reduction in bending moment for worst loaded column leads to section reduction.
- In case of arrangement of partially braced frames it is seen that symmetrical bay wise bracing patterns offer more economy than bare frame.
- Only central bay braced frame gives maximum savings as case 2 for cross- type braced frame and for 3 bay G+12,G+14,G+18 structures as compared to bare frame, also for diagonal -type bracing
- Bending moment gets reduced for worst loaded column almost to the same extent as that of a fully braced frame by providing level wise partially braced frames which offer more economy with respective to bay wise braced frame in comparison with bare frame.
- Due to substantial reduction in bending moment for worst loaded column leads to section reduction.
- In case of multilevel bracing it is observed that the optimum positions of levels to be braced is found at position immediate above the ground floor level/position gives consequent change in cross section.

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