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A seismic study of steel braced RC frame with different arrangements

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***Abstract*—— Steel braced frame is one of the techniques amongst retrofitting for resisting horizontal forces like: seismic and wind forces reinforced concrete multi-strayed buildings. Braced members take tension and compression thereby countering with these forces. Bracing system increases stiffness and strength of RC multi-storey building and decreases their deformation. Seismic coefficient method (linear static analysis) has been conducted to estimate the effect of different planning of bracing members in the building frame and influence of the different steel cross-section. Present study is a fifteen-story building assumed to be located in seismic zone IV as per the seismic zone map of India. Two steel profiles ISA, ISMC were utilized as bracing members by considering same cross-sectional area. The bracing was providing for peripheral columns. A four-story building was analyzed for seismic zone IV as per IS 1893: 2002 using STAAD Pro software. The effectiveness of various types of steel bracing in rehabilitating a G +15 storey building was examined. The effect of the distribution of the steel bracing along the height of the RC frame on the seismic performance of the rehabilitated building was studying. Seismic protection of buildings was a need-based concept aimed to improve the performance of any structure under future earth-quakes. It was found that the X type of steel bracing significantly contributes to the structural stiffness. It is also found that the various arrangements of bracing systems had great influence on seismic concert of the building frame and angle section gives better result as compared ISMC section**.

***Keywords*—— Earthquake retrofit; Seismic performance; Analysis; RC frames; X bracing, Bending moment; Shear force**

I. INTRODUCTION

India at present is fast developing country which requires demands in boost of infrastructure facilities along with the increase of residents. Due to increased population, the demand of land for housing is increasing day by day. To fulfil the need of the land for housing and other commercial offices, vertical development that is multi-story buildings are the only option [1]. This type of development requires safety because these multi-story buildings are highly susceptible to additional lateral loads due to earth quake and wind. In broad, as the elevation of building increases, its reaction to lateral loads increases. Multi-story reinforced concrete buildings are weak to unnecessary deformation, which impose the introduction of special measures to diminish this deformation. Steel braced frame is one of the lateral loads rivalling frame works in multi-story structures. This system enhances the resistance of the structure against horizontal forces by expanding its stiffness and immovability. Bracings hold the structure stable by exchanging the horizontal loads for example tremble or wind burdens down to the ground and oppose sidelong loads, in that way keep the influence of the structure. Its members in RC multi-story building is conservative, simple to situate, engage less space and give obliged quality and inflexibility. There are varieties of bracing systems like X bracing, K bracing, V bracing, inverted V bracing, diagonal bracing and so on [2].

A. *Retrofitting of RC Structures for Earthquake Resistance*

Assessment of an existing building will reveal the deficiencies at local and global level; the designer will use his experience and engineering judgement to select the most appropriate measure or combination of measures to improve the performance of the building. Earthquake manifests great devastation due to un-predicted seismic motion striking extensive damage to buildings. This damage causes large irreparable loss of life with large number of casualties [3]. Rather than replacement of building strengthening of structure proves to be better option for providing immediate shelter. Moreover it has been often seen that retrofitting of buildings is generally more efficient as compared to demolition and reform. Therefore, seismic strengthening of building structures swing divine serious view for mitigating quivering hazards chiefly in shock apt areas.

B. *Methods of Strengthening*

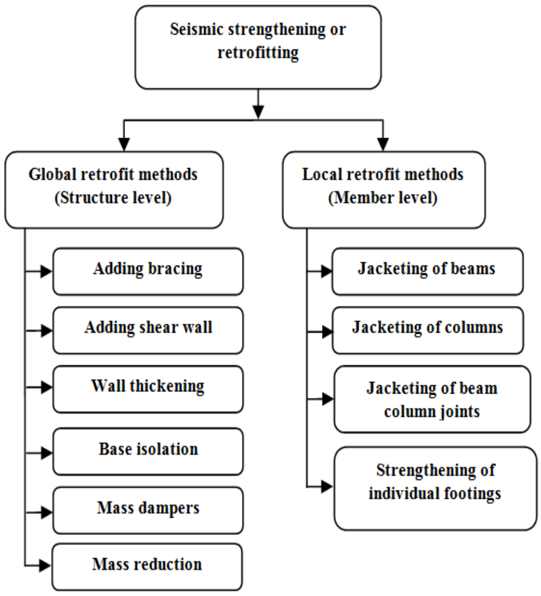

Fig. 1 Type of Retrofitting

Seismic strengthening (retrofitting) is generally approved out in the following ways as shown in figuer 1.

1) Global retrofit methods (Structure level): In Structure level or global retrofit methods two approaches are used for structure level retrofitting.

- *Conventional Methods-* Conventional methods of strengthening are used to enhance the seismic resistance of existing structures by eliminating or reducing the adverse effects of design or construction. The methods include the options like adding of shear wall, in-fill walls or steel braces.

- *Nonconventional Methods-* Seismic base isolation and addition of supplemented device techniques are the most fashionable. These techniques proceed with quite different idea in the sagacity that it is fundamentally conceived to diminish the horizontal seismic forces.

2) Local retrofit methods (Member level): The member level retrofit or local retrofit of strengthening approach is to upgrade the strength of the members which are seismically wanting. This approach is more cost effectual as compared to the structure level retrofit. The most common process of enhancing the entity member strength is jacketing. It includes the addition of concrete, steel or fibre reinforced polymer (FRP) jackets for use in confining reinforced concrete joints, columns, beams and practicalities.

C. *Strengthening of RC Structures with Economy*

Construction cost is a fundamental parameter. In most cases, it should be examined together with the cost of non-structural interventions (e.g. removal and reconstruction of finishing, temporary measures during construction), the value of the contents of the building and the cost related to the disruption of use of the building (e.g. temporary housing of occupants, business interruption and relocation of services). On the other hand, a building with upgraded seismic safety will lead to higher rental prices and lower insurance premium, which will (at least partially) compensate the rehabilitation cost. The construction cost might not govern, though, in cases of buildings that house expensive equipment and high-revenue business activities. Steel bracing is a well capable and economical method of resisting horizontal forces in a frame structure. Bracing has been used to stabilize across the popular of the world's tallest building structures as well as one of the main strengthening measures. Bracings' resourceful because the diagonals work in axial stress and therefore call for minimum member sizes in providing rigidity and power against horizontal shear. A number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and ductility of existing buildings [4]. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the adding up of the bracing system, load could be transferred elsewhere of the frame and into the braces, bypassing the weak columns while increasing strength. Steel braced frames are competent structural systems for buildings subjected to seismic or wind lateral loadings. Hence, the use of steel bracing systems for retrofitting reinforced concrete frames with inadequate lateral resistance is attractive [5].

D. *Cross Bracing Considerations for RC Frames*

In this process of strengthening, it is required to notice the following cases which have a direct effect on the seismic behaviour of the structure and to think of a suitable policy for each of them

- Vast stiffness caused by using cross bracings in concrete frames
- Tremor induced loads transferring from apex stories to the lower stories and foundations
- Compressive and buckling potency of cross bracing elements
- Extra stresses occurred in the elements
- Extra loads which will be obligatory on the foundations
- Column strength against shear force caused by cross bracings
- Beam and column links in the locations of the cross bracing links
- Cross bracing links to the concrete frames

Steel cross bracing system in amalgamation with moment resisting frame may cause enlarge in the stiffness and strength of the structure. In common, moment resisting frame and cross bracing system have two diverse performances which vary from each other in their type of warp against lateral loads. The major deformation mode of the cross bracing system is flexural which resembling vertical cantilever, although, moment resisting frames usually deforms in shear mode. The effect of this fact on the performance of cross braced frames depends on their height as follows:

In lowest buildings with moment resisting frames which are strengthened by steel cross bracing system, the distinction between the deformation modes of frame and cross bracing system is not significant and secondary stresses do not have much effect on the stability of cross bracing frame in a severe trembling.

In these buildings, the lateral stiffness of the moment resisting frame can be predictably deserted and design the structure arrogant that the cross bracing system can carry the lateral loads or design the cross bracing system for lateral loads glut the moment resisting frame capacity [6].

In upper buildings which have mutually moment resisting and cross bracing systems, each system compensation the other's weak points to be improved so that there will be a raise in the stiffness and lateral strength of the structure. Moreover, the diversity between the performances of the two systems will lead to a non-uniform delivery of the shear forces between them. This is done in a manner that during the lateral deformation in the structure's moment resisting frame in the inferior stories, the edge leans to the cross bracing system and in the higher stories the moment resisting frame itself stops the cross bracing system from deformation. Hence, in these stories the shear forces conceded by the moment resisting frame may be more than the entire applied shear forces on the structure because of the unconstructive effect of the performance of the system in the superior stories. Here, according to the common simple methods, the circulation of the shear forces proportional with the strength of structural elements, will lead to dubious results**.** It should be noticed that since carrying the whole lateral forces by the cross bracing system is not that much reliable, so it is also compulsory to take the interface of both systems into consideration. Concerning the above mentioned points, it should be founded that in those buildings which are strengthened by steel cross bracing system, the behaviour of the combined structure will be entirely different from that of the primary structure. Hence, in the design of cross bracing systems, apposite selection of the changes of response modification factor (R) of the building should be taken into concern thoroughly [7].

II. TYPES OF BRACINGS

There are two types of bracing systems [8, 10]

A. Concentric Bracing System

Concentric bracing systems are the most widely used for retrofitting concrete frames. They contribute to the lateral-load resistance of the structure through the horizontal projection of the axial force (mainly axial tension) developing in their inclined members. Appropriate concentric bracing systems are those with: Diagonal bracings, in which there is a single diagonal per braced bay of the frame; X (or cross-diagonal) bracings, with braces along both diagonals of a braced bay; V or inverted V bracings (termed chevron bracings in the USA), in which a pair of Inclined braces is connected to a point near or at the mid-span of a horizontal member (Beam or slab) of a bay of the frame.

B. Eccentric Steel Bracing

Eccentrically braced frames are an efficient technique for enhancing the seismic resistance of existing frame buildings because, in addition to strength and stiffness, they provide ductility. Forces are transferred to the brace members through bending and shear forces developed in the ductile steel link. K bracings, in which the inclined braces are connected to a point within the clear height of a column, should not be used, because the column may fail in shear when the high axial force of the brace is transferred as a horizontal force to a column with reduced height [12, 15].

III. STRUCTURAL MODELLING & ANALYSIS

A G+15 storey reinforced concrete building with X type bracing provided on various positions in the building are analyzed for earthquake loading. The method of seismic analysis used in this current study is seismic coefficient method which is a linear static approach. Building is designed according to IS: 456-2008 and tremor loading is applied as per the recommendation of IS: 1893-2002. Construction is assumed to be located in seismic region IV of India and relax on medium soil condition. Following seismic parameters considered for the present study.

- Region part for seismic zone IV = 0.24
- Soil site factor for medium soil state = 2
- For important building Importance factor = 1.5
- Response reduction factor = 3
- Damping ratio = 0.05

The structures are established by utilizing computer programming **Staad-ProV8I**. The floor load is taken as 12 KN/m^2 including floor finishing load as 10 KN/m^2. The live load is taken as 4 KN/m^2. Load combinations are useful as per the recommendation of Indian standard codes as shown in figure 2.

Total 11 samples are analyzed in this study. One bare frame model, five models of X bracing ISA 150x150x12, five models of X bracing ISMC225 of approximately same cross-sectional area are used for bracing members.

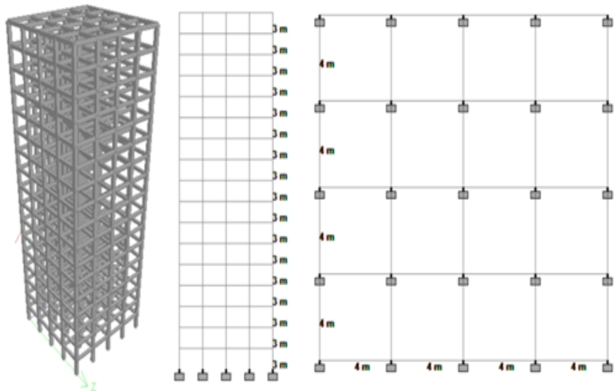

Fig.2 Building with its elevation and plan view

In the following described figures the term arrangement refers to the different positions on which bracing are provided so as to study and analyse building.

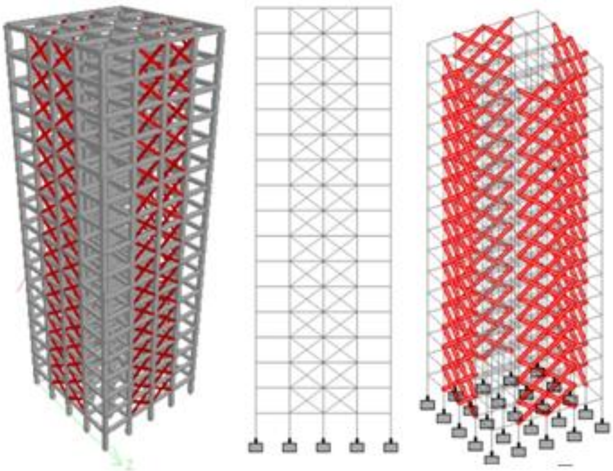

Fig. 3 RC Building with X-Bracing in 3D- view (Arrangement 1)

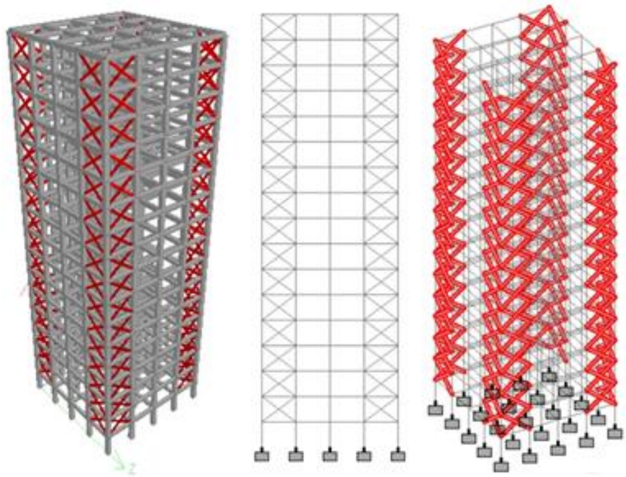

Fig. 4 RC Building with X-Bracing in 3D- view (Arrangement 2)

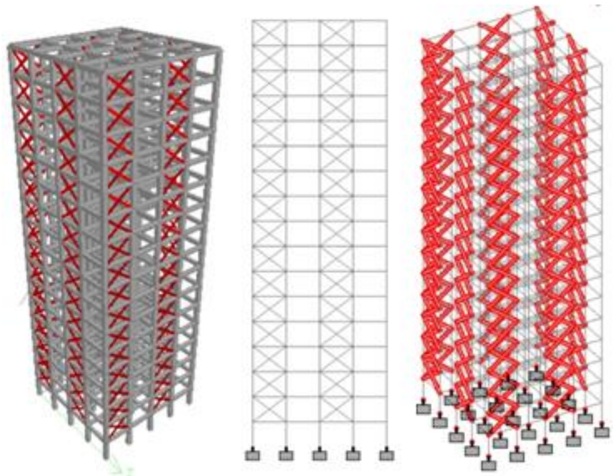

Fig. 5 RC Building with X-Bracing in 3D- view (Arrangement 3)

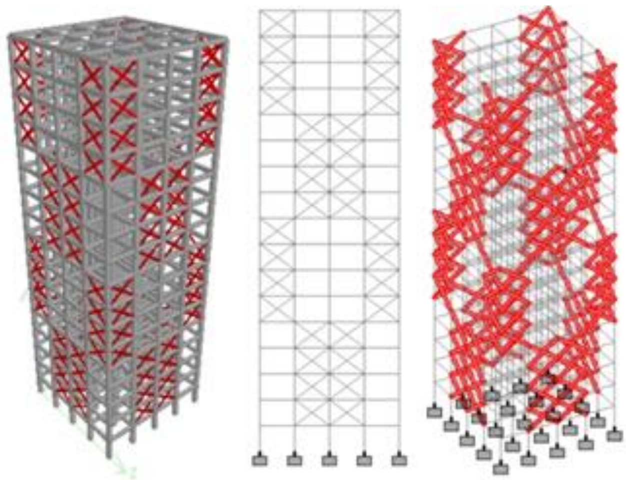

Fig. 6 RC Building with X-Bracing in 3D- view (Arrangement 4)

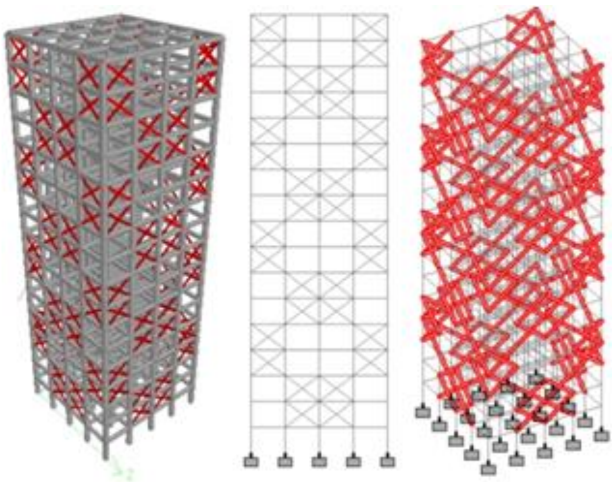

Fig. 7 RC Building with X-Bracing in 3D- view (Arrangement 5)

IV. RESULTS AND DISCUSSIONS

The present diagram demonstrates the Percentage reduction in bending moment and shear force for ISA and ISMC type bracing system when compared with bare frame model. This graph shows that ISA bracing systems have maximum reduction in bending moment (about 54%) and shear force (about 42.5%) than ISMC bracing as shown in figure 8. This means that angle type bracing system significantly reduces shear force and bending moment in the structure as compared to channel bracing system. Also the arrangement 4 of angle bracing shows better result than other arrangements. Arrangement 3 has minimum reduction in bending moment and shear force.

V. CONCLUSIONS

The following conclusions can be made from the present investigation:

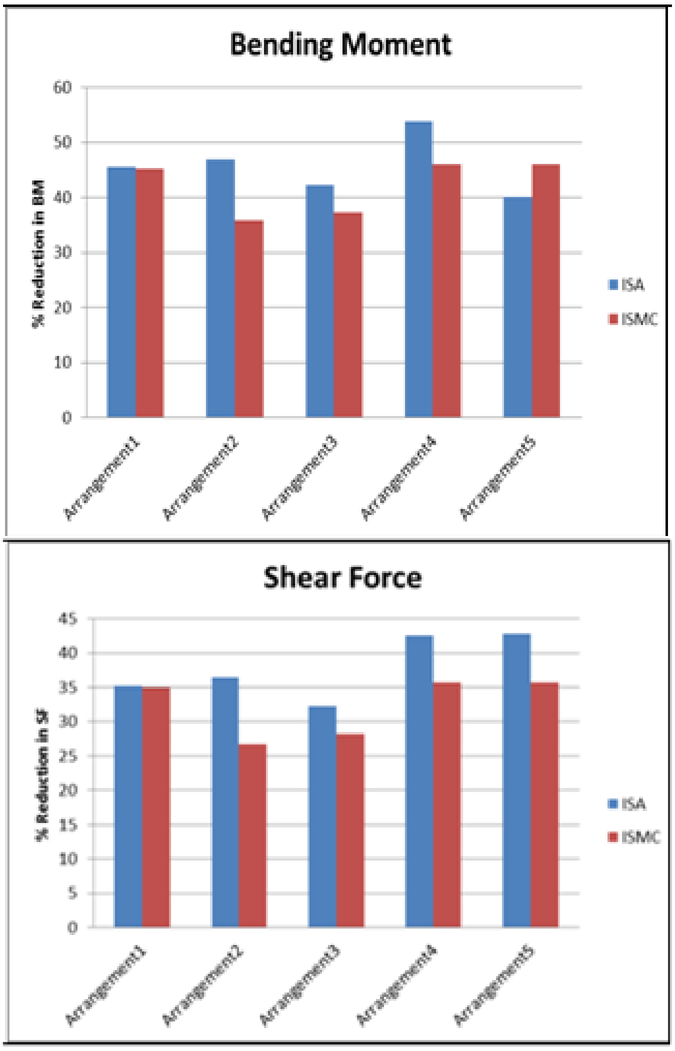

Fig. 8 Percentage reduction in Bending Moment and Shear Force

- Steel bracing system represents the efficient and economical measures for RC multi-story buildings sited in high seismic regions. Bracing system appreciably reduces the bending moment and shear force.
- It is concluded that arrangements of bracing systems has considerable effect on seismic performance of the building. From all five arrangements of bracing system, arrangement four gives better performance.
- From the result it is found that angle section gives better results than ISMC section. The analysis performed on the rehabilitation X bracing system significantly improves the stiffness and the strength of structure. It also showed an upgrade in structural performance level.
- It is possible to further enhance the lateral load capacities of existing R/C frame

structures rehabilitated by changing the position of X-bracing.

- Sectional Weight of ISA 150 x150 x 12 sections is lesser as compared to ISMC225 and other sections (equal sectional areas were compared) but it gave better results in percentage reduction of shear force and bending moment values.

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