Analysis of Seismic Retrofitting on RC Building

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***Abstract*:- Many existing reinforced concrete structure in present world are inadequate for earthquakes. Recent earthquakes which occurred during last decade have indicated that major damage occurred was not directly due to actions of earthquakes but due to poor performance of structure during earthquake. The existing building structure, which were design and constructed according to early codal provisions, do not satisfy requirements of current seismic code and design practices. It is recognized that the most effective method of reducing the risk of damaging structure is seismic retrofitting. In recent years, there is a significant improvement of retrofitting techniques. This study highlights the principles of assessing and retrofitting of structure against seismic events. A three dimensional R.C. frame designed with linear elastic dynamic analysis using response spectrum method. The computer software package STAAD Pro is used for dynamics analysis technique is used to assess the performance of a reinforced concrete building. The different retrofitting methods such as steel and concrete jacketing and application of fibre reinforced polymer (FRP) composites which were used to improve the load bearing capacity of individual structure elements are highlighted and methods such as shear walls and shear cores which can be used to improve overall stability of buildings. Most retrofitting techniques will result an increase in stiffness and slightly increase in mass which causes in return a shorter period. Shortening in period of vibration often results an increase in strength and ductility of retrofitted structure. Thus, a proposed retrofit scheme can be said to be successful if it results an increase in strength and ductility capacity of the structure which is greater than the demands imposed by earthquakes.**

Keywords:- Retrofitting, Seismic Events, FRP, Jacketing, Stiffness.

INTRODUCTON

The main purpose of this study is to increase knowledge and proficiency in earthquake resistant design and seismic rehabilitation of existing structures and to gain familiarity with modeling and analyzing buildings against seismic loads by using computer software. The objectives of this research are: (i) to investigate the effects of earthquake forces on buildings and literature search on earthquake resistant design (ii) to evaluate the feasibility of seismic evaluation of buildings and advantages of applying the retrofit measures developed for strengthening (iii) to analyze performance based design and compare different seismic analysis method (iv) to model a real building with a structural analysis software and investigate the earthquake effects with different analysis methods prescribed in codes & standards and propose appropriate rehabilitation methods in terms of the performance. Most earthquakes occur through the sudden movement of earth crust in faults zones. The sudden movement releases strain energy and causes seismic waves through the crust around the fault. These seismic waves cause the ground surface to shake and this ground shaking is the principal concern of structural engineering to resist earthquakes among many other effects. Historical records and geological records of the earthquakes are the main data sources in estimating the possibility of ground shaking or seismicity at a certain location. Both data sets have been taken into account to develop the seismic hazard maps.

The primary objective of earthquake resistant design is to prevent building collapse during earthquakes to minimize the risk of death or injury to people. Severe earthquakes have extremely low probability of occurrence during the life time of a structure. In the traditional structural design against most type of loads, stresses and strains are not permitted to approach the elastic limit. However in earthquake design, structures are permitted to strain beyond elastic limit in response to ground motion. If a structure has to resist such earthquakes elastically, it would require an expensive lateral load resisting system. During a severe earthquake, the structure is likely to undergo inelastic deformation and has to rely on its ductility and hysteric energy dissipation capacity to avoid collapse. Modern buildings can be designed to be safe under severe ground shaking by avoiding collapse. An effective earthquake engineering design requires that the designer controls the building's response. This can be achieved by selecting a preferred response mode, adopting inelastic deformations to acceptable zones by providing necessary detailing and preventing the development of the undesirable response modes which could lead to building collapse.

LITREATURE REVIEW

There are three key concepts in seismic design that were fully developed by researchers and engineers. First, earthquake ground motions generate inertial loads that rapidly change with time. Thus, it is common that calculations include a term labeled with a unit of time (usually seconds) and these terms include periods of vibration or their inverse, frequencies; accelerations and velocities. In many other structural engineering problems such as calculations of gravity loads, no unit of time is used.

Second, due to the large uncertainty associated with the forces and structural responses. The earthquake occurrence time, its magnitude, rupture surface features and dynamic response behavior of the structure cannot be predicted with certainty. Methods of probability and statistics are required to include these uncertainties and their effects on the structural performance evaluation and design.

The third fundamental earthquake engineering concept that distinguishes this field is that the earthquake loading can be so severe that the materials must often be designed to behave in elastically. Within the domain of Hooke's Law, stress is proportional to strain, but beyond that point, behavior becomes complex. Most of the analytical and experimental work investigating inelastic behavior began approximately in the 1960s.

Choices for the Lateral Force-Resisting Elements OfStructural Systems

The choices of lateral-force-resisting systems in buildings are limited to the following, with very few exceptions: braced frames (vertically-oriented truss elements), moment-resistant frames, shear walls, diaphragms and response modification techniques that change the seismic demand on the lateral-force-resisting elements. Such techniques focus on changing the forces in the structure due to ground motion (e.g. seismic isolation) or changing the displacement within the structure due to the ground motion (e.g. damping devices). The materials, of which these elements can be made, with very few exceptions, are limited to: steel (including aluminum or other metals), reinforced masonry, reinforced concrete and wood.

Earthquake Design Philosophy

The engineering intention behind earthquake resistant design is not to make earthquake-proof buildings that will not get damaged even during the rare but strong earthquake; such buildings will be too robust and also too expensive. Instead, the engineers make buildings to resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, safety of human life and contents inside of the building are assured in earthquake resistant buildings. This is a major objective of seismic design codes throughout the world. The earthquake design philosophy may be summarized as follows;

(i)Under minor but frequent shaking, the main members of the building resist earthquake impact without being damaged (staying at elastic range); however building parts that do not carry load may sustain repairable damage.

(ii)Under moderate but occasional shaking, the main members may sustain some repairable damage, while the other parts of the building may be damaged even may need replacement.

(iii)Under strong but rare shaking, the main members may sustain severe (even irreparable) damage, but the building should not collapse.

The important buildings, like hospitals and fire stations, play a critical role in post-earthquake activities and must remain functional immediately after the earthquake. These structures must sustain very little damage and should be designed for a higher level of earthquake protection. Likewise, dams, nuclear power plant, etc. should be designed for higher level of earthquake motion not to cause another disaster after a strong ground motion. Figure 1 shows schematic system behavior for seismic demands.

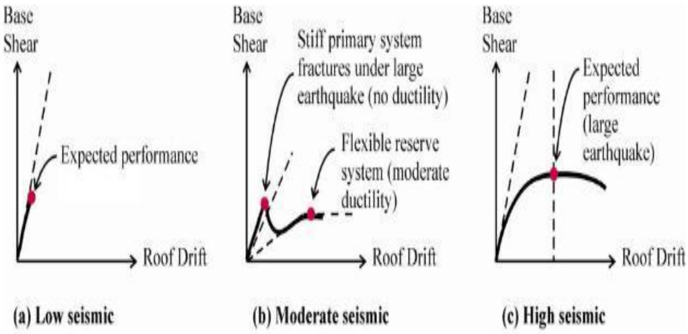


Fig. 1:Schematic system behavior for low, moderate and high seismic demands

RELATED WORK

<u>Adding New Shear Walls</u>- Frequently used for retrofitting of non-ductile reinforced concrete frame buildings. The added elements can be either cast-in-place or precast concrete elements. New elements preferably be placed at the exterior of the building. Not preferred in the interior of the structure to avoid interior mouldings.

Fig. 2: Additional shear wall

- **Wood Shear Walls**- They are typically wood frame stud walls coveredwith a structural sheathing material like plywood.

- **Reinforced Concrete Shear Walls**- The reinforced concrete shear walls generally start at foundation level and are continuous throughoutthe building height. Shear walls carry large horizontal earthquake forces, the overturning effects on them are large.

- **Reinforced Masonry Shear Walls**- Masonry is one of the oldest construction materials.It combines high strength manufactured concrete and clay masonry units along with grouting and reinforcing steel.

- **Steel Shear Walls**- Steel shear walls can be very efficient and economical lateral load resisting systems and due to having high initial stiffness.Steel plate shear walls allow for less structural wall thickness in comparison to the thickness of concrete shear walls and result in a lesser building weight.
- **Adding Steel Bracings**- An effective solution when large openings are required.Potential advantages for the following reasons: higher strength and stiffness,opening for natural light,amount of work is less since foundation cost may be minimizedadds much less weight to the existing structure.

Fig. 3: RC Building retrofitted by steel bracing

Seismic Isolation

Isolation of superstructure from the foundation is known as base isolation.It is the most powerful tool for passive structural vibration control technique.Base isolation systems or seismic isolation system are of two types which include**Elastomeric Bearings** and**Sliding System.**

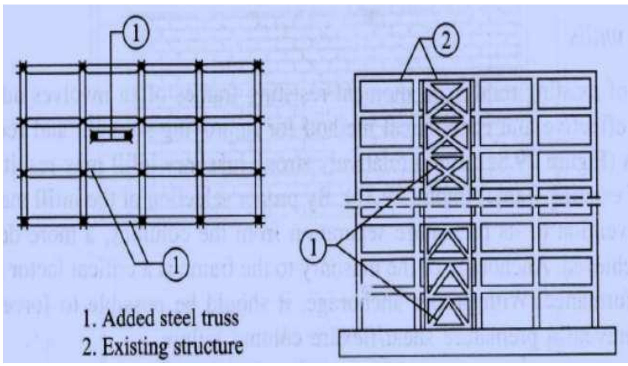


Fig. 4: Base Isolated Structures

Seismic Dampers

Seismic Dampers are used in place of structural elements, like diagonal braces, for controlling seismic damage in structures.It partly absorbs the seismic energy and reduces the motion of buildings. Types of seismic dampers are:

- **Viscous Dampers-**energy is absorbed by silicone-based fluidpassing between piston-cylinder arrangement
- **Friction Dampers** - energy is absorbed by surfaces with frictionbetween them rubbing against each other
- **Yielding Dampers-** energy is absorbed by metallic componentsthat yield

BUILDING MODELING

The RC building used in this study is eight storied (G+7) building have same floor plan with 4 bays having 4m distance along longitudinal direction and 3 bays having 4m distance along transverse direction as shown in figure5

Load combinations

Load combinations that are to be used for Limit state Design of reinforced concrete structure are listed below.

1.5(DL + LL)
1.2(DL + LL ± EQ – X)
1.2(DL + LL ± EQ –Y)
1.5(DL ± EQ –X)
1.5(DL ± EQ –Y)
0.9DL ± 1.5EQ – X
0.9DL ± 1.5EQ - Y

Structural Details

The floor to floor height is 3m for all the stories.
The live load = 3KN/m^2 for all floors.
The gravity load = 12KN/m^2 for all floors.
Thickness of shear wall = 200mm
The unit weight of concrete = 20KN/m3
The compressive strength of concrete = 20N/mm2
Yield strength of steel = 415 N/mm2
The modulus of elasticity of concrete = 25000 N/mm2
The modulus of elasticity of steel = 2×105 N/mm2
The steel bracing used is ISA 110 ×110 ×10
Located in seismic region V sub-soil type 2 (medium)
Importance factor = 1
Response Modification Coefficient = 5
Seismic analysis is carried out on building models using the software Staad pro V8i.
The load cases considered in the seismic analysis are as per IS 1893 – 2002 and IS 456 - 2000

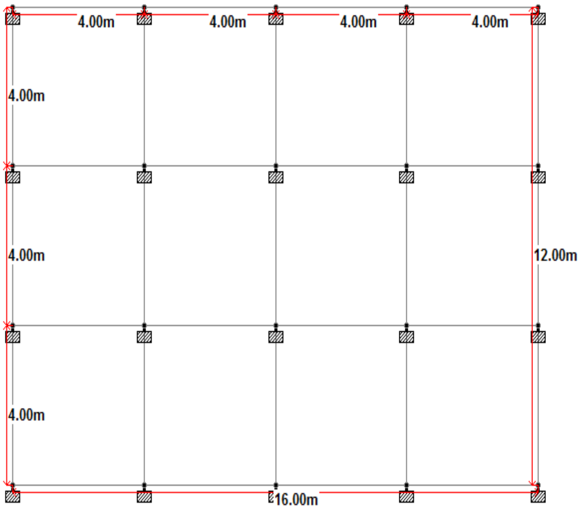
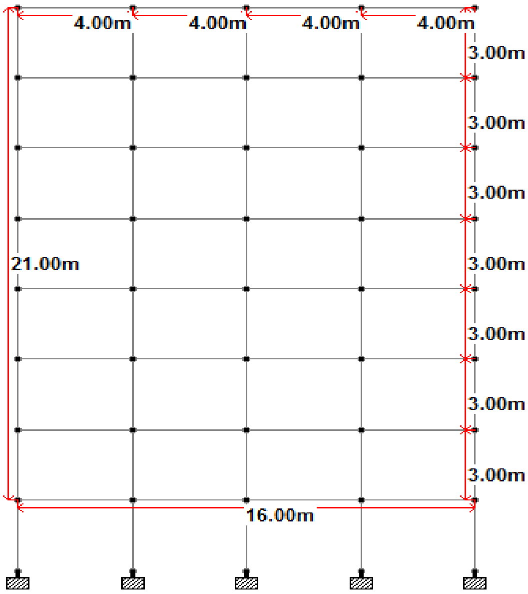


Fig.5: Building plan



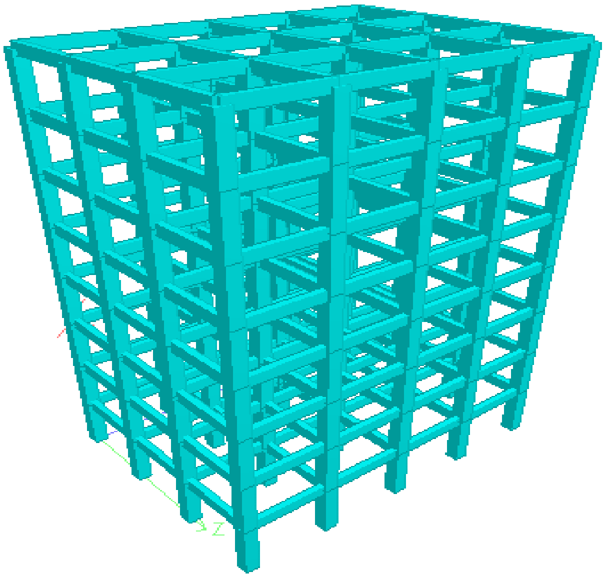


Fig. 6: Building without Bracing

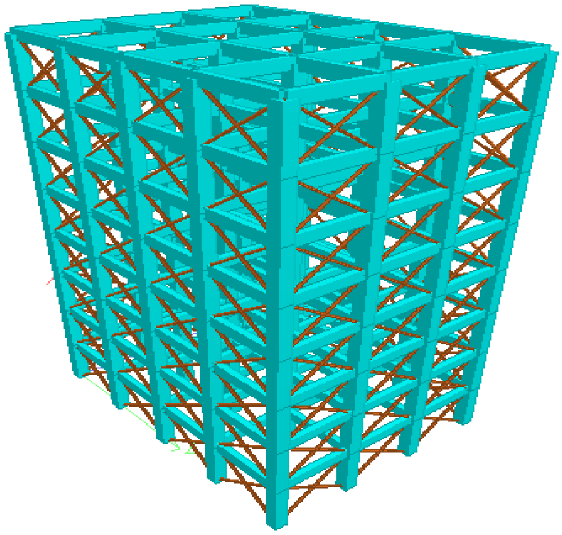


Fig. 7: Building with Bracings

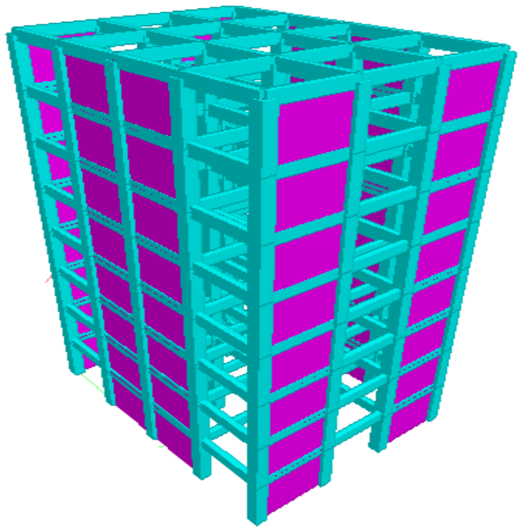


Fig. 8: Building with Shear Walls

Distribution of the horizontal seismic forces

Load and base shear calculation has been done as per IS 1893 – 2002. The base shear is calculated and distributed throughout the height at each floor of the building and the lateral seismic force induced at any level is determined.

Indian standard IS – 1893 2002:

IS 1893 2002 is denoted as "Criteria for earthquake resistant design of structure" Part 1 General provisions and buildings.The design lateral force shall first be computed for the building as a whole. The design lateral force shall then be distributed to the various floor levels. This overall design seismic force thus obtained at each floor level shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

The design base shear calculated shall be distributed along the height of the building as per the following expression.

$$Q_i = V_B \frac{W_i h_i^k}{\sum_{j=1}^{n} W_j h_j^k}$$

RESULTS

- ***Lateral Displacement***
  It is observed that the lateral displacements are reduced to adding shear wall into the frame, while the displacement is maximum for the bare frame.

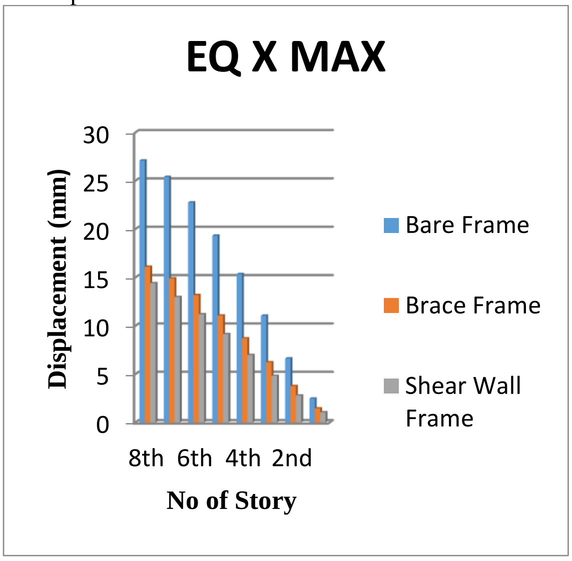


Fig. 9: Graph of Maximum Lateral Displacement (mm) in X Direction

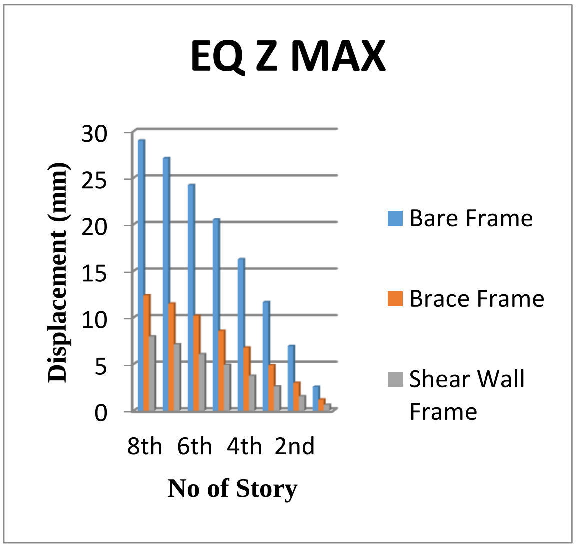


Fig. 10: Graph of Maximum Lateral Displacement (mm) in Z Direction

- ***Story Drift***
  It can be observed from the graph that the story drift are reduced to largest extent for shear wall frame and bracing frame, while these are maximum for the bare frame.

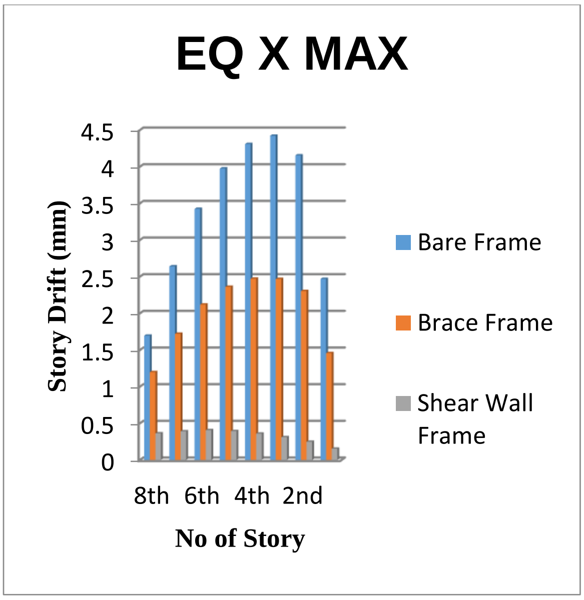


Fig. 11: Graph of Storey Drift Displacement (mm) in X Direction

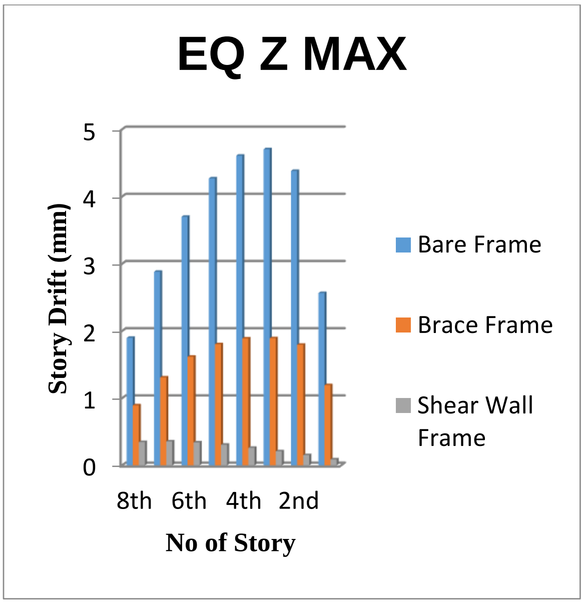


Fig. 12 Graph of Storey Drift Displacement (mm) in Z Direction

- ***Axial Force***
  It can be observed from the graph that the axial forces are maximum for shear wall frame, while these are minimum for the bare frame.

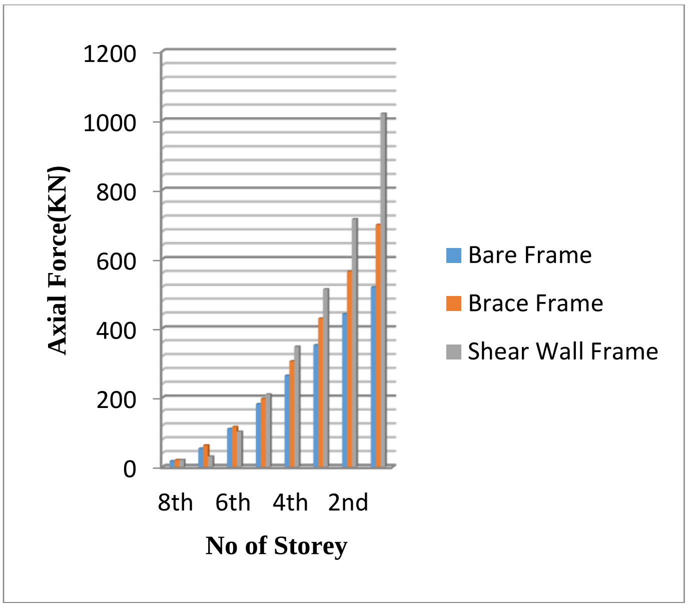


Fig. 13:Graph of Axial Force (KN) in Column

- ***Base Shear***

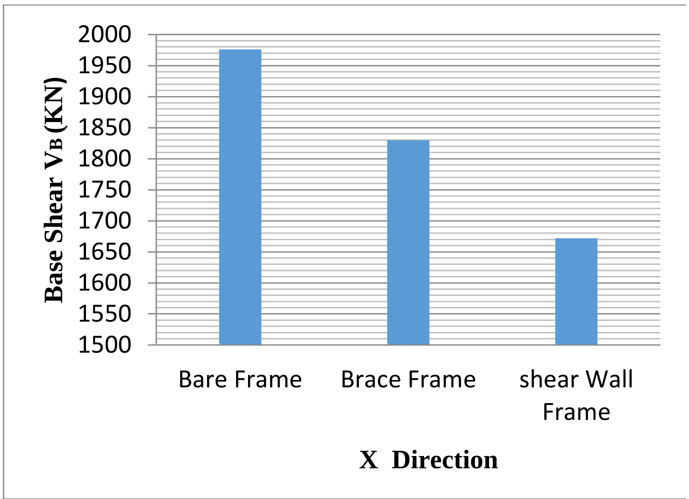


Fig. 14: Graph of Base shear in X Direction (KN)

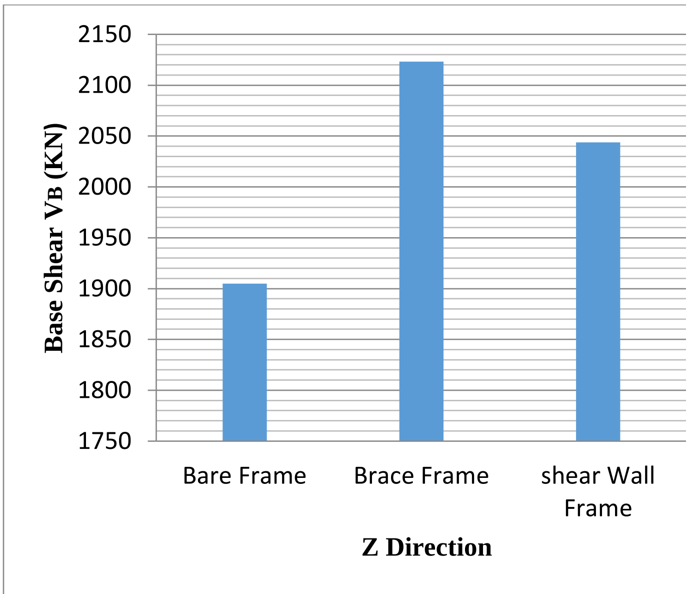


Fig. 15: Graph of Base shear in Z Direction (KN)

CONCLUSION

- Shear wall elements are very much efficient in reducing lateral displacement of frame as drift and horizontal deflection induced in shear wall frame are much less than that induced in braced frame and plane frame.
- The location of shear-wall and brace member has significant effect on the seismic response than the plane frame.
- The location of shear-wall- 3 is favorable as they are effective in reducing actions induced in frame with less horizontal deflection and drift.
- Shear wall construction will provide large stiffness to the building by reducing the damage to the structure.
- The concept of using steel bracing is one of the advantageous concepts which can be used to strengthen or retrofit the existing structures.
- Steel bracings can be used as an alternative to the other strengthening or retrofitting techniques available as the total weight on the existing building will not change significantly.
- Steel bracings reduce flexure and shear demands on beams and columns and transfer the lateral loads through axial load mechanism.
- The lateral displacements of the building studied are reduced by the use of X type of bracing systems.
- The building frames with X bracing system will have minimum possible bending moments in comparison to other types of bracing systems.
- Using steel bracings the total weight on the existing building will not change significantly.
- The lateral displacement of the building is reduced by 40.56% by the use of X Type steel bracing system and 46.81% by the use of shear wall as compare to the bare frame, so shear wall reduces the maximum displacement.

REFERENCES

[1] IS 15988:2013, Seismic Evaluation And Strengthening Of Existing Reinforced Concrete Buildings –Guidelines, Bureau of Indian Standards, New Delhi, 2013.
[2] IS 875:1987(Part 2), Design Loads For Buildings and Structures-BIS, New Delhi, 1987.
[3] IS 1893:1987(Part 2), Codeof Practice for Design Loads for Buildings and Structures (earthquake) - BIS, New Delhi, 1987.
[4] IS 456:2000, Plain and Reinforced Concrete, Bureau of Indian Standards, New Delhi, 2000
[5] Design and Detailing of RC Jacketing for Concrete Columns Nikita Gupta, PoonamDhiman, Anil Dhiman, AETM, 2015.
[6] Materials and Jacketing Technique for Retrofitting Of Structures, Shri. Pravin B. Waghmare, International Journal of Advanced Engineering Research and Studies, 2011.
[7] Handbook on Externally Bonded FRP Reinforced for RC Structures by FIB Federation.
[8] Analysis & Design of R.C.C. Jacketing for Buildings-Vedprakash C. Marlapalle, P. J. Salunke, N. G. Gore
[9] FIB Model Code for Concrete Structures, Design of FRP Jacketing-2010.
[10] Strengthening of a reinforced concrete column by SFRC, by P Nibasumba, Tsinghua University, China,2001