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Analysis of RC Building Frames for Seismic Forces Using Different Types of Bracing Systems

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Abstract- **In this study, seismic analysis of high rise RC building frames have been carried out considering different types of bracing systems. Bracing systems is very efficient and unyielding lateral load resisting system. Bracing systems serves as one of the component in RC buildings for increasing stiffness and strength to guard buildings from the incidence caused by natural forces like earthquake force. In proposed problem G+ 10 story building frame is analysed for different bracing system under seismic loading. STADD-Pro software is used for analysis purpose. The results of various bracing systems (X Bracing, V Bracing, K Bracing, Inverted V Bracing, and Inverted K Bracing) are compared with bare frame model analysis to evaluate the effectiveness of a particular type of bracing system in order to control the lateral displacement and member forces in the frame. It is found that all the bracing systems control the lateral displacement of frame very effectively. However Inverted V bracing is found to be most economical.**

***KEYWORDS -- Seismic; Bracing system; moment; Shear force; Storey displacement; storey drift; Inverted V Bracing, etc*.**

I. INTRODUCTION

Structures are built to facilitate the performance of various activities connected with residence, office, education, healthcare, sports and recreation transportation, storage, power generation, etc. All the structures should sustain the loads coming on them during their service life by possessing adequate strength and also limit the deformation by possessing enough stiffness. Strength of a structure depends on characteristics of the material with which it constructed and Stiffness depends upon the cross sectional and geometrical property of the structure. Tall building or multi-storied building defined as virtue of its height (more than 30 m), 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. Structural analysis deals with the mechanism of regeneration of loads applied on the system into local element force, using various theories and theorems enunciated by eminent engineers and investigators. It also deals with the computation of deformations these members suffer under the action of induced forces.

The essential work of members of framed structure is to transfers the gravity loads and lateral loads to the foundation of structure and then to the earth. The main loads comes in the structure is gravity loads consists dead load, live loads and some service loads. Beside this there is probability of structure may undergo through lateral forces caused due to seismic activity, wind forces, fire, and blasts etc. Here the columns and beams of the structures are used to transfers the major portion of the gravity loads and some portion of lateral loads but that is not significant to the stability of structure. So we provide bracing systems, shear walls, dampers etc to resist or transfer these lateral forces to the structure uniformly without affecting the stability and strength of the structure.

Sabelli et al. (1999) investigated to identify ground motion and structural features that control the response of concentrically braced frames, and to identify improved design procedures and code provisions. The focus of this paper is on the earthquake response of three and six story concentrically braced frames utilizing buckling-restrained braces. A brief discussion is provided regarding the mechanical properties of such braces and the benefit of their use. Results of detailed nonlinear dynamic analyses are then examined for specific cases as well as statistically for several suites of ground motions to characterize the effect on key response parameters of various structural configurations and proportions.

Mahmoud R. Maher, R. Akbari (2003), carried out the study for the earthquake behaviour factor (*R*) for steel X-braced and knee-braced RC buildings. The *R* factor components including ductility reduction factor and over strength factor are extracted from inelastic pushover analyses of brace-frame systems of different heights and configurations. The effects of some parameters influencing the value of *R* factor, including the height of the frame, share of bracing system from the applied load and the type of bracing system are investigated. The height of this type of lateral load-resisting system has a profound effect on the *R* factor, as it directly affects the ductility capacity of the dual system. Finally, based on the findings presented, tentative *R* values are proposed for steel-braced moment-resisting RC frame dual systems for different ductility demands.

P. Jayachandran (2009), carried out the study to enables optimization of initial structural systems for drift and stresses, based on gravity and lateral loads. The design issues are efficiency of systems, rigidity, member depths, balance between sizes of beam and column, bracings, as well as spacing of columns, and girders, and areas and inertias of members. Drift and accelerations should be kept within limits. Good preliminary design and optimization leads to better fabrication and erection costs, and better

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construction. The cost of systems depends on their structure weight. This depends on efficient initial design. The structural steel weight is shown to be an important parameter for the architects, construction engineers and for fabrication and assembly optimization.

R.K. Gajjar, Dhaval P. Advani (2011), investigated, the design of multi-storeyed steel building is to have good lateral load resisting system along with gravity load system because it also governs the design. They presented to show the effect of different types of bracing systems in multi storied steel buildings. For this purpose the 20 stories steel buildings model is used with same configuration and different bracings systems such as knee brace, X brace and V brace is used. A commercial package STADD Pro is used for the analysis and design and different parameters are compared.

Kevadkar, Kodag et al (2013), concluded that the structure in heavy susceptible to lateral forces may be concern to severe damage. In this they said along with gravity load (dead load, live load) the frames able to withstand to lateral load (loads due to earthquake, wind, blast, fire hazards etc) which can develop high stresses for that purpose they used shear wall and steel bracing system to resist the such type of loading like earthquake, wind, blast etc. In study according to author R.C.C. building is modelled and analyzed in STADD & results are compared in terms of Lateral Displacement, Story Shear and Story Drifts, Base shear and Demand Capacity (Performance point).

II. MODELLING

The effectiveness of different bracing system in different seismic zones is evaluated to find out the most effective bracing system. For this STAAD Pro commercial software is used to generate the 3D model and carry out the analysis. In this bracing system are used to resist the lateral forces and their orientation is done by using STAAD Pro. The gravity loads and lateral loads acting on the structure are considered as per codal provisions.

(a) MODELLING OF BUILDING FRAMES

Building frame with the following geometrical types are considered for analysis in 3 different seismic zones (Zone II, Zone III and Zone IV) for seismic and gravity loading in each case.

CASE-1: G+10 building frame without bracing system (Bare Frame).

CASE-2: G+10 building frame with X bracing system.

CASE-3: G+10 building frame with V bracing system.

CASE-4: G+10 building frame with K bracing system.

CASE-5: G+10 building frame with Inverted V bracing system.

CASE-6: G+10 building frame with Inverted K bracing system.

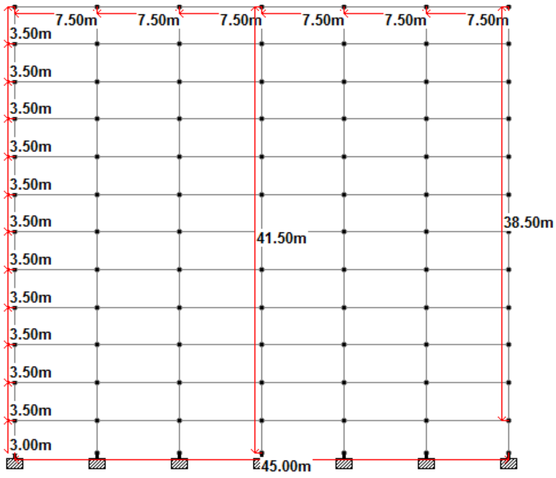


Fig 1: Elevation of proposed structural frame

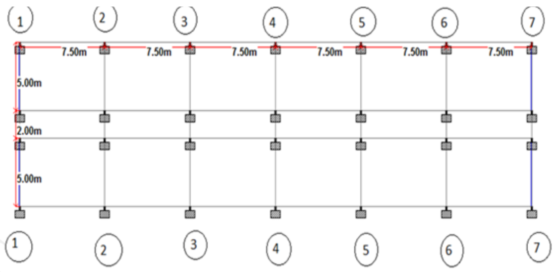
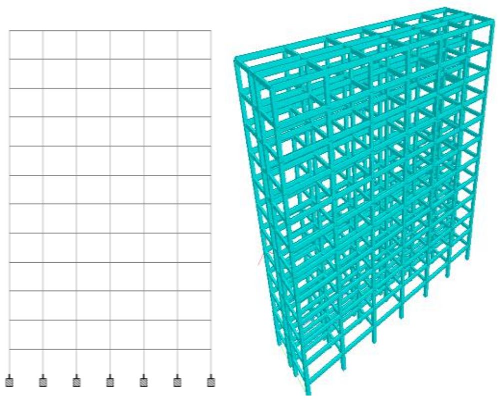
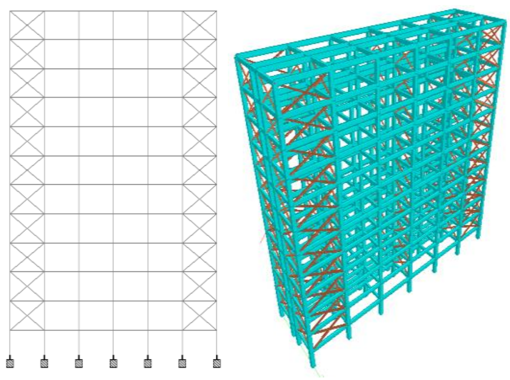


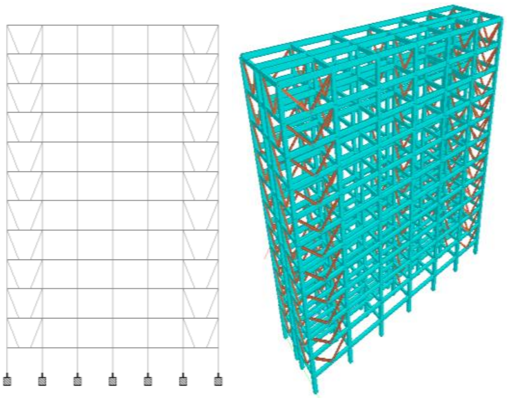
Fig 2: Plan of proposed structural frame



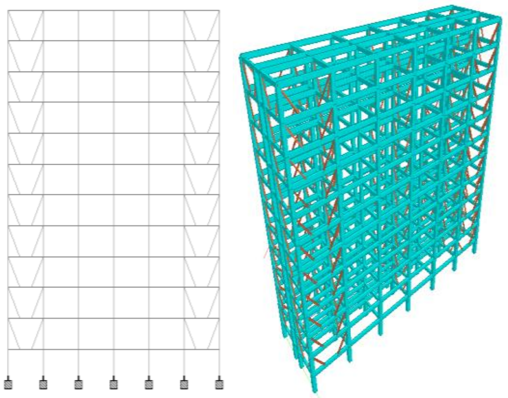
Case 1: Structure frame without Bracing system



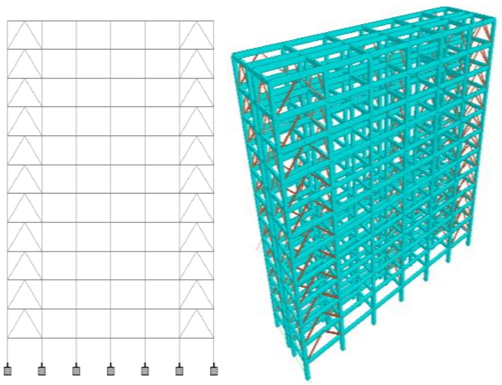
Case 2: Structure with X Bracing system



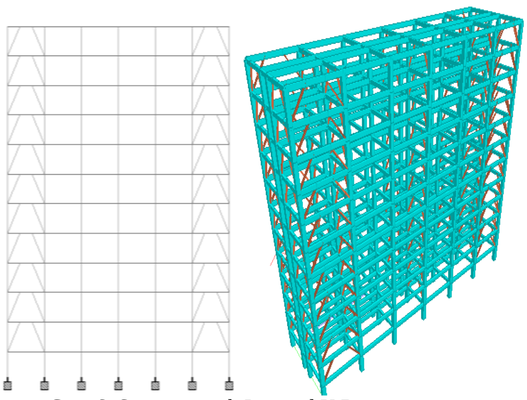
Case 3: Structure with V Bracing system



Case 4: Structure with K Bracing system



Case 5: Structure with Inverted V Bracing system



Case 6: Structure with Inverted K Bracing system

Fig 3: Proposed structure with different type of bracing systems

(b) MATERIAL AND GEOMETRICAL PROPERTIES

Following material properties are considered for the modelling of the proposed structure frame:-

Table 1: Details of Material and geometrical property

S. No.	Description	Parameter
1	Depth of foundation	3.0 m
2	Floor to Floor height	3.50 m
3	Grade of concrete	M-25
4	Type of steel	Fe-415
5	Column size (Bottom 2 storey)	0.6 m x0.6 m
6	Column size (top 8 storey)	0.5 m x0.5 m
7	Beam size in x-dir	0.3 m x 0.6 m
8	Beam size in z-dir	0.3 m x 0.5 m
9	Unit wt. of masonry wall	20 kN/m^3
10	Slab thickness	150 mm

(c) LOADING CONDITIONS

Following loadings are adopted for analysis:-

1) Dead Loads:
   a. Self weight of Slab = 3.75 kN/m^2
   b. Floor Finish load = 1 kN/m^2
   c. Wall Load in X direction= 11.6 kN/m
   d. Wall Load in Z direction= 12 kN/m

2) Live Loads:
   a. Live Load on typical floors = 4 kN/m^2

3) Earth Quake Loads: The earth quake loads are derived for following seismic parameters as per IS: 1893(2002)

   a. Earth Quake Zone-II,III,IV
   b. Response Reduction Factor: 5
   c. Importance Factor: 1
   d. Damping: 5%
   e. Soil Type: Hard Soil

III. RESULT & DISCUSSION

Find the results for axial force, shear force, bending, displacement, story drift etc & then compare the results to distinguish the effective system between provided different bracing systems in different seismic zones. Following tables and graphs are presented to find optimum system to resist seismic forces under following heads :-

a. MAXIMUM LATERAL DISPLACEMENT

The comparative study of lateral displacements in structures having different bracing systems is shown in table 2 & 3 and in Fig 4 & 5. It is found that the minimum displacement in structures are seen in X bracing and in Inverted V bracing for all seismic zones.

Table 2: Lateral Displacement (mm) in structures frames

Displacements (mm) Structure In X (Transverse) Direction			
Structure Types	ZONE-II	ZONE-III	ZONE-IV
Bare Frame	80.18	128.87	193.08
X Bracing	35.19	54.55	75.19
V Bracing	40.79	61.81	86.37
K Bracing	51.85	80.19	110.54
Inverted V Bracing	37.26	56.53	79.79
Inverted K Bracing	48.57	74.95	100.77

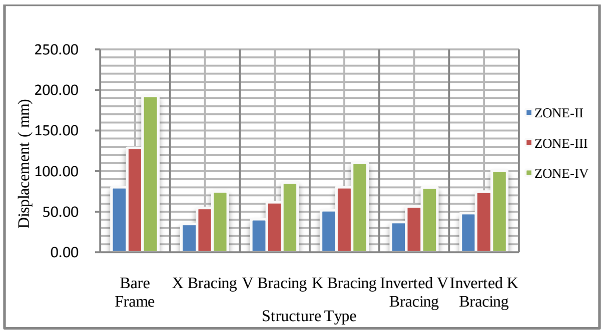


Fig 4: Lateral Displacements (mm) in X direction

Table 3: Lateral Displacement (mm) in structures frames

Top Story of The Structure In Z (Transverse) Direction			
Structure Types	ZONE-II	ZONE-III	ZONE-IV
Bare Frame	55.19	88.27	132.37
X Bracing	19.45	31.05	43.51
V Bracing	23.92	36.98	52.91
K Bracing	30.18	47.46	64.05
Inverted V Bracing	21.31	33.34	47.67
Inverted K Bracing	27.95	44.16	57.83

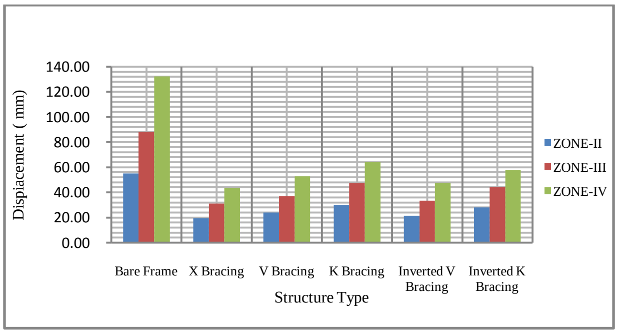


Fig 5: Lateral Displacements (mm) in Z direction

b. COLUMN FORCES

It is found that in Zone II minimum axial force comes in X bracing, in Zone III minimum axial force in Inverted V bracing, in Zone IV minimum axial Force is in X bracing. So in overall it may say that axial forces are reduced when we provide bracing system as they might be distributed in between members. It is observed that bending moment is significantly decreased in Zone II in Inverted K bracing, in Zone III in Inverted K bracing, in Zone IV in V bracing. It is observed that moments are considerably reduces by using bracing systems. It is also observed from study that minimum bending moment (in Z direction) observed in all Zones is in Bare Frame itself, but after providing bracing system moment may increases by some amount. This may be called as a limitation of bracing system which increases the moment in structure.

Table 4: Maximum Axial Forces (kN) in columns

Structure Type	ZONE II	ZONE III	ZONE IV
Bare Frame	7128.06	7128.06	7128.06
X Bracing	6956.89	6983.01	6938.43
V Bracing	6990.70	6987.18	6978.44
K Bracing	7010.99	7009.02	6996.74
Inverted V Bracing	6966.60	6964.09	6954.89
Inverted K Bracing	6998.48	6997.19	6983.22

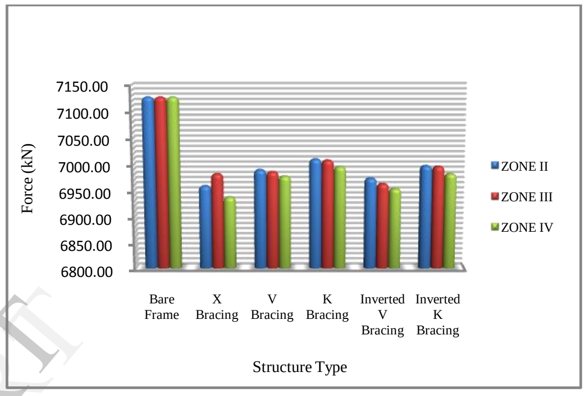


Fig 6: Maximum Axial forces in columns

Table 5: Maximum moments (kN-m) in columns

Structure Type	ZONE II	ZONE III	ZONE IV
Bare Frame	179.65	260.82	369.03
X Bracing	167.06	269.13	368.00
V Bracing	156.32	243.91	356.64
K Bracing	163.35	251.25	376.45
Inverted V Bracing	159.66	248.63	362.98
Inverted K Bracing	155.89	240.46	363.82

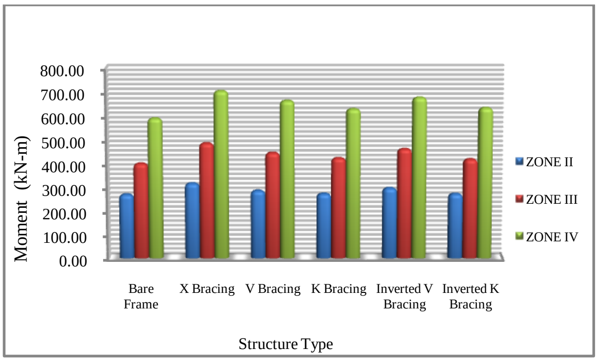


Fig 7: Maximum moment (M_y) in column of the structures

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c. BEAM FORCES

It is observed that bending moment in beams are maximum in bare frame structure. The use of bracing system reduces the bending moments in beams. Moment in beam members of structure is reduced by using bracing system up to a level of 17.34% in zone II in Inverted K bracing, 29% in zone III in Inverted V bracing, 37% in zone IV in Inverted V bracing system. Shear force in beams of structure systems is reduced to a level up to 2.22% in zone II in K bracing, 4.63% in zone III in V bracing, 29.07% in zone IV in V bracing system.

Table 6: Maximum Moments (kN-m) in beams

Structure Type	ZONE II	ZONE III	ZONE IV
Bare Frame	400.94	512.65	661.89
X Bracing	347.50	369.69	423.17
V Bracing	336.68	367.93	428.41
K Bracing	334.90	388.28	513.44
Inverted V Bracing	344.17	364.05	417.64
Inverted K Bracing	331.42	376.85	527.15

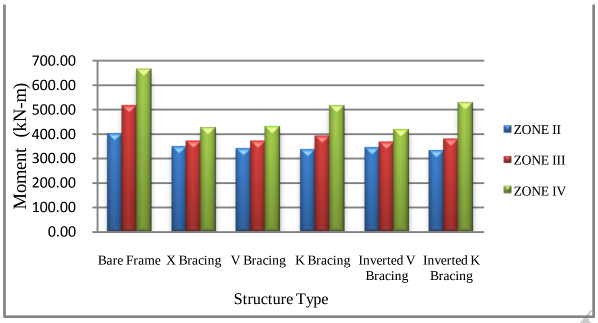

Fig 8: Maximum Bending Moments in beams

Table 7: Maximum Shear Forces (kN) in beams

Structure Type	ZONE II	ZONE III	ZONE IV
Bare Frame	230.29	236.44	319.39
X Bracing	228.04	228.50	229.91
V Bracing	225.23	225.50	226.55
K Bracing	225.18	268.93	417.16
Inverted V Bracing	227.26	227.52	228.59
Inverted K Bracing	225.79	266.79	421.51

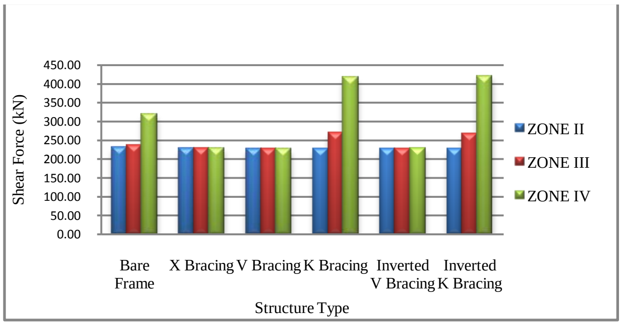

Fig 9: Maximum Shear force in beams

d. STORY DRIFT

After analysing the different structures in different seismic zones, it is observed that minimum story drift among different type of bracing system is in X bracing but Inverted V bracing also served in same manner as X bracing. Bracing reduces the drift up to a certain level such as X bracing reduces up to 55.83%, V bracing reduces up to 30.78%, K bracing reduces up to 19.50%, Inverted V bracing up to 56.79%, Inverted K bracing up to 55.07%.

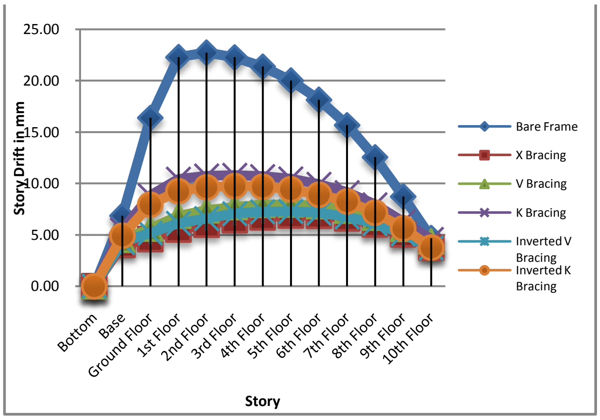

Fig 10: Story Drift (mm) in Floors of the structure

e. STORY DISPLACEMENT

Section displacement is also reduced to a great level such as X bracing reduces up to 62.05%, V bracing reduces up to 55.02%, K bracing reduces up to 39.72%, Inverted V bracing up to 57.77%, Inverted K bracing up to 44.45%. X bracing and V bracing are found to be more effective to control the story displacements.

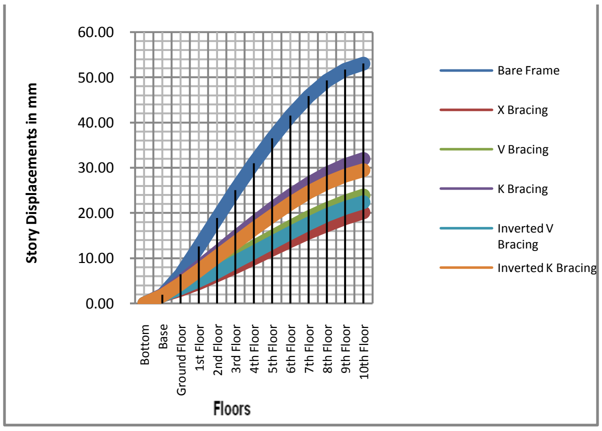

Fig11: Story Displacements (mm) in the Structures

f. QUANTITY OF MATERIAL USED

From table 8 & graphs 12 it is observed that required quantity of concrete is almost same in all the structure types but total weight of steel is comparatively minimum in inverted V bracing among all other bracing systems.

Table 8: Quantity of materials used in structure

Structure Type	Concrete (m3)	Steel Reinforcement (kN)	Bracing Weight (kN)	Total Steel used(kN)
Bare Frame	806.80	1208.29	0.00	1208.29
X Bracing	829.60	817.56	1161.42	1978.98
V Bracing	836.50	844.47	523.61	1368.08
K Bracing	838.30	927.81	720.62	1648.43
Inverted V Bracing	834.00	799.28	472.05	1271.32
Inverted K Bracing	838.30	907.73	782.18	1689.91

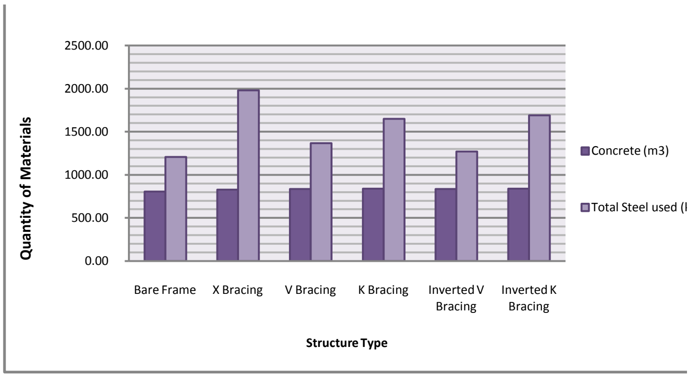

Fig 8: Comparison of Quantity of material used in structure

CONCLUSIONS

Following are the salient conclusions of the study:-

1. The concept of using steel bracing is advantageous to resist the seismic forces.
2. The bracing system effectively reduces the lateral displacement (up to 80%) of the structure compared to Bare frame.
3. Steel bracings the amount of forces in members significantly reduces.
4. Bracing system proves as a effective member to control the story drift (up to 56%) in structures as compare to Bare frames.
5. After using bracing member as a resistive member margin of safety against collapse increased.

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