SEISMIC PERFORMANCE OF A DIFFERENT (G+10) COMPOSITE RESIDENTIAL BUILDING FRAME

[1]*Mr. A. S. BOKE*, [2] *Prof. M. M. JOSHI*
[1]*PG Scholar* , [2]*Head of Department*
Department of Civil Engineering,
Pankaj Laddhal Institute of Technology Buldhana, S.G.B.A.U. University,
Buldhana–443001, Maharashtra, India.
anantaboke@gmail.com

ABSTRACT :
The majority of building frames are designed and constructed in reinforced concrete structures, depending upon the availability of constituent materials and the workmanship required in construction industry along with practicality of the existing design codes. Now a day to fulfill the demand of increasing population there is need of high rise building construction and today in India RC construction is popular to fulfill the demand of the construction industry. But since from last two decades construction industry experiences drastic changes due to increasing population demand, market condition, and availability of resources (men, money & material) etc. Which results new techniques of construction are introduced in the industry by inventors which give alternative solution to conventional construction. These are mix type or hybrid construction called as a composite construction, which are making efficient use of constituent material which can be more effective than conventional RC construction. The composite structures are the structures in which sections are made up of building different types of materials such as steel and concrete, which are used for construction of beams, columns, slabs, etc. Numbers of the studies are carried out on composite construction techniques by different researchers in different parts of the world and found it to be better seismic resistant and more economical as compared to RCC construction.

KEY WORDS : *Composite Consruction, Shear Connector, Pushover Curve, etabs software.*

1. Introduction

Now a day the steel-concrete composite construction can be a best suitable alternative to fulfill the rapidly increasing urbanization demand as compared to only steel or only reinforced concrete structure. Today the researchers or scientist in relevant field has got considerable success to understand the behavior of such type of mix-system or hybrid system. The much work is carried out in the foreign countries like us & japan. This type of hybrid structure is well understood & described in the foreign code such as ACI 318, Eurocode 4 etc. But there are no any such specific codal provisions in India, is 11384-1985 has provides some guidance related to shear connectors while connecting to steel beam but no any specific guideline or provisions for designing the steel-concrete composite structure. Hence there is lot of scope to improve the codal provision in relevant field to meet the design requirement. And there is lot of opportunity in Indian topography to meet the need of rapidly increasing urbanization in limited area. By study it is proved that the steel-concrete is best alternative in seismic region as the hybrid frame resist repeated loading very effectively compare to RCC. Hence this proposed work helps to understand the behavior of steel-concrete hybrid structure up to some extent which might be helpful to those who try to understand the behavior of composite or hybrid construction in all respect.

1. Now it is the demand of time that every structure must be analyzed and designed for lateral forces such as earthquake and wind forces.
2. Generally it is found that for resistance designs, the cross sectional area of RCC structural member comes out very heavy with large amount of steel, which takes large space in construction of multistory building, although in metropolitan cities there is a problem of space availability.
3. Under such circumstances composite structure is one of the best options, which not only takes care for earthquake forces but also gives less cross sectional area.
4. In composite construction economy of the construction and proper utilization of material is achieved.

Necessity of high rise Building :

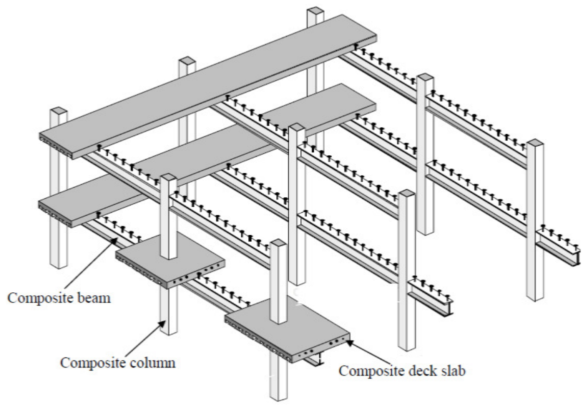
There are many reasons to construct high rise buildings and these are as follows:

1. Rapid growth of population in urban communities, and therefore the constant pressure of the limited land area affected the evolution of building.
2. Expensive land prices.
3. Restriction of random expansion in major cities adjacent to agricultural land.
4. The high cost of setting up infrastructure for new cities.

5. Expression of progress and civilization
6. Other factors, such as terrain conditions or the lack of land area.

2. COMPOSITE FRAME ELEMENT

A composite member is constructed by combining concrete member and steel member so that they act as a single unit. As we know that concrete is strong in compression and weak in tension on the other side steel is strong in tension and weak in compression. The strength of concrete in compression is complemented by strength of steel tension which results in an efficient section. By the concept of this composite member the concrete and steel are utilized in well-organized manner



The primary structural components used in composite construction consist of the following elements.

1. Composite slab
2. Composite beam
3. Composite column
4. Shear connector

3 DESIGN CONCEPT

For building design, it is commonly accepted to use rough estimates of the stiffness properties for reinforced concrete structures which gives many necessary simplifications employed for analysis and a presumption that can be modest variations in the member stiffness coefficients will not appreciably change the resulting member sizes. Consequently, traditional thumb rules, such as using one-half the gross moment of inertia for beams and the full moment of inertia for columns, are widely employed, even though they are known to be quite approximate. Advanced computer analysis technologies, improved knowledge about structural behavior and loads, and initiatives to develop multi-level performance-based design and analysis methods suggest a re-evaluation of stiffness properties used in design.

Deflections:

The assumed stiffness coefficients will directly impact on the design of structures which controlled by deflection criteria or slender of structure sensitivity to second-order effects. The 1995 edition of the ACI-318 building code incorporated for the first time explicit recommendations for stiffness parameters to use in the second-order analysis of slender columns, but this does not accept in wide range (i.e., at different limit states) of deflection related issues in design. For example, in studying seismic requirements for composite steel-concrete (RCS) frames, the structures are usually controlled by drift limits and thereby sensitive to stiffness modeling assumptions.

Internal Force Distributions:

For structures with conventional framing systems and regular geometry that are designed based on elastic analysis, the internal force distributions is usually not sensitive to the assumed stiffness coefficient. However this is not generally true for all cases. For example, where structures are inelastically designed to resist earthquakes and structural components are distinguished as either "force" or "deformation" controlled, accurate calculation of stiffness properties and the resulting internal forces become more important. Alternatively, in non-conventional systems such as hybrid wall & frame systems or mixed steel-concrete structures, the calculated internal force distribution can significantly vary depending on the assumed stiffness properties. The degree to which the calculated force distribution is inconsistent with the actual distribution can lead to larger than anticipated inelastic force redistribution and deformations.

Dynamic Response:

It gives the natural vibration frequencies of a structure which are proportional to the square root of its stiffness, the stiffness coefficients will affect dynamic effects induced by earthquakes or wind effects in flexible structures. Depending on the loading characteristics, and whether or not inelastic effects are modeled in the analysis, changes in the stiffness can have either a positive or negative effect on structural performance.

Performance-based engineering is another area where more accurate analysis techniques are warranted. Refinements applied to frame analyses would include more explicit modeling of-

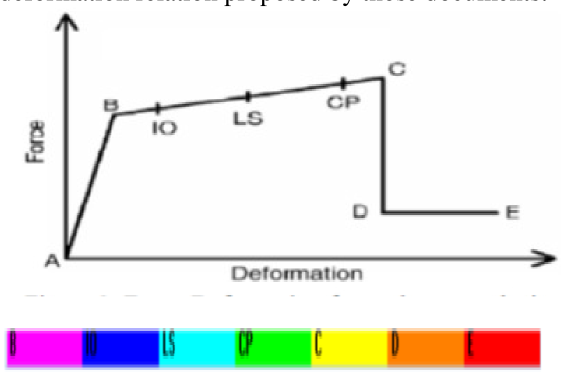
(1) Basic geometric features such as finite joint sizes, wall and foundation elements, etc.
(2) Second-order geometric effects, and
(3) Inelastic behavior of members and connections associated with concrete cracking, steel yielding, bond/slip, and nonlinear concrete compression behavior.

4 INELASTIC FRAME ANALYSIS

Aside from their use for elastic (linear) analyses, effective stiffness coefficients corresponding to initial yield conditions are often used to model the initial loading regions for inelastic analyses. There are two general categories of nonlinear analysis methods for frame structures, referred to herein as concentrated-hinge and spread-of-plasticity methods. The concentrated-hinge type can employ several strategies to model bi-linear, multi-linear or nonlinear response. One is through a mathematical assembly of multiple parallel elastic elements connected through rigid-plastic hinges that capture abrupt change of stiffness at various load levels. Alternatively, linear or nonlinear elastic-plastic springs can be devised to achieve similar behavior. Bi-linear models are often used where the first break-point occurs at member yielding, and in such cases the initial member stiffness would be the same as that used to model behavior up to the onset of yielding in an elastic analysis. For beam members, the hinges can be controlled by bending moments at the member ends, whereas for beam-columns, the hinges should take into account the interaction of moments and axial load. The spread-of-plasticity approach is more accurate than the concentrated-hinge method in that it directly models the distribution of nonlinear behavior through the cross section and along the member length. There are many variations on spread-of-plasticity implementations, but most rely on modeling inelastic cross section behavior at discrete sampling points along the member, either by explicitly integrating stresses and strains or through a stress-resultant yield-surface approach. The yield-surface implementation for reinforced concrete beam-columns is given herein for completeness. It employs an inner loading and outer bounding surface to model moment-curvature and axial force-strain behavior of the cross section under combined axial load and biaxial bending. Comparing this model to the cross section behavior, the elastic region inside the loading surface employs an effective stiffness bounded between the cracked and uncracked section properties that depend on the level of axial load. The rapid nonlinear reduction in stiffness outside the loading surface is represented by the kinematic hardening model that involves tracking the movement and proximity of the two surfaces to one another.

5. DETAILS OF PUSHOVER ANALYSIS

Pushover analysis provides a wide range of application options in the seismic evaluation and retrofit of structures. Mainly two guidelines are available for this analysis- fema356 and ATC 40. The pushover analysis of the structure represents a static nonlinear analysis under constant vertical loads and gradually increasing lateral loads. Equivalent static lateral loads approximately represent seismic generated forces. Analysis is carried out till to failure of the structures. This analysis identifies weakness in the structure so that appropriate retrofitting could be provided in governing element. Basically, demand and capacity are the two component of the performance based analysis and design where demand is a representation of the seismic ground motion and capacity is a representation of the structure ability to resist seismic demand. The performance is dependent in a manner that the capacity is able to handle the seismic demand. Once the capacity curve and demand displacement are defined, a performance check can be done. In our study, nonlinear static pushover analysis was used to evaluate the seismic performance of the structures. The numerical analysis was done by ETAB 2015 and guidelines of ATC-40 and FEMA 356 were followed. Overall evaluation was done using base shear, deflection, story drift and stages of number of hinges form. A plastic hypothesis was used to mark the nonlinear behavior according to which plastic deformations are lumped on plastic hinges and rest of the system shows linear elastic behavior. The discrete structural performance levels are- immediate occupancy (S-1), life safety (S-3), collapse prevention (S-5) and not considered (S-6). Whereas intermediate structural performance ranges are the damage control range (s-2) and the limited safety range(s-4).this definition of performance ranges is served by FEMA 356, 2000. The model frame used in the static nonlinear pushover analysis is based on the procedures of the material defining force – deformation criteria for the hinges used in the pushover analysis. Figure describes the typical force-deformation relation proposed by those documents.



Five points labeled A, B, C, D and E are used to define the force deflection behavior of the hinge and these points labeled A to B – elastic state, B to IO- below immediate occupancy, IO to LS – between immediate occupancy and life safety, LS to CP- between life safety to collapse prevention, CP to C – between collapse prevention and ultimate capacity, c to d- between c and residual strength, D to E- between D and collapse >E – collapse. In ETAB 2015, those points could be identified by color bands to understand how plastic hinges form in each stage. Where IO, LS and CP mean immediate occupancy, life safety and collapse prevention respectively.

Steps for Pushover Analysis of Buildings Using ETABS

ETABS provides a good interface for nonlinear statics analysis of structures. Following are the procedure followed for nonlinear static analysis of the buildings.

1. All the material properties, frame sections, load cases are defined and assigned.
2. Select all the beams and columns and assign hinge properties as per atc-40 to the frame elements. For beams default hinge of flexure (M3) and shear (V2) is

assigned and for column default hinges of axial force and bending moment (P M2 M3) is assigned.
3. Two static pushover cases are defined. Initially gravity load is applied to the structure and then lateral load along longitudinal direction is applied to the structure.
4. Initially linear static analysis is performed and building is designed as per is 456-2000 for defined load combinations.
5. After the design of building, static nonlinear analysis is performed to determine the pushover curve and performance point.
6. 3D models are created for all the considered building structures.

6. PLANNING SCHEDULE

The proposed building presented in report work for pushover analysis is multistoried (G+10) residential building.

Analysis of frame consists- confined steel-concrete composite frame as

1. CIS-RC (confined I section column with RC beam),
2. CIS-SB (confined I section column with steel beam),
3. CFT-RC (concrete filled square tube with RC beam),
4. CFT-SB (concrete filled square tube with steel beam),
5. EIS-RC (encase I section column with RC beam),
6. EIS-SB (encased I section with steel beam),
7. RCC frame
8. Steel frame

The analysis of pushover curve carried out using ETABS 2015

Table -1: Geometric & Material Properties

Description	RCC structure	Steel structure	Composite structure
Plan dimension	31m X 19m	31m X 19m	31m X 19m
Height of each story	3.00m	3.00m	3.00m
Total height	33.2m	33.2m	33.2m
Depth of footing	2m	2m	2m
Size of beam	300mm X 650mm	ISWB 550	300mm X 650mm ISWB 500
Size of column	750mm X 900mm	450mm X 900mm	Encased I section ISWB 550 300mm X 900mm 450mm X 900mm 600mm X 900mm 750mm X 900mm
Slab thickness	125mm	125mm	125mm
	150mm	150mm	150mm
Dead load	2kN/m2	2kN/m2	2kN/m2
Live load	4kN/m2	4kN/m2	4kN/m2
Seismic zone	III	III	III
Soil condition	Medium	Medium	Medium
Response reduction factor	5	5	5
Importance factor	1	1	1
Zone factor	0.16	0.16	0.16
Grade of concrete	M30	M30	M30
Grade of steel	Fe500	Fe500	Fe500

7. PUSHOVER CURVE RESULT

The seismic performance of a building can be evaluated in terms of pushover curve. The base shear vs. Roof displacement curve is obtained from the pushover analysis from which the maximum base shear capacity of structure can be obtained. Pushover analysis in ETAB software performs under FEMA 356 & ATC 40 guidelines. Software provides pushover curve which helps to know behavior of frame under gradually increasing loading. The graphs presented here are obtained for push 1 case.

RCC Frame

Monitored displacement MM	Base force KN
0	0
43.8	10354.5141
70.6	15156.8757
101.9	17986.8233
241.9	22581.529
350.9	24703.9025
354.5	24750.5151
357.1	24752.5751
360.2	24743.9216

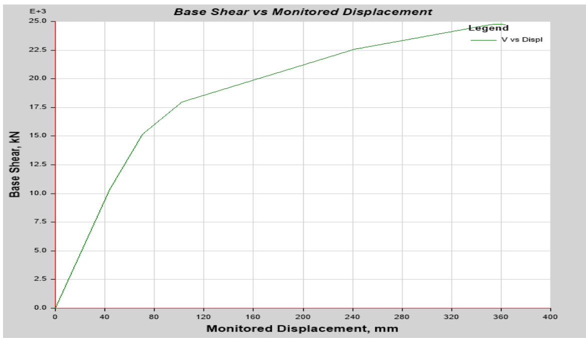


Fig 1. Pushover curve for RCC

Upto displacement 0 to 48.8 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 70.6 mm the structure goes to plastic stage till 101.9 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Steel Frame

Upto displacement 0 to 125.4 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 165.9 mm the structure goes to plastic stage till 189.9 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
125.4	19192.3463
165.9	24548.7908
189.9	26028.1243
224.1	26970.7248
224.1	26759.7195
225.2	26813.4262
297.4	28567.1307
209.7	15107.7012

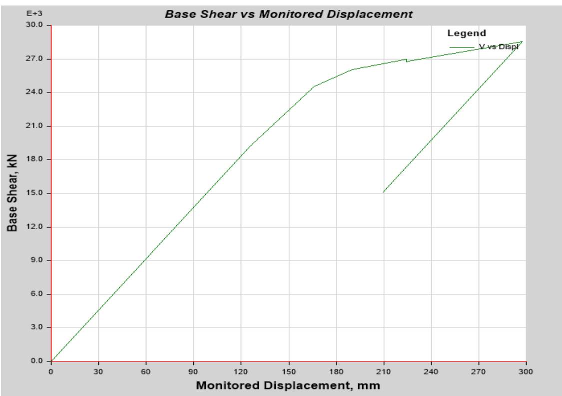


Fig 2 Pushover curve for Steel frame

CIS-RC Frame

Upto displacement 0 to 42.7 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 65.2 mm the structure goes to plastic stage till 94.3 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
42.7	10091.2311
65.2	14063.0811
94.3	16709.9512
224.7	20932.0989
349.3	23289.8722
351.6	23318.1492
355.2	23334.0121
357.6	23335.2062
361.7	23323.1588

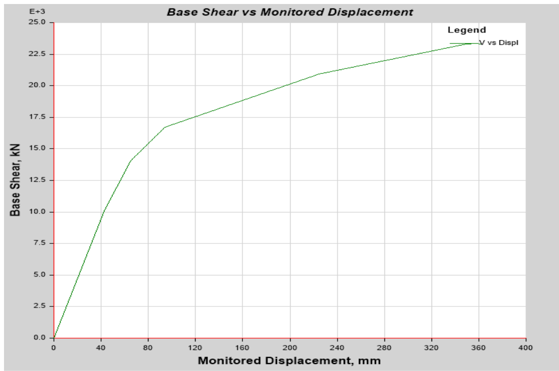


Fig 3 Pushover curve for CIS-RC Frame

CIS-SB FRAME

Upto displacement 0 to 152 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 157.4 mm the structure goes to plastic stage till 239.8 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
152	14030.6035
157.4	14524.2407
239.8	21192.4044
396.3	25852.3934
396.3	25325.1959
407	25731.8159
420	26009.2668
420	25465.6748

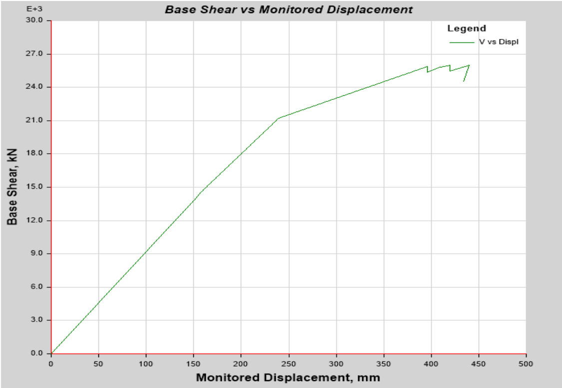


Fig.4 Pushover curve for CIS-SB Frame

CFT-RC Frame

Upto displacement 0 to 20.5 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 29.3 mm the structure goes to plastic stage till 30.9 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
20.5	11984.3918
29.3	16755.226
30.9	17234.956
37.6	18467.1215
75.6	21600.3172
279	28727.2144
279	28339.8221
280.1	28480.6769

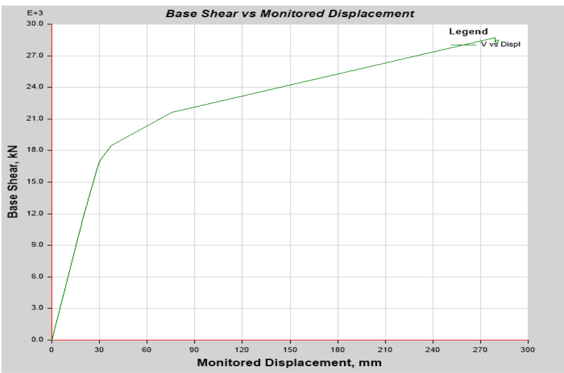


Fig.5 Pushover Curve For CFT-RC

CFT-SB

Upto displacement 0 to 125.4 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 165.9 mm the structure goes to plastic stage till 189.9 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
104.2	19571.9411
139.9	25494.2578
281.1	33209.9319
383.2	36789.6133
419.4	37499.7121
468.9	37982.7087
476.5	38014.7712
498.6	38195.4839

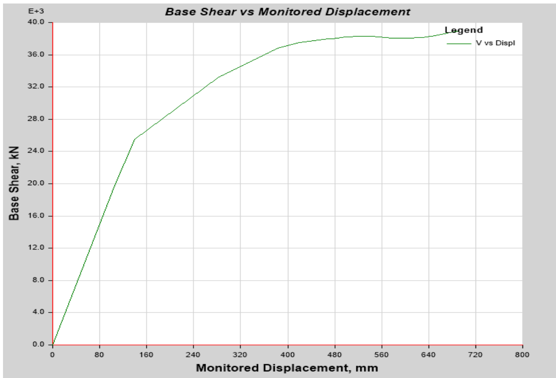


Fig.6 Pushover Curve For CFT-SB

EIS-RC Frame

Upto displacement 0 to 43.8 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 70.6 mm the structure goes to plastic stage till 101.9 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards the ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
43.8	10354.5141
70.6	15156.8757
101.9	17986.8233
241.9	22581.529
350.9	24703.9025
354.5	24750.5151
357.1	24752.5751
360.2	24743.9216

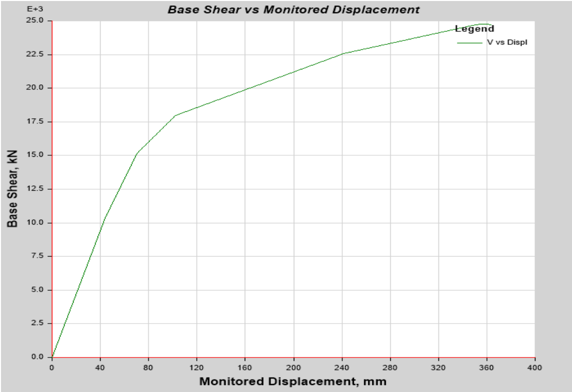


Fig.7 Pushover Curve for EIS-RC Frame

EIS-SB Steel-Concrete Composite Frame

Upto displacement 0 to 117.9 mm Hooks law is obeyed by the structure, the region is known as elastic region, here base shear is directly proportional to displacement, structure can regain its original shape after removal of load. After 160.1 mm the structure goes to plastic stage till 340.2 mm is reached at this point cross-sectoinal area of material starts decreasing and moves towards ultimate point where structure leads to failure.

Monitored displacement MM	Base force KN
0	0
117.9	18032.1051
160.1	23666.4292
340.2	30876.7708
375.4	31607.0578
392.2	31745.9052
392.2	31745.9053
395.3	31749.9938

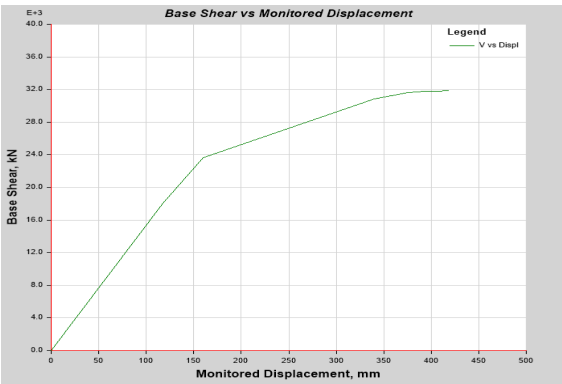


Fig. 8 Pushover Curve For EIS-SB

From the above given figures 1 to 8, it is seen that the structure behave in linear way provided the maximum base shear value experienced by respective frame in the adjacent table.

8. CONCLUSION

The base shear of composite with steel beam reduces up to 15% which also reduces seismic effect on structure as compared to RCC & composite with RC beam. Steel-concrete composite frame with steel beam shows maximum variation of displacement as compared to steel-concrete composite frame with RC beam & RCC frame. The most feasible column section is CFT-SB which gives minimum self-weight and base shear than others with high performance.

Hence briefly; steel-concrete composite with steel beam has better performance as compared to steel-concrete composite with RC beam & RCC frame. As the steel-concrete composite with steel beam is more ductile it gives better response to seismic forces as compared to composite with RC beam & RCC frame. And also all composite frames satisfies strong column weak beam concept.

9 REFERENCES:

1. Euro code 4, ―design of composite steel and concrete structure, European committee for standardization committee European de normalization europaisches committee fur normung.
2. Is: 456 (2000), "code of practice for plain and reinforced concrete", bureau of Indian standards, New Delhi.
3. Is: 11384 (1985), "code of practice for composite construction in structural steel and concrete", bureau of Indian standards, New Delhi.
4. Balaji. U. A, Mr. Selvarasan M.E. design and analysis of multi-storeyed building under static and dynamic loading conditions using ETABS international journal of technical research and applications e-issn: 2320-8163,www.ijtra.com volume 4, issue 4 (july-aug, 2016), pp. 1-5
5. K. Mukesh Kumar, H. Sudarsana Rao, seismic analysis of steel concrete composite, international journal of science and research (IJSR)
6. Anirudh gottala, Kintali sai nanda kishore and Dr. Shaik Yajdhani comparative study of static and dynamic seismic analysis of a multistoried building IJSTE - international journal of science technology & engineering volume 2 issue 01 july 2015 issn (online): 2349-784x
7. Mahesh N. Patil, Yogesh N. Sonawane seismic analysis of multistoried building issn: 2277-3754 iso 9001:2008 certified international journal of engineering and innovative technology (ijeit) volume 4, issue 9, march 2015
8. S. C. Pednekar, h. S. Chore, S. B. Patil pushover analysis of reinforced concrete

structures international journal of computer applications (0975 – 8887) international conference on quality up-gradation in engineering, science and technology (2015)

9. G. Urian A. Haupt-Karp- bulletin of the Transilvania university of Braşov, 2015, frame structures. Steel-concrete composite structures versus traditional ones- vol. 8 (57) special issue no. 1 – 2015
10. Mr. Nitish A. Mohite1, Mr. P .K. Joshi, dr. W. N. Deulkar, comparative analysis of RCC and steel-concrete-composite (B+G+ 11 storey) building, international journal of scientific and research publications, volume 5, issue 10, october 2015
11. Anamika Tedia, Dr. Savita Maru cost, analysis and design of steel-concrete composite structure RCC structure iosr journal of mechanical and civil engineering (iosr-jmce) e-issn: 2278-1684,p-issn: 2320-334x, volume 11, issue (jan. 2014), pp 54-59
12. A. Zona , M.M. Barbato & J. P. Conte, nonlinear dynamic analysis of steel-concrete composite frame structures under earthquake excitation
13. Shweta A. Wagh, dr. U. P. Waghe, comparative study of RCC and steel concrete composite structures int. Journal of engineering research and applications issn : 2248-9622, vol. 4, issue 4(version 1), april 2014, pp.369-376