Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 4, Issue 12, December -2017

Seismic Analysis of Multistory Buildings Using ETABS-A Review

Mayur R. Rethaliya[1], Nirav S. Patel [2], Dr.R.P.Rethaliya [3]

[1] *P G Student, Civil Engineering Department,*
Sardar Patel College of Engineering ,Bakrol, Anand.

[2] *Assistant Professor, Civil Engineering Department,*
Sardar Patel College of Engineering ,Bakrol, Anand.

[3] *Senior Lecturer, Applied Mechanics Department,*
B.&B.Institute of Technology,Vallabh VidyaNagar-388120,Anand.

Abstract — *India is prone to strong earthquake shaking, and hence earthquake resistant design is essential. The Engineers do not attempt 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. Practically no building can be made earthquake proof. The engineering intention is to make buildings earthquake resistant, such buildings resist the effects of ground shaking, although they may get damaged severely but would not collapse during the strong earthquake. Thus, the safety of people and contents is assured in earthquake resistant design of buildings and thereby a disaster is avoided. This is a major objective of seismic design codes throughout the world in recent times. The sixth revision of IS 1893 (Part 1): 2016, "Criteria For Earthquake Resistant Design Of Structures" have been published by Bureau of Indian Standards recently in December 2016. In this new code many changes have been included considering standards and practices prevailing in different countries and in India.*
Extended Three-dimensional Analysis of Building Systems – "ETABS 16.2" is a special purpose computer program developed specifically for building systems .The main objective of this study is to review seismic analysis of multi story buildings by various researchers using ETABS as per the provisions of IS 1893 (Part 1): 2016. The various parameters considered in analysis by researchers are Geometric irregularity, mass irregularity, re-entrant corners, different locations of shear walls, different building shapes, masonry infill walls, etc.

Keywords*- Seismic analysis, Earthquake Resistant Design, Re-entrant corners, Shear wall, Geometric irregularity.*

I. INTRODUCTION

Design of buildings wherein there is no damage during the strong but rare earthquake is called earthquake proof design. The engineers do not attempt 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. The aim of the earthquake resistant design is to have structures that will behave elastically and survive without collapse under major earthquakes that might occur during the life of the structure. To avoid collapse during a major earthquake, structural members must be ductile enough to absorb and dissipate energy by post elastic deformation.

The design philosophy adopted in the code is to ensure that structures posses at least a minimum strength as below:

(1) Under minor but frequent shaking the main members of the building that carry vertical and horizontal forces should not be damaged, however, non-load bearing elements may sustain repairable damage. i.e. minor earthquake < DBE.

Design Basis Earthquake [DBE] is defined as the maximum earthquake that reasonably can be expected to occur at least once during the design life of the structure.

(2) Under moderate but occasional shaking, the main members may sustain repairable damage while the other parts of the building may be damaged such that they may even have to be replaced after earthquake. i.e. moderate earthquake = DBE.

(3) Under strong but rare shaking, the main members may sustain severe damage but the building should not collapse. i.e. major earthquake > MCE. Generally, the DBE is half of MCE.

Methods of Elastic analysis :

Following methods of elastic analysis are covered under IS 1893 (Part 1)-2002 and 2016:

(a) Equivalent static method
or Seismic coefficient method
or Static coefficient method

(b) Dynamic analysis method.
Dynamic Analysis can be performed in three ways:
-Response spectrum method
- Modal Time History method, - Time history method.

@IJAERD-2017, All rights Reserved

II. LITERATURE REVIEW

S.K.Ahirwar, S.K.Jain and M.M.Pande(2008)[1] estimated earthquake loads on multi storey R.C. Framed buildings as per IS:1893-1984 and IS:1893-2002 recommendations. They considered three, five, seven and nine storey buildings and each were analyzed individually. For each building a set of five individual sequences were decided in process. The methods of analysis adopted were Seismic Coefficient method, Response Spectrum method and Modal Analysis method. Seismic responses viz. storey shear , base shear computed as per the two versions of IS:1893 for all the four buildings were compared. The following conclusions were drawn from the above study:
In both versions of codes IS: 1893-1984 and IS:1893-2002, the seismic design approach is to design strong and ductile structure to take care of inertia forces generated by earthquakes. The new version of IS:1893-2002, clearly reflects that the design seismic force is much lower than what can be expected from strong ground shaking.
Seismic forces obtained by IS:1893-2002 are relatively higher than that obtained by IS:1893-1984.
As per IS:1893-1984, Seismic Coefficient method gives higher base shear values as compared to Response Spectrum method and Modal Analysis method. Modal Analysis method gives higher values of lateral forces for upper storey.

S.Mahesh and Dr.B.Panduranga Rao(2014)[2] made comparative study of analysis and design of multi storey building using ETABS and STAAD PRO, with regular and irregular configurations, different seismic zones and different soil conditions. A G + 11 storey residential building was analyzed considering earthquake force and wind acting simultaneously. The structure response in the form of storey drift, displacements and base shear have been plotted for different seismic zones and different soil conditions, namely, soft, medium and hard.
The results shows that the regular configuration gives higher values of base shear as compared to irregular configuration because regular configuration structure has more symmetrical dimensions. Further, soft soil yields higher base shear as compared to medium and hard soils. The storey drift values are also more in building with regular configuration. Finally, STAAD PRO gives higher values of base shear as compared to ETABS. The steel requirement is about 8-10% more with STAAD PRO.

Ramanujam I V R and Dr. H Sudarsana Rao(2015)[3] made comparative study of seismic forces based on Static and Dynamic analysis as per IS:1893-2002(part I). Two case studies have been studied. Case-1 building is G+11 storey building having 42.45m height resting on hard soil, situated in seismic zone-II. The structure was modeled as space frame with DL, LL, WL and EL were applied as member weights. Alternatively, these weights can be applied as joint weights (lumped masses).
Case-2 building consists of basement + stilt floor + 11 floors, totaling 13 floors. The height of building was 42.70m resting on hard soil strata and situated in seismic Zone-III.
For case-1, the result shows that the base shear values by static analysis [Seismic coefficient method] and dynamic analysis [Response Spectrum method] are comparable in X-direction and Z-direction. Dynamic analysis yields lower values of storey shear as compared to static analysis. Further, storey moments by dynamic analysis are also have smaller values as compared to static analysis.
For case-2, dynamic analysis gives higher base shear values than static analysis in X-direction, but in Z- direction dynamic analysis gives lower values. The storey shear values obtained by dynamic analysis are lower than those obtained by static analysis.Further, storey moments by dynamic analysis are also have smaller values as compared to static analysis. Static analysis gives higher storey shear values compared to dynamic analysis, hence, Response Spectrum method may be used for seismic zone-II and III to optimize the design.

Haroon Rasheed Tamboli and Umesh N Karadi(2012)[4] studied seismic analysis of RC framed structure with and without brick masonry infill walls. In RC framed buildings masonry infill are considered as non-structural elements. The stiffness contribution of masonry infill walls is generally ignored in practice, such an approach may lead to an unsafe design.
The masonry infill panels has the significant impact on the behavior of structure during earthquake shaking. The masonry infill walls act as diagonal struts and increases structural strength and stiffness (relative to a bare frame). It reduces the lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. The considerations of infill walls in the analysis and design leads to slender frame members, thus, reducing the overall cost. The brick infill walls(panels) results in stiffer structure, reducing storey drift. The total base shear experienced by a building during earthquake depends on its time period. Stiffer buildings have smaller time period and thus, experiences larger base shear. Brick infill panels increases lateral resistance and energy dissipation of the structure. Hence, it is more realistic to consider brick infill walls in structural design as a structural element for earthquake resistant design.
Three types of RC frame building models have been considered in this study-namely, bare frame, infilled frame and open first storey frame. The seismic analysis has been performed using Equivalent lateral force method by using ETABS software. The masonry infill panels were modeled by Equivalent diagonal strut method. The parameters studied are time period, natural frequency, base shear and storey drift.
The analysis results shows that the time period of infilled frame is shortened because of increase in stiffness of the frame. The natural frequency of the infilled frame increases due to decrease in time period. The storey drift of the infilled frame is also less as compared to bare frame. The base shear of the infilled frame is more than that of bare frame.

The consideration of infill wall significantly affect the seismic behavior of the structure, increasing strength and stiffness of the structure. The seismic analysis of structure without infill walls leads to under estimation of base shear leading to collapse of the structure during earthquake. Hence, it is important to consider brick infill walls in the seismic analysis of structures for safer design.

Deshmukh Vishwajeet and Dr. Shrirang Tande(2016)[5] studied the effect of masonry infill on the seismic response of a RC framed structure using Response Spectrum method. They consider three models for the analysis- bare frame, in filled frame and in filled frame with opening. The parameters to be studied were time period, base shear and displacement. For modeling of masonry in fill panels equivalent diagonal strut method was used. The analysis was carried out using ETABS 2015 software.
The thickness of masonry infill and the number of frame panels in filled with brick masonry, affect the stiffness of the frame. For designing masonry infill frame, two different approaches can be considered. As first approach, masonry infill is considered as part of the structural system and assumed to brace the frame against lateral loading. In the second approach, the frame is designed to carry total vertical and lateral loading. IS:1893-2002 does not give any provision for considering the masonry infill in analysis.
For the modeling of in-filled frame structure, the Equivalent diagonal strut method is widely used. In this model, columns and beams are designed as frame members having six degree of freedom at each node and the brick infill is replaced by diagonal strut with pin joints at ends.

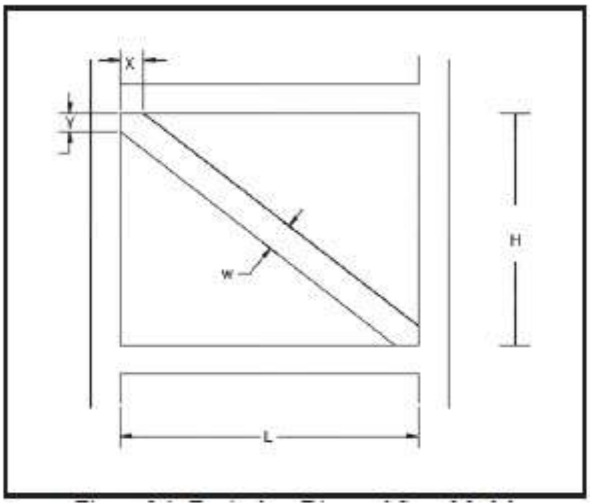

Fig. 1 Equivalent Diagonal Strut Model

The width of the equivalent diagonal strut can be computed using Smith's formula as under: [Fig.1]
$w = 1/2\sqrt{(X^2 + Y^2)}$
where, $X = \pi/2 \times \sqrt[4]{[4E_f I_c H/E_m t \sin 2\Theta]}$
$Y = \pi \times \sqrt[4]{[4E_f I_b L/E_m t \sin 2\Theta]}$
where,
w= width of equivalent diagonal strut
E_m= Elastic modulus of the masonry infill material
E_f= Elastic modulus of the frame material
L= length of the infill wall
H= height of the infill wall
I_c= Moment of inertia of column
I_b= Moment of inertia of beam,
t = thickness of infill wall
Θ= Slope of the infill diagonal with horizontal
The ETABS analysis results shows that the storey shear for infill frame is more as compared to bare frame and infill frame with openings. Bare frame gives least storey shear. The ground storey experiences the maximum storey shear. Similarly, the displacement of infill frame is less as compared to bare frame and infill frame with openings because of increase in stiffness due to infill. The time period of infill frame is less as compared to bare frame and infill frame with openings.
The authors concluded that the accounting of masonry infill as equivalent diagonal strut reduces the displacement of the structure and storey drift and gives higher values of base shear.

Balaji U.A and Selvarasan M.E.B(2016)[6] carried out analysis and design of multi storey residential building G + 13, in ETABS under static and dynamic conditions. Linear Static procedure, Response Spectrum method and Time history analysis were used for analysis.

@IJAERD-2017, All rights Reserved

The graphical output shows that the displacement of structure increases with increase in building height. For the first five stories, the results obtained by different methods do not differ much. The Time history analysis gives the maximum displacement of the centre of mass.

Mahesh N Patil and Yogesh N Sonaware(2015)[7] studied earthquake response of multistoried building, 8 storey, 22.5m x 22.5m symmetric in plan, with uniform storey height of 3m. They carried out manual calculations of base shears as per IS:1893-2002 and the results were compared with analysis done in ETABS 9.7.1. The structure is situated in seismic zone-III, soil type-II and response reduction factor as 3. The time period was calculated as per IS:1893-2002 as 0.427 second.
They observed that there is gradual increase in lateral force from bottom floor to top both in software analysis and manual calculations. The seismic weight calculations by manual procedure and software yields the same results. But the base shear values obtained by manual calculations were found to be slightly higher than that of software analysis. The authors suggested to compare their results with Response Spectrum method and Time history analysis.

Ni Ni Win, Kyaw Lin Htat(2015)[8] presented comparative study of Static and Dynamic analysis of multistoried RC framed building 12 storied, subjected to earthquake loads. The analysis was done in ETABS, load combinations are based on Uniform Building Code-UBC 1997 and the structure was designed as per American Concrete Institute-ACI-318-99 provisions. The structure was analyzed, firstly, with static analysis and then with response spectrum method (Dynamic analysis) and the comparison of results was made. The various parameters compared are- displacement, storey shear, storey drift and storey moments.
The authors found that in X- direction, from storey 1 to 4, the displacements in static analysis were less than dynamic analysis, but were higher in storey 5 to 12 than dynamic analysis. But, in Y-direction, the displacements in static analysis were less than dynamic analysis in all stories. In X- direction the difference of storey moment in both methods was higher. The difference of storey drift was insignificant in both the directions. The authors were of the opinion that for irregular buildings static analysis is insufficient, and dynamic analysis must be carried out.

Mohit Sharma and Savita Maru(2014)[9] carried out static and dynamic analysis of G + 30 storied regular building as per the guidelines of IS: 1893-2002(Part-I) using STAAD PRO for zone-II and III. The plan dimensions of building are 25m x 45m, storey height 3.6m and depth of foundation as 2.4m.
The authors found that the values of torsion at different points in beams were negative in static analysis, but in dynamic analysis torsion values were positive. The displacement values in beams at different points were 17 to 28% higher in dynamic analysis than in static analysis. Similarly, the moments values were 10 to 15% higher in dynamic analysis than in static analysis.

N Janardhana Reddy, D Gose Peera, T Anil Kumar Reddy(2015)[10] studied seismic analysis of high rise building 14 storied, with different locations of shear walls using ETABS-2013. They studied to determine the ideal location of shear walls in high rise buildings to minimize the effect of torsion. Two different zones -II and V were considered for seismic analysis. The analysis was done by Equivalent Static method and Response Spectrum method.
The authors concluded that the maximum displacement reduces considerably by providing shear walls. The shear force and moments values are also reduced considerably for a building with shear walls. In symmetric structures, as centre of mass and centre of stiffness are closer, the performance of structure with shear wall is better. The inclusion of shear wall in buildings increases stiffness and reduces displacements. By providing shear walls, shear force and moments resisted by columns is reduced as major forces are resisted by shear walls. The shear walls provided from foundation to the top of the building are very effective in resisting lateral loads. For symmetrical buildings, shear walls placed symmetrically on the outer periphery of the building are more effective.

Paradeshi Sameer and N G Gore (2016)[11] carried out seismic analysis of multistoried buildings with symmetrical and asymmetrical configurations. Response Spectrum analysis was carried out for regular and irregular buildings. Time history analysis was carried out for regular building. G + 15 storied buildings models were analyzed using ETABS as per IS:1893-2002, and ductile detailing was carried out as per IS:13920-1993.
Four types of plan irregularities-regular shape, L-shape, T-shape and + shape were considered for analysis. In mass irregularity, uniform mass distribution was considered except swimming pool at seventh and thirteenth floor with weight 20 kN/m^2. The ground storey was soft storey.
The regular and L-shaped buildings have storey displacement almost similar. T-shaped building experienced maximum storey displacements. For T-shaped building storey drift was maximum and for + shaped building it was minimum. The base shear values for regular shape, L-shape and T-shape were nearly same, and for + shape building base shear values were smaller. Therefore, plan configurations of buildings has significant effect on seismic response of the structure. It was recommended that Time history analysis should be performed as it predicts the structural response more precisely than Response Spectrum method.

@IJAERD-2017, All rights Reserved

Mohammed Rizwan Sultan, D.Gouse Peera (2015)[12] carried out dynamic analysis of a 15 storey multistoried building with different shapes like rectangular, L-shape, H-shape, and C-shape. The analysis was done in ETABS 9.7.1. They studied parameters like, storey overturning moment, storey drift, displacements, design lateral forces, etc.
Results shows that buildings with higher irregularity, produces more deformations. The L-shaped building gives lowest base shear values, while rectangular building gives higher base shear values. C-shaped building is more vulnerable compare to other shaped buildings. The authors concluded that regular shaped buildings perform well during earthquake as compared to irregular shaped buildings.

Jiang Zhinan and Zhao Zhonghai(2012)[13] carried out comparison of horizontal seismic forces (base shear) computed by equivalent lateral force method using new Chinese Seismic Code- GB50011-2010, American Code - ASCE/SE17-05 and European Code- Euro code 8. The base shear calculation method given in respective codes were followed. They studied three story reinforced concrete frame building under the same conditions.
The Chinese Seismic Code- GB50011-2010 has specified seismic influence coefficient curve from which design response spectrum can be determined for fundamental time period T. For maximum horizontal seismic influence coefficient (α_{max}) values are given for different intensity from 6 to 9. Characteristic period Tg values are given for seismic group 1, 2 and 3 and five types of site conditions. [Fig.2]

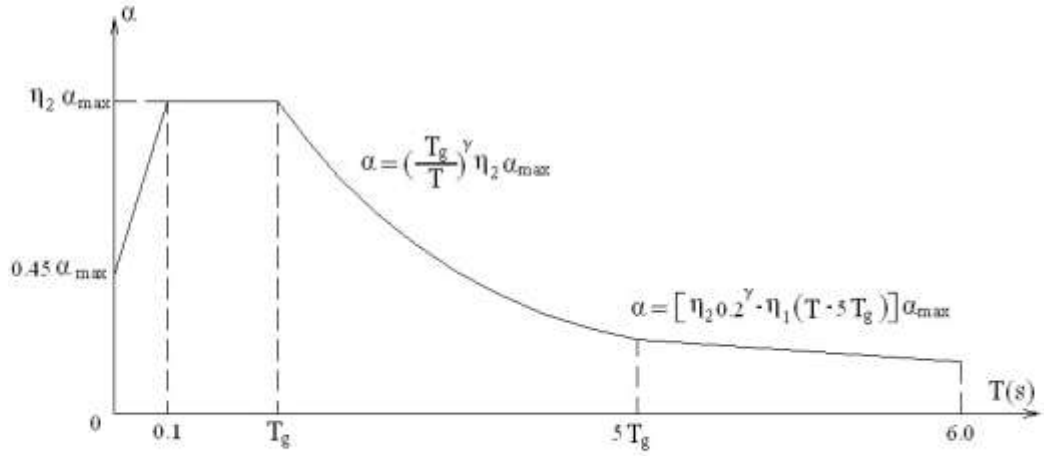

Fig. 2 Seismic Influence Coefficient curve [GB50011-2010]

Equations for power index of the curvilinear decrease section γ, adjustment factor of slope for the linear decrease section η_1 and damping adjustment factor η_2 are specified in the code.
For structures less than 40m height, distribution of mass and stiffness is almost uniform throughout the height and deformation is mainly produced by shear. The structure is regarded as a single mass system, one degree of freedom and base shear method is used. The horizontal seismic force can be determined by:
$F_{EK} = \alpha_1 . G_{eq}$
where, $F_{EK=}$ Characteristic value of total horizontal seismic action of structure.
α_1= horizontal seismic influence coefficient
G_{eq}= equivalent total gravity load of a structure
The American Code - ASCE/SE17-05, has indicated response spectrum curve as under. [Fig.3]

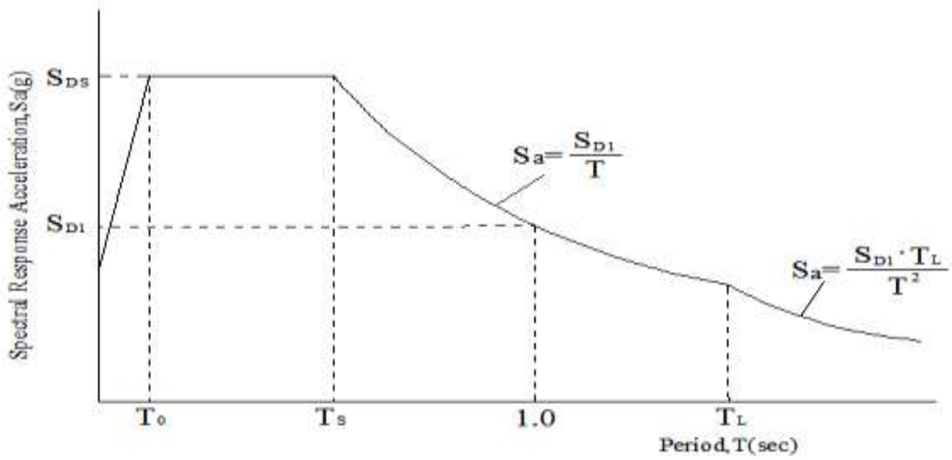

Fig.3 Design Response Spectrum in ASCE/SEI7-05

The equivalent lateral force method can be applied to- regular or irregular buildings in seismic class B and C, all light frame buildings, regular buildings having natural period less than 3.5 seconds, or only horizontal or vertical irregular building in seismic class D, E and F.

The seismic base shear V can be determined as under:

$V= C_s W$

where, V= seismic base shear

C_s= seismic response coefficient

W= effective seismic weight of structure

The Euro code 8 [EN1998-1:2004] has given horizontal elastic response spectrum curve as below: [Fig.4]

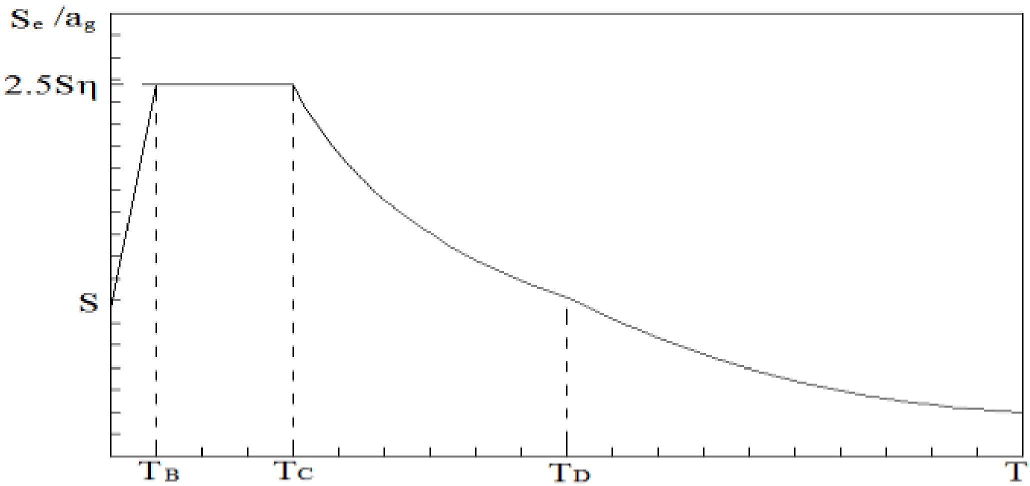

Fig 4 Elastic response spectrum [Euro code 8]

The seismic base shear F_b shall be determined as:

$F_b= S_d. T_1. m\lambda$

Sd (T_1) = the ordinate of the design spectrum at period T_1;

T_1= the fundamental period of vibration

m = the total mass of the building

λ = the correction factor, the value of which is equal to : λ = 0.85 if T_1< 2TC and the building has more than two stories, or λ = 1.0 otherwise.

The results shows that the base shear values computed from Chinese Seismic Code- GB50011-2010, is largest followed by American Code - ASCE/SE17-05 and European Code- Euro code 8.

The error in horizontal shear at top may be up to 25% in case of long period. Chinese Seismic Code- GB50011-2010 uses top additional horizontal seismic action for adjustment, while the other two codes have not given any conditions.

For vertical distribution of base shear on each story, Chinese and American code assign the base shear with each floor load multiplied by distance of floor from bottom. Euro code 8 use each floor load multiplied by the displacement of that floor in the fundamental mode shape.

Gunay Ozmen , Konuralp Girgin, and Yavuz Durgun (2014)[14]investigated torsional irregularity in multi storey structures. They investigated six groups of typical structures with varying shear wall positions, story, and axis numbers. They found that torsional irregularity coefficients increase as the story numbers decrease, i.e., maximum irregularity coefficients occur for single-story structures As per ASCE 7-10(2010) torsional irregularity coefficient is defined as :

$\eta_t =\delta_{max}/\delta_{avg}$

where, δ_{max}= maximum displacement at level x

δ_{avg}= average displacement at extreme points of the structure at level x

The other conclusions derived are, as the story number increase the floor rotation increases.

Torsional irregularity coefficient reaches maximum values when the asymmetrical shear walls are placed close to the centre of mass. Floor rotations attained their maximum values when shear walls are in farthest position from the centre of mass. The results of torsional irregularity and floor rotations are contradictory. As per their opinion floor rotations are the real representative of the torsional behavior, torsional irregularity coefficients as defined in various codes should be amended. They proposed new definition of torsional irregularity as

$\eta_{ti} = K.\theta i$

where, θi= rotation of ith floor in radians and preliminary value of K=1500.

M. S. Razzaghi and M. Javidnia (2015)[15] studied evaluation of the effect of infill walls on seismic performance of RC dual frames. Masonry infill have beneficial as well as disadvantageous effect on the performance of RC framed buildings. Practicing engineers normally neglect the effect of masonry infill on seismic behavior of structures. The

@IJAERD-2017, All rights Reserved

authors investigated seismic response of 18 models of the same structure with different arrangement of the infill walls to 4 different ground motions using PERFORM 3D software.
To investigate the effect of the arrangement of infill on seismic performance of building non-linear history analyses were performed. They revealed that with different arrangements of infill, seismic performance in terms of energy dissipation and experienced damage state changes significantly. The cumulative energy dissipation in different arrangements of infill walls may vary up to 400 %. The location of plastic hinges also changes. Out of the elements like column, beam, infill and shear wall, maximum energy dissipation takes place in infill walls. [Fig.5]

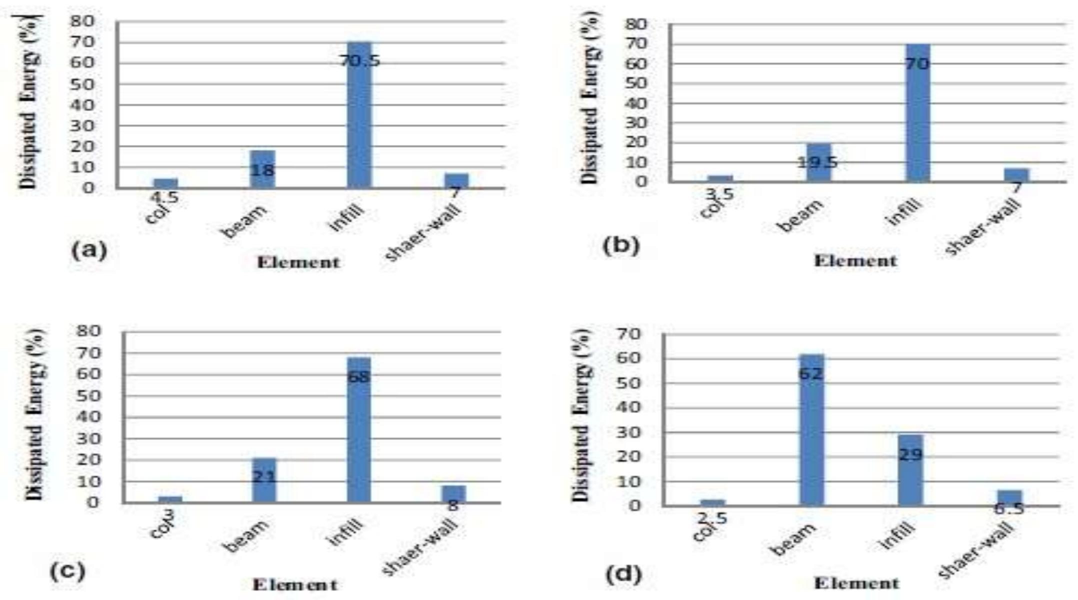

Fig. 5 Relative energy dissipation in structural elements and infill walls due to
a Van earthquake b Northridge Earthquake
c El-Centro earthquake d Chi–Chi earthquake

III. CONCLUSIONS

The following conclusion are made from the literature review as mentioned above:
1. The literature available is based on the provisions of old seismic codes IS 1893-1984 and IS 1893-2002.
2. Majority of researchers have made comparison of lateral forces, base shears, story moments, etc. by - changing seismic zones
- changing number of stories, introducing vertical mass irregularity, introducing horizontal mass irregularity
- introducing vertical stiffness irregularity, changing structural system, OMRF, SMRF, etc.
3. Few researchers have carried out comparison of horizontal seismic forces (base shear) computed by equivalent lateral force method using new Chinese Seismic Code- GB50011-2010, American Code - ASCE/SE17-05 and European Code- Euro code 8.
The results shows that the base shear values computed from Chinese Seismic Code- GB50011-2010, is largest followed by American Code - ASCE/SE17-05 and European Code- Euro code 8.
4. Study on effect of shape of building shows that buildings with higher irregularity, produces more deformations. The L-shaped building gives lowest base shear values, while rectangular building (regular shaped) gives higher base shear values. C-shaped building is more vulnerable compare to other shaped buildings. The authors concluded that regular shaped buildings perform well during earthquake as compared to irregular shaped buildings.
5. One of the study revealed that Seismic forces obtained by IS:1893-2002 are relatively higher than that obtained by IS:1893-1984.
As per IS:1893-1984, Seismic Coefficient method gives higher base shear values as compared to Response Spectrum method and Modal Analysis method.
6. Comparative study of analysis and design of multi storey building using ETABS and STAAD PRO, with regular and irregular configurations, different seismic zones and different soil conditions shows that the regular configuration gives higher values of base shear as compared to irregular configuration because regular configuration structure has more symmetrical dimensions.
Further, soft soil yields higher base shear as compared to medium and hard soils. The storey drift values are also more in building with regular configuration.

@IJAERD-2017, All rights Reserved

Finally, STAAD PRO gives higher values of base shear as compared to ETABS. The steel requirement is about 8-10% more with STAAD PRO.

7. Comparative study of seismic forces based on Static and Dynamic analysis as per IS:1893-2002(part I)for 42 m high building in zone-III, shows that Dynamic analysis gives higher base shear values than static analysis in X-direction, but in Z- direction dynamic analysis gives lower values. The storey shear values obtained by dynamic analysis are lower than those obtained by static analysis. Further, storey moments by dynamic analysis are also have smaller values as compared to static analysis. Static analysis gives higher storey shear values compared to dynamic analysis, hence, Response Spectrum method may be used for seismic zone-II and III to optimize the design.

8. Seismic analysis of RC framed structure with and without brick masonry infill walls revealed that masonry infill walls act as diagonal struts and increases structural strength and stiffness (relative to a bare frame). It reduces the lateral deflections and bending moments in the frame, thereby decreasing the probability of collapse. The considerations of infill walls in the analysis and design leads to slender frame members, thus, reducing the overall cost.

The brick infill walls(panels) results in stiffer structure, reducing storey drift. The total base shear experienced by a building during earthquake depends on its time period. Stiffer buildings have smaller time period, higher natural frequency and thus, experiences larger base shear. Brick infill panels increases lateral resistance and energy dissipation of the structure. Hence, it is more realistic to consider brick infill walls in structural design as a structural element for earthquake resistant design.

9. IS:1893-2002 does not give any provision for considering the masonry infill in analysis. Only the equation for calculating the fundamental natural period(T_a) for moment resisting frame with brick in fill panels has been specified.

10. Research shows that there is gradual increase in lateral force from bottom floor to top.

11. Many authors were of the opinion that for irregular buildings static analysis is insufficient, and dynamic analysis must be carried out.

12. The study on provision and location of shear walls concluded that the inclusion of shear wall in buildings increases stiffness and reduces displacements.

By providing shear walls, shear force and moments resisted by columns is reduced as major forces are resisted by shear walls. The shear walls provided from foundation to the top of the building are very effective in resisting lateral loads. For symmetrical buildings, shear walls placed symmetrically on the outer periphery of the building are more effective.

13. Plan configurations of buildings has significant effect on seismic response of the structure. It was recommended that Time history analysis should be performed as it predicts the structural response more precisely than Response Spectrum method.

14. Study on behavior of building with re-entrant corners and their strengthening revealed that re-entrant corners in a building causes stress concentration and torsion in buildings. The possible solutions to treat reentrant corners are- by providing separation, strengthening the notch part by shear walls and by providing bracings.

15.Comparative study of Static and Dynamic Seismic Analysis of a multistoried Buildings shows that the dynamic analysis gives 30 to 35 % higher values of bending moments as compared to static analysis. Similarly, the column displacement values are about 40 to 45% higher in dynamic analysis.

16. Study on torsional irregularity in multi storey structures found that torsional irregularity coefficients increase as the story numbers decrease, i.e., maximum irregularity coefficients occur for single-story structures. Torsional irregularity coefficient reaches maximum values when the asymmetrical shear walls are placed close to the centre of mass. Floor rotations attained their maximum values when shear walls are in farthest position from the centre of mass.

REFERENCES

1. S.K.Ahirwar, S.K.Jain and M.M.Pande, " Earthquqke Loads on Multistorey Buildings as Per IS:1893-1984 and IS: 1893-2002 : A Comparative Study." 14th World Conference on Earthquake Engineering(WCEE),Oct-2008, Beijing, China.
2. S.Mahesh and Dr.B.Panduranga Rao, " Comparison of Analysis and Design of Regular and Irregular Configuration of Multi Story Building in Various Seismic Zones and Various Types of Soils Using ETABS and STAAD." IOSR Journal of Mechanical and Civil Engineering(IOSR-JMCE), e-ISSN :2278-1684, p-ISSN:2320-334X, Volume 11, Issue 6, Nov-Dec-2014, pp.45-52.
3. Ramanujam I V R and Dr. H Sudarsana Rao, " Comparative Study of Seismic Forces Based on Static and Dynamic Analysis as per IS: 1893-2002." international Journal of Structural and Civil Engineering Research, ISSN:2319-6009, Vol. 4 Feb 2015, pp. 63-74.
4. Haroon Rasheed Tamboli and Umesh N Karadi, " Seismic Analysis of RC Frame Structure With and Without Masonry Infill Walls." Indian Journal of Natural Sciences, ISSN: 0976-0997, vol.3, Issue 14, Oct 2012, pp.1137-1148.
5. Deshmukh Vishwajeet and Dr. Shrirang Tande, " Analysis of Masonry Infill in Multi Story Structure." International Journal of Latest Trends in Engineering and Technology (IJLTET), ISSN: 2278-621X, Vol. 7, Issue 1, May 2016, pp. 757-761.
6. Balaji U.A and Selvarasan M.E.B, "Design and Analysis of Multi-Storied Building Under Static and Dynamic Loading Conditions Using ETABS." International Journal of Technical Research and Applications, e-ISSN:2320-8163, Vol. 4, Issue 4, July 2016, pp. 1-5.

7. Mahesh N Patil and Yogesh N Sonaware, " Seismic Analysis of Multistoried Building", International Journal of Engineering and Innovative Technology (IJEIT), Vol.4, Issue 9, March 2015, pp.123-130.
8. Ni Ni Win, Kyaw Lin Htat, " Comparative Study of Static and Dynamic Analysis of Irregular Reinforced Concrete Building due to Earthquake." International Journal of Scientific Engineering and Technology Research, Volume 3, Issue 7, May 2014.
9. Mohit Sharma and Savita Maru, " Dynamic Analysis of Multistoried regular building." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), e-ISSN:2278-1684, p-ISSN:2320-334X, Volume 11, Issue 1, Jan 2014, pp. 37-42.
10. N Janardhana Reddy, D Gose Peera, T Anil Kumar Reddy, " Seismic Analysis of Multistoried Building with Shear walls Using ETABS-2013." International Journal of Science and Research (IJSR), ISSN: 2319-7064, Volume 4, Issue 11, Nov 2015, pp. 1030-1040.
11. Paradeshi Sameer and N G Gore, " Study of Seismic Analysis of Multi storey Symmetrical and Asymmetrical Building." International Research Journal of Engineering and Technology (IRJET), p-ISSN: 2395-0072, Volume 3, Issue 1, Jan 2016, pp-732-737.
12. Mohammed Rizwan Sultan, D.Gouse Peera," Dynamic Analysis of Multi- storey Building of Different Shapes." International Journal of Innovative Research in Advanced Engineering (IJIRAE), ISSN: 2349-2162, Volume 2, Issue 8, August 2015, pp-85-91.
13. Jiang Zhinan and Zhao Zhonghai, " Comparison of Base Shear method in the Seismic Design Codes of China, America and Europe." Applied Mechanics and Materials, Trans Tech Publications, Switzerland, Vols. 166-169, 2012, pp-2345-2352.
14. Gunay Ozmen, Konuralp Girgin, and Yavuz Durgun, "Torsional Irregularity in Multi story Structures." International Journal of Advanced Structural Engineering, SPRINGER, DOI 10.1007/s40091, Volume 6, 2014, pp-121-131.
15. M. S. Razzaghi and M. Javidnia, "Evaluation of the Effect of infill walls on Seismic Performance of RC Dual Frames." International Journal of Advanced Structural Engineering, SPRINGER, DOI 10.1007/s40091, Volume 7, 2015, pp-49-54.
16. IS: 1893(Part 1): 2002
17. IS: 1893(Part 1): 2016