ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

OPTIMIZED MODELING AND DESIGN OF STEEL FRAMES IN DIFFERENT SEISMIC ZONES USING ETABS SOFTWARE

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ABSTRACT
In the Present analysis, a steel framed building with 15 floors (each story is 4m height) is analyzed and designed in all seismic zones by using software "ETABS" an engineering software product that caters to multi story building analysis and design. The project consists of design based on a set of user specified load combinations. The design involves calculating story drift, story shear, displacements in all seismic zones and comparing the results. Optimization is an act, process, or methodology of making something as fully perfect, functional, or effective as possible. In steel structures best way of modeling can be possible by effective placing of steel braces to counter the lateral forces acting on the structure. Lateral forces always try to overturn the structure so effective placing of braces is required. Diagonal braces can be placed in interior elevations of the building. The intent of the braced frame at this location was to provide resistance to lateral loads in both shear and overturning. The horizontal truss elements at the roof and mid-height of the building are transfer trusses to help distribute overturning forces from the interior braces to the building exterior

KEYWORDS: Steel Frames, Braced Frames,Optimization, Seismic Zones.

INTRODUCTION

A) Steel as Construction Material

Structural steel is a material used for steel construction, which is formed with a specific shape following certain standards of chemical composition and strength. They can also be defined as hot rolled products, with a cross section of special form like angles, channels and beams/joints. There has been an increasing demand for structural steel for construction purposes in the United States and India.

Measures are been taken by the structural steel authority for ready availability of structural steel on time for the various projects. The people at every level are working hard to realize the purpose of producing steel on time, like, service centers, producers, fabricators and erectors along with the general contractors, engineers and architects are all working hand in hand. Steel has always been more preferred to concrete because steel offers better tension and compression thus resulting in lighter construction. Usually structural steel uses three dimensional trusses hence making it larger than its concrete counterpart.

The structural steel all over the world pre-dominates the construction scenario. This material has been exhaustively used in various constructions all over The world because of its various specific Characteristics that is very much ideally suited for construction.

B) Importance of Structural Steel

Structural steel sections are usually used for construction of buildings, buildings, and transmission line towers (TLT), industrial sheds and structures etc. They also find in manufacturing of automotive vehicles, ships etc.

Steel exhibits desirable physical properties that make it one of the most versatile structural materials in use.

Its great strength, uniformity, light weight, easy of use, and many other desirable properties makes it the material of choice for numerous structures such as steel bridges, high rise buildings, towers, and other structure.

1. Elasticity: steel follows hooks law very accurately.
2. Ductility: A very desirable of property of steel, in which steel can withstand extensive deformation without failure under high tensile stresses, i:e., it gives warning before failure takes place.
3. Toughness: Steel has both strength and ductility.

Additions to existing structures: Example: new bays or even entire new wings can be added to existing frame buildings, and steel bridges may easily be widened.

C) Steel frames

Steel frame is a building technique with a "skeleton frame" of vertical steel columns and horizontal I-beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. The development of this technique made the construction of the skyscraper possible.

The rolled steel "profile" or cross section of steel columns takes the shape of the letter "I". The two wide flanges of a column are thicker and wider than the flanges on a beam, to better withstand compressive stress in the structure. Square and round tubular sections of steel can also be used, often filled with concrete. Steel beams are connected to the columns with bolts and threaded fasteners, and historically connected by rivets. The central "web" of the steel I-beams is often wider than a column web to resist the higher bending moments that occur in beams.

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LITERATURE REVIEW

2.1 L. m .c simoes (1997) described a computer-based method for the optimum design of steel frameworks accounting for the behaviour of semi-rigid connections. The described optimization procedure provides an effective means to account for the cost of both members and connections in the design of steel building frameworks. it was concluded that the semi- rigid behaviour of connections results in designs that are less costly than when, as is usually done, the connections are idealized as being fully rigid.

2.2 Tremblay et al., (ASCE) 0733-9445 (2003) Tremblay et al. performs an experimental study on the seismic performance of concentrically braced steel frames with cold-formed rectangular tubular bracing system. Analysis is performed on X bracing and single diagonal bracing system. One of the loading sequences used is a displacement history obtained from nonlinear dynamic analysis of typical braced steel frames. Results were obtained for different cyclic loading and were used to characterize the hysteretic response, including energy dissipation capabilities of the frame. The ductile behaviour of the braces under different earthquake ground loading are studied and used for design applying the codal procedures. Simplified models were obtained to predict plastic hinge failure and local buckling failure of bracing as a ductility failure mode. Finally, inelastic deformation capabilities are obtained before failure of moment resisting frame and bracing members.

2.3 H. Moghaddam, I. Hajirasouliha and A. Doostan (2005) presented a methodology for optimization of dynamic response of concentrically braced steel frames subjected to seismic excitation, based on the concept of uniform distribution of deformation. In order to obtain the optimum distribution of structural properties, they adopted an iterative optimization procedure. . It was concluded that optimum structures suffer relatively less damage as compared with conventional structures.

2.4 Jose manuel cabrero, Eduardo basyo (2005) developed practical design methods for steel structures with semi rigid connections Two design examples were proposed to demonstrate the application of the proposed semi-rigid design methods, and their results compared to pinned and rigid alternatives. The semi-rigid approach results in more economical solutions.

2.5 K.jarmai, J.farkas, Y.kurobane (2006) studied about Optimum seismic design of a multi-storey steel frame. An interior three-storey frame structure with a column and 4 beams in each floor was investigated. The welded box columns and rolled I-section beams were designed for minimum weight and cost. The beam-to-column connections are selected from a number of structural versions improved for seismic resistance. They concluded that the fabrication cost has little effect on the optimum design, since it varies proportionally with the mass according to the present calculating method. Thus, the minimum weight design gives suitable results.

2.6 Seismic response assessment of concentrically braced steel frame buildings (The 14th World conference on earthquake engineering October 12-17, 2008, Beijing, China) Improvement of performance based design and analysis procedure for better understanding of conventionally used concentrically braced frame and buckling restrained braced frames is discussed.

2.7 Christopoulus et al. (2008) an advanced cross bracing system has been used in University of Toronto called (SCEDs) Self centring energy dissipating frames. Alike, Special moment resisting frames and Buckling reinforced braced frames, they also dissipate energy, but they have self-centring capabilities which reduce residual building deformation after major seismic events.

2.8 Tremblay et al. (2008) an extensive analytical study is performed to compare the Buckling restrained braced frames with self-cantering energy dissipating frames. According to the results, the residual deformation of SCED brace frame systems is negligible under low and moderate hazard levels and is reduced significantly under MCE or maximum considered earthquake level.

2.9 Nizal bel hadj ali (2009) studied about Multi-stage production cost optimization of semi-rigid steel frames using genetic algorithms. He concluded that the multi-stage design optimization results in substantial cost benefits between 10% and 25% compared to traditional design of steel frames. the developed methodology is shown to be capable of measuring the possible impact of design choices in the early design stage thus assisting designers to make better design decisions.

BRACED FRAMES

A Braced Frame is a structural system which is designed primarily to resist wind and earthquake forces. Members in a braced frame are designed to work in tension and compression, similar to a truss. Braced frames are almost always composed of steel members.

Braced frames are a very common form of construction, being economic to construct and simple to analyse. Economy comes from the inexpensive, nominally pinned connections between beams and columns. Bracing, which provides stability and resists lateral loads, may be from diagonal steel members or, from a concrete 'core'. In braced construction, beams and columns are designed under vertical load only, assuming the bracing system carries all lateral loads

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Braced frames

BRACING SYSTEMS

In a multi-storey building, the beams and columns are generally arranged in an orthogonal pattern in both elevation and on plan. In a braced frame building, the resistance to horizontal forces is provided by two orthogonal bracing systems.

Vertical Bracings

Bracing in vertical planes (between lines of columns) provides load paths to transfer horizontal forces to ground level and provide lateral stability.

In a braced multi-storey building, the planes of vertical bracing are usually provided by diagonal bracing between two lines of columns, as shown in the figure below. Either single diagonals are provided, as shown, in which case they must be designed for either tension or compression, or crossed diagonals are provided, in which case slender bracing members carrying only tension may be provided.

Horizontal Bracings

Bracing in a horizontal plane, generally provided by floor plate action, provides a load path to transfer the horizontal forces (mainly from the perimeter columns, due to wind) to the planes of vertical bracing.

A horizontal bracing system is needed at floor level, to transfer horizontal forces (chiefly the forces transferred from the perimeter columns) to the planes of vertical bracing that provide resistance to horizontal forces.

TYPES OF BRACINGS

There are two types of bracing systems.

Concentric Bracings

Concentric bracings increase the lateral stiffness of the frame thus increases the natural frequency and also usually decreases the lateral storey drift. However, increase in the stiffness may attract a larger inertia force due to earthquake. Further, while the bracings decrease the bending moments and shear forces in columns and they increase the axial compression in the columns to which they are connected.

Eccentric Bracings

Eccentric Bracings reduce the lateral stiffness of the system and improve the energy dissipation capacity. The lateral stiffness of the system depends upon the flexural stiffness property of the beams and columns, thus reducing the lateral stiffness of the frame.

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

SEISMIC ZONES OF INDIA

The Indian subcontinent has a history of devastating earthquakes. The major reason for the high frequency and intensity of the earthquakes is that the Indian plate is driving into Asia at a rate of approximately 47 mm/year. Geographical statistics of India show that almost 54% of the land is vulnerable to earthquakes. A World Bank & United Nations report shows estimates that around 200 million city dwellers in India will be exposed to storms and earthquakes by 2050. The latest version of seismic zoning map of India given in the earthquake resistant design code of India [IS 1893 (Part 1) 2002] assigns four levels of seismicity for India in terms of zone factors. In other words, the earthquake zoning map of India divides India into 4 seismic zones (Zone 2, 3, 4 and 5) unlike its previous version which consisted of five or six zones for the country. According to the present zoning map, Zone 5 expects the highest level of seismicity whereas Zone 2 is associated with the lowest level of seismicity.

Zone 1:

Since the current division of India into earthquake hazard zones does not use Zone 1, no area of India is classed as Zone 1. Future changes in the classification system may or may not return this zone to use.

Zone 2:

This region is liable to MSK VI or less and is classified as the Low Damage Risk Zone. The IS code assigns zone factor of 0.10 (maximum horizontal acceleration that can be experienced by a structure in this zone is 10% of gravitational acceleration) for Zone 2.

Zone 3:

The Andaman and Nicobar Islands parts of Kashmir, Western Himalayas fall under this zone. This zone is classified as Moderate Damage Risk Zone which is liable to MSK VII. and also 7.8 The IS code assigns zone factor of 0.16 for Zone 3.

Zone 4:

This zone is called the High Damage Risk Zone and covers areas liable to MSK VIII. The IS code assigns zone factor of 0.24 for Zone 4. The Indo-Gangetic basin and the capital of the country (Delhi), Jammu and Kashmir fall in Zone 4. In Maharashtra the Patan area (Koyananager) is also in zone no-4. In Bihar the northern part of the state like- Raksaul, Near the border of India and Nepal, is also in zone no-4 that "almost 80 per cent of buildings in Delhi will yield to a major quake and in case of an unfortunate disaster, the political hub of India in Lutyens Delhi, the glitz of Connaught Place and the magnificence of the Walled City will all come crumbling down."

Zone 5:

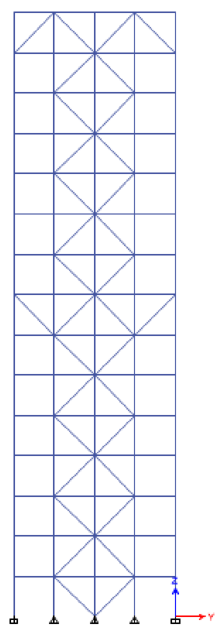
Zone 5 covers the areas with the highest risks zone that suffers earthquakes of intensity MSK IX or greater. The IS code assigns zone factor of 0.36 for Zone 5. Structural designers use this factor for earthquake resistant design of structures in Zone 5. The zone factor of 0.36 is indicative of effective (zero period) level earthquake in this zone. It is referred to as the Very High Damage Risk Zone. The region of Kashmir, the western and central Himalayas, North and Middle Bihar, the North-East Indian region and the Rann of Kutch fall in this zone.

OPTIMIZATION

Optimisation is an act, process, or methodology of making something as fully perfect, functional, or effective as possible.

Optimized Modelling

The way of modelling a steel structure plays an important role in total cost of the structure it is desirable to adopt the best way of modelling to reduce total cost of the structure. In steel structures best way of modelling can be possible by effective placing of steel braces to counter the lateral forces acting on the structure. Lateral forces always try to overturn the structure. Normal Steel frames cannot resist lateral forces effective placing of braces is required.



Braced Frames at Interior Elevations

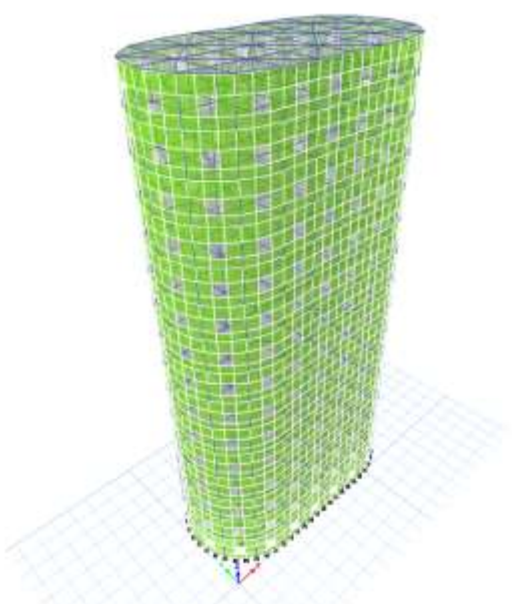
The intent of the braced frame at this location was to provide resistance to lateral loads in both shear and

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

overturning. The horizontal truss elements at the roof and mid-height of the building are transfer trusses to help distribute overturning forces from the interior braces to the building exterior. If the top and bottom chord elements of the horizontal trusses are to be modelled properly, the joints must be disconnected from the rigid floor diaphragms to allow shortening or elongation of the horizontal truss chord elements. Horizontal bracings can also be placed at top and middle stories to reduce lateral load on beam sections.

Optimized Design

In general there are so many methods to optimise steel sections but designing a steel structure by using ETABS does not require manual calculations the program itself optimises the steel frames. User has to define auto selection list. During design process the program optimises the sections from auto select list. Program compares and matches the analysed sections and designed sections by iterative process to select the most effective sections.



3d model Of The Building

LOAD CALCULATIONS

Super imposed dead load = 1.65 kn/m2
Live load = 4 kn/m2

Wind Load Calculation

Exposure Parameters
Exposure From = Shell Objects
Structure Class = Class C
Terrain Category = Category 4
Top Story = Story15
Bottom Story = Base
Include Parapet = No

Windward Coefficient $C_{p,wind} = 0.8$

Leeward Coefficient $C_{p,lee} = 0.5$

Factors and Coefficients

Risk Coefficient, k_1 [IS 5.3.1] $k_1 = 1$

Topography Factor, k_3 [IS 5.3.3] $k_3 = 1$

Lateral Loading

Design Wind Speed, V_z [IS 5.3] $V_z = V_b k_1 k_2 k_3 = 29.568$

Design Wind Pressure, p_z [IS 5.4] $p_z = 0.6 V_z^2$

Seismic Load Calculation

Direction and Eccentricity
Direction = Multiple
EccentricitRatio = 5% for all diaphragms
Structural Period
Period Calculation Method = Program Calculated
Factors and Coefficients

Seismic Zone Factor, Z [IS Table 2] $Z =$ 0.1 for zone 2; 0.16 for zone 3; 0.24 for zone 4; 0.36 for zone 5

Response Reduction Factor, R [IS Table 7] $R = 4$

Importance Factor, I [IS Table 6] $I = 1$

Site Type [IS Table 1] = II

Seismic Response
Spectral Acceleration Coefficient, S_a /g [IS 6.4.5] $\frac{S_a}{g} = 2.5$

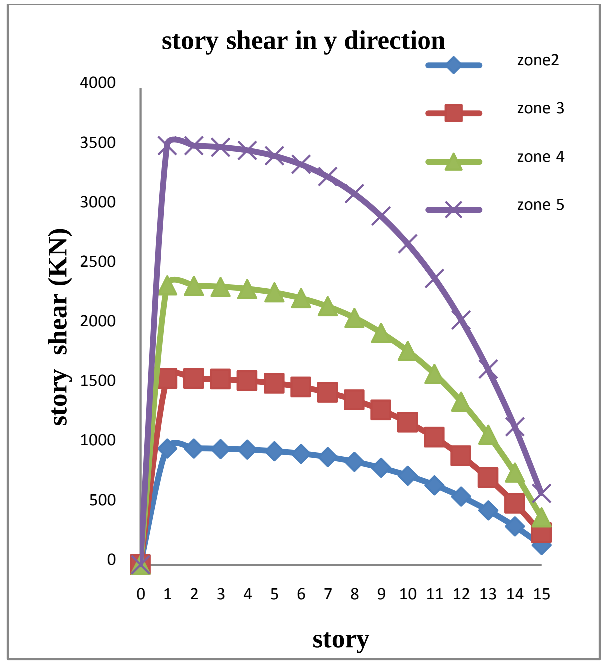
Equivalent Lateral Forces

Seismic Coefficient, A_h [IS 6.4.2] $A_h = \frac{ZI\frac{S_a}{g}}{2R}$

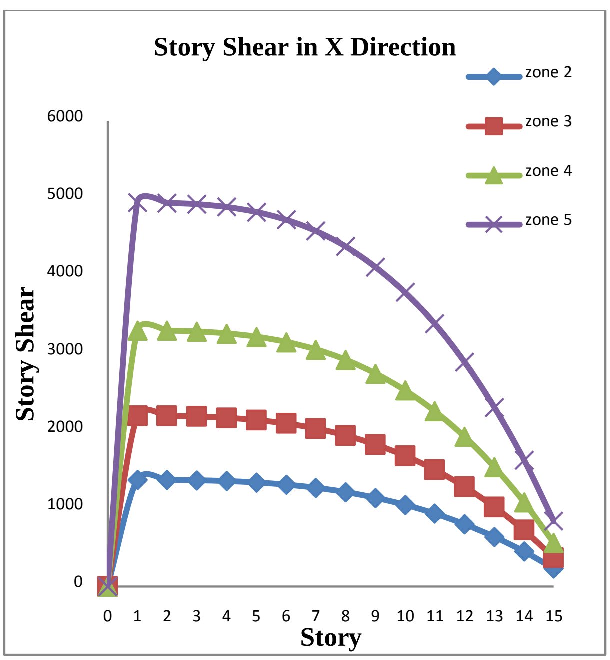
ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

INITIAL DESIGN LOADS

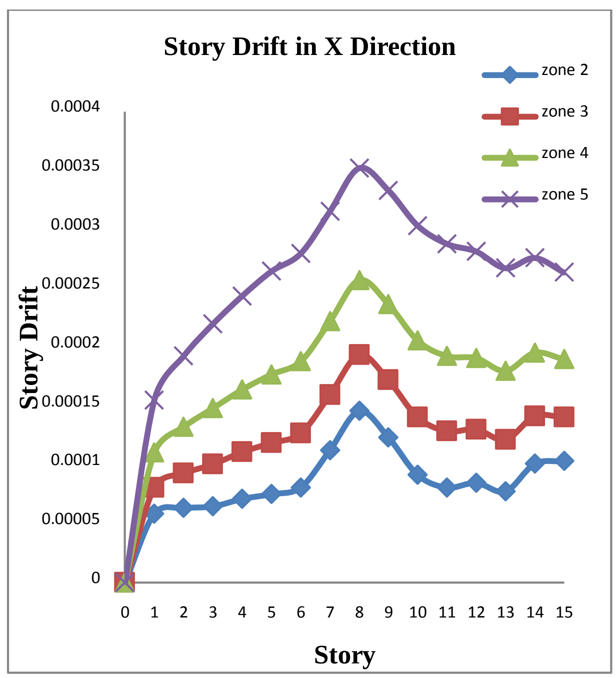
Name	Type	Self-Weight Multiplier	Auto Load
Dead	Dead	1	
Live	Live	0	
sdead	Superimposed Dead	0	
windy	Wind	0	Indian IS875:1987
eqy	Seismic	0	IS1893 2002
eqx	Seismic	0	IS1893 2002
windx	Wind	0	Indian IS875:1987



Story Shear in Y Direction

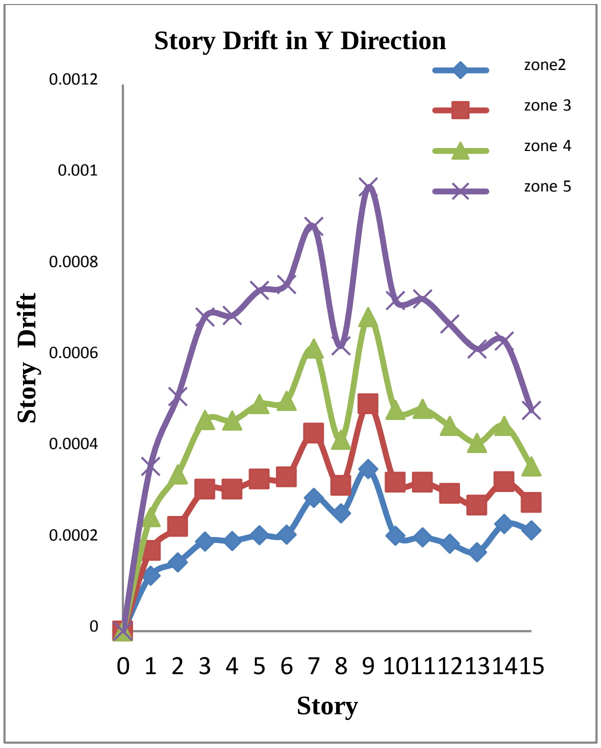


Story Shear in X Direction

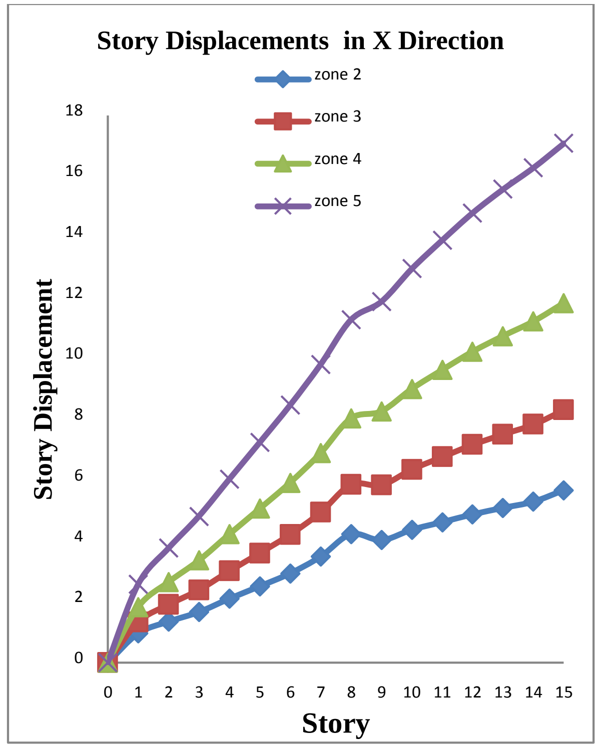


Story Drift in X Dirction

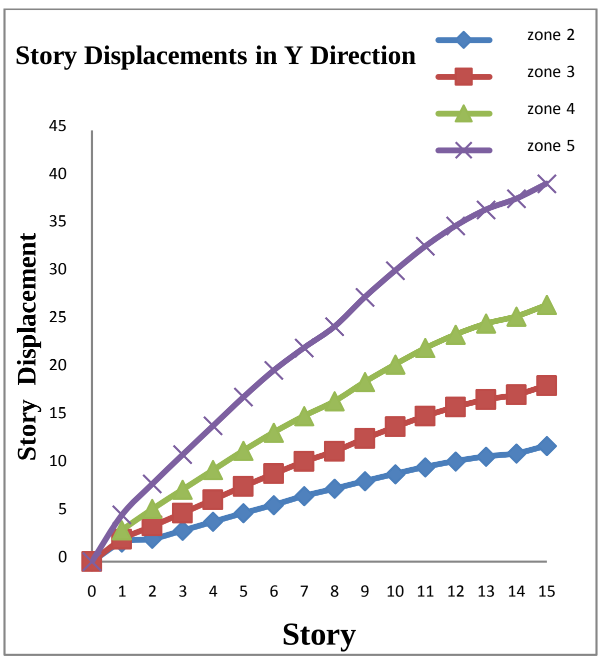
ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785



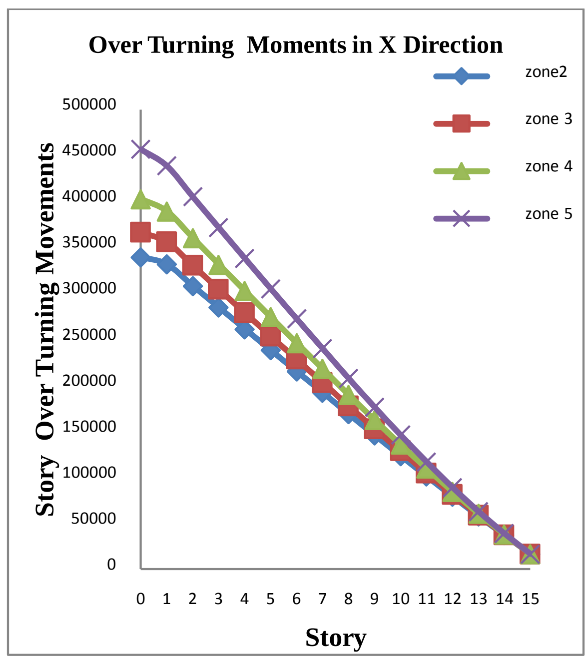
Story Drift in Y Direction



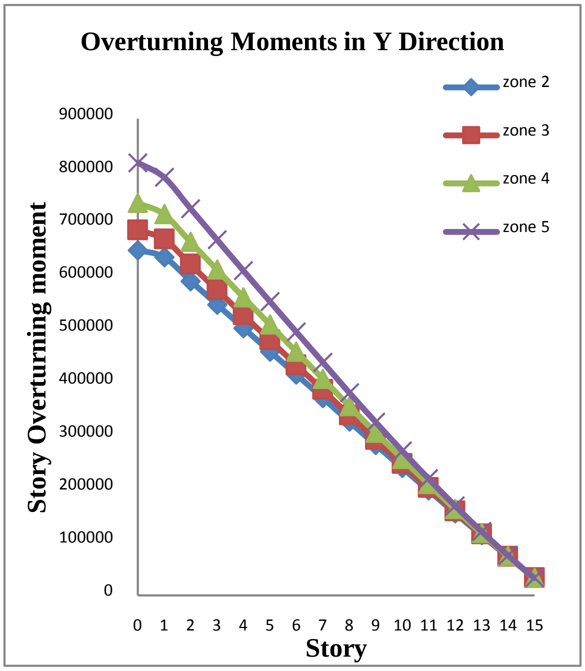
Story Displacements in X Dirction



Overturning Moments in X Direction



Overturning Moments in X Direction



Overturning Moments in Y Direction

DISCUSSION OF RESULTS

1. Story shear in x and y directions is decreased from 1st story to 15th story.
2. Story shear in x direction is decreased from 1375 KN to 234 KN for zone 2, from 2200 KN to 374 for zone 3, from 3300 to 771 for zone 4 and for zone 5 it decreased from 4950 KN to 842 KN.
3. Story shear in y direction is decreased from 976 KN to 155 KN for zone 2, from 1561 KN to 265 KN for zone 3, from 2342 KN to 398 KN for zone 4, from 3518 KN to 597 KN for zone 5.
4. Story drift in x direction is maximum at 8th story and minimum at 1st story for all seismic zones.
5. The maximum value of story drift in x direction is 0.000146 for zone 2, 0.000193 for zone 3, 0.000257 for zone 4 and 0.000352 for zone 5.
6. The minimum value of story drift in x direction is 0.0000586 for zone 2, 0.0000808 for zone 3, 0.00011 for zone 4, 0.000155 for zone 5.
7. Story drift in y direction is maximum at 9th story and it is minimum at 1st story.
8. the maximum value of story drift in y direction is 0.000356 for zone 2, 0.000499 for zone 3, 0.00069 for zone 4, 0.000975 for zone 5.
9. the minimum value of story drift in y direction is 0.000122 for zone 2, 0.000177 for zone 3, 0.000251 for zone 4 and it is 0.000362 for zone 5.
10. Story Displacement in x and y directions is increased from 1st story to 15th story for all seismic zones.
11. Story Displacement in x direction is increased from 0.96 mm to 5.67 mm for zone 2, from 1.33mm to 8.31mm for zone 3, from 1.83mm to 11.82mm for zone 4 and from 2.57mm to 17.07mm for zone 5.
12. Story displacement in y direction is increased from 2.03 mm to 12.08 mm for zone 2, from 2.35 mm to 18.39 mm for zone 3, from 3.31 mm to 26.8 mm for zone 4 and from 4.9 mm to 39.4 mm for zone 5.
13. Overturning moments in x and y directions are decreased from 1st story to 15th story for all seismic zones.
14. Overturning moments in x direction are decreased from 339237 KN-m to 16622 KN-m for zone 2, from 366295 KN-m to 16622 KN-m for zone 3, from 402380 KN-m to 16622 KN-m for zone 4, from 456689 KN-m to 16622 KN-m for zone 5.

CONCLUSIONS

1. . Story shear in X and Y Direction is maximum at bottom stories than top stories for all seismic zones. The curve of the graph is steeper at top stories so it can be concluded that the rate of decreasing in story shear varies from story to story and it is maximum at the top stories.
2. Story drift in x direction is maximum at 8th story and story drift in y direction is maximum at 9th story. There is a sudden fall in story drift from 7th to 8th story in y direction.
3. Story displacement in x and y directions is maximum at 15th story and it is minimum at bottom story. Story displacement in y direction is far greater than story displacement in x direction for all seismic zones.
4. The curves of overturning moments for zone 2,3,4,5 are very closer when compared to other.
5. During the design process all analyzed sections match to the design section so complete optimization of steel sections

ISSN: 2277-9655
(I2OR), Publication Impact Factor: 3.785

has been carried. All sections passed for strength and capacity check.

6. All properties Story shear, story drift, story displacements, overturning moments are increased by increasing zone factor. All curves have same slopes with increasing values.

It is obvious that the most reliable structure with less story shear, less story drift, less overturning moments and less displacements can be formed in " zone 1" and Current designed model is capable of resisting earth quake forces in all seismic zones by keeping all properties within the limits.

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