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Seismic risk assessment of an industrial steel building

Habibur Rahaman
mldhabib@gmail.com
Al-Falah University, Dhouj, Haryana

Faiyaz Azam
faiyazazam303@gmail.com
Al-Falah University, Dhouj, Haryana

Mirza Aamir Baig
aamirmirzagarri@gmail.com
Al-Falah University, Dhouj, Haryana

ABSTRACT

The industrial building plays an important role in the operation and production. Industrial Buildings are designed for wind loads in the transverse direction as steel lattice towers are less sensitive to earthquake loads. Recent times the collapse of transmission lines towers, under wind loading, has been increasing. Although the damages are controllable the threat under wind hazard is big concerns for designers. Similarly, the seismic analysis of Industrial Building is equally important as the response due to an earthquake may be severe than due to wind load. Recent cases of damage to Industrial Building during earthquake are during the 1994 Northridge earthquake two Industrial Building collapsed due to large ground motion, during the 1999 Chi-Chi earthquake led to blackouts in the central and northern regions of Taiwan The main aim of the study provides which method is most economical method and, high bending strength, more load carrying capacity and high flexural strength by analysis of both working stress and limit state method. An investigation of the seismic response of an existing industrial steel building is presented in the following. Starting from as-built data collection, the study has been addressed to develop the complete process of seismic risk assessment, through the use of current performance-based analysis methods. This paper is focused on the main modelling aspects and results from analysis of seismic performance upon integration with site-specific hazard, the structural risk assessment, that is, a probability of failures. These buildings require large and clear areas unobstructed by the columns. The large floor area provides sufficient flexibility and facility for later change in the production layout without major building alterations. The industrial buildings are constructed with adequate headroom for the use of an overhead traveling crane. There are various international codes available for the design of steel structures. Developments are still going on, to achieve the great economy by using different methods as well as by using different codes of practice. By using this study, we can make a relation between the different parameter of codes, to achieve the above goals of a structural engineer.

Keywords— *Limit state method, Working stress method, Flexural strength, Fink type roof trusses, STAAD pro*

1. INTRODUCTION

Any building utilized by the business to oblige the creation movement, stock crude materials, stock completed item before supply is known as a modern building. Rooftop support and entryway outline are utilized to cover and sanctuary the zone of a mechanical building. According to the prerequisite of a modern building, the reasonable sort of rooftop support and gateway outline is used. Rooftop support is intended for dead load, live load, wind stack, and their blends according to Indian Standards. An economy of a modern building relies upon the arrangement of structure, kind of rooftop bracket and gateway outline used, powers following up on building and determination of steel segments required according to drive utilized.

A Structural steel is a material utilized for steel development, which is framed with a particular shape following certain norms of concoction creation and quality. They can likewise be characterized as hot moved items, with a cross area of extraordinary shapes like points, channels and pillars/joists. There has been an expanding interest for auxiliary steel for development purposes in India. Steel has dependably been more wanted to concrete since steel offers better strain and pressure in this manner bringing about lighter development. Typically, auxiliary steel utilizes three-dimensional supports henceforth making it bigger than its solid partner.

Preference of steel as a basic material is that the basic steel displays attractive physical properties that make it a standout amongst the most adaptable basic materials being used. Its awesome quality, consistency, light weight, usability, and numerous other attractive properties settle on it the material of decision for various structures, for example, modern structures, steel spans, elevated structures, towers, and other structure.

2. COMPONENT OF AN INDUSTRIAL BUILDING

The elements of industrial buildings are listed below:

(1) Purlins
(2) Sag rods

(3) Principal Rafters
(4) Roof Truss
(5) Gantry Girders
(6) Bracket
(7) Column and Column base
(8) Girt Rods
(9) Bracings

The elements are briefly explained as below.

2.1 Purlins

Beams provided over trusses to support roof coverings are known as Purlins. Purlins spans between top chords of two adjacent roof trusses. When purlin supports the sheeting and rests on rafter then the purlins are placed over panel point of trusses. Purlins can be designed as simple, continuous, or cantilever beams. Purlins are often designed for normal component of forces.

2.2 Sag Rod

These are round sections rods and are fastened to the web or purlin. The roof covering in industrial buildings are not rigid and do not provide proper support. Therefore, sag rods provided between adjacent purlins to extend lateral support for purlins in their weaker direction. A sag rod is designed as a tension member to resist the tangential component of the resultant of the roof load and purlin dead load. The tangential component of the roof load is considered to be acting on the top flange of purlins, here as the normal component and purlin dead load is assumed to act at its centroid. Therefore, the sag rod should be placed at a point where the resultant of these forces act

2.3 Principal Rafter

The top chord member of a roof truss is called as a principal rafter. They mainly carry compression but they may be subjected to bending if purlins are not provided at panel points.

2.4 Roof Trusses

Roof trusses are elements of the structure. The members are subjected to direct stresses. Truss members are subjected to direct tension and direct compression. Different members of the truss are shown as in the following figure.

2.5 Gantry Girder

Gantry girders are designed as laterally unsupported beams. Overhead traveling cranes are used in industrial buildings to lift and transport heavy jobs, machines, and so on, from one place to another. They may be manually operated or electrically operated the overhead traveling crane. A crane consists of a bridge made up of two truss girders which move in the longitudinal direction. To facilitate movement, wheels are attached to the ends of crane girders. These wheels move over rails placed centrally over the girders which are called gantry girders.

3. OBJECTIVES OF THE PROJECT

The main aim of the study to provide the analysis of practical industrial building by limit state method and also which method is a most economical method and, high bending strength, more load carrying capacity and high flexural strength by analysis of both working stresses and limit state method.

The object of limit state design can be paraphrased as the achievement of an acceptable probability that a part or whole structure will not become unfit for its intended use during its lifetime owing to collapse, excessive deflection etc. under the action of all loads and load effects. For achieving the design objectives, the design shall be based on characteristic values for material strength and applied loads, which take into account the probability of variations in the material strengths and in the loads to be supported. The characteristic values shall be based on statistical data, if available. Whereas such data is not available, these shall be based on experience.

The industrial building stock of many countries is significantly contributed by steel buildings. Although these structures are generally relatively lightweight and, in most of the cases, designed for wind actions, the assessment of their seismic performance is important for the estimation of the possible consequences of earthquakes, in terms of direct damage and/or business interruption. The seismic analysis of existing industrial steel structures presents some peculiar modelling aspects which have been the subject of relatively little investigation with respect to other types of existing structures. One frequent type of damage observed in past earthquakes is brace buckling. Specific research efforts have been addressed to investigate the role and the modelling of roof panels. An investigation of the seismic response of an existing industrial steel building is presented in the following. Starting from as-built data collection, the study has been addressed to develop the complete process of seismic risk assessment, through the use of current performance-based analysis methods. This paper is focused on the main modelling aspects and results from analysis of seismic performance upon integration with site-specific hazard, the structural risk assessment, that is, the probability of failures

4. METHODOLOGY

4.1 General

The design Method used is as following:

(1) Working Stress Method (WSM)
(2) Limit State Design (LSD)

4.1.1 Working Stress Method (WSM): This is the old systematic analytical design method (IS 800:1984). In this method, stress strain relation is considered linear till the yield stress. To take care of uncertainties in the design, permissible stress is kept as a fraction of yield stress, the ratio of yield stress to working stress itself known as a factor of safety. The members are sized so as to keep the stresses within the permissible value. The allowable stress method of design, the critical combination of loads is found out the members are designed on the basis of working stresses. These stresses should never increase the permissible stresses is considered. The method considers material behaviour is elastic. Thus the permissible stresses may be elaborated in terms of a factor of safety, which takes care of overload or other unknown factors.

Thus, Permissible stress = Yield stress/factor of safety
And, Working stress ≤ Permissible stress

4.1.2 Limit State Method (LSM): In the Limit State Design method (IS800:2007), the structure shall be designed to withstand safely all loads likely to act on it throughout its life. It shall also satisfy the serviceability requirements, such as limitations of deflection and vibration and shall not collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent not originally expected to occur.

The acceptable limit for the safety and serviceability requirements before failure occurs is called a *limit state*. The objective of design is to achieve a structure that will not become unfit for use with acceptable target reliability. In other words, the probability of a limit state being reached during its lifetime should be very low. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states. Steel structures are to be designed and constructed to satisfy the design requirements for stability, strength, serviceability, brittle fracture, fatigue, fire, and durability. The reliability of a design is assured by satisfying the requirements. Design action ≤ Design strength

5. LOADS ON THE STEEL INDUSTRIAL SHED

The shed structures are subjected to a dead load, live load, crane load, wind load, and seismic load etc.

5.1 Dead Load (DL)

The dead loads of the truss include a dead load of roofing materials, purlins, trusses, and bracing system.

5.2 Live Load (LL)

The Live load on sloping roofs with inclination up to 10 degrees is taken as 0.75KN/m2 of the plan area. For roofs with slopes more than 10degree, The Live load is taken 0.75kN/m2 – (0.02 KN/m2 for every degree increase in slope over 10 degrees), subject to a minimum of 0.4 KN/m2.

5.3 Wind Load (WL)

Wind load on the roof trusses, unless the roof slope is too high, would be usually uplift force perpendicular to the roof, due to the suction effect of the wind blowing over the roof. Hence the wind load on roof truss usually acts opposite to the gravity load, and its magnitude can be larger than gravity loads, causing a reversal of forces in truss members. The horizontal and vertical bracings employed in single and multi-storey buildings are used primarily to resist the wind and other lateral loads. These bracings minimize the differential deflection between the different frames due to crane surge in industrial buildings. They also provide lateral support to columns in small and tall buildings, thus increasing the buckling strength. Wind load is the most critical load on an industrial building.

Wind force (F) = (Cpe – Cpi) A Pd

6. RESEARCH ELABORATION

Design data of Industrial Shed, the building is located in industrial area of Patparganj Delhi

The span of the roof truss	= 16 m.
The spacing of the truss (a span of purlin)	= 4 m.
Height of column	= 11m.
Length of building	= 48 m.
The rise of the truss	= 4 m.
The slope of the roof (ϴ)	= 26.56 degree
Length along the slopping roof	= 8.94 m.
Let us place the purlin at panel points.	
Length of each panel (c/c spacing of purlin)	= 2.235 m.

7. WIND LOADS: (Ref. IS: 875 PART 3) 1987

Let us assume the life of the industrial building to be 50 years and the land to be plain and surrounded by small buildings.

Risk coefficient (k1) taken from IS 875- 1975 (life of building 50 years)	= 1
Terrains category (k2) taken from IS 875- 1975 (Terrine category "3" class "B")	= 0.89
Topography factor (k3) taken from IS 875- 1975 (plain ground of Delhi)	= 1
Basic wind speed (Vb) Delhi	= 47 m/sec
Design wind speed (Vz) = k1 x k2 x k3 x Vb	= 41.83 m/sec
Design wind pressure P_d = (0.6 x Vz^2)	= 1049.85 N/sq.m.
	= 1.05 KN/sq.m.

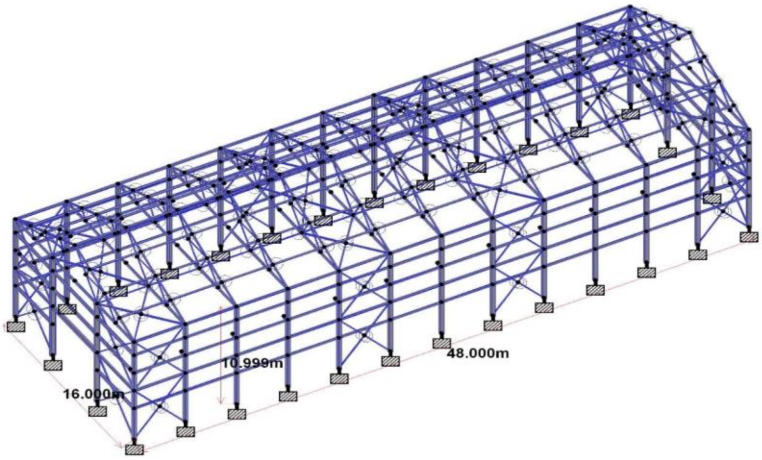

Fig. 1: STAAD pro. model

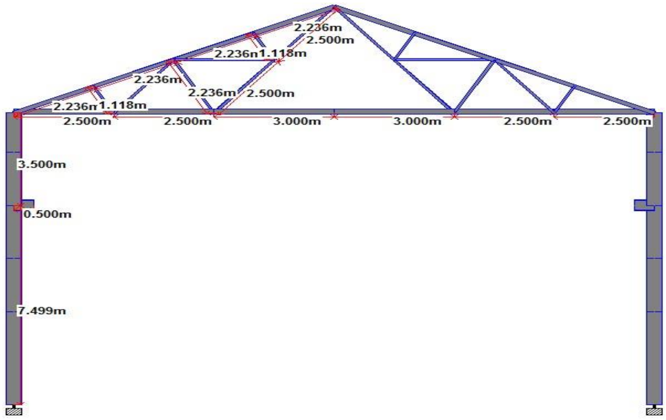

Fig. 2: Internal mainframe with crane brackets

8. SEISMIC RISK ANALYSIS

Structures are exposed to damage when earthquakes are triggered. This damage can cause losses including lives and properties. In past earthquake events, such as the Kobe earthquake in 1995, the Aceh earthquake in 2004, and the Kashmir earthquake in 2005, buildings and infrastructures were severely damaged and collapsed (Petal et al. 2008). During these events, the worst damages were often recorded in cities. For example, many people were killed by falling building debris. Therefore, building damage is the main source of seismic losses during earthquakes. To solve this problem, fragility curves were introduced by researchers to serve as one of the main tools for assessing damage and loss during earthquakes. In general, the curves are generated from real earthquake damage data to estimate or predict whether the damage meets or exceeds a certain performance level for a given set of ground motion parameters. In addition, the curves can be applied to predict both pre- and post-earthquake situations. These curves are unique because every building has a specific fragility analysis. Previous studies have reported different methodologies used to develop fragility curves. The upcoming sections provide a comprehensive review of these methodologies and the importance of the fragility curves. These sections focus on the seismic fragility assessment of buildings. Based on prior investigations, these sections present the significant elements that influence building vulnerability; it also aims to briefly discuss the fragility background, introduce the method, and summarize the existing methodologies. The pushover analysis (POA) and incremental dynamic analysis (IDA) were performed by using the Etabs software. For the dynamic analysis, three sets of near-field (NF) and far-field (FF) ground motion records were used.

9. 4.5 GROUND MOTION RECORD

Based on IS-1893, the elastic response spectrum can be developed. The elastic response spectra were developed from 0.2 to 0.8 g with an increment of every 0.1 g. for of ground motion. The elastic response spectrum is used to scale-up or scale-down the ground motions. A set consists of 2 Near-Field ground motion and another consist of 2 Far-Field ground motion.

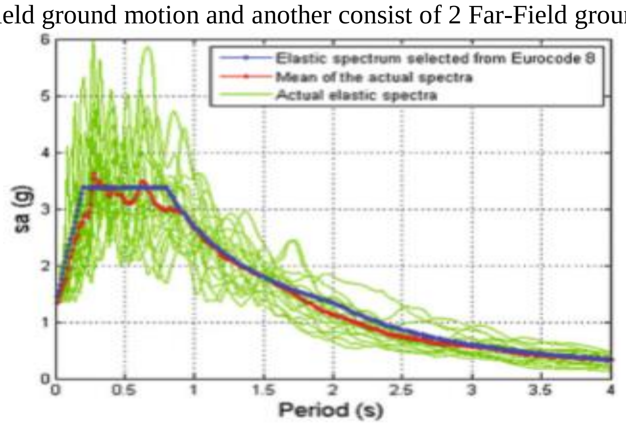

Fig. 3: Graph showing elastic response spectra

10. RESULT ANALYSIS

Table 1: Comparative table of different parameter

S. No.		LSM			WSM		
1.	**Shear Force**	Max Fx	Max Fy	Max Fz	Max Fx	Max Fy	Max Fz
		374.30	268.51	14.29	399.50	255.61	18.28
2.	**Bending Moment**	Max Mx	Max My	Max Mz	Max Mx	Max My	Max Mz
		0.14	15.65	228.66	0.10	20.23	187.50
3.	**Reaction**	X	Y	Z	X	Y	Z
		56.67	442.81	57.59	67.22	490.16	40.45

10.1 Estimate of material

Table 2: Steel quantity required by LSM

Profile	Length (Meter)	Weight (Kg)
ST ISWB400	354.98	23636.111
ST ISWB175	624.00	13735.415
LD ISA200X100X10	208.00	9515.400
LD ISA150X75X10	232.55	7869.714
LD ISA90X65X6	96.00	1355.117
LD ISA75X50X5	376.28	3548.901
ST ISMB225	192.00	5970.938
ST ISWB200H	104.00	5409.440
LD ISA90X60X6	336.54	4566.013
ST ISMC150	160.14	2671.942
	Total =	**78278.992**

Table 3: Steel quantity required by WSM

Profile	Length (Meter)	Weight (Kg)
ST ISHB450	298.98	25996.933
ST ISWB175	624.00	13735.415
LD ISA200X100X12	208.00	11340.271
LD ISA150X75X10	232.55	7869.714
LD ISA90X65X6	96.00	1355.117
LD ISA75X50X6	376.28	4220.952
ST ISMB250	192.00	7159.110
ST ISWB400	56.00	3728.549
ST ISWB200H	104.00	5409.440
LD ISA100X75X6	336.54	5325.257
ST ISMC150H	160.14	2835.019
	Total =	**88975.778**

10.2 Comparison of weight by working stress method and limit state method of design

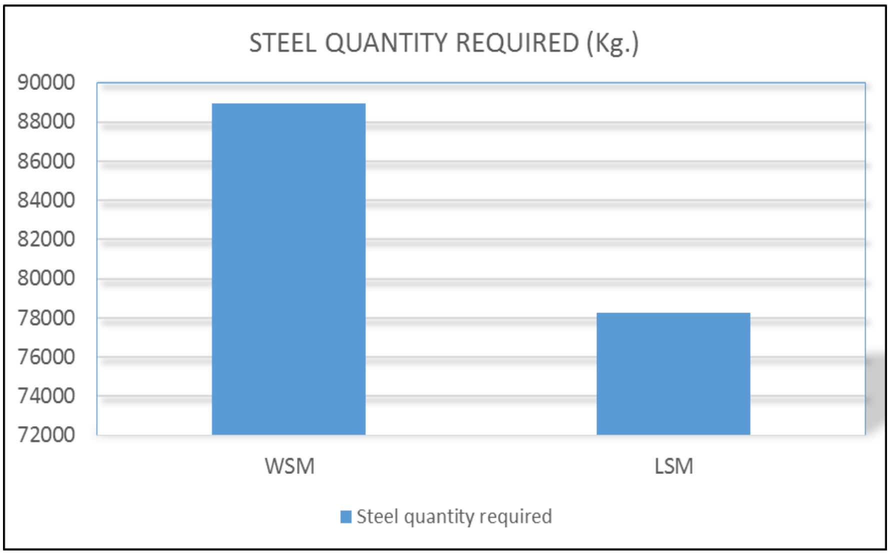

Fig. 4: Comparison of required steel quantity

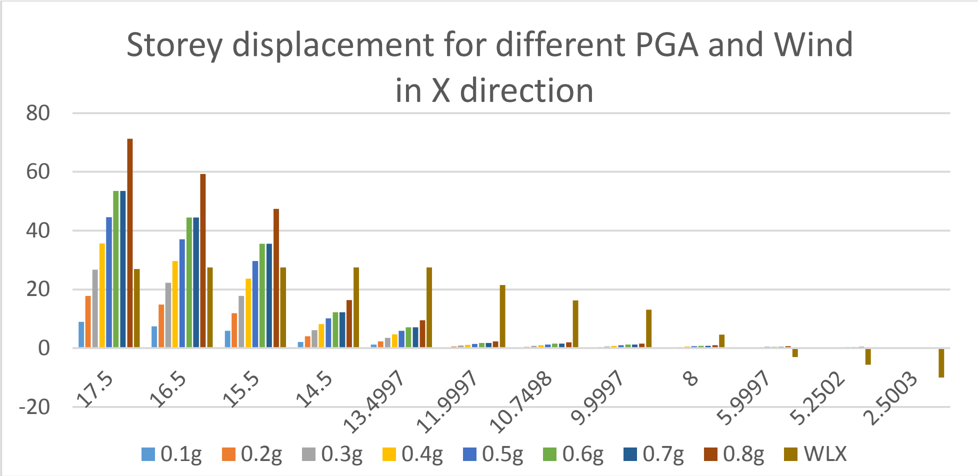

Fig. 5: Storey Displacement for earthquake load in X direction

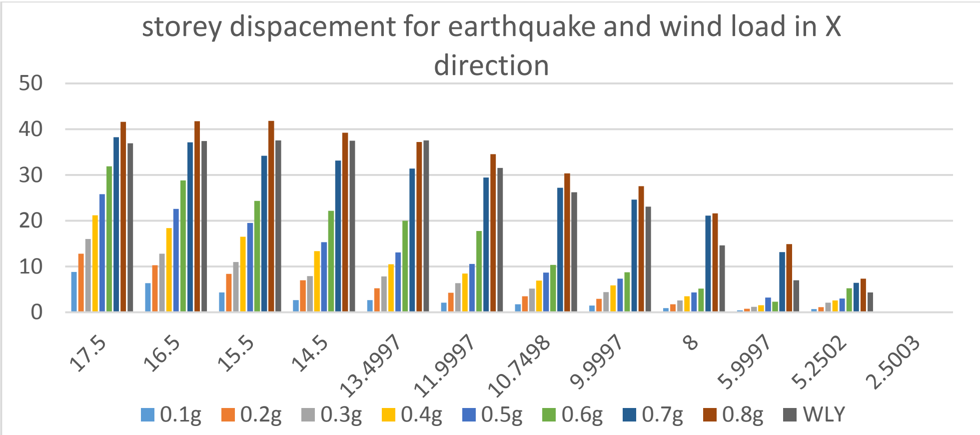

Fig. 6: Storey displacement for earthquake load in X direction

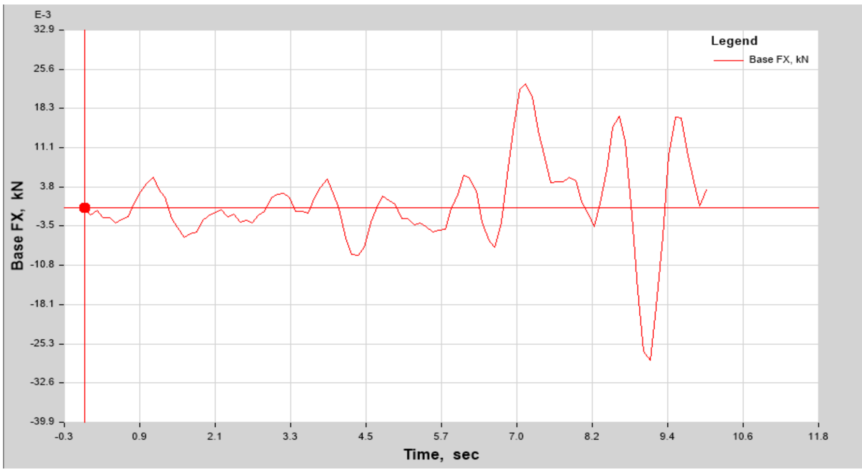

Fig. 7: Base shear for Bhuj earthquake

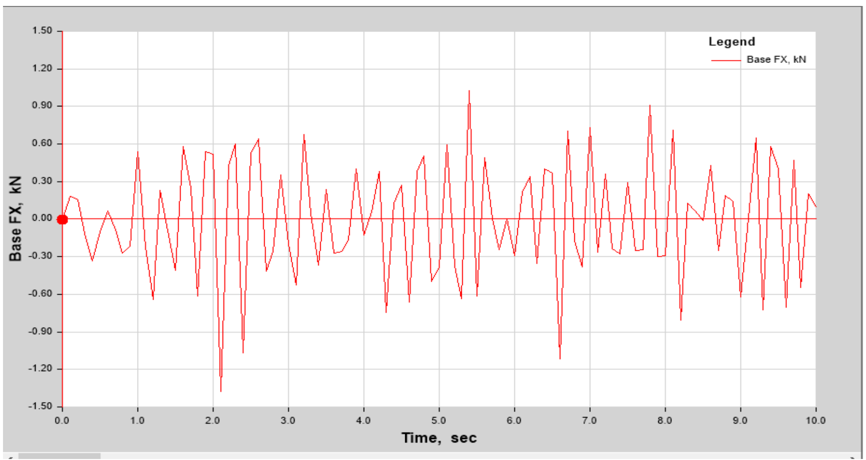

Fig. 8: Base shear for India Burma

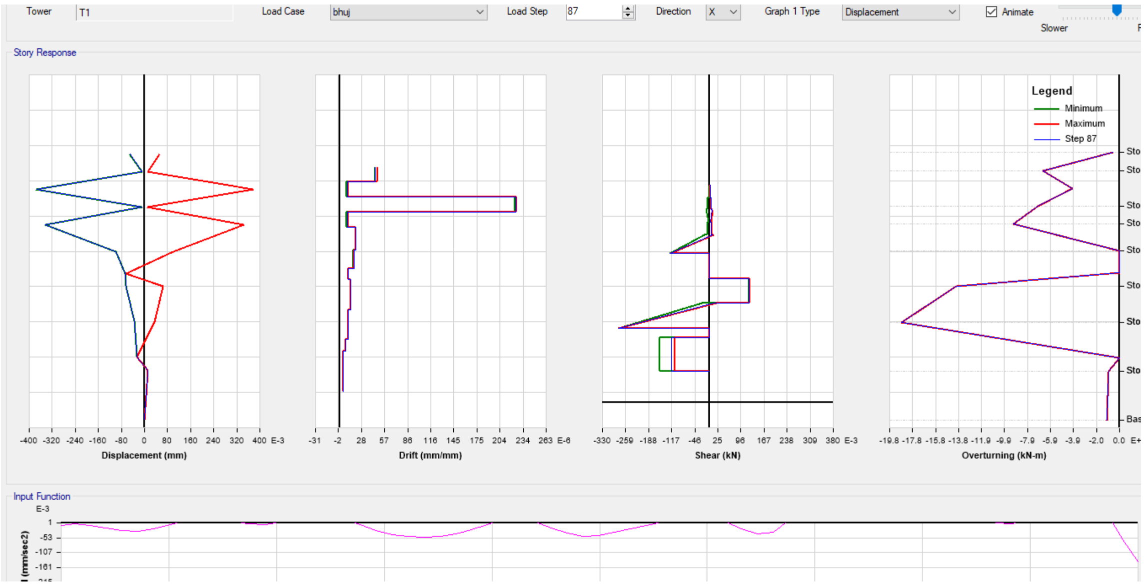

Fig. 9: Storey response Bhuj earthquake

11. FRAGILITY CURVES

The fragility curves were compared according to different types of PGA. Fig 9 to 12 shows the fragility curve of industrial building assuming a normal distribution. Based on Fig. 4.13 to 4.17, when the weak ground motions are exposed at 0.2 g, the probability of reaching or exceeding the regular low rise is 0%. At the CP level, the probability for the regular frame is 100% when the ground motion is more than 2.0 g and the irregular frame is 1.90 g.

The probability of OP level is 100% for the frame when the ground motion is 1.0 and 1.70 g for the irregular frame. Meanwhile, for the CP level, 100%. Various ground motion taken for consideration are scaled up from 0.2g to 2g. The probability of exceedance of ductility index is calculated using Etabs software and the tabulated graphs are ploted for different PGA and Storey Drift.

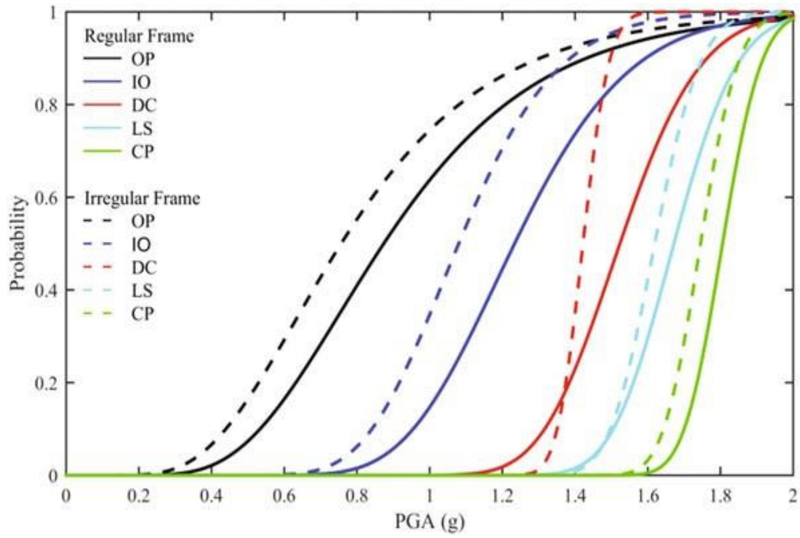

Fig. 10: Fragility curve for Bhuj earthquake assuming normal distribution

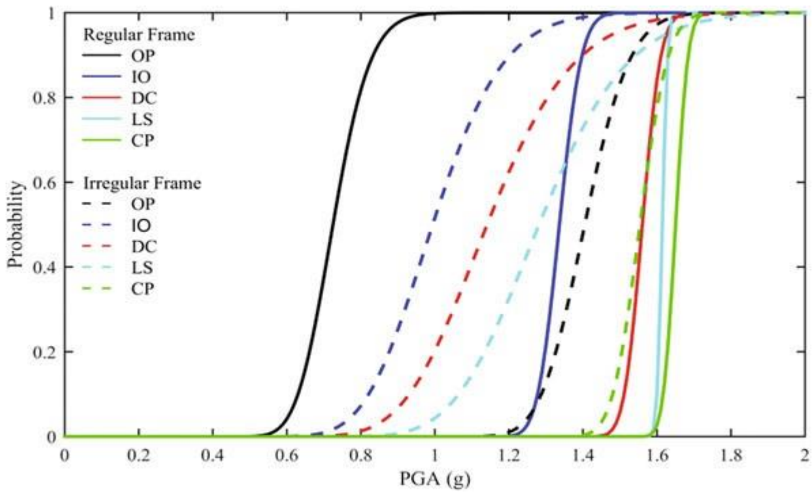

Fig. 11: Fragility curve for India Burma earthquake assuming normal distribution

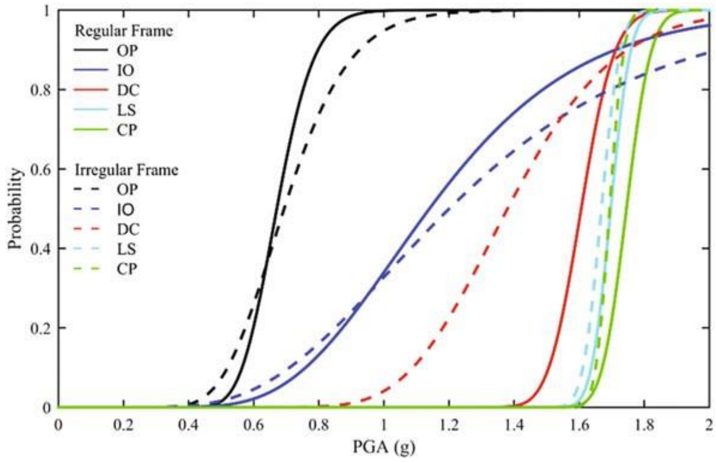

Fig. 12: Fragility curve for Uttarkashi earthquake assuming normal distribution

12. CONCLUSIONS

Generally, the Industrial building is designed or critical for wind load. The past research and study showed that several industrial building collapses due to wind load. Now in this study, the ground acceleration is scaled up to catch the response of the building if it is located near to the fault. The ground motion has a different character in the near-field zone.

Bhuj Earthquake, India Burma, Uttarkashi and Chi-Chi time history are taken into consideration. Results show that up to 0.6g wind load predominates the design but after 0.6g seismic forces are critical for design.

Various ground motion taken for consideration are scaled up from 0.2g to 2g. The probability of exceedance of ductility index is calculated using Etabs software and the tabulated graphs are plotted for different PGA and Storey Drift. Results showed that after 0.8g the members are in the collapsed state.

From the above outcomes, we can see that, the segments outlined utilizing Limit State Method are more temperate than the areas that are planned by the Working Stress Method. In this examination, the aggregate material load setup is the same in both the working pressure and cutoff state technique. However, a region of the area is roughly 12% less required to restrict state technique in contrast with the working pressure strategy. In IS 800 (1984) the neighborhood clasping is stayed away from by determining b/t limits. Thus we don't consider nearby clasping. Be that as it may, In IS 800 (2007), the neighborhood clasping is the main perspective to the extent the bar configuration is worried (by utilizing area characterization). The segment composed according to LSD is having more save limit with respect to BM and SF when contrasted with WSM.

In this examination with the assistance of the outcomes got we can presume that point of confinement state strategy is more solid and efficient than the working pressure technique for planning structure. The consequences of the point of confinement state strategy for twisting minute and load conveying limit is higher than working pressure technique. The consumption of steel is less in LSM with respect to WSM. For same working forces, WSM will require higher steel section than LSM.

- Working stress method is simple to use but does not give consistent values of a factor of safety. That is the reason Limit states methods were developed.
- The limit states provide a checklist of the basic structural requirements for which design calculations may be required. Limit states design, by providing consistent safety and serviceability, ensures an economical use of materials and a wide range of applications.

13. ACKNOWLEDGMENT

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