Seismic Analysis of Industrial Structure Using Bracings and Dampers

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Abstract— Resistance of structures against earthquake plays an extensive role in construction industry. A structure should consist of strength, stability and ductility to accommodate both horizontal and vertical loadings. Horizontal loading leads to the production of sway and further results in vibration and storey drift. Strength and stiffness are two major keys for any structure to resist gravity and lateral loads. Provision of bracings or dampers to any structure contributes to lateral stability. After assigning dampers or bracings, the general system changes to lateral load resisting system (LLRS). The present work involves in proposing the suitability of type of damper or bracing for controlling the seismic activity on industrial structures in respective seismic zones II of India. Industrial structures also associate high dead load as it provides residence to heavy sized members. Therefore, this is necessary to investigate seismic response of buildings with various bracings and dampers to control vibration, lateral displacement and storey drift. Natural time period, frequency, roof displacements are the major parameters considered for observing response of structures. Response spectrum analysis of 3D industrial structure with distinct concentric bracings and dampers using SAP 2000 will be carrying in this research under respective base shear. In this study it is concluded that with bracings and dampers we can resist structural stability and make structure economic.

Keywords: Steel Structure, Analysis, Industrial Frame, Drift, Seismic Zone, SAP2000, Cost

I. INTRODUCTION

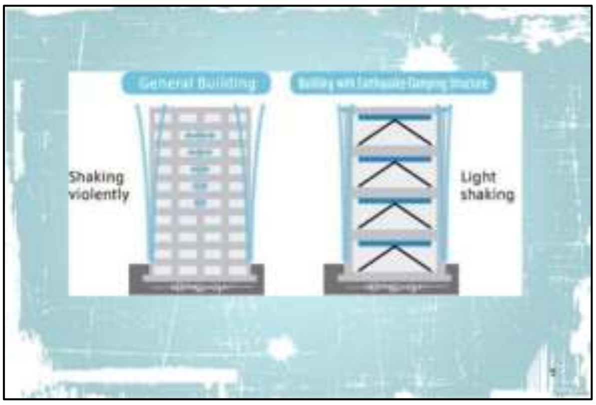
Earthquakes are perhaps the most unpredictable and devastating of all natural disasters. They not only cause great destruction in terms of human casualties, but also have a tremendous economic impact on the affected area. An earthquake may be defined as a wave like motion generated by forces in constant turmoil under the surface layer of the earth (lithosphere), travelling through the earth's crust. It may also be defined as the vibration, sometimes violent, of the earth's surface as a result of a release of energy in the earth's crust. This release of energy can cause by sudden dislocations of segments of the crust, volcanic eruption, or even explosion created by humans. Dislocations of crust segments, however, lead to the most destructive quakes. In the process of dislocation, vibrations called seismic waves are generated. These waves travel outward from the source of the earthquake at varying speed, causing the earth to quiver or ring like a bell or tuning fork. The concern about seismic hazards has led to an increasing awareness and demand for structures designed to withstand seismic forces. In such a scenario, the onus of making the building and structure safe in earthquake-prone areas lies on the designers, architects, and engineers who conceptualize these structures. Codes and recommendations, postulated by the relevant authorities, study of the behavior of structures in past earthquakes and understanding the physics of earthquake are some of the factors that helps in the designing of an earthquake resistant structure.

Earthquakes create vibrations on the ground that are translated into dynamic loads which cause the ground and anything attached to it to vibrate in a complex manner and cause damage to buildings and other structures. Civil engineering is continuously improving ways to cope with this inherent phenomenon. Conventional strategies of strengthening the system consume more materials and energy. Moreover, higher masses lead to higher seismic forces. Alternative strategies such as passive control systems are found to be effective in reducing the seismic and other dynamic effects on civil engineering structures.

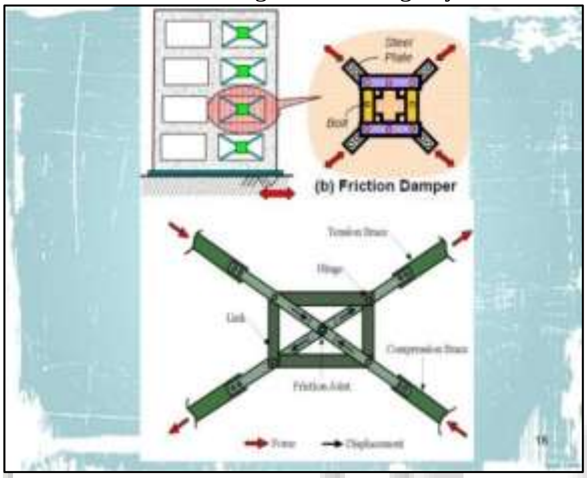
Steel moment resisting frames are susceptible to undergo lateral displacement during earthquake. Horizontal (seismic/wind) load is the unreliable load that is coming on the structure. Any structure should be designed in such a way that, it should resist from both gravity and lateral loads. Gravity loads includes dead load, live load, dust load etc. Whereas lateral load includes seismic load, wind load and blast load. Due to this lateral loads, high stresses are produced which then leads to sway or vibration. So, every structure should contain strength to resist vertical (gravity) loads and stiffness to resist (horizontal).

The present experimental investigation involves the analytical investigation of a Pre- Engineered building. The golden opportunities lied in the static analysis in the configuration of the analysis to imagine the scenario of the diaphragm and manage the equities of the ceruaningiti9es of the system and management of the criteria's and issue the sculpture of the tired budget and manage the finances of the steel frame and got to manage the framework.

Seismic effect on steel Industry



a. Building with Bracings System



b. Structure with Dampers

Structure with Resisting Systems

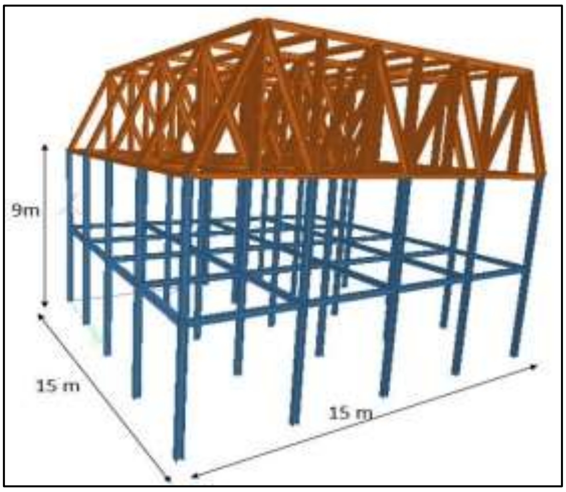
II. METHODOLOGY

A. Step-1 Literature survey related to industrial steel structures.

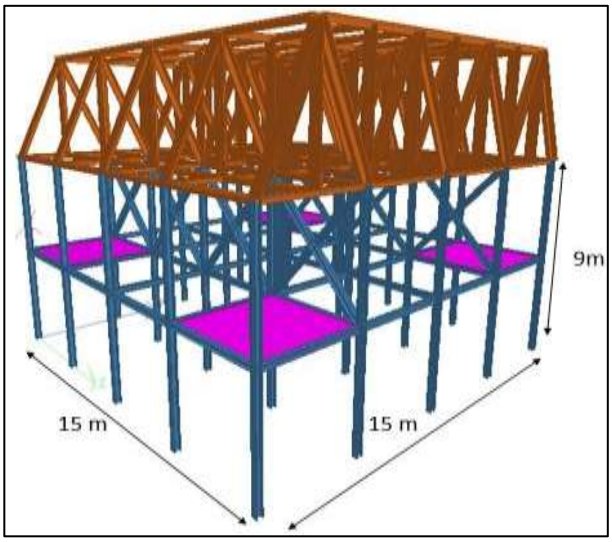
The past research papers were examined for basic investigation. Progressively modern examination techniques keep on improving the exactness with which the conduct of structures can be anticipated.

B. Step-2 Second step is to model structures using analysis tool SAP2000

1) Case I: 15 x 15 m



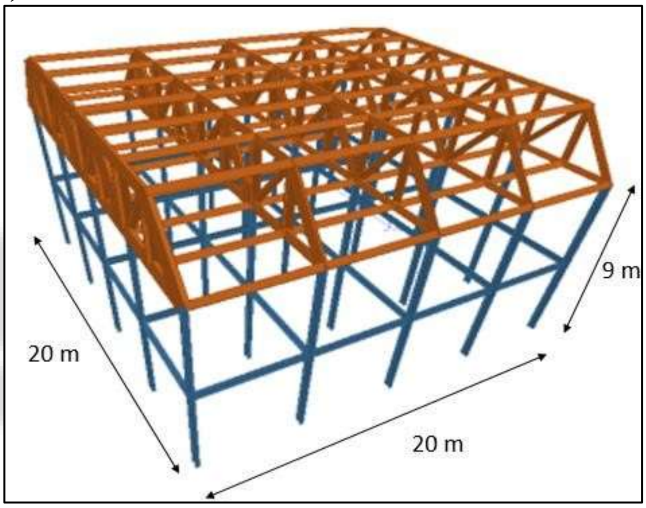
a. General Structure



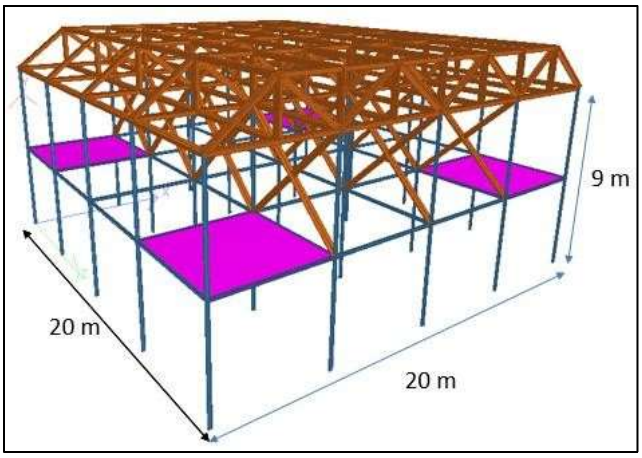
b. Structure with bracing & Dampers

Modelling of Industrial structure 15 x 15 m using SAP2000

2) Case II: 20 x 20 m structure



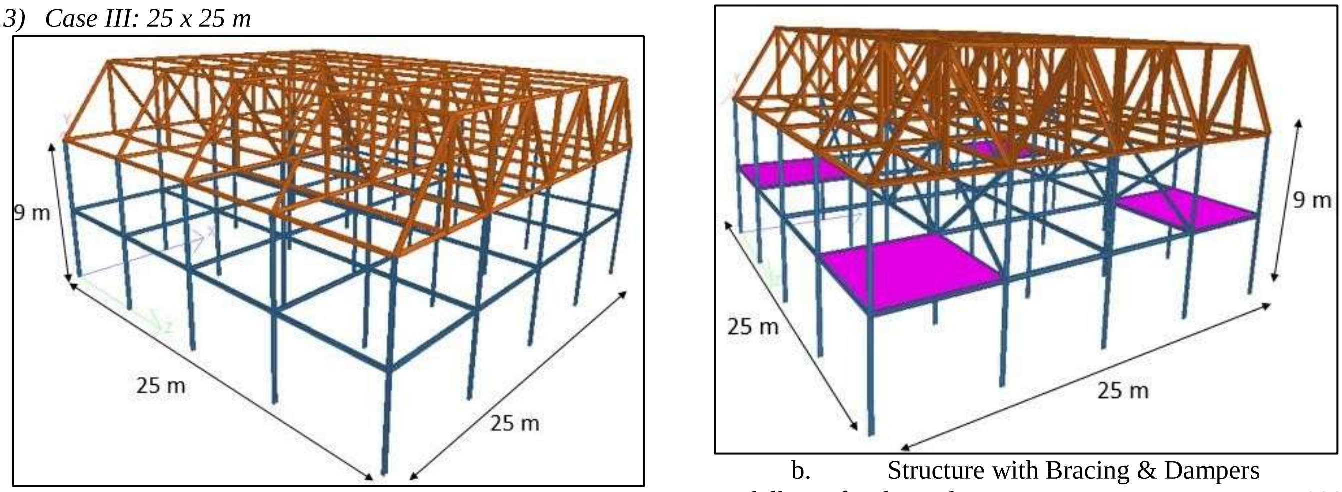
a. General Structure



b. Structure with Bracing & Dampers

Modelling of Industrial structure 20 x 20 m using SAP2000

3) Case III: 25 x 25 m

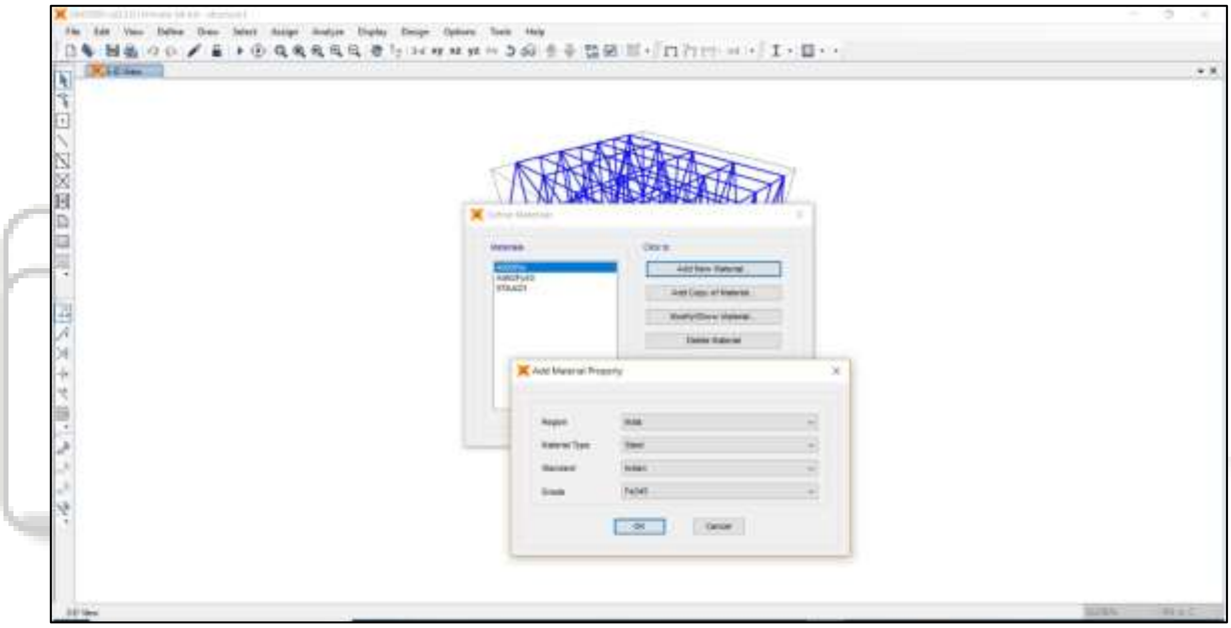


a. General Structure

b. Structure with Bracing & Dampers

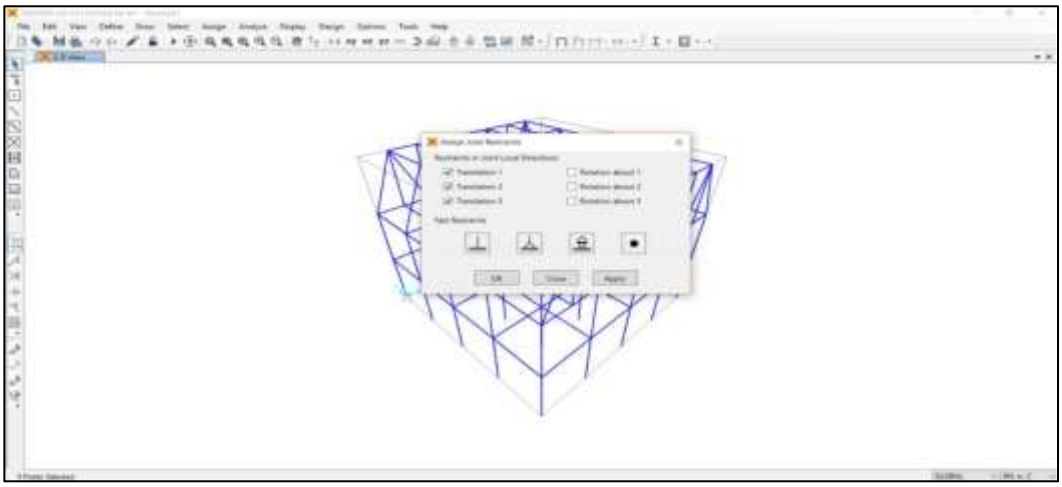
Modelling of Industrial structure 25 x 25 m using SAP2000

C. Step-3 to assign section data as per Steel Table and material properties.



Assigning Material properties

D. Step-4 to Assign support conditions



Assigning support conditions

E. Step-5 To assign Seismic Forces as per selected zone and soil type.

A Load combination results when more than one Loading condition follows up on the structure. Development guidelines usually decide a combination of weight mixes with trouble factors (weightings) for each load type to ensure the security of the structure under different most extraordinary foreseen stacking circumstances. It oversees loads and weights impacts on account of temperature changes, soil and hydrostatic loads, inside making stresses, (due to. creep, shrinkage, differential settlement, etc), unexpected, etc, to be considered in the structure of structures as reasonable. This part also joins heading on loading combinations. Burdens to be considered for a particular condition is to be arranged in structuring judgment.

Seismic load

Load combinations as per I.S. 875-V

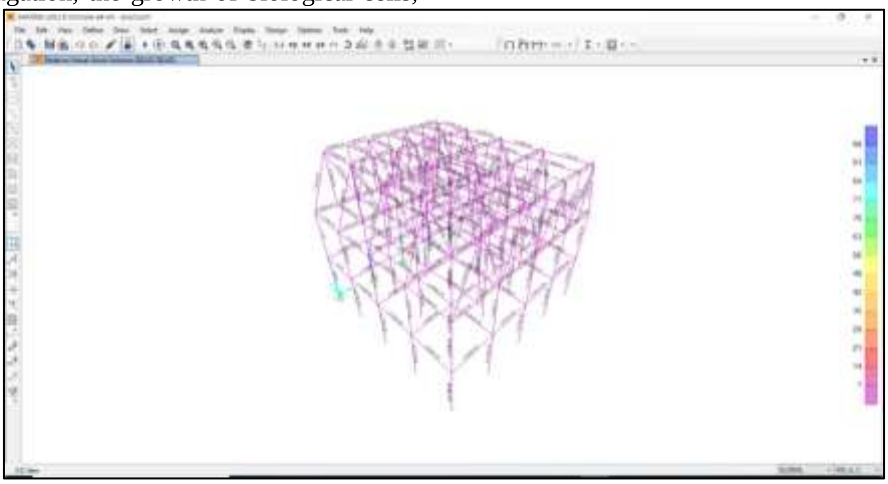
LOAD CASE NO.	LOAD CASES
1	D.L
2	L.L
3	T.H
4	(D.L+L.L)
5	(D.L+EQ)
6	1.5(D.L+L.L)
7	1.5(D.L+EQ)
8	1.2(D.L+L.L+EQ)

F. Step 6 To perform finite element analysis

The Finite Element Analysis (FEA) is the simulation of any given physical phenomenon using the numerical technique called Finite Element Method (FEM). Engineers use it to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster.

It is necessary to use mathematics to comprehensively understand and quantify any physical phenomena such as structural or fluid behavior, thermal transport, wave propagation, the growth of biological cells, etc. Most of these processes are described using Partial Differential Equations (PDEs). However, for a computer to solve these PDEs, numerical techniques have been developed over the last few decades and one of the prominent ones, today, is the Finite Element Analysis.

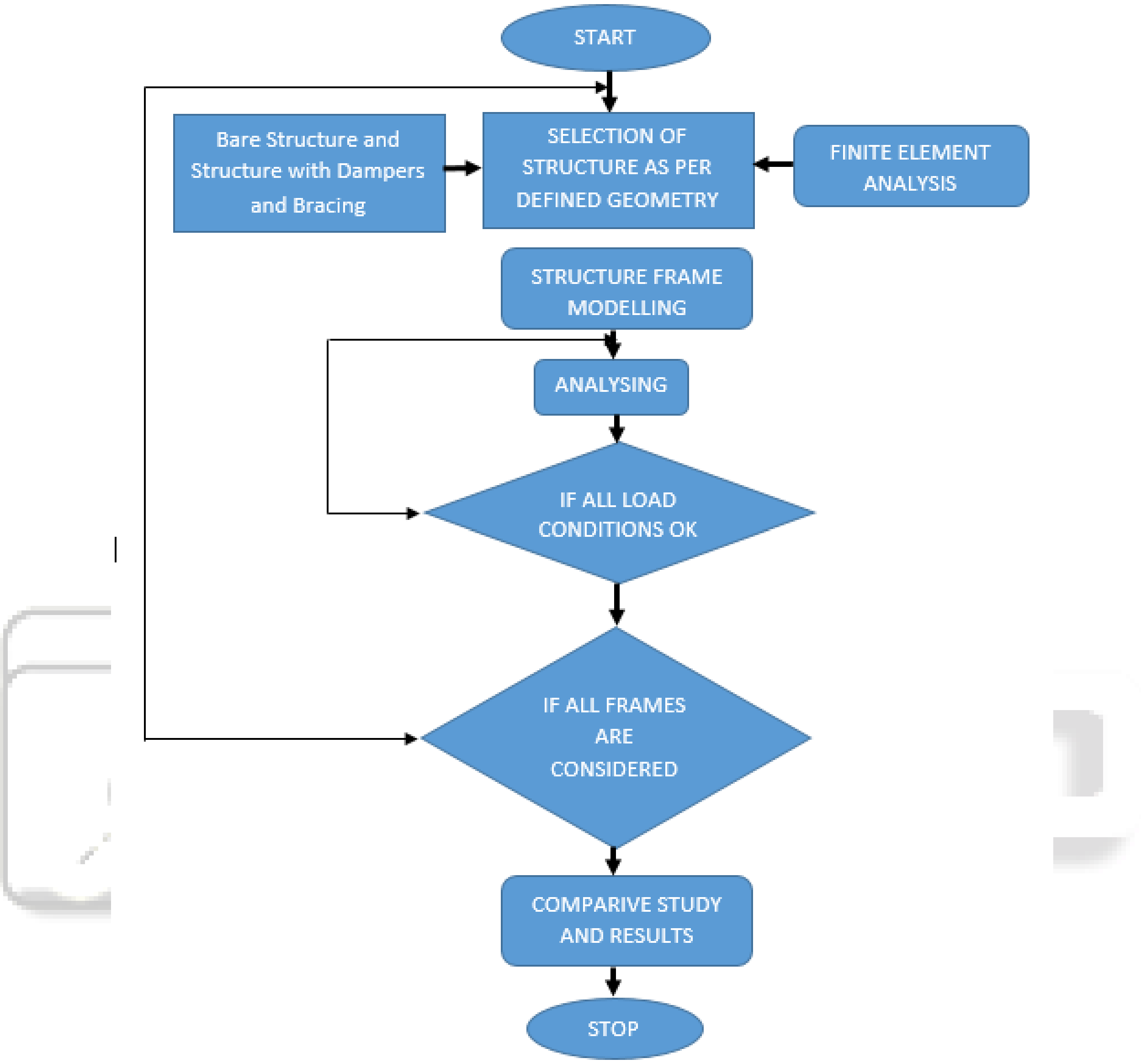
Differential equations can not only describe processes of nature but also physical phenomena encountered in engineering mechanics. These partial differential equations (PDEs) are complicated equations that need to be solved in order to compute relevant quantities of a structure (like stresses (ϵ), strains (ϵ), etc.) in order to estimate a certain behavior of the investigated component under a given load. It is important to know that FEA only gives an approximate solution of the problem and is a numerical approach to get the real result of these partial differential equations. Simplified, FEA is a numerical method used for the prediction of how a part or assembly behaves under given conditions. It is used as the basis for modern simulation software and helps engineers to find weak spots, areas of tension, etc. in their designs. The results of a simulation based on the FEA method are usually depicted via a color scale that shows for example the pressure distribution over the object.



Analysis results

G. Step 7 to prepare comparative result in M.S. excel.

H. Step 8 to provide conclusion as per results



Flow Chart of the Study

1) Geometrical Data and Load Calculations

Geometrical properties of the structure

1	Number of Stories	Ground + 1
2	Height of stilt floor	4.5 m.
3	Height of upper stories	4.5 m.
4	Depth of foundation	4.5 m
5	Grade of Steel	Fe 345
6	Steel Sections	Fe 345
7	Seismic Zone	II
8	Bracing	X
9	Sections Consider	Beam (ISMB 200) & Angle Section (150X150X10)
10	Width & Length	15 m x 15 m, 20 m x 20 m, 25 m x 25 m.

Load Assessments and Calculations

S.No.	Load Type	As per I.S.
1	Self Load	I.S. 875-PART-1
2	Live Load	I.S. 875-PART-2
3	Earth Quake	I.S. 1893-PART-1

1) Dead Load (DL)
   It is total dead load of structure bracings and dampers
2) Live load
   In this study we are considering load of Gantry Crane which is consider as 3 KN at nodal points of the members.
3) Earthquake Loads: All frames are analyzed considering seismic zone II

The seismic load calculation are as per IS: 1893 (part-1)-2016. Seismic force parameters for proposed issue.

Seismic Load Calculation

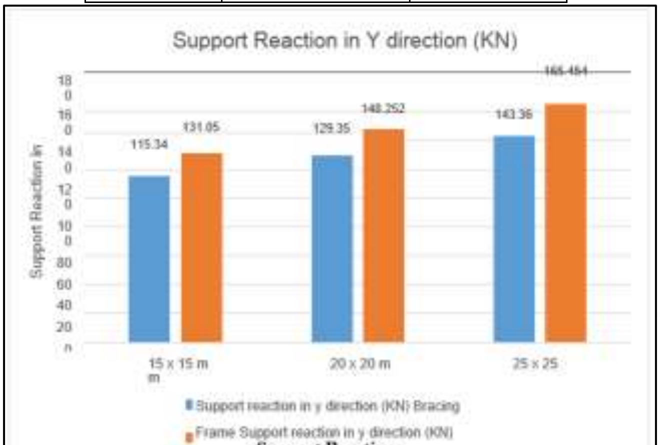
S. No.	Parameter	Value
1	Seismic load zone	II
2	Damping ratio	0.05
3	Importance factor	1.5
4	Response Reduction Factor	5
5	Soil site factor	Soft

III. RESULTS AND DISCUSSION

A. Support Reaction

Support Reaction

Support reaction in y direction (KN)		
Cases	Bracing Frame	Steel Frame
15 x 15 m	115.34	131.05
20 x 20 m	129.35	148.252
25 x 25 m	143.36	165.454

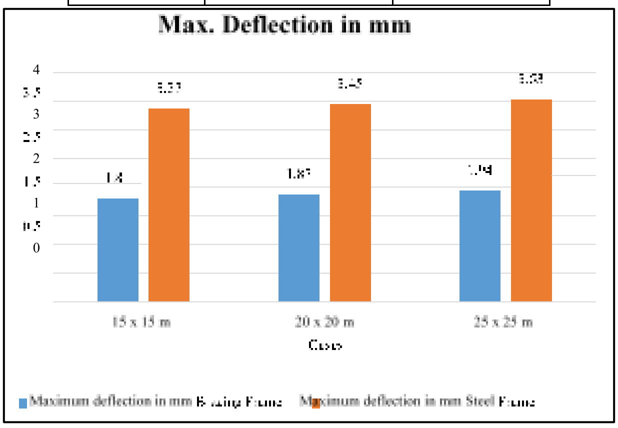


Support Reaction

B. Maximum Deflection

Maximum Deflection

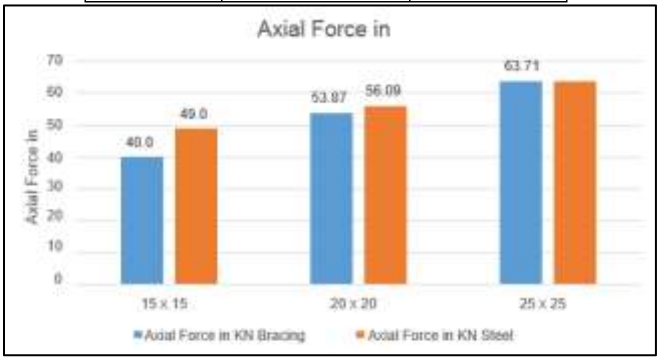
Maximum deflection in mm		
Cases	Bracing Frame	Steel Frame
15 x 15 m	1.8	3.37
20 x 20 m	1.87	3.45
25 x 25 m	1.94	3.53



C. Axial Force in KN

Axial Force

Axial Force in KN		
Cases	Bracing Frame	Steel Frame
15 x 15 m	40.04	49.03
20 x 20 m	53.875	56.094
25 x 25 m	63.71	63.8

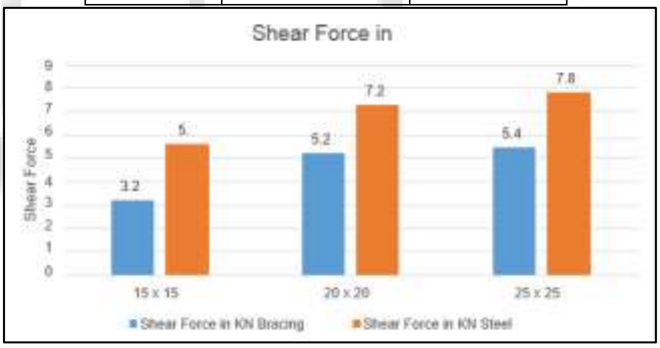


Axial Force in KN

D. Shear Force (KN)

Shear Force in KN

Shear Force in KN		
Cases	Bracing Frame	Steel Frame
15 x 15 m	3.21	5.6
20 x 20 m	5.21	7.28
25 x 25 m	5.45	7.83



Shear Force in KN

E. Analysis of 15 x 15 m Frame

Analysis of 15 x 15 m bare frame:

Forces on steel Frame 15 x 15 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	51.46	5.67	7.9	0	0	2.12
1	53.56	5.9	8.84	0	3.09	3.2
5	55.66	6.13	9.78	0	4.97	4.28
7.5	57.76	6.36	10.72	0	6.75	5.36
10	59.86	6.59	11.66	0	8.597	6.44
15	61.96	6.82	12.6	0	10.43	7.52

Analysis of 15 x 15 m frame with bracings and dampers

Forces on Bracing steel Frame 15 x 15 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	48.32	3.76	6.54	0	0	0
1	48.21	3.9	7.54	0	0	0
5	49.05	4.9	8.54	0	4.32	1.654
7.5	49.89	5.327	9.54	0	5.43	2.67
10	50.73	5.897	10.54	0	6.65	2.01
15	51.57	6.467	11.54	0	11.45	2.176

F. Analysis of 20 x 20 m frame

Analysis of 20 x 20 m General frame

Forces on steel Frame 20 x 20 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	55.45	6.21	8.75	0	1.45	0
1	58.73	4.8	9.57	0	3.21	1.09
5	62.01	5.31	10.39	0	4.97	4.32
10	65.29	7.45	11.21	0	6.73	7.55
15	68.57	9.59	12.03	0	8.49	10.78
20	71.85	11.73	12.85	0	10.25	14.01

Analysis of 20 x 20 m frame with bracings and dampers

Forces on Bracing steel Frame 20 x 20 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	49.68	4.03	7.55	0	0	0
1	51.87	4.123	8.21	0	2.54	0
5	54.06	5.53	8.87	0	4.62	2.34
10	56.25	6.937	9.53	0	6.7	2.69
15	58.44	8.344	12.65	0	8.78	3.04
20	60.63	9.751	13.21	0	10.86	3.39

G. Analysis of 25 x 25 m frame

Analysis of 25 x 25 m frame

Forces on steel Frame 25 x 25 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	62.56	3.23	3.24	0	0	0
1	64.58	5.67	7.43	0	4.8	3.24
5	66.6	8.11	10.45	0	5.89	1.89
10	68.62	10.55	2.34	0	6.98	7.9
12.5	70.64	12.99	4.8	0	8.07	8.32
15	72.66	15.43	10.45	0	9.16	8.74
20	74.68	17.87	12.45	0	10.25	9.16
25	76.7	20.31	17.64	0	11.34	16.42

Analysis of 25 x 25 m frame with bracings and dampers

Forces on Bracing steel Frame 25 x 25 m						
Section	Axial Force kN	Shear-Y kN	Shear-Z kN	Torsion kNm	Moment-Y kNm	Moment-Z kNm
0	53.21	4.21	7.8	0	0	0
1	55.32	4.39	8.42	0	3.21	0
5	57.43	4.57	9.04	0	4.86	3.11
10	59.54	4.75	9.66	0	6.51	3.4
12.5	61.65	2.45	10.28	0	8.16	3.69
15	63.76	7.42	10.9	0	11.32	3.98
20	65.87	10.46	11.52	0	14.48	4.27
25	67.98	13.5	12.14	0	17.64	4.56

H. Cost Analysis

Cost Analysis for General Structure			
Cases	Qty Steel (FE 345)	Rate per KG	Total Cost
15 x 15 m	28970.5	65	1883082.5
20 x 20 m	34900.78	65	2268550.7
25 x 25 m	39790.04	65	2586352.6

Cost Analysis for damper Structure			
Cases	Qty Steel (FE 345)	Rate per KG	Total Cost
15 x 15 m	26420.56	65	1717336.4
20 x 20 m	31700.66	65	2060542.9
25 x 25 m	35400.5	65	2301032.5

IV. Conclusions

A. Conclusions

In this study we are comparing three different geometric conventional Steel structure with steel structure utilizing bracing system i.e. X type to resist lateral load & enhancing its life span.

B. Following observations are in 15 x 15 m structure:

1) In 15 x 15 m structure we observed that support reaction value decreases by 11.8% which shows stability of the structure in distributing load to the soil.
2) Here it is observed that bracing and dampers resisting the deflection of the structure generating due to Gantry crane load by 46.6 % which is very important aspect for safety.
3) In terms of forces it is observed that unbalanced forces decreases from 5.6 KN to 3.21 KN which shows structure stability and stiffness.
4) In terms of Cost with considering bracing system there is a reduction of 165746 Rs in overall structure.

C. Following observations are in 20 x 20 m structure:

1) support reaction value decreases by 13.2 % which shows stability of the structure in distributing load to the soil.
2) Here it is observed that bracing and dampers resisting the deflection of the structure generating due to Gantry crane load by 45.79 % which is very important aspect for safety.
3) In terms of forces it is observed that unbalanced forces decreases from 7.28 KN to 5.21 KN which shows structure stability and stiffness.
4) In terms of Cost with considering bracing system there is a reduction of 208007 Rs in overall structure.

D. Following observations are in 25 x 25 m structure:

Support reaction value decreases by 12.35% which shows stability of the structure in distributing load to the soil.

1) Here it is observed that bracing and dampers resisting the deflection of the structure generating due to Gantry crane load by 42.79 % which is very important aspect for safety.
2) In terms of forces it is observed that unbalanced forces decreases from 7.83 KN to 5.45 KN which shows structure stability and stiffness.
3) In terms of Cost with considering bracing system there is a reduction of 285320 Rs in overall structure

E. Future Scope

1) In this structure we are considering seismic forces whereas in future one can select wind pressure.
2) In this study we are considering industrial frame whereas in future steel house can be consider.
3) In this study we are analyzing using SAP2000 whereas in future any other analysis tool can be use.

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