Analysis of Conventional Chevron Braced Frame and Diagrid Frame with Plan Irregularity

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Abstract : High-rise buildings are more vulnerable to collapse due to high wind and earthquake pressure. In such a building risk of failure can be minimized by adopting lateral load resisting system. In this study, we compared three lateral load resisting frame i.e. diagrid frame and chevron braced frame with conventional frame system. The seismic analysis is done on these three frames. The structures are analyzed by linear static method. The building is considered to be irregular in plan. For irregular plan, C-shape plan, T-shape plan considered. The results are obtained after analysis are compared by various parameters like storey drift, absolute displacement, base shear, moment and axial forces. The First Comparison is between diagrid system, chevron braced system and conventional frame system for C-Type and T-Plan separately and after that second overall comparison is between C-Plan and T-plan. The analysis is done on by using STAAD Software. The result of work showed that diagrid system resist lateral more efficiently than chevron braced system and conventional frame system as it yields the least value for absolute displacement, storey drift, top storey shear and base shear.

***Keywords* - Diagrid frame system, Chevron braced frame system, plan Irregularity.**

I. Introduction

In the today's generation, the rate of Population is increased day by day. Due to this space required for land is insufficient. So, civil engineer construct a building in sufficient space with maximum height with regular and irregular plan. In old days, this high-rise buildings only use for a commercial purpose. But, Now-a-days, it is used for both commercial and residential purpose due to lack of space. So, for safety, strength and aesthetical point of view structural engineer and architect construct a high-rise building with some shear wall, wall frame, rigid frame, braced tube system. Recently, For increasing the stability of structure diagrid frame, braced frame with diagonal grid is usually used.

Diagrid frame is a particular form of space truss system. Dia-Frame consists of perimeter grid made up of a series of triangulated truss system. It is formed by intersecting the diagonal and horizontal components of structure of the building. Diagrid frame has better appearance in view and it is easily recognized. Diagrid frame structure has triangular configuration and high efficiency because of this the number of structure elements required for construct a building is reduces. Because of reduction in outer structural elements therefore it create less obstruction to outside view. Diagrid allow significant flexibility with the floor plan because the structural efficiency of diagrid system helps in avoiding interior and corner columns. The diagonal members of diagrid frame system carry dead load, live load, gravity load as well as lateral forces effectively in any seismic zone area due to their triangulated configuration. Diagrid frame structures are more effective in minimizing shear deformation in the building.

The main difference between lateral load resisting diagrid structure model and conventional frame structure is that in diagrid structures almost all exterior conventional vertical columns are eliminated. Because of exterior frame consist of diagonal members which can carry gravity loads as well as lateral loads in diagrid structure because of their triangulated configuration, whereas conventional structure can carry only lateral loads. Diagrid structures are more effective in case of minimizing shear deformation than a conventional structure or other type of structure. One of the drawback of diagrid structure is that conventional structure has maximum ductility than it.

Chevron braced frame are common configuration for providing lateral load resistance in steel framed building frame or concrete building frame. Chevron bracing is of inverted V-type of Shape. It involves two members meet at the middle point on the upper horizontal member of building. In Chevron structure members are designed for both tension and compression loads. chevron bracing allows the maximum space for doorways or corridors through the bracing opening.

Objectives of this study-

1) To determine the best and the appropriate structural system for the different type of high-rise buildings and to understand chevron braced frame and diagrid frame action in high rise building.

2) To analyze diagrid, chevron braced and conventional frame structural systems using STAAD software for irregular plan.

3) To compare the performance of the building with diagrid structural system and chevron braced conventional frame system under seismic loading.

4) To obtain the response in terms of parameter such as storey displacement, storey drift, storey shear.

II. ANALYSIS OF DIAGRID STRUCTURE SYSTEM AND CHEVRON BRACED SYSTEM

In this study six models are considered with C-Type plan and T-type plan layout. For C-Type layout, Model is divide into three part and for T-type, model is also divide into 3 part, in their there are total 6 models named as C-1,C-2,C-3,T-1,T-2,T-3.The categorization of model is shown in below. The models are analyzed by using STAAD Software.

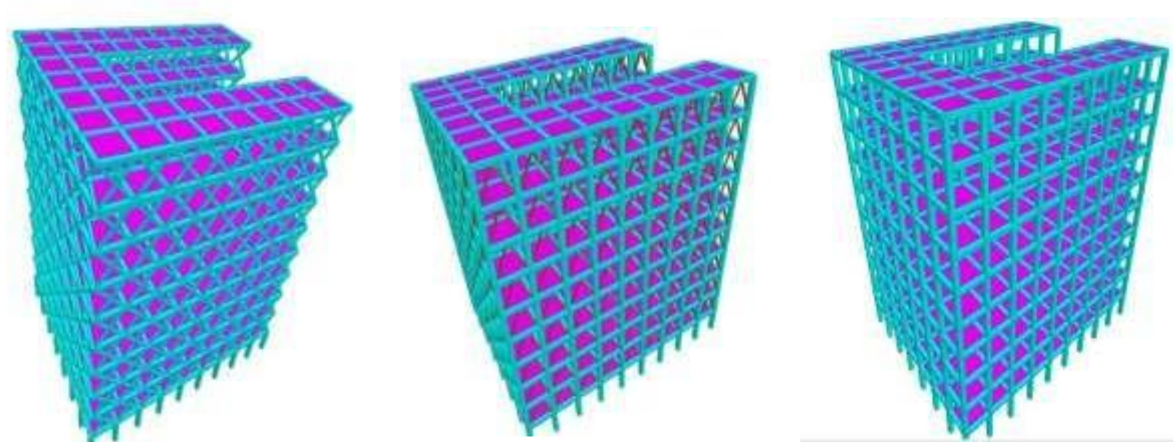
C-1: Diagrid Structure corresponding to an C-Base plan.

C-2: Chevron Braced Conventional Structure corresponding to an C-Base plan.
C-3: Conventional Structure corresponding to an C-Base plan.
T-1: Diagrid Structure corresponding to an T-Base plan.
T-2: Chevron Braced Conventional Structure corresponding to an T-Base plan.
T-3: Conventional Structure corresponding to an T-Base plan.

Modelling:

C-shape plan of structure-

For study the effect of different frames following analysis is carried out by considering C-shape base plan building. The analysis is carried out on reinforced cement concrete building. The building with C-base plan having area of 378 m2. The building height consider to be 30m with 10 storey. Each storey height is considered to be 3m.



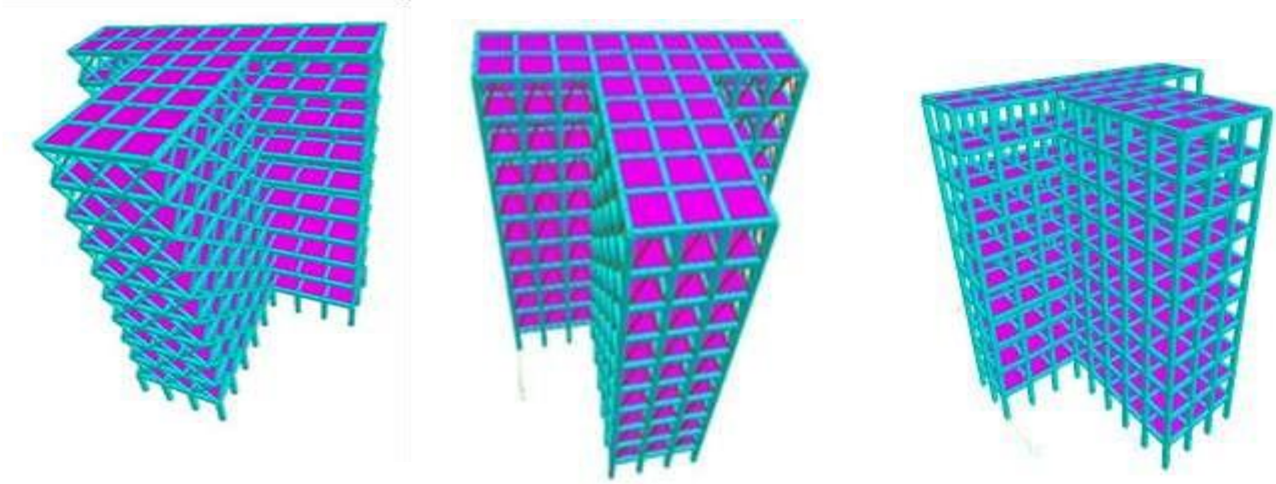
C1:3D view C diagrid structure C2:3D view C Chevron braced structure C3:3D view C Conventional structure

Figure 1. 3D Rendering view of C Base plan structures in STAAD Software

After categorization of model, the C shape building model is designed in STAAD Software. After assigning all the properties of material such as beam size, column size to the building, finally 3d rendering view of model obtained. Fig.1 (a) shows the 3d rendering view of c shape diagrid model building where vertical member replaced by diagonal members. Fig.1(b) shows the 3d rendering view of C shape chevron model. The inverted v shaped bracings provided in building. Fig.1(c) shows the 3d rendering view of simple conventional structure.

T-shape plan of structure-

For the study of different type of building frame another irregular T base plan building considered. For this reinforced concrete cement building is considered. T-plan having area of 297 m^2.



T1:3D view T diagrid structure T2: 3D view T Chevron braced structure T3: 3D view T Conventional frame

Figure 2. 3D Rendering view of T Base plan structures in STAAD Software

After categorization of model, the T shape building model is design in STAAD Software. After assigning all the properties of material such as beam size, column size to the building, finally 3d rendering view of model obtained. Fig. 1 (a) shows the 3d rendering view of T shape diagrid model building where vertical member replaced by diagonal members. Fig. 1(b) shows the 3d rendering view of T shape chevron model. The inverted v shaped bracings provided in building. Fig.1(c) shows the 3d rendering view of T shape simple conventional structure.

The description of building, The height building is considered to be 30m. The building is divided into 10 storeys. Each storey has 3m height. The span between column to column is 3m. The building frame consider to be SMRF. The end condition for footing consider to be fixed. The size of column consider to be 450 mm by 450 mm. The size of beam consider to be 380 mm by 380 mm. Grade of concrete taken as M40 and grade of steel taken has Fe600. The dead load on building consider to be 3.61KN/m2. And live load on building consider to be 3.5 KN/m2.

The frame property For diagrid structure, reinforced cement concrete beam is considered. Size of diagrid diagonal takes as 230 mm by 230 mm. For chevron braced frame, ISA steel angle section consider. The size of chevron bracings taken as 200x10x20mm.

The data for seismic analysis taken from IS1893-2002(Part-1).For zone delhi(iv), The zone factor taken to be 0.24. Rock and soil type factor taken to be 1. Importance factor taken as 1. Response reduction factor taken as 5.From the above property of building, property of frame, seismic data the model is analyses by linear static analysis. The analysis is done with help of STAAD software. After analysis comparison between model take place.

For the comparison between models, the one internal column and two internal and corner beam are selected. The interlocation of column is shown in figure.3 below.

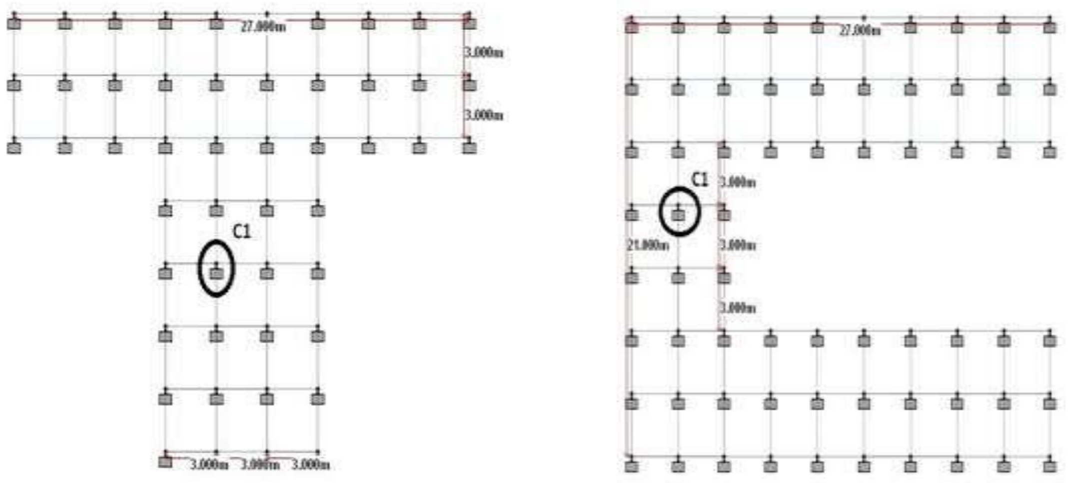


Figure 3: Location of Internal Column for Observation

III. RESULT AND DISCUSSION

After analyzing and designing of all models for C and T structures in STAAD Software, the results obtained in terms of storey drift, base shear, displacement, top shear. The comparisons between diagrid model, chevron model and conventional model shown below in terms of graphical representation.

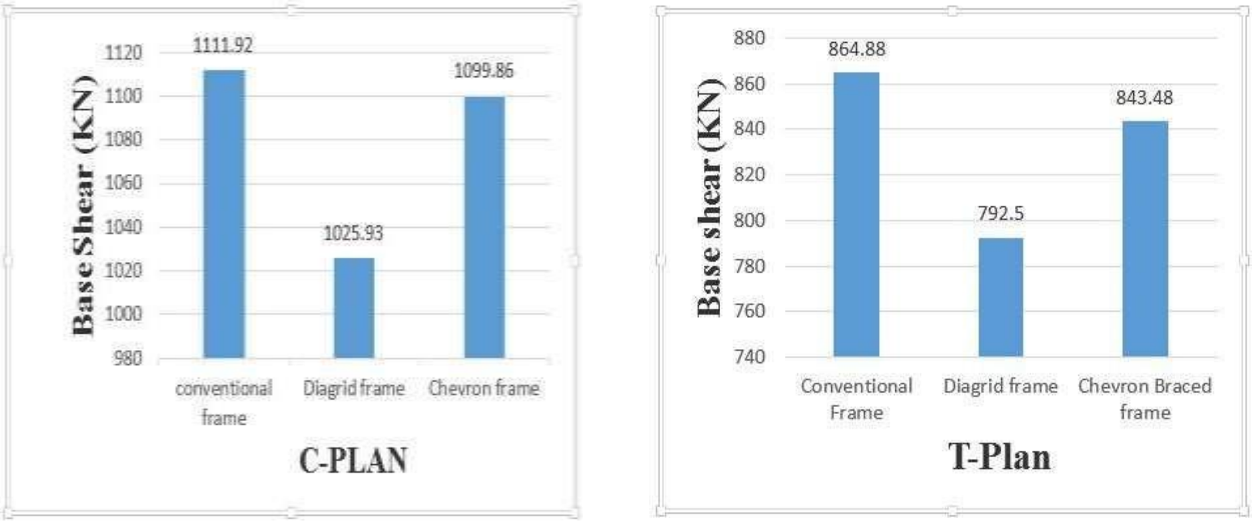
III.1. Base Shear –

Table 4 represents the value of base shear with respect to plan of building. For C or T shape plan of building, the base shear value for diagrid frame structure, chevron braced structure and conventional frame structure is given below. From the table it is observed that the value of base shear for diagrid structure is less than other two frame structures.

Table 1. Base shear values for frame after analysis

Plan	C-Type Of Structure			T-Type Of Plan Structure		
	Diagrid frame	Chevron Braced frame	conventional frame	Diagrid frame	Chevron Braced frame	conventional frame
Base Shear	1025.93	1099.86	1111.92	792.5	843.48	864.88

representation of base shear value is shown in graph 1 for C-plan or T-plan of structure. In graph x-axis represents the different type of earthquake resisting frames and y-axis represents the value of base shear. From graph can be conclude that diagrid structure is more convenient for base shear**.**

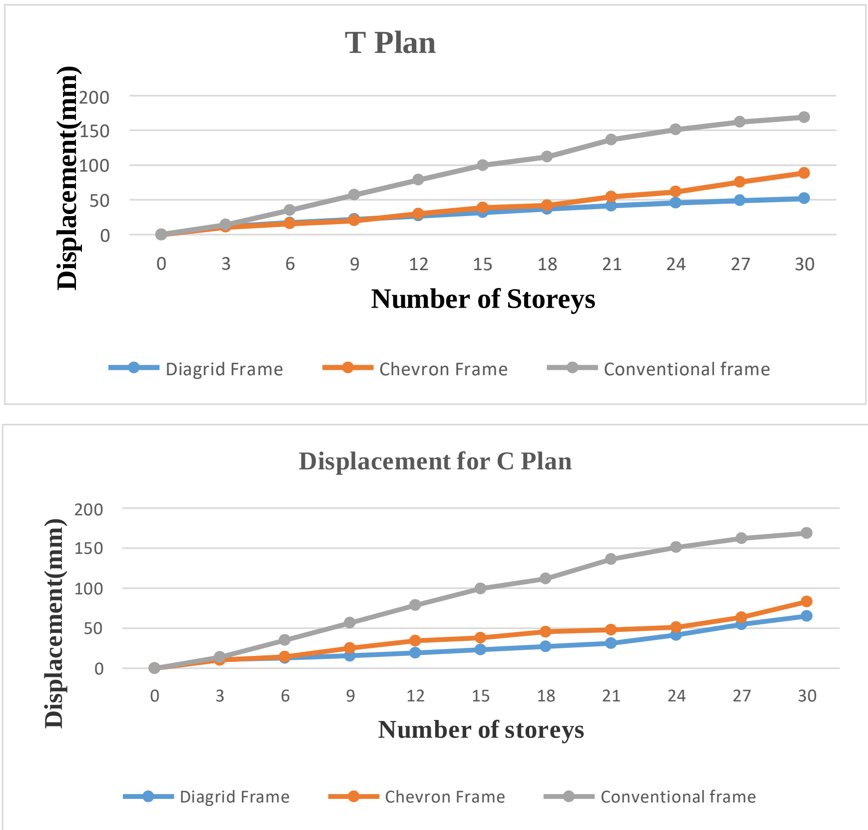


Graph 1. Comparison of Base Shear For C And T Base Plan

III.2. Storey Displacement-

The value of storey displacement is shown in table2. In table 2, displacement value for diagrid frame, chevron braced frame and conventional frame are given. From the table it is observed that diagrid frame shows less displacement because the weight of diagrid members less than chevron brace members and conventional frame members.

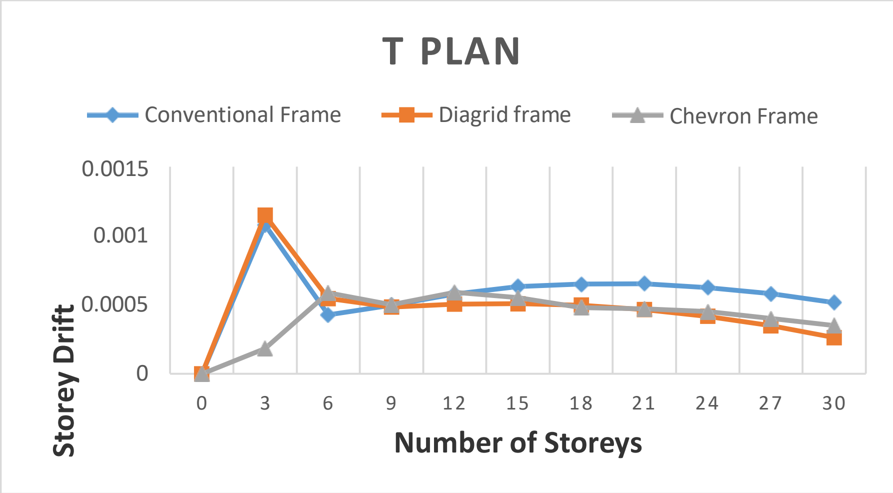
Graph 2 represents the value of storey displacement. In graph x-axis represents the increasing number of storeys and y-axis represents the displacement occurred in building after application of lateral force. As we go upward side the value of storey displacement is increases with respect to height of building. For diagrid frame, the value displacement is lesser than the other two frames. Hence the deflection occur in deflection is smaller for diagrid frame. Other two frames deflects slightly greater than diagrid frame.

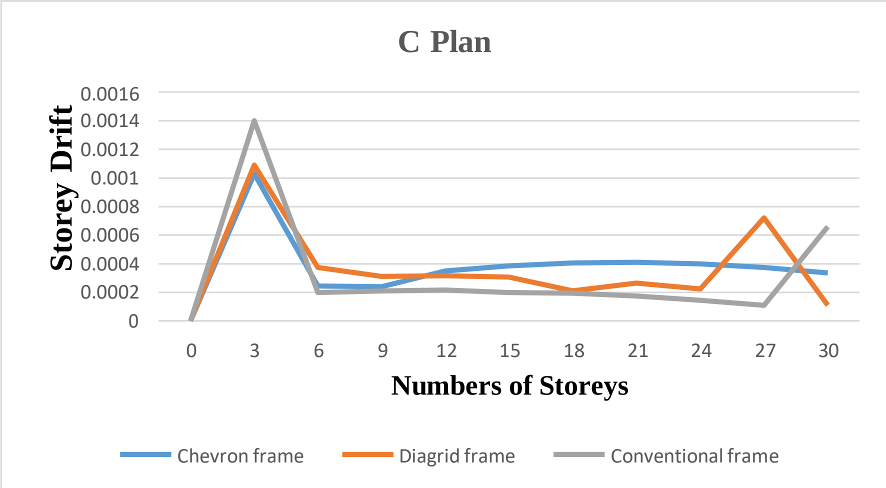


Graph 2. Comparison Of Displacement For C And T Base Plan

III.3. Storey Drift-

The value of storey drift is given in table 2. In this table, story drift value for diagrid structure, chevron braced structure and for conventional structure is given. from this observed that diagrid structure has minimum storey drift than chevron braced and conventional frame structure.





Graph 3. Comparison of Storey Drift For C And T Base Plan

Graph 3 represents the value of storey drift. In graph x-axis represents the number of storeys and y-axis represents the change in storey drift value. From the graph it is observed that for chevron braced frame and conventional frame the value storey drift is maximum with respect to height of building. For diagrid frame value is minimum i.e. it has less storey drift.

Table.2 Displacement and Storey drift for C-Plan and T-Plan

	DISPLACMENT						STOREY DRIFT					
STOREY	C-PLAN			T-PLAN			C-PLAN			T-PLAN		
0	0	0	0	0	0	0	0	0	0	0	0	0
3	11.51	10.86	14.04	10.38	10.9	14.04	0.00103	0.00109	0.0014	0.00108	0.00115	0.00018
6	16.97	15.8	35.13	12.82	14.66	35.13	0.000244	0.000374	0.0002	0.000427	0.000546	0.00058
9	21.81	20.12	57.03	15.76	17.7	57.03	0.00024	0.000311	0.00021	0.000498	0.000484	0.0005
12	26.86	30	78.69	19.25	20.8	78	0.000349	0.000315	0.000216	0.000579	0.000505	0.00059
15	31.94	38.63	99.59	23.10	23.90	99.56	0.000385	0.000307	0.0002	0.000633	0.000508	0.00055
18	36.94	41.86	111.9	26.5	27.15	119.4	0.000405	0.000209	0.000195	0.00065	0.000498	0.0004
21	41.55	54.33	136.48	29.76	31.24	136.76	0.000409	0.000263	0.000174	0.000653	0.000465	0.00039
24	45.71	61.59	151.1	31.76	35.23	151.11	0.000399	0.000224	0.000146	0.000626	0.000417	0.00032
27	49.21	75.61	162.08	55.66	58.90	162.11	0.000373	0.00072	0.000109	0.00058	0.000349	0.0003
30	51.84	88.63	168.7	70.65	88.13	168.67	0.000335	0.00011	0.00066	0.000516	0.000263	0.00029

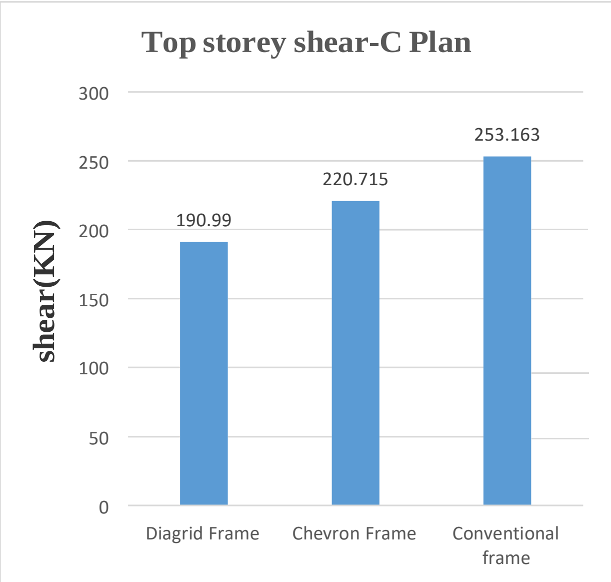
III.4. Top Storey Shear-

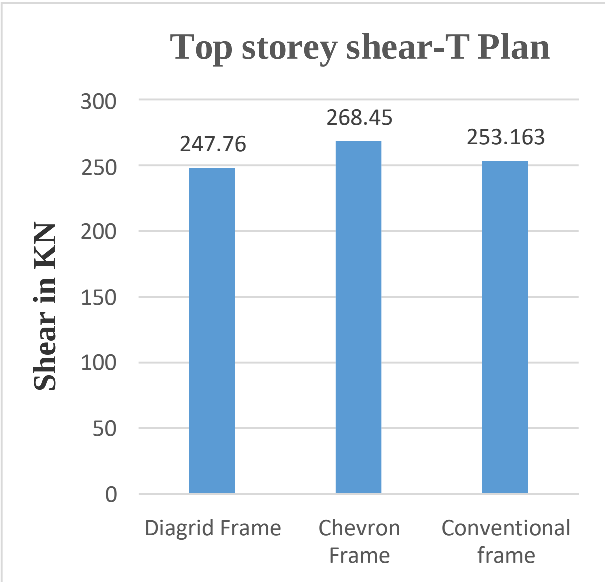
Table.3 represents the top storey shear value with respect to various frame of building. In table, top storey value for diagrid structure, chevron braced structure, and conventional frame structure is given. from table it is observed that Diagrid structure has less top shear value because weight of diagrid structure is less than that of chevron braced structure and conventional structure

Table 3. Top storey shear values for frame after analysis

Plan	C-Type Of Structure			T-Type Of Plan Structure		
	Diagrid frame	Chevron Braced frame	conventional frame	Diagrid frame	Chevron Braced frame	conventional frame
Top storey Shear	190.99	220.715	256.16	247.76	288.45	253.163

Graph 4 represents the value top storey shear value. In graph x-axis represents the various frame of structures and y-axis represents the top shear value of structure. From the graph it is observed that clear comparison between diagrid structure, chevron braced structure and conventional structure with respect to top storey shear.





Graph 4. Comparison of Top Storey Shear For C And T Base Plan

III.5. Axial Force in Interior column:

The comparison of axial force in interior columns between diagrid building, chevron braced building and conventional building for C-type plan and T-type plan are shown in table 5. The use of diagrid and chevron braced has increased the column axial force in all the column for the considered load cases at location of column. The maximum axial force is found to be 807.86 kN at the bottom column and the minimum is found in top most column to be 79.09 kN in case of conventional building, in case of diagrid building the maximum axial force is found to be 787.90 kN in the bottom column and the minimum is found in top most column to be 76.522 kN whereas , in case of chevron braced building the maximum axial force is found to be 1107.641 kN in the bottom column and the minimum is found in top most column to be 122.296 kN for C-Plan. The maximum axial force is found to be 829.58 kN at the bottom column and the minimum is found in top most column to be 80.198 kN in case of conventional building, in case of diagrid building the maximum axial force is found to be 1020.139 kN in the bottom column and the minimum is found in top most column to be 76.522 kN whereas , in case of chevron braced building the maximum axial force is found to be 841.598 kN in the bottom column and the minimum is found in top most column to be 82.831 kN for T-Plan. Figure 4 shows the variation of axial force for diagrid, chevron braced and conventional frame for C-Plan obtained from STAAD software.

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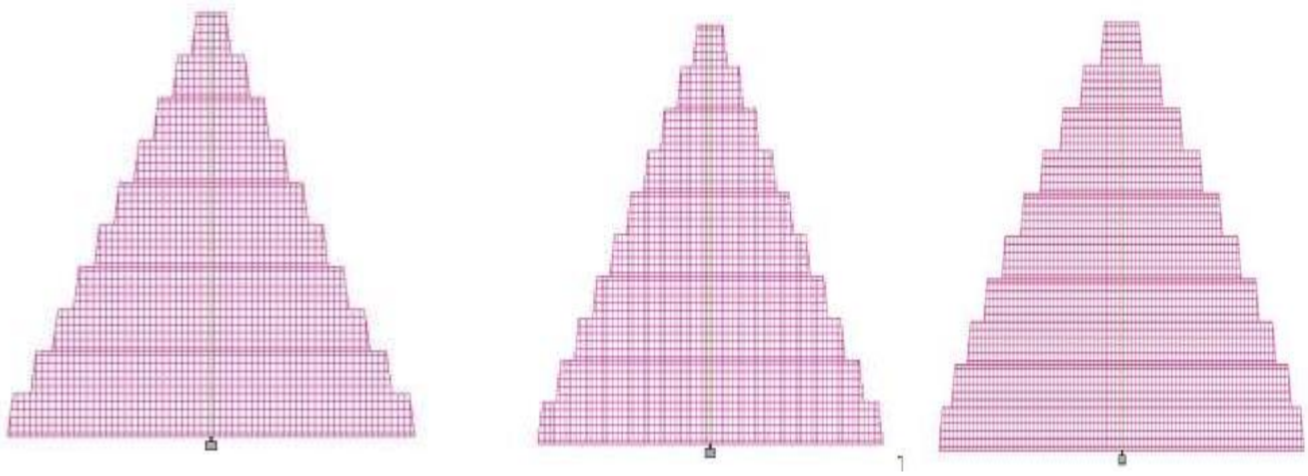


(a) Diagrid frame (b) Chevron braced frame (c) Conventional frame

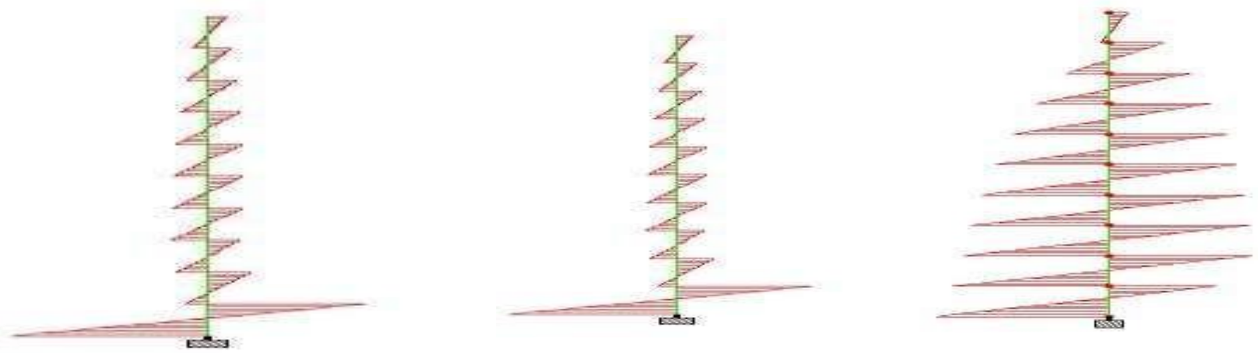
Figure 4: Axial force in interior column for C-Plan

III.6 Shear Force in Interior column:

The comparison of Shear Force in interior columns between diagrid building, chevron braced building and conventional building for C-type plan and T-type plan are shown in table 5. The use of diagrid and chevron braced has increased the column Shear Force in all the column for the considered load cases at location of column. The maximum Shear Force is found to be 26.285 kN at the bottom column and the minimum is found in top most column to be 1.705 kN in case of conventional building, in case of diagrid building the maximum Shear Force is found to be 19.988 kN in the bottom column and the minimum is found in top most column to be 3.77 kN whereas , in case of chevron braced building the maximum Shear Force is found to be 23.139kN in the bottom column and the minimum is found in top most column to be 0.423 kN for C-Plan. The maximum Shear Force is found to be 28.58 kN at the bottom column and the minimum is found in top most column to be 2.501 kN in case of conventional building, in case of diagrid building the maximum Shear Force is found to be 21.234kN in the bottom column and the minimum is found in top most column to be 22.144kN whereas, in case of chevron braced building the maximum Shear Force is found to be 22.128 kN in the bottom column and the minimum is found in top most column to be 1.802 kN for T-Plan.

III.7 Bending Moment in internal column:

The comparison of bending moment in interior columns between diagrid building, chevron braced building and conventional building for C-type plan and T-type plan are shown in table 5. Diagrids has effectively reduces the bending moment in interlocation of column. The maximum bending moment is found to be 48.52 kN at the bottom column and the minimum is found in top most column to be 1.254 kN in case of conventional building, in case of diagrid building the maximum bending moment is found to be 32.507 kN in the bottom column and the minimum is found in top most column to be 5.043 kN whereas , in case of chevron braced building the maximum bending moment is found to be 38.586 kN in the bottom column and the minimum is found in top most column to be 0.428 kN for C-Plan.The maximum bending moment is found to be 53.33 kN at the bottom column and the minimum is found in top most column to be 2.146 kN in case of conventional building, in case of diagrid building the maximum bending moment is found to be 37.05 kN in the bottom column and the minimum is found in top most column to be 29.294 kN whereas , in case of chevron braced building the maximum bending moment is found to be 41.072 kN in the bottom column and the minimum is found in top most column to be 2.66 kN for T-Plan. Figure 5 shows the variation of bending moment for diagrid, chevron braced and conventional frame for C-Plan obtained from STAAD software.



(a) Diagrid frame (b) Chevron braced frame (c) Conventional frame

Figure 5: Bending moment in interior column for C-Plan

Table.5 Comparison of Axial force, bending moment and shear force in Interior Column between Diagrid building, chevron braced building and conventional building for C-Plan and T-Plan.

	AXIAL FORCE						BENDING MOMENT						SHEAR FORCE					
	C-PLAN			T-PLAN			C-PLAN			T-PLAN			C-PLAN			T-PLAN		
storey	C-1	C-2	C-3	T-1	T-2	T-3	C-1	C-2	C-3	T-1	T-2	T-3	C-1	C-2	C-3	T-1	T-2	T-3
GL	787.908	1107.641	807.86	1020.139	841.598	829.58	32.507	38.586	48.517	37.05	41.072	53.333	19.988	23.139	26.285	21.234	24.128	28.585
1	699.244	1031.635	719.687	930.962	750.193	737.973	-0.072	4.058	43.854	2.323	7.546	48.115	0.724	4.097	28.062	3.557	6.203	30.701
2	614.434	937.217	634.36	839.353	662.441	649.775	5.559	5.086	40.178	13.303	7.048	44.873	3.302	3.53	26.566	9.069	4.696	29.575
3	532.559	834.511	551.192	742.837	576.298	563.987	6.114	5.875	37.742	18.318	7.259	42.444	3.873	3.868	25.153	12.381	4.663	28.223
4	453.051	725.356	469.806	642.666	491.596	480.193	6.489	5.313	34.584	22.144	6.262	39.181	4.213	3.555	23.26	14.921	4.09	26.292
5	375.413	611.126	389.85	539.565	408.092	397.949	6.668	4.722	30.585	24.618	5.13	34.88	4.393	3.19	20.821	16.612	3.411	23.689
6	299.217	492.863	311.029	433.952	325.587	316.936	6.605	3.917	25.435	26.192	3.761	29.239	4.404	2.691	17.643	17.686	2.574	20.224
7	224.13	371.442	233.116	326.248	243.918	236.959	6.337	2.908	18.895	26.958	2.132	22.024	4.276	2.065	13.573	18.277	1.563	15.743
8	149.734	247.637	155.786	216.986	162.867	157.834	5.797	1.615	10.572	26.288	0.307	13.012	3.965	1.225	8.262	17.463	0.466	10.054
9	76.522	122.296	79.545	105.931	82.831	80.198	5.043	0.428	1.254	29.294	-2.665	2.146	3.77	0.423	1.705	22.144	-1.802	2.501

IV. CONCLUSION

In this study the seismic analysis performed on building by using STAAD Software. Initially, the comparison between diagrid model, chevron braced and conventional model for C-Type and T-Type done separately by using various parameter like shear force, bending moment, axial force, displacement and storey drift. The following observations are drawn from the results obtained through analyses.

According to analysis results it is observed that,

1. In c-plan structure, For base shear, diagrid structure is 7.20% effective than chevron braced structure and 8.38% effective than conventional frame structure.
2. In c-plan structure, Storey drift and displacements structure on each storey in diagrid are observed to be less in diagrid structure as compared to chevron braced system and simple conventional frame system. The value of storey drift is observed to be in limit 0.004xh) where h is storey height.
3. For top storey shear, diagrid structure is 15.56% better than chevron braced structure and 34.12% better than conventional frame structure for C-Plan.
4. In T-Plan, Considering base shear, diagrid frame is 6.4% effective than a chevron braced frame structure and 9.1% effective than a conventional frame system.
5. In T-Plan, Considering storey drift and displacement, diagrid structure shows less value than chevron braced structure and conventional frame structure. The value of storey drift is observed to be in limit 0.004xh) where h is storey height.
6. For top shear value, diagrid structure is 16.42% better than chevron braced structure and 21.80% better than a conventional frame structure in T-Plan.
7. A significant decrease of bending moment, shear force and axial force in interior column of diagrid building is found in comparison to conventional building and chevron braced building.

After that, overall performance between C-plan and T-plan studied here. These two plan are compared by various parameter like base shear, displacement, storey drift.

1. Considering base shear T-Type building frame is best suited.
2. Considering top storey shear C-Type building frame is better choice.
3. Considering top storey displacement, C-Type building frame is more efficient.

V. ACKNOWLEDGMENT

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