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Analysis of Concrete Diagrid System with Different Storey Module

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Abstract - *This research study investigates the change structural system of reinforced concrete moment resisting frame diagrid frame buildings and its comparison with different storey modules diagrid. The Diagrid system has strong structural efficiency than other systems. Diagrid structure has a unique geometric configuration used for various heights of structure. Diagrid structure has a better architectural view. A set of different building models have been developed to perform the analysis as a diagrid frame building with 4 storey, 8 storey and 12 storey level buildings has been analyzed. Nonlinear dynamic time history analysis direct integration method, using nine ground motion records. All selected nine ground motions time duration is not equal also different peak ground accelerations, the ground motions are scaled to give references data from model time period mode 1 and mode 2. The selected nine unscaled ground motion records have been used with calculated scale factor to meet better result. The nine ground excitations are applied separately with scale factor and perform analysis. The structural software package SAP2000 has been used in developing the building models and performing dynamic analysis. The analysis results in terms of story displacement, story drift, etc. are obtained for all the considered configurations and presented comparatively, keeping the same plan area and structural data for diagrid system for time-history analysis, but different storey modules for example one storey module, two storey module, four storey module. Based on the time-history results, it has been found that dynamic story responses for diagrid system for different storey modules and find optimum result.*

***Key Words*: Time-history analysis, time period, diagrid frame building, Ground motion records, Storey Module etc.**

1. INTRODUCTION

All over the world, there is a high demand for the construction of many types of buildings. Such buildings are very strong in seismic behavior as well as view looks like aesthetics. The height of the building increase, the lateral load resisting system becomes more important than the structural system that resists the gravitational loads. The diagrid-Diagonal grid structural system is widely used for buildings due to its structural efficiency and aesthetic potential provided by the unique geometric configuration of the system.

Diagrid consists of a perimeter grid made up of a series of the triangulated truss system. The famous examples of diagrid structures all around the world are the Swiss re in London, Hearst tower in New York, Cyclone tower in Asan (Korea), Capital gate tower in Abu Dhabi, IBM building, and O-14 building as shown in Fig.

Fig. 1 Swiss Re London

Fig. 2 Hearst Tower

Fig. 3 Cyclone Tower

Fig. 4 Capital Gate Tower

Fig. 5 IBM Building

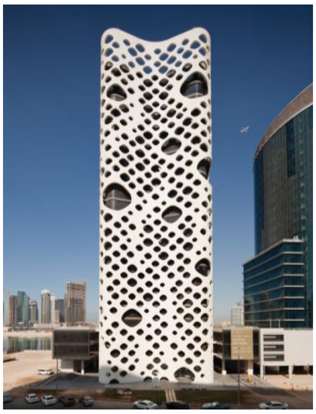

Fig. 6 O-14 Building

In this paper, the analysis of diagrid building for different levels and module using non-linear direct integration time-history analysis. A dynamic time-history analysis of reinforced concrete moment-resisting frame building of diagrid system, nine ground motions records of Chalfant Valley-01 (1986), Chalfant Valley-02 (1986), Imperial valley 06 (1979), Imperial valley 07 (1979), mammoth lakes01 (1980), mammoth lakes02 (1980), Managua Nicaragua-01 (1972), Whittier Narrows 01(1987), Whittier Narrows 02 (1987), has been considered.

SAP2000 software packages are used to perform dynamic analysis. Although quick and easy for simple structures, SAP2000 can also handle non-linear behaviors, making it a tool of choice for structural engineers in the building industry.

2. MATERIAL AND METHODS

2.1 Structural Models

To non-linear direct integration time-history analysis investigates diagrid building of four-story, eight-story and twelve-story reinforced concrete moment-resisting frame building is considered. Building structure is described as bay size 5m X 5m with same height of each floor 3.5 m, as per IS code zone V, with zone factor = 0.36, importance factor = 1.5, response reduction factor (R) = 5 as per IS 1893:2016, M40 N/mm^2 grade of concrete and grade of steel is Fe500 N/mm^2 for building is taken for design and analysis. Diagrid member are used outer periphery of building instead of external columns.

Typical floor plan of four storey, eight storey and twelve storey diagrid building with different storey modules shown in fig 7.

Fig. 7 Typical floor plan of 4, 8 and 12 storey Reinforced Concrete diagrid building

Table -1: All required data for making model and design and analysis of diagrid structure.

Parameters in detail			
Plan Area	100m2	**Size of diagrid**	
Concrete	M40	**For 4 storey**	0.4m x 0.4m
Steel (rebar)	Fe500	**For 8 storey**	0.5m x 0.5m
Storey height	3.5m	**For 12 storey**	0.6m x 0.6m
Size of beam	0.3m X 0.5m	**Wall load**	18 kN/m
Building frame type	SMRF	**Slab load**	28.75 kN/m

2.2 Modeling of diagrid building

In the diagrid system, the outer periphery used diagonal members instead of vertical columns only this difference in conventional and diagrid structure. Fig. shows all diagrid building models using the SAP2000 software package.

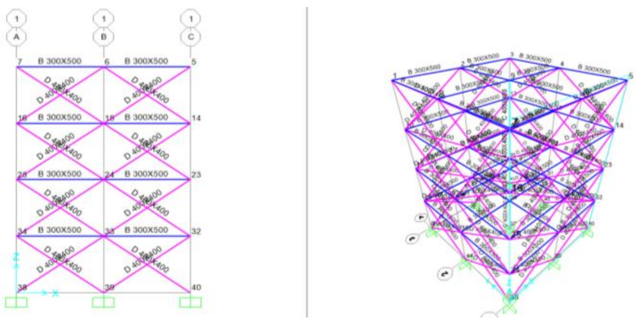

Fig. 8 4 storey level-1 storey module Diagrid building

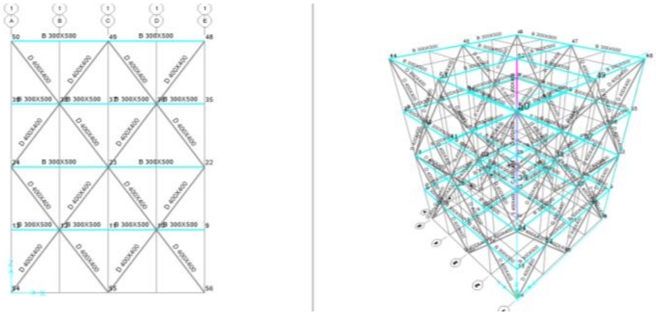

Fig. 9 4 storey level-2 storey module Diagrid building

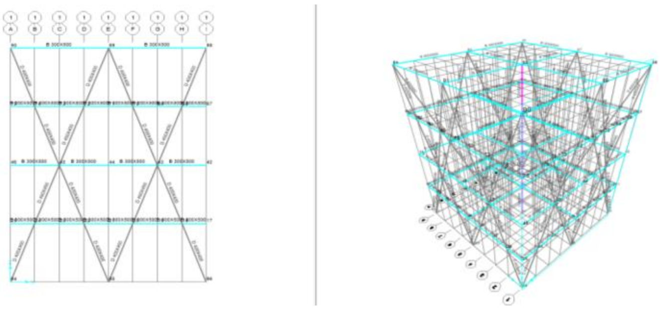

Fig. 10 4 storey level-4 storey module Diagrid building

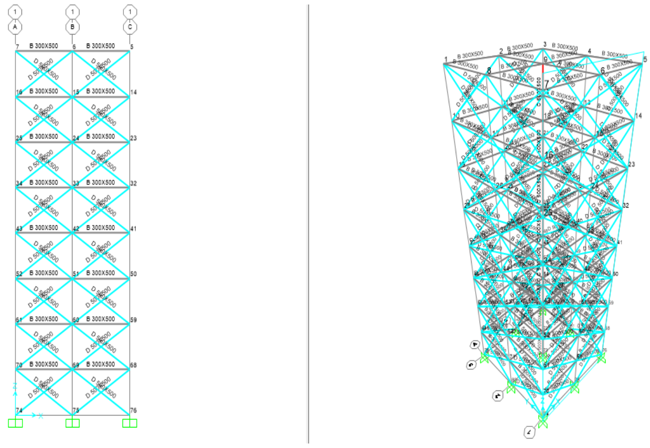

Fig. 11 8 storey level-1 storey module Diagrid building

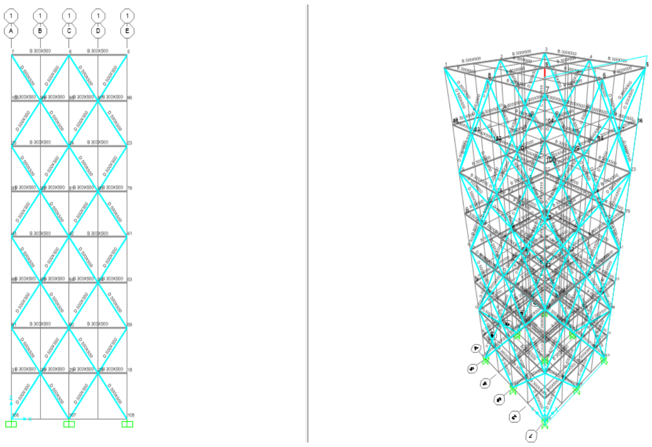

Fig. 12 8 storey level-2 storey module Diagrid building

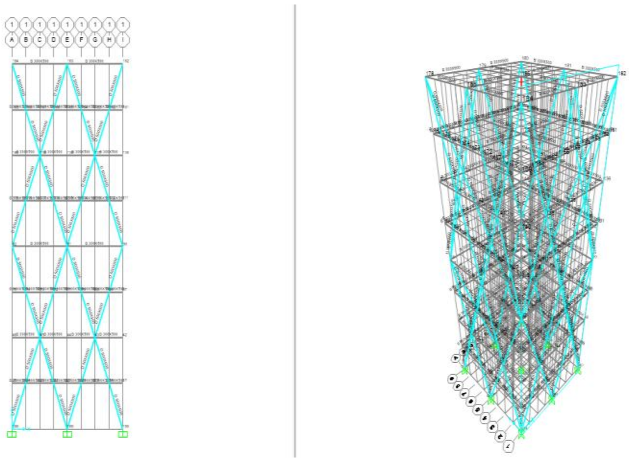

Fig. 13 8 storey level-4 storey module Diagrid building

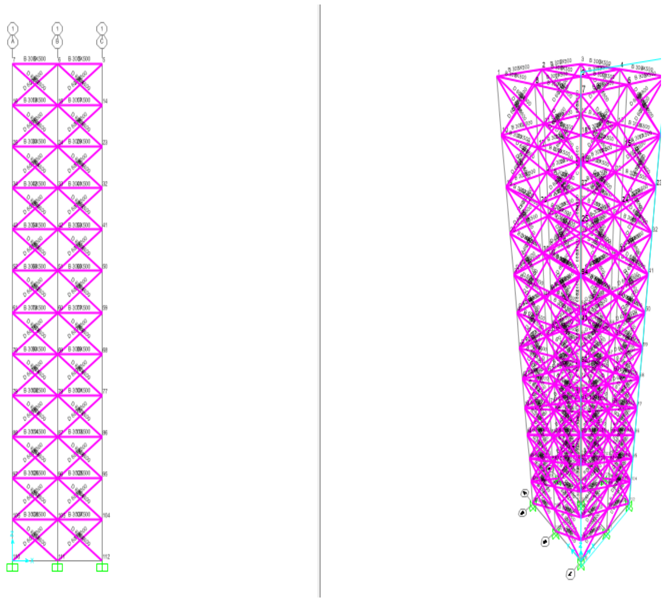

Fig. 14 12 storey level-1 storey module Diagrid building

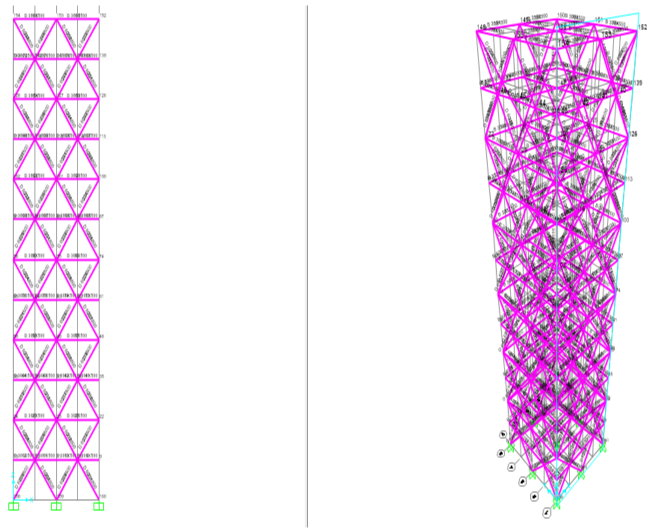

Fig. 15 12 storey level-2 storey module Diagrid building

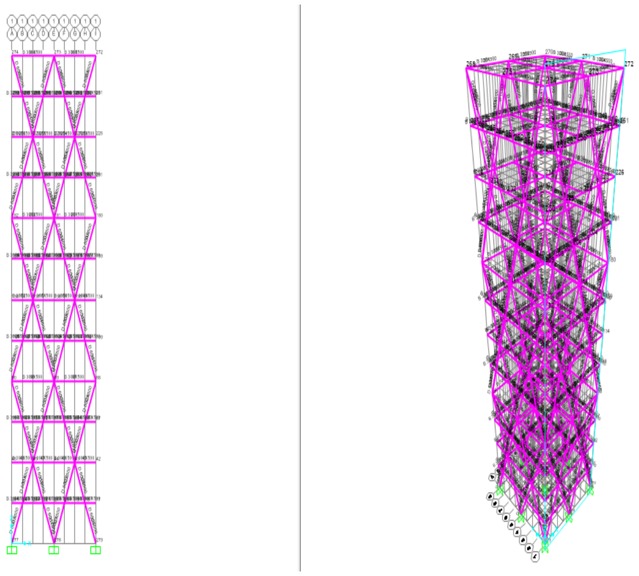

Fig. 16 12 storey level-4 storey module Diagrid building

2.3 Non-linear Time-History analysis

The time-history analysis, as a nonlinear dynamic analysis, is the best technique to evaluate structural response under earthquake excitations described by ground acceleration records. Dynamic earthquake loads incrementally affect the structure with time intervals, and the governing equation of motion is solved using a step-by-step procedure.

For nonlinear time history analysis, nine different ground motions have been selected to perform the dynamic analysis of the current study. One of these three ground motion records data has been taken from PEER NGA strong motion database record (http://peer.berkely.edu/smcall) of the Chalfant Valley-01 (1986), Chalfant Valley-02 (1986), Imperial valley 06 (1979), Imperial valley 07 (1979), mammoth lakes01 (1980), mammoth lakes02 (1980), Managua Nicaragua-01 (1972), Whittier Narrows 01(1987), Whittier Narrows 02 (1987), Fig. shows the acceleration vs. time for the nine earthquake ground motions used for analysis.

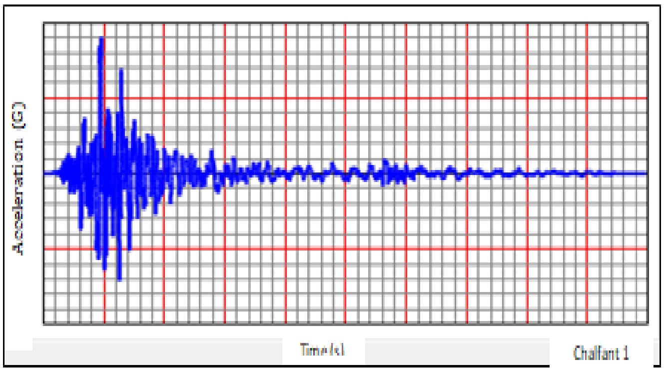

Fig. 17 Ground motion of Chalfant Valley 1 (1986)

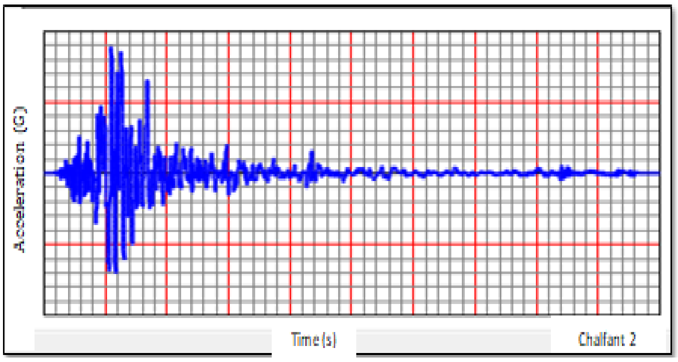

Fig. 18 Ground motion of Chalfant Valley 2 (1986)

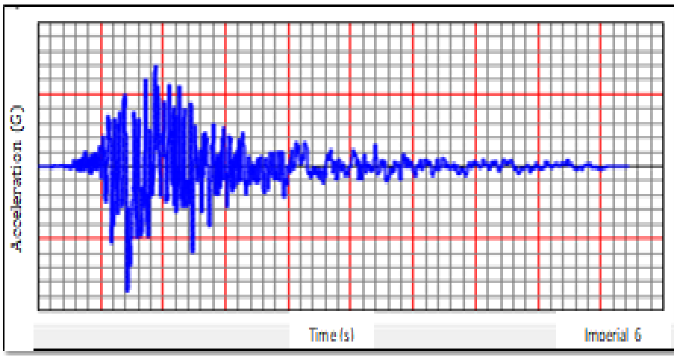

Fig. 19 Ground motion of Imperial Valley 6 (1979)

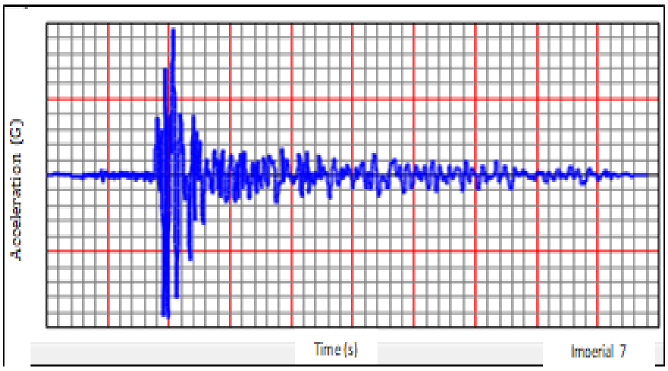

Fig. 20 Ground motion of Imperial Valley 7 (1979)

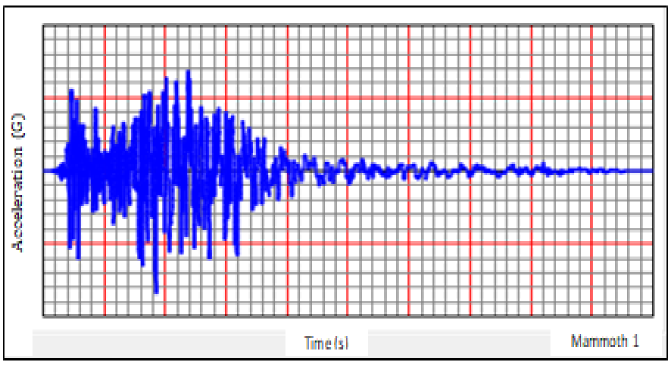

Fig. 21 Ground motion of Mammoth lakes 01 (1980)

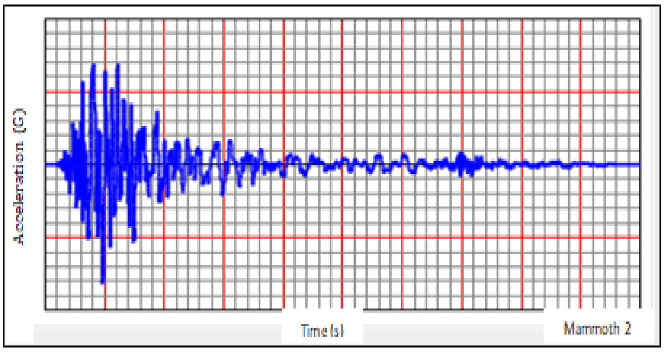

Fig. 22 Ground motion of Mammoth lakes 02 (1980)

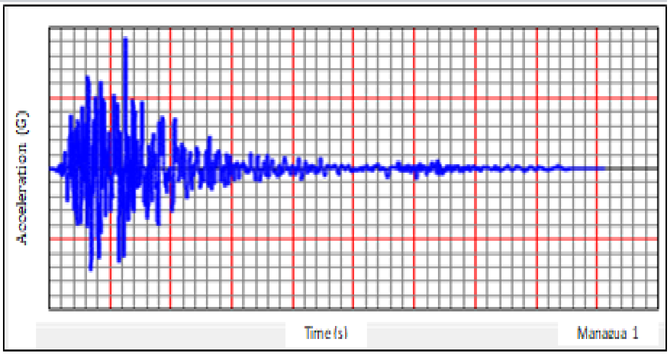

Fig. 23 Ground motion of Managua Nicaragua-01 (1972)

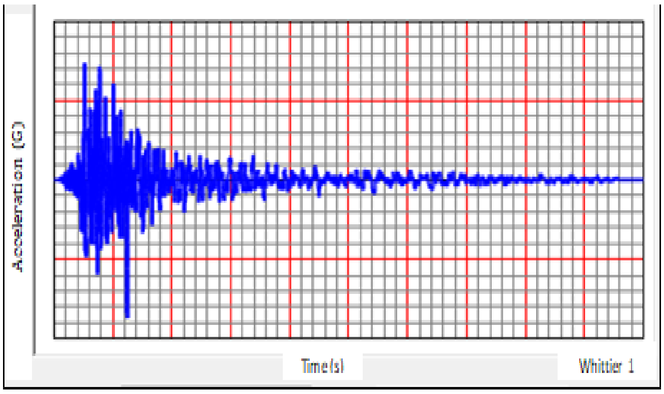

Fig. 24 Ground motion of Whittier Narrows 01(1987)

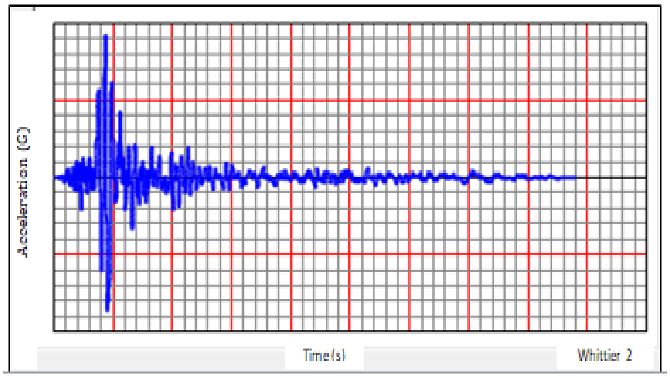

Fig. 25 Ground motion of Whittier Narrows 02 (1987)

On this paper nonlinear time-history analysis performed. Nonlinear analysis in terms of material nonlinearity provided as nonlinear hinges and run nonlinear analysis case. Nonlinearities are considered as a reliable structural analysis capable of simulating the proper behaviour of the material and the deformation of structural elements under the applied dynamic loads. When the material moves within the yield strength limits, the behaviour of such materials follows a linear trend.

3 RESULTS AND DISCUSSION

In time-history analysis provides the structural response of the considered building models Diagrid building overtime during and after the application of seismic load. In time-history analysis nonlinear time-history analysis perform a 4 storey, 8 storey and 12 storey reinforced concrete Diagrid building with different storey modules, under selected nine ground motion records with scale factor. Analysis results shows the in terms of storey displacement shown below.

3.1 Four storey building model result

3.1.1 Four storey level- one storey module Diagrid Reinforced concrete building

Table -2: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

Floor	Joint no.	Chalfant 01	Chalfant 02	Imperial 06	Imperial 07
base	45	0	0	0	0
1	31	1.93	2.11	1.96	2.28
2	22	3.48	3.92	3.19	4.42
3	13	6.03	5.51	5.62	6.13
4	4	9.40	9.10	9.64	8.42

mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	0	0	0	0
2.16	1.50	3.10	2.82	4.01
3.45	2.82	5.02	5.10	5.49
5.54	5.66	5.65	6.21	6.17
8.44	9.36	10.07	9.01	9.42

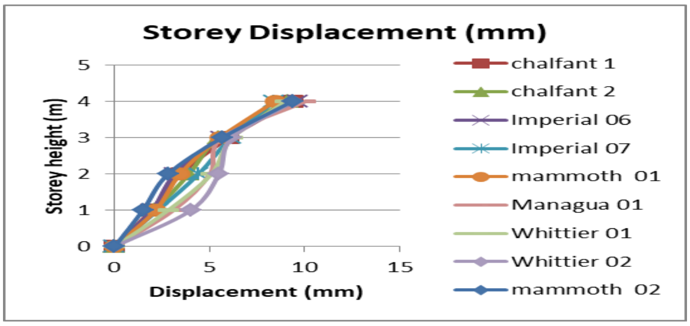

Fig. 26 Result of Storey displacement of diagrid building

3.1.2 Four storey level- Two storey module Diagrid Reinforced concrete building

Table -3: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

FLOOR	JOINT NO.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	56	0	0	0	0	0	0	0	0	0
1	9	2.08	1.66	1.65	1.62	2.26	1.56	2.09	1.67	1.86
2	22	3.93	3.70	3.39	3.46	4.47	3.58	3.62	3.14	3.02
3	35	5.41	5.72	5.38	5.04	5.85	5.75	5.32	5.04	4.28
4	48	7.22	7.44	7.24	7.18	6.74	7.39	7.70	6.83	8.50

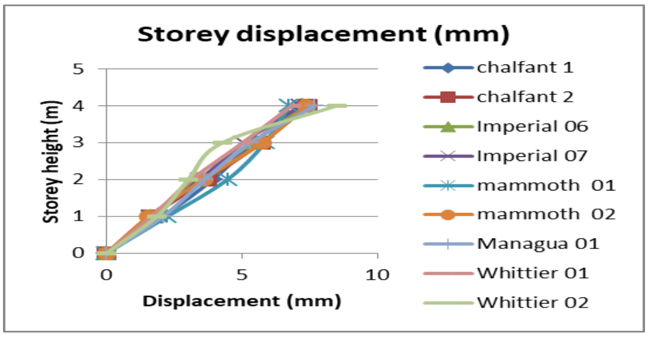

Fig. 27 Result of Storey displacement of diagrid building

3.1.3 Four storey level- Four storey module Diagrid Reinforced concrete building

Table -4: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

FLOOR	JOINT NO.	chalfant 1	chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	101	0	0	0	0	0	0	0	0	0
1	13	2.00	2.20	1.94	2.59	2.57	1.74	2.23	3.94	2.60
2	40	4.73	5.21	4.52	6.08	5.87	4.45	5.29	5.49	5.30
3	63	7.32	7.58	7.30	7.59	7.40	7.27	7.74	6.44	7.55
4	87	9.82	8.92	9.33	8.91	8.36	9.35	9.52	9.59	9.80

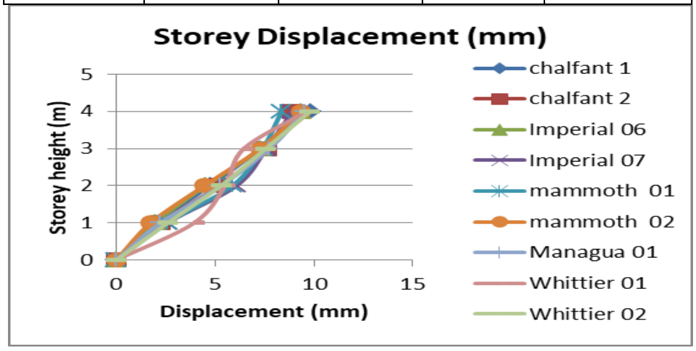

Fig. 28 Result of Storey displacement of diagrid building

3.2 Eight storey building model result

3.2.1 Eight storey level- One storey module Diagrid Reinforced concrete building

Table -5: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	81	0	0	0	0	0	0	0	0	0
1	67	3.69	3.58	1.98	5.09	2.69	3.69	3.06	3.76	5.61
2	58	6.67	8.50	5.76	11.80	6.84	8.59	7.23	6.85	12.16
3	49	11.64	13.79	10.87	16.79	12.32	13.37	10.62	11.33	16.97
4	40	18.43	19.26	17.04	19.38	18.89	17.75	16.16	16.86	20.47
5	31	24.76	24.87	23.89	20.39	26.01	21.25	23.15	22.03	23.88
6	22	30.82	31.78	31.23	22.54	32.84	29.68	31.86	28.16	28.85
7	13	39.20	41.53	39.61	39.10	38.82	41.61	42.98	38.45	37.78
8	4	51.10	53.61	49.48	61.24	51.04	55.25	56.12	51.33	57.07

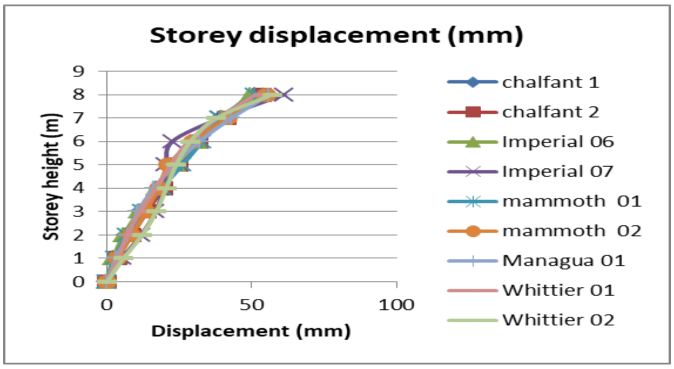

Fig. 29 Result of Storey displacement of diagrid building

3.2.2 Eight storey level- Two storey module Diagrid Reinforced concrete building

Table -6: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07
0	113	0	0	0	0
1	16	1.28	0.88	1.86	1.54
2	58	2.47	2.24	4.14	3.27
3	51	4.12	3.79	6.51	5.24
4	40	5.82	5.12	8.14	6.80
5	77	8.00	6.53	9.79	9.26
6	22	10.51	9.38	11.18	11.81
7	94	13.56	13.36	13.77	15.40
8	4	16.31	16.66	16.62	18.26

mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	0	0	0	0
1.15	1.81	1.81	1.83	3.19
2.62	4.45	3.65	3.43	7.42
4.48	7.13	5.15	4.35	11.35
5.92	8.60	6.61	5.91	11.89
8.19	10.12	8.43	8.42	12.42
10.89	11.22	10.67	10.92	12.60
13.84	14.45	13.94	13.69	16.66
16.28	17.46	16.80	15.95	22.92

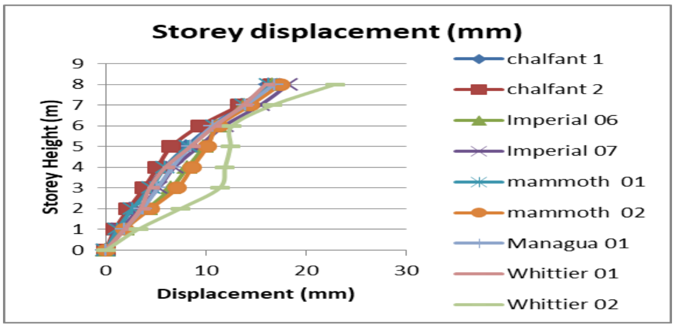

Fig. 30 Result of Storey displacement of diagrid building

3.2.3 Eight storey level- Four storey module Diagrid Reinforced concrete building

Table -7: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07
0	193	0	0	0	0
1	13	1.22	1.14	1.49	2.10
2	40	3.15	3.09	4.57	5.19
3	63	5.20	5.45	8.13	7.23
4	89	7.58	7.77	11.07	9.53
5	107	9.69	9.57	12.79	11.89
6	134	12.88	11.46	13.74	14.73
7	157	15.55	13.53	14.28	16.69
8	181	17.41	15.42	15.14	18.74

mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	0	0	0	0
1.40	1.63	1.50	1.43	1.80
3.91	4.71	4.24	3.58	5.75
5.78	8.33	6.46	5.81	11.09
7.93	11.27	7.63	8.14	15.42
9.98	12.92	9.58	10.36	15.89
12.65	13.83	12.60	12.84	16.43
15.17	14.61	15.58	14.92	16.99
17.21	16.70	18.14	16.67	18.43

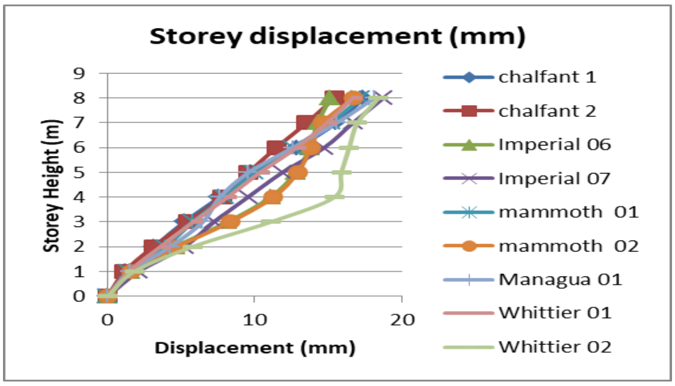

Fig. 31 Result of Storey displacement of diagrid building

3.3 Twelve storey building model result

3.3.1 Twelve storey level- One storey module Diagrid Reinforced concrete building

Table -8: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	117	0	0	0	0	0	0	0	0	0
1	103	8.66	6.46	3.18	30.60	5.26	8.93	3.16	9.87	10.58
2	94	21.08	16.18	10.55	51.87	11.00	19.41	9.38	17.27	12.21
3	85	35.05	25.90	21.53	62.42	17.73	29.23	18.49	25.59	25.20
4	76	51.28	34.38	36.07	67.44	28.51	49.70	31.13	40.34	41.17
5	67	66.67	47.31	53.64	105.51	42.64	72.71	46.64	56.92	58.41
6	58	79.64	65.29	73.55	144.55	59.89	94.04	64.54	72.90	75.20
7	49	93.16	84.96	95.10	153.33	79.57	112.08	84.10	87.82	90.89
8	40	111.60	106.25	117.79	172.79	100.86	125.42	104.77	103.01	105.91
9	31	129.84	129.04	141.28	176.21	123.19	133.63	126.12	120.65	120.86
10	22	148.25	152.95	165.24	184.39	146.04	137.86	147.82	138.06	136.55
11	13	183.95	177.93	189.47	200.93	168.76	165.16	169.69	163.86	151.30
12	4	230.19	204.66	213.91	283.23	191.36	205.57	191.62	195.68	181.95

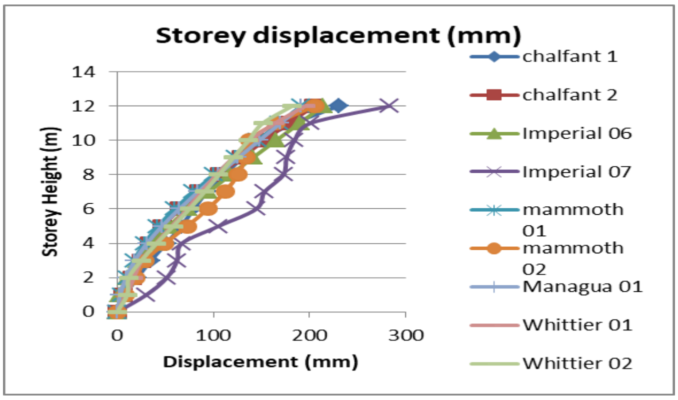

Fig. 32 Result of Storey displacement of diagrid building

3.3.2 Twelve storey level- Two storey module Diagrid Reinforced concrete building

Table -9: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	165	0	0	0	0	0	0	0	0	0
1	7	2.63	1.37	1.65	2.81	2.38	2.08	1.29	3.75	2.49
2	21	5.59	3.58	4.03	6.35	5.49	4.67	2.88	7.43	5.87
3	33	8.71	6.58	6.87	10.82	9.23	7.44	5.20	11.60	10.08
4	47	9.77	9.65	9.04	14.25	12.21	10.37	6.72	13.65	13.42
5	59	11.56	13.22	11.83	18.53	15.50	13.64	8.56	16.72	17.42
6	73	14.42	15.77	14.26	20.19	17.10	15.69	11.00	18.89	19.57
7	85	17.53	18.49	17.34	22.93	18.94	17.96	13.89	22.20	22.07
8	99	20.43	20.82	20.35	24.00	19.46	20.19	16.46	24.93	22.61
9	111	25.92	26.10	25.00	26.80	21.86	25.45	19.33	28.63	24.99
10	125	32.68	31.79	30.34	31.35	26.78	32.31	22.05	31.74	33.15
11	137	40.67	38.46	36.59	40.85	32.72	40.20	25.25	36.40	42.94
12	151	47.63	44.58	42.22	49.44	37.79	46.99	28.45	41.28	51.16

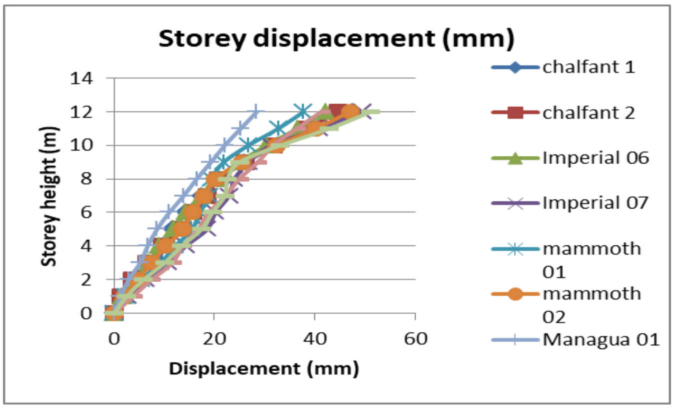

Fig. 33 Result of Storey displacement of diagrid building

3.3.3 Twelve storey level- Four storey module Diagrid Reinforced concrete building

Table -10: All The results in terms of storey displacement, for time-history analysis of nine ground motions.

floor	joint no.	Chalfant 1	Chalfant 2	Imperial 06	Imperial 07	mammoth 01	mammoth 02	Managua 01	Whittier 01	Whittier 02
0	284	0	0	0	0	0	0	0	0	0
1	13	1.57	1.49	1.15	1.94	1.73	1.24	1.15	1.79	1.33
2	40	4.25	4.32	3.40	5.23	4.80	3.31	3.46	5.03	3.78
3	63	6.80	7.14	5.65	7.97	6.83	4.92	6.21	8.33	5.96
4	87	8.91	9.73	7.81	10.90	9.49	6.40	9.18	11.61	9.04
5	105	11.51	11.90	9.72	13.15	11.60	8.86	12.07	13.51	12.30
6	132	14.80	14.22	12.51	15.44	13.62	11.39	15.25	14.63	15.84
7	155	17.49	16.79	15.85	17.05	15.61	13.60	18.01	17.30	18.74
8	179	19.78	19.64	19.18	18.52	18.99	16.21	20.66	20.43	20.97
9	197	21.99	22.40	22.20	21.76	22.75	18.33	23.04	22.67	22.32
10	224	27.21	25.33	25.36	25.68	26.84	20.94	25.80	25.08	24.62
11	247	32.39	28.21	28.55	29.53	30.69	24.13	28.73	27.26	29.27
12	271	37.74	31.21	31.93	34.80	34.83	27.69	31.84	29.55	34.74

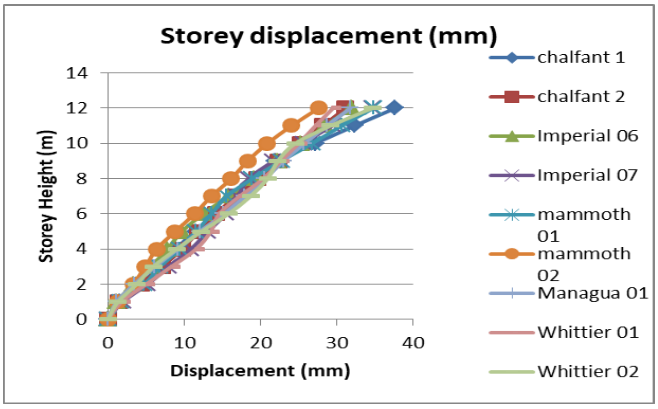

Fig. 34 Result of Storey displacement of diagrid building

3.4 Discussion

Ground motions are damage to structure so order to take safe against, it is important to know the characteristics of ground motion. Dynamic time history analysis performed, applies nine ground motion records. Nonlinear time history analysis is performed in SAP2000 software. The outputs of buildings are given in terms of storey displacement. The following conclusion has shown for four storey, eight storey and twelve storey diagrid reinforced concrete buildings with different storey modulus. Reinforced concrete diagrid building of all storey displacement result are compare to (< 0.004 x h), where (h= storey height) and values come within a limit.

4. CONCLUSIONS

From all analysis results, we have to conclude that the nonlinear dynamic time history analysis of all perform models. Story displacement of four storey, eight storey and twelve storey level diagrid building of different storey modules are used for optimization of result. Finally, in four storey and eight storey diagrid buildings with average an, nine ground motion records result, two storey modules model are least displacement value found compare to one storey modules and four storey modules model. Then, twelve storey diagrid building with average an, nine ground motion records result, four storey modules model are least displacement value as compare to one storey and two storey modules model. The results are varying with models time period in case time history analysis.

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