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Investigation on the Structural Behaviour of High-Rise Structures Exposed to Dynamic Loading in a Seismic Zone using Various Bracing Methods

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Abstract: ***Bracing is a common method used by multi-story buildings to counteract the lateral stresses that are applied by the environment. In a frame construction, the use of bracing is a method that is both highly effective and cost-efficient in resisting horizontal forces. Structures that have their frames braced are meant to be more resistant to the effects of earthquakes and wind loads. Because of their exceptional rigidity, braced frames are well suited for seismic retrofitting. Steel members are almost always used in the construction of braced frames. Vertical loads are supported by the structural parts of the building, such as beams and columns, whereas lateral loads are supported by the bracing system. By using braced frames, it is possible to minimize the amount of side displacement as well as the bending moment in the columns. Steel bracing is adaptable and can be constructed to fulfill the needed strength and stiffness requirements. In addition to being cost-effective, quick to install, and taking up less space than wood bracing, steel bracing is also gentle on the environment. It makes it possible to obtain a large increase in lateral stiffness while simultaneously increasing weight just a little. This indicates that preexisting constructions that have low side stiffness may considerably benefit from incorporating it. Bracings are given in RCC constructions in order to withstand lateral stresses such as those caused by earthquakes and wind pressure. There are several different kinds of conventional bracing that may be employed. The purpose of this examination is to analyze the dynamic behavior of a multi-story building located in a seismic zone and equipped with a variety of bracings. The work being done right now is on a multi-story structure that is situated in Zone V, and it is being done on three distinct stories: 12, 20, and 30. The research was carried out using X, K, V, and O bracings, as well as X-O, V-O, and K-O bracings for each individual tale. FEM uses SAP 2000 to perform a non-linear time history analysis to complete the research. In addition, we established a number of factors, such as tale displacement and story drift. When compared to other sorts of combinations of bracing and individual bracings, it has been shown that the K-O bracing combination results in 12% less narrative displacement and 11% less story drift.***
Keywords: Tall buildings, O-grid, K-grid, Dynamic Analysis.

I. INTRODUCTION

Each year, thousands of earthquakes occur all over the earth's surface. Strong- motion earthquakes are caused by those who are interested in structural engineering. Over 2.5 million people have died due to earthquakes since the turn of the century, despite their social and economic effects, which means that large earthquakes rank among the top few natural catastrophes in terms of the number of lives lost. A better understanding of seismic engineering is the result of this. Constructions are better equipped to resist tremendous stresses and reduce the devastating loss of life. There is a typical use of frames in public buildings in seismically active areas that house large crowds. In order to lower the risk of death and increase the ability of critical facilities to function during and after an earthquake, this work will contribute to the development of earthquake-resistant frames. An earthquake can be described as an energy exchange process between the ground and the structure from an energetic standpoint. In orderto be earthquake resistant, a structure must be able to store and disperse seismic energy safely. Defined in this way, an excellent structural design manages how input energy is transformed by designing non-structural and structural damage in a way that prevents collapse. This thesis investigates a novel form of seismic frame bracing system based on this theory. When it comes to the frame's energy dissipation capability and yield sequence, stiffness and strength significantly impact it. We examine energy dissipation techniques and the torsional coupling aspect of Steel 3 frames in this chapter. Lastly, the scope and aims of this research aresummarised in the final section.

A. Need of the Study

Buildings with multiple floors often use bracing as a means of resisting lateral loads from the outside. Using bracing to resist horizontal forces in a frame structure is a highly effective and cost-effective solution. Structures with braced frames are designed to resist wind loads and earthquake forces. The high stiffness of braced frames makes them ideal for seismic retrofit. Almost always, braced frames are made of steel members. Structural members, such as beams and columns, bear vertical loads, while the bracing system bears lateral loads. Using braced frames can help reduce the amount of side displacement and bending moment in columns. Economical, easy to install, and take up less space than wood bracing, steel bracing is versatile and can be designed to meet the required strength and stiffness requirements. It allows a significant increase in lateral stiffness to be achieved with the minimal weight increase. That means existing structures with low side stiffness can benefit greatly from it. In RCC structures, to resist lateral forces like earthquake and wind pressure, bracings are provided.

To resist wind loads and earthquake forces, structures are designed with braced frames so that the high stiffness of braced frames makes them ideal for seismic retrofit. There are many conventional type of bracings used till now, in order to get high effectiveness and cost effective solutions. Some of the Bracings like K bracings are concluded to be not much effective brace to be used in highly seismic zone like zone V.

In past years only single type of braces are used. In order to get highly effective and cost effective solutions combination of bracings can be more suitable. The major criteria is that structure should be economical installation of bracings would be easy, along with that brace should provide lateral stiffness. For that criteria a new type of Bracing is introduced in this studies along with combination of that bracing with other type of bracings.

B. Objective of the study

The present work is on search for an effective way to reduce the response of structures subjected to earthquakes. Practical improvements to RCC structural buildings are given special attention.

The present work aims at the following objectives:

1) Study of Seismic demands of regular R.C buildings using nonlinear time history analysis.
2) The main objective of the thesis is to identify the most efficient and suitable lateral loads resistant bracing types that give the minimum lateral displacements, minimum story drift, and increase shear capacity of RC frame from the selected groups of bracings types like O-grid, X-grid, inverted V grid, K grid and combination of O- X, O-K, and O-V grid.
3) A comparative study has been done regarding roof displacement time periods.

C. Scope of the Study

The present work aims to demonstrate the effect of the O-grid, K-grid, andO & k grid combination. Bracing system techniques for symmetric high-rise structures. The building studied in this work is a 12, 20 and 30 reinforced concrete moment resisting frame Designed for Gravity and Seismic Loads Using Linear Analysis. The structure is evaluated following seismic code IS-1893:2016 using nonlinear time history analysis with the helpof the SAP 2000 software (CSI Ltd) analysis engine. The primary goal of this thesis is to provide valuable insights into the current development of high-performance braces in the hope that such a system can be more widely adopted and utilized by practicing engineersin designing new earthquake resistance structures.

II. METHODOLOGY

This chapter deals with the methodology adopted for carrying out the dissertation work. The following chapter presents the geometrical properties and analysis parameters of the three building models. By using SAP 2000 software, which helps to analyse and design the models, the analysis method used for this study is the Nonlinear dynamic Time History analysisfor providing story vs. displacement curves of the structure.

A. Building models used in the study

The Layout of the plan having 5x5 bays of an equal length of 6m. The buildings considered are Reinforced ordinary concrete moment-resisting space frames of 12, 20 and 30 Storeys to account for the Nonlinear Behavior of Seismic demands. All these buildings have been analysed by the NLTHA method. The story height is kept uniform of 3 m for all kinds of building models below. The analysis illustrates the step-by-step procedure for the determination of forces.

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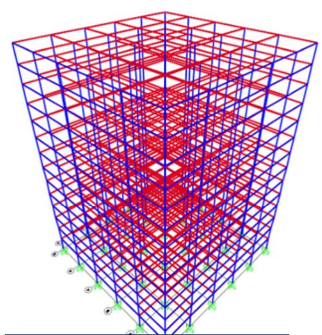
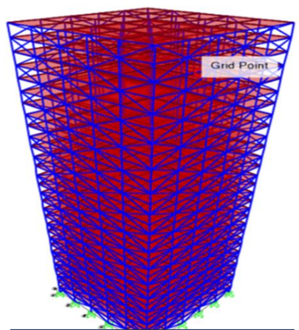
The Plan configuration consists of

1) Model 1 – Normal Building
2) Model 2 – Building with K-brace
3) Model 3 – Building with O-brace
4) Model 4 – Building with X brace
5) Model 5 – Building with V- brace
6) Model 6 – Building with a combination of X-O brace
7) Model 7 – Building with the combination of K-O brace
8) Model 8 – Building with the combination of V-O brace



Model 1



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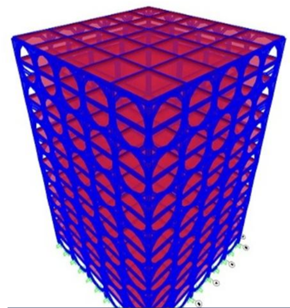

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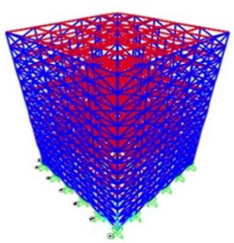

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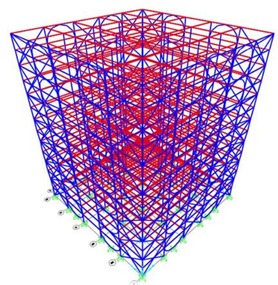

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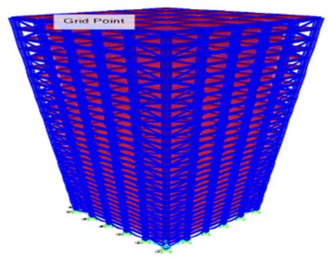

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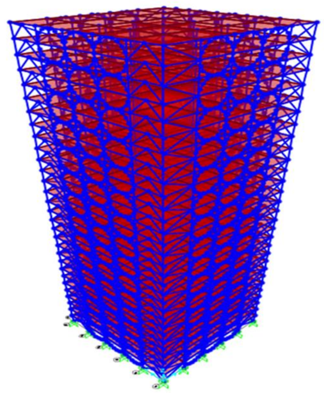

Model 8

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III. RESULTS AND DISCUSSIONS

In this part, the result of each building will be obtained, and then the result will becomparative between building with in the following categories:

A. *Story Displacement*

Results for 30 story building

Table 1: Story displacement in X- Direction

	STORY DISPLACEMENT in mm							
stories	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
BASE	0	0	0	0	0	0	0	0
story 1	1.18433	0.962588	1.186245	1.063878	0.951264	1.019105	1.096076	1.110335
story 2	3.659398	2.657024	3.666028	3.052768	2.630254	3.03136	3.313695	3.357079
story 3	6.675894	4.548662	6.68414	5.33874	4.507781	5.436636	5.965182	6.042419
story 4	9.930297	6.534143	9.938462	7.737397	6.480419	8.052126	8.827485	8.937093
story 5	13.29761	8.589323	13.30419	10.21047	8.523717	10.81278	11.80566	11.94585
story 6	16.72417	10.70427	16.72829	12.7304	10.62755	13.68874	14.87313	15.04072
story 7	20.18454	12.87151	20.18559	15.29729	12.7843	16.65979	18.0022	18.1952
story 8	23.66423	15.08389	23.66172	17.89496	14.9867	19.70958	21.18719	21.40295
story 9	27.15277	17.33419	27.14636	20.52411	17.22743	22.82272	24.40862	24.64557
story 10	30.64088	19.61503	30.63018	23.16995	19.499	25.98476	27.66203	27.91812
story 11	34.11938	21.91884	34.10417	25.83132	21.79376	29.18149	30.92943	31.20346
story 12	37.57876	24.23783	37.55864	28.49403	24.10382	32.39906	34.2053	34.49567
story 13	41.00894	26.564	40.98378	31.15499	26.4211	35.62384	37.47227	37.77802
story 14	44.3993	28.88912	44.36869	33.80035	28.7373	38.84223	40.72344	41.04331
story 15	47.73854	31.20475	47.70241	36.42492	31.04387	42.0409	43.94192	44.27508
story 16	51.01476	33.50219	50.97272	39.01545	33.33206	45.20636	47.11938	47.46477
story 17	54.21545	35.77256	54.1675	41.56504	35.59289	48.3255	50.23934	50.59614
story 18	57.32745	38.00676	57.27318	44.06077	37.81718	51.38487	53.2921	53.65933
story 19	60.33701	40.19547	60.27651	46.49413	39.99555	54.37158	56.26157	56.63832
story 20	63.22976	42.32921	63.16258	48.85243	42.1184	57.27229	59.13676	59.522
story 21	65.99075	44.39832	65.91709	51.12571	44.17601	60.07445	61.90203	62.29465
story 22	68.6046	46.393	68.5234	53.30147	46.15848	62.765	64.54525	64.94405
story 23	71.05483	48.30331	70.96755	55.36848	48.05578	65.33195	67.05128	67.45483
story 24	73.32539	50.11924	73.23092	57.31434	49.85781	67.76279	69.40712	69.81389
story 25	75.3994	51.83071	75.29814	59.12684	51.55437	70.04645	71.59829	72.00642
story 26	77.26043	53.42762	77.15176	60.79373	53.13528	72.17138	73.6114	74.01891
story 27	78.89349	54.89999	78.77784	62.30258	54.59045	74.1278	75.43335	75.83784
story 28	80.28815	56.23847	80.16473	63.64297	55.91044	75.90549	77.05259	77.45159
story 29	81.4459	57.43673	81.315	64.80949	57.08889	77.49547	78.46273	78.85374
story 30	82.39951	58.50554	82.26017	65.82011	58.1368	78.88732	79.67139	80.05335

Based on the results obtained from SAP 2000 software a graph was plotted between displacement and number of stories of the building with equal interval. Above table are plotted for displacement in X direction for both, different bracings and combination of bracings

Above tables shows that displacement using O grid is high compared to other type of bracings. But using O bracings as a combination with other type of bracings gives effective results and combination of bracings is also economical compared to individual bracings.

Table 2: Story Displacement in Y Direction

	STORY DISPLACEMENT in mm							
stories	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
BASE	0	0	0	0	0	0	0	0
story 1	1.466076	1.104029	1.465136	1.232884	1.0939	1.195216	1.307881	1.175908
story 2	4.527426	3.011924	4.525541	3.522477	2.988568	3.526655	3.924925	3.482655
story 3	8.253767	5.122304	8.244076	6.116401	5.087249	6.29605	7.038714	6.235462
story 4	12.26815	7.326742	12.24701	8.837494	7.281279	9.299926	10.38727	9.23027
story 5	16.41543	9.600555	16.37991	11.62245	9.545645	12.46718	13.86772	12.39575
story 6	20.62916	11.93357	20.57756	14.46333	11.86998	15.76518	17.44667	15.69754
story 7	24.87806	14.31805	24.80916	17.34094	14.24638	19.1713	21.09649	19.11268
story 8	29.14449	16.74653	29.05733	20.25594	16.66729	22.66719	24.80749	22.62149
story 9	33.41581	19.21144	33.3097	23.19257	19.12502	26.23526	28.56028	26.20605
story 10	37.68087	21.705	37.55511	26.14998	21.61169	29.85911	32.34699	29.84895
story 11	41.92866	24.21919	41.78282	29.11311	24.11917	33.52245	36.14924	33.53348
story 12	46.14774	26.74573	45.98121	32.07897	26.63909	37.20947	39.95843	37.2431
story 13	50.32599	29.27608	50.13854	35.03292	29.16283	40.90449	43.75634	40.96168
story 14	54.45054	31.80142	54.24166	37.96991	31.68148	44.59197	47.53328	44.67311
story 15	58.50776	34.31267	58.27744	40.87558	34.18587	48.25659	51.27106	48.3616
story 16	62.48323	36.80048	62.231	43.74295	36.66654	51.88288	54.95879	52.01129
story 17	66.36172	39.25522	66.08782	46.55787	39.1138	55.4558	58.5783	55.6066
story 18	70.12724	41.66701	69.83129	49.31153	41.51768	58.95991	62.11751	59.13183
story 19	73.76302	44.02573	73.44549	51.98992	43.86795	62.38044	65.55833	62.57165
story 20	77.25153	46.32103	76.91211	54.58254	46.15418	65.70206	68.88751	65.91055
story 21	80.57449	48.54233	80.2139	57.0755	48.36568	68.91043	72.08713	69.13359
story 22	83.71287	50.67887	83.33089	59.45677	50.49161	71.99052	75.14294	72.22562
story 23	86.64702	52.71972	86.24463	61.71247	52.52092	74.92863	78.03731	75.17235
story 24	89.35668	54.65381	88.9337	63.82931	54.44244	77.71037	80.75517	77.95927
story 25	91.82129	56.46995	91.37897	65.79336	56.24487	80.32307	83.27945	80.57311
story 26	94.02063	58.15692	93.55877	67.59047	57.91686	82.75341	85.59473	83.00044
story 27	95.93628	59.70353	95.45628	69.20703	59.44713	84.99016	87.68536	85.22948
story 28	97.55548	61.09921	97.05697	70.6303	60.82499	87.02141	89.53788	87.24824
story 29	98.88033	62.33656	98.3645	71.85449	62.043	88.83646	91.14405	89.04601
story 30	99.95191	63.42772	99.41799	72.89987	63.11358	90.42125	92.51187	90.61055

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A. Results for 12 story building

Table 3: Story displacement in X- Direction for 12 story

	STORY DISPLACEMENT in mm							
stories	without brace	X brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
BASE	0	0	0	0	0	0	0	0
story 1	2.896858	1.617427	2.740129	2.23264	1.591894	1.931152	2.131737	1.584249
story 2	7.876273	3.655739	7.46137	5.230154	3.608613	4.788816	5.266533	4.014822
story 3	13.27091	5.747	12.56156	8.242999	5.683555	8.006064	8.703365	6.801395
story 4	18.69903	7.885139	17.68618	11.2946	7.808919	11.50839	12.24831	9.865902
story 5	24.02998	10.0332	22.7127	14.30702	9.94672	15.19724	15.91367	13.11465
story 6	29.17294	12.15202	27.54855	17.25721	12.05674	18.98086	19.55118	16.45898
story 7	34.03255	14.19784	32.10488	20.0665	14.09419	22.7651	23.13586	19.80977
story 8	38.49993	16.12259	36.26572	22.68319	16.00997	26.45807	26.53859	23.07888
story 9	42.45068	17.87404	39.91881	25.02464	17.7508	29.971	29.70207	26.18255
story10	45.74448	19.39636	42.91606	27.01473	19.25974	33.21656	32.51381	29.03718
story11	48.22036	20.62933	45.13986	28.56309	20.47537	36.11886	34.89227	31.57057
story12	49.77254	21.52098	46.50893	29.60036	21.34495	38.53049	36.69895	33.64774

B. Results for 20 story building

Table 4: Story displacement in X Direction for 20 story

	STORY DISPLACEMENT in mm							
stories	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
BASE	0	0	0	0	0	0	0	0
story 1	1.219501	1.16963	1.221068	1.107672	1.009482	1.263609	1.368529	1.355517
story 2	3.759595	3.174564	3.765244	3.168614	2.774986	3.710262	4.090138	4.04794
story 3	6.840916	5.369345	6.847388	5.516887	4.726553	6.589973	7.308007	7.230543
story 4	10.14464	7.635269	10.15022	7.959042	6.750771	9.681099	10.73792	10.62404
story 5	13.53537	9.942254	13.53866	10.44724	8.818148	12.90259	14.26903	14.11913
story 6	16.95002	12.27473	16.95021	12.95085	10.91366	16.21299	17.85529	17.67041
story 7	20.35314	14.61872	20.34984	15.46021	13.02408	19.58054	21.46213	21.24335
story 8	23.71899	16.95954	23.71177	17.95444	15.13564	22.97642	25.06541	24.81401
story 9	27.02436	19.28144	27.01317	20.42231	17.23368	26.37194	28.63629	28.35355
story10	30.24568	21.56747	30.23013	22.84222	19.30251	29.73802	32.14955	31.83699
story11	33.35787	23.79949	33.33812	25.19891	21.32541	33.04532	35.57463	35.23383
story12	36.33393	25.95824	36.30954	27.46923	23.28469	36.26352	38.88282	38.51569
story13	39.14481	28.02328	39.11613	29.63396	25.16164	39.36245	42.04121	41.64979
story14	41.75947	29.97309	41.72597	31.66787	26.93665	42.31071	45.01756	44.60427
story15	44.14519	31.78511	44.10737	33.54739	28.5892	45.07777	47.77692	47.34443
story16	46.26828	33.43581	46.22546	35.2464	30.09796	47.63177	50.28432	49.83572
story17	48.09602	34.9009	48.04884	36.73912	31.44101	49.94287	52.50459	52.04329
story18	49.60136	36.15622	49.54882	38.00084	32.5967	51.98077	54.40485	53.93469
story19	50.77433	37.18218	50.71694	39.01518	33.54795	53.72067	55.96331	55.48824
story20	51.65168	37.9909	51.58822	39.80224	34.306	55.14891	57.19172	56.71511

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Table 5: Story displacement in Y Direction for 20 story

	STORY DISPLACEMENT in mm							
stories	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
BASE	0	0	0	0	0	0	0	0
story 1	1.511179	1.16963	1.221068	1.289125	1.009482	1.263609	1.2796	1.042888
story 2	4.657621	3.174564	3.765244	3.667679	2.774986	3.710262	3.833937	3.094193
story 3	8.471725	5.369345	6.847388	6.344513	4.726553	6.589973	6.859232	5.532568
story 4	12.55752	7.635269	10.15022	9.126111	6.750771	9.681099	10.08774	8.166443
story 5	16.74696	9.942254	13.53866	11.94474	8.818148	12.90259	13.41252	10.92207
story 6	20.96189	12.27473	16.95021	14.78255	10.91366	16.21299	16.7906	13.7622
story 7	25.15858	14.61872	20.34984	17.61571	13.02408	19.58054	20.18814	16.65726
story 8	29.30541	16.95954	23.71177	20.43283	15.13564	22.97642	23.58308	19.58165
story 9	33.3739	19.28144	27.01317	23.21121	17.23368	26.37194	26.94747	22.50907
story 10	37.33513	21.56747	30.23013	25.93532	19.30251	29.73802	30.2581	25.41387
story 11	41.15831	23.79949	33.33812	28.5807	21.32541	33.04532	33.48566	28.26957
story 12	44.81025	25.95824	36.30954	31.12722	23.28469	36.26352	36.60349	31.04948
story 13	48.25519	28.02328	39.11613	33.54841	25.16164	39.36245	39.58026	33.72672
story 14	51.45486	29.97309	41.72597	35.81977	26.93665	42.31071	42.38584	36.27372
story 15	54.3689	31.78511	44.10737	37.91276	28.5892	45.07777	44.98716	38.66351
story 16	56.95575	33.43581	46.22546	39.79913	30.09796	47.63177	47.3514	40.86828
story 17	59.17502	34.9009	48.04884	41.44895	31.44101	49.94287	49.44546	42.86188
story 18	60.99336	36.15622	49.54882	42.83387	32.5967	51.98077	51.23852	44.61811
story 19	62.39877	37.18218	50.71694	43.93488	33.54795	53.72067	52.71032	46.1158
story 20	63.43745	37.9909	51.58822	44.77469	34.306	55.14891	53.87208	47.34427

B. Time Period

Table 6: Time period in X Direction for 12 story

	TIME PERIOD							
MODES	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
1	2.352178	0.978821	2.331773	1.243898	0.972243	1.459252	1.635667	1.421132
2	2.352178	0.978821	2.331773	1.242843	0.972243	1.459252	1.634423	1.421132
3	2.230874	0.591565	2.181221	0.801786	0.59137	0.967325	1.143086	0.937668
4	0.76673	0.324126	0.760534	0.411536	0.325003	0.448494	0.522966	0.448477
5	0.76673	0.324126	0.760534	0.411173	0.325003	0.448494	0.522447	0.448477
6	0.72642	0.200055	0.711375	0.267776	0.200039	0.302326	0.370079	0.30203
7	0.440123	0.197878	0.437051	0.238914	0.197808	0.239211	0.289629	0.240383
8	0.440123	0.190264	0.437051	0.238679	0.190297	0.239211	0.289258	0.240383
9	0.41705	0.190264	0.409734	0.200119	0.190297	0.200134	0.205929	0.200125
10	0.29886	0.185622	0.297106	0.190399	0.186188	0.19058	0.201514	0.190561
11	0.29886	0.185622	0.297106	0.190398	0.186188	0.19058	0.20125	0.190561
12	0.281858	0.180871	0.277671	0.18133	0.180901	0.181314	0.200174	0.181319

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Table 7: Time period for 12 story

	TIME PERIOD							
MODES	without brace	x brace	O brace	K brace	v brace	x-o brace	k-o brace	v-o brace
1	2.473309	1.522237	2.466805	1.800355	1.516927	2.098784	2.215681	2.213661
2	2.473309	1.522237	2.466805	1.80001	1.516927	2.098784	2.215681	2.088195
3	2.250839	0.980273	2.233763	1.259332	0.979901	1.575123	1.760136	1.655361
4	0.800848	0.49632	0.799042	0.587432	0.496916	0.663607	0.71148	0.711115
5	0.800848	0.49632	0.799042	0.587314	0.496916	0.663607	0.71148	0.66424
6	0.731622	0.32581	0.726675	0.417183	0.325673	0.502407	0.570322	0.534154
7	0.453019	0.280482	0.452306	0.334249	0.280983	0.363431	0.396708	0.396663
8	0.453019	0.280482	0.452306	0.334174	0.280983	0.363431	0.396708	0.364074
9	0.4185	0.199458	0.41649	0.247225	0.199243	0.27706	0.321935	0.297848
10	0.304724	0.196204	0.304421	0.231199	0.196499	0.246495	0.269332	0.269341
11	0.304724	0.196204	0.304421	0.231149	0.196499	0.246495	0.269332	0.246958
12	0.281632	0.194346	0.280616	0.199571	0.194245	0.199647	0.221242	0.204808

C. Modes Shapes of 12 Story Building

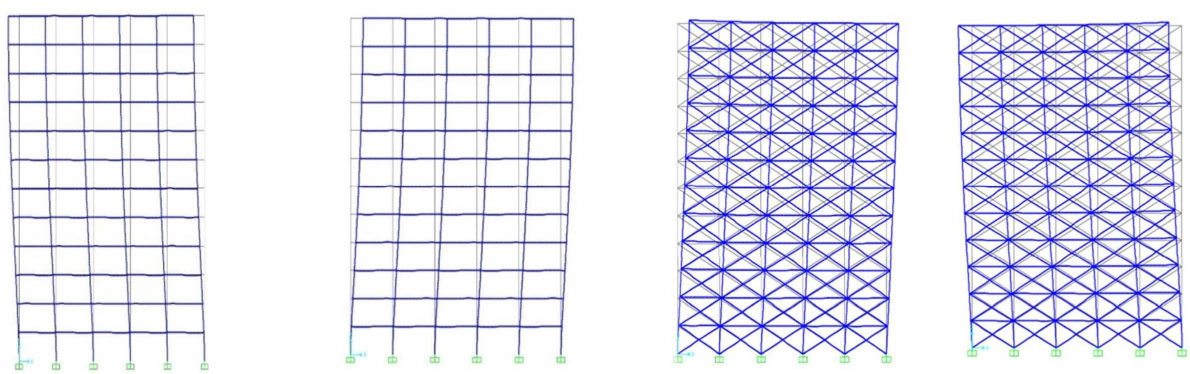

Fig 2: Normal building, X Braced building

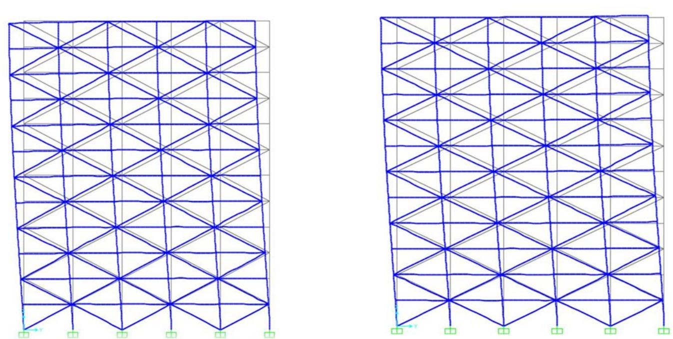

Fig 3: K Braced building

IV. CONCLUSIONS

Based on the observations and the results obtained during this study, the followingconclusions can be arrived:

1) As per the results obtained from the analysis of different bracing method, K brace (65.8 mm) are less effective when compared with X (58.5 mm) and V (58.13mm) brace, as displacement due to K brace is 1.2 times of the displacement due to V brace.
2) K-O brace combination is effective as the displacement is less compared to other combination as V-O brace system.
3) Based on above results, it is concluded that concentrically braced frames had high ductility performance. Concentrically bracing system can easily retrofit with framed structures and can effectively control the various responses of the buildings such as story drift, displacement etc
4) Story displacement is also reduced to a great level such as X bracing reduces up to 58 mm, V bracing reduces up to 58 mm, K bracing reduces up to 65 mm , when compared to un braced structure with 82 mm. X bracing and V bracing are found to be more effective to control the story displacements
5) This study proposed new type of bracing system O-Grid bracing system, a braced frame with a circular brace attached to a moment-resistant frame (MRF) with a joint connection to resist lateral forces. O-Grid braces, unlike other braces, have a structure and form that allows them to be employed in any portion of the structure without sacrificing architectural space or architectural form. The O-Grid bracing system is ductile and rigid.
6) Story drift in the MRF model is more than other systems, and the x-bracing model is less than other systems. The combination of the k-O model has 11% lower story drift (0.00047) than other models, and in all models story drift is within the limit as per code.

Providing the combination of K-O grid is more effective and economical compared to other combinations and also individual O grid is not much effective compared to combinations of bracings

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