Elimination of ILL-Effects of Torsion in Irregular Building through Introduction of Anti Torsion Column

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Abstract— **This research paper focuses on eliminating torsion in columns and displacements due to torsion in reinforced concrete (RCC) and steel buildings while resisting lateral forces (earthquake and wind) through introduction of an innovative structural element defined as anti-torsion column (ATC). While existing popular software tools analyze torsion in buildings, they do not provide design solutions specifically targeting torsion effects. Even there are codal provisions to substantially reduce torsion in a building .In this study, efforts are made to address this gap by proposing ATC in the form of a steel tube positioned near the center of mass (C.G.) of the building. To study torsion the research utilizes E Tab, a widely used software to analyze displacements at terrace corners of irregular buildings. The objective is to evaluate the effectiveness of the ATC in eliminating torsional effects. Results of the study demonstrates that introduction of the ATC successfully eliminates torsion effects in columns and torsion related displacements in RCC buildings. Buildings with very irregular shapes can be planned without affecting architectural planning by introducing ATC.**

Index Terms— **Anti-Torsion, Column, Torsion, Seismic**

1. INTRODUCTION

Now a days irregular buildings are inevitable. Structural engineer's role becomes more challenging if these building are located in seismic zone. It is noticed that irregular buildings undergo larger torsional deformation as compared to regular buildings when subjected to lateral loads. Reports from various sources, including the most recent earthquake in Turkey demonstrate that failure in some structures was due to torsional irregularity. To eliminate torsional irregularity structural engineer and architect has to work on many alternatives of structural systems of frames and shear walls and sometimes sacrificing utility aspect. The process is really tedious and time consuming. Today various popular software and codes lack ability to design members for torsion resistance. All international codes simply suggest to avoid torsion .Here torsion is allowed but it is resisted by the ATC to eliminate all ill effects of torsion. This study suggests a simple alternative to previous approaches by providing a separate torsion resisting column (ATC) which would be safe as well as economical. A high strength circular steel tube is introduced near the center of rigidity of vertical members.

The study utilizes E Tab, a widely used software tool to analyze torsion by studying displacements at terrace corners of buildings with different shapes. The primary objective is to assess the effectiveness of the proposed ATC in eliminating torsion related unwanted effects. Instead of a traditional concrete column, a circular steel tube is suggested as an alternative due to its superior torsion resistance properties. Also it is very easy to analyze and design a steel tube for torsion and even combination of torsion with bending and direct compression. To simulate the torsion resistance provided by the ATC, a torsion modifier of 100 is applied in E Tab, effectively attracting all torsion forces within the building. Furthermore, the torsion stiffness of all other columns is set to one, ensuring that only the ATC attracts all torsion effects. Torsion at base of the ATC is observed, which is determined by multiplying the base shear of building by the eccentricity (Distance between center of rigidity and center of mass).Study reveals that introduction of ATC successfully removes torsion from all other columns and also torsion related displacements from the structure by transferring all torsional forces through beams and slabs to the ATC. The ATC acts as a centralized element for torsion resistance.

More than one ATC with reduced diameter and thickness were tried and found effective. The ATC is also found effective in stepped multistory buildings with loading as well as mass and stiffness irregularity. ATC can be placed in utility ducts to avoid any interference with serviceability of the building. A lift shaft can be modified into a circular steel tube. At door opening stress concentration will occur and shall be studied. It was noted that Introduction of ATC makes other column sections economical.

2. FURTHER STUDY :

However, a major concern arises regarding applicability of the torsion modifier in E Tab. The paper questions whether the modifier for torsion can exceed a value of one, and whether a value of 10 or even 100 is a valid assumption.

Here torsion of entire building is transferred to the ATC through slabs and beams. E-Tab has limitations in studying behavior of slabs.

Manuscript received July 28, 2023

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The paper should be supported by experiments and further study using software like ANSYS .

Design of footing for ATC will be a challenging job.

3. RCC Structure :Material Methods And Preliminary Data

For this research paper a L-Shape building, P+20 of dimension 35m x 35 m is considered with 66 m height . Concrete grade M40, Rebar Fe500 and for ATC Fe345.ATC is provided near center of rigidity of building.
Slab Thickness – 150 mm modelled as thin shell
Column size 1200 mm x 1200 mm and 1700mm x 1700 mm
Beam size 350 mm x 900 mm and 350 mm x 1000 mm
ATC column size Dia. 2000mm of 40 mm thickness
Seismic Zone IV
Importance Factor -1.2
Response reduction factor – 5
Basic wind speed 39 m/s
Column to column distance 5 m
Deflection check for load combination – 1.5DL+ 1.5 SPEC X and 1.5DL+ 1.5 SPEC Y

RCC BUILDING : Load combination : 1.5DL+ 1.5 SPEC X

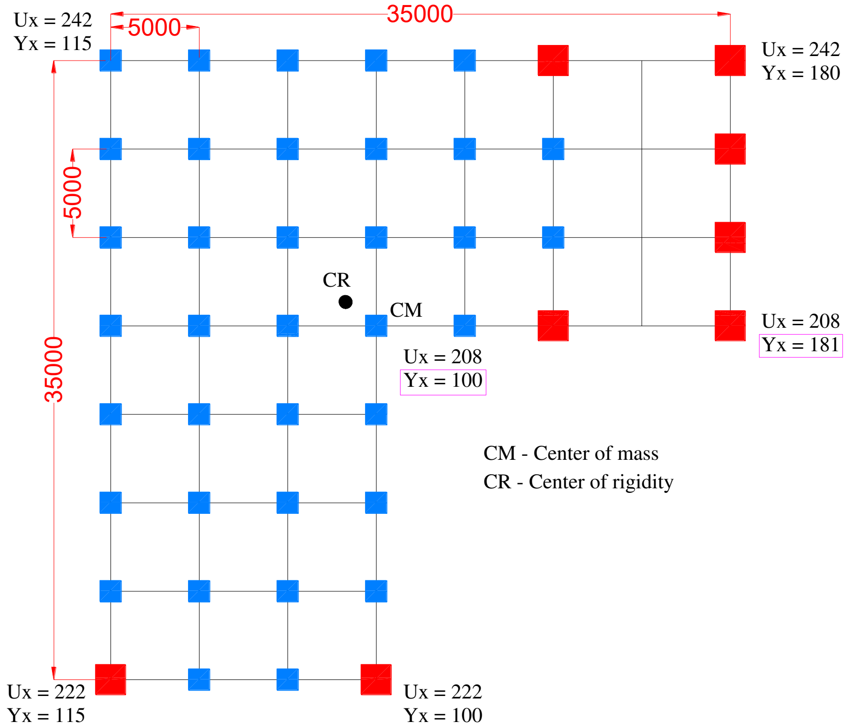


Fig-1. P+20 Building without ATC
Showing displacements (mm) at corner

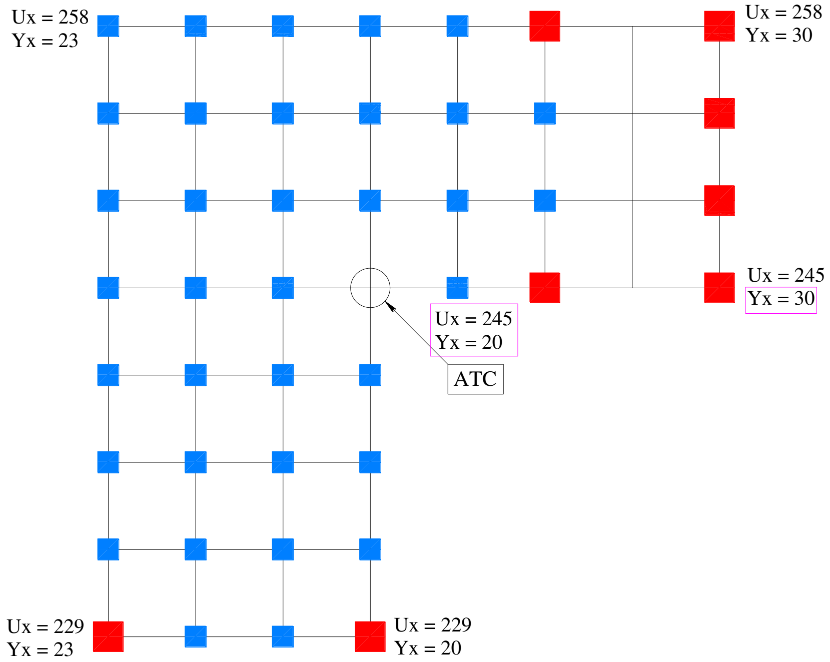
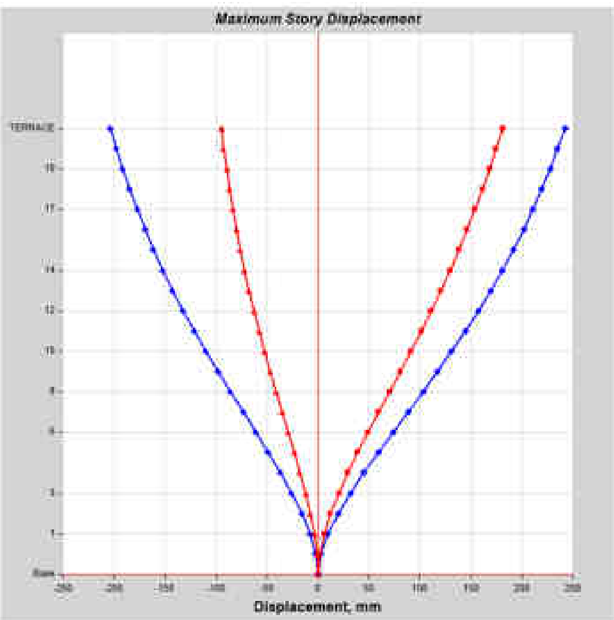
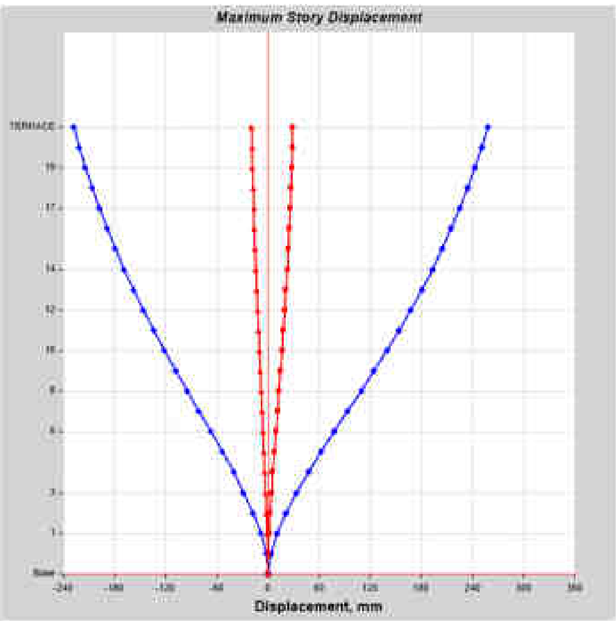


Fig-2. P+20 Building with ATC
Showing displacements (mm) at corner

OBSERVE - DISPLACEMENT IN 'Y' DIRECTION IS VERY LESS AS IN COMPARISION WITH FIG-1

RCC BUILDING

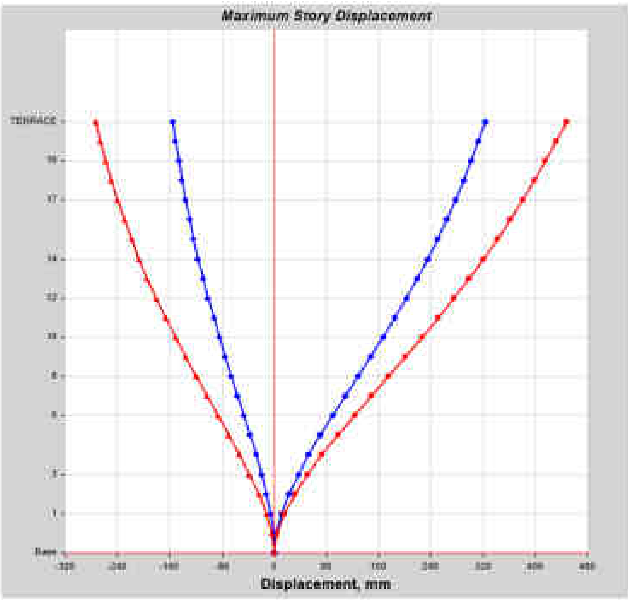




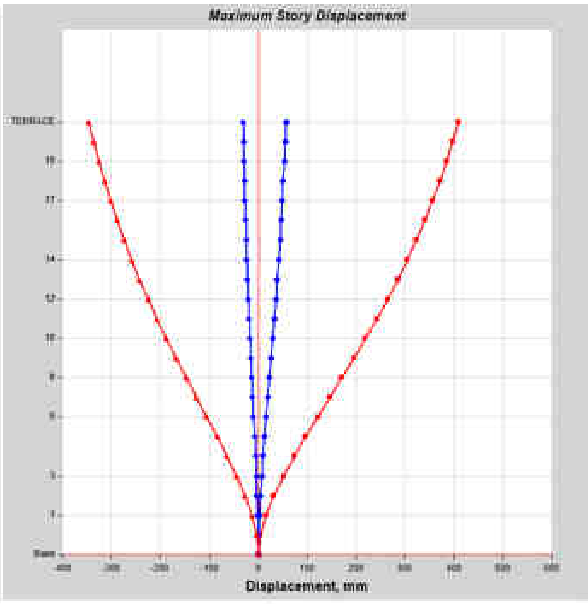
Displacement Graph without ATC For 1.5 DL+ Spec X

Displacement Graph with ATC For 1.5 DL+ Spec X

RCC BUILDING



Displacement Graph without ATC for
1.5 DL+ Spec Y



Displacement Graph with ATC For
1.5 DL+ Spec Y

Above two graphs show that displacement due to torsion are reduced at all floors.

Results and Tables (RCC BUILDING)

Story Response Values –displacement in mm for Combination 1.5 DL + 1.5 Spec X Without ATC and With ATC

			Without ATC				With ATC			
Story	Elevation	Location	X-Dir Max	X-Dir Min	Y-Dir Max	Y-Dir Min	X-Dir Max	X-Dir Min	Y-Dir Max	Y-Dir Min
	m		mm	mm	mm	mm	mm	mm	mm	mm
TERRACE	66	Top	242.069	-203.409	180.977	-94.862	257.8	-227.965	29.571	-18.963
20	63	Top	234.879	-197.491	174.606	-92.372	250.251	-221.049	28.761	-18.468
19	60	Top	227.364	-191.267	168.035	-89.711	242.323	-213.809	27.907	-17.939
18	57	Top	219.359	-184.593	161.157	-86.804	233.836	-206.093	26.987	-17.362
17	54	Top	210.756	-177.377	153.901	-83.608	224.676	-197.795	25.989	-16.726
16	51	Top	201.483	-169.561	146.224	-80.099	214.772	-188.852	24.904	-16.028
15	48	Top	191.493	-161.112	138.102	-76.268	204.086	-179.228	23.727	-15.265
14	45	Top	180.763	-152.02	129.529	-72.115	192.6	-168.911	22.455	-14.437
13	42	Top	169.295	-142.293	120.513	-67.648	180.326	-157.911	21.087	-13.543
12	39	Top	157.116	-131.961	111.08	-62.878	167.294	-146.26	19.626	-12.576
11	36	Top	144.281	-121.069	101.272	-57.825	153.562	-134.01	18.078	-11.538
10	33	Top	130.863	-109.682	91.146	-52.513	139.206	-121.232	16.45	-10.449
9	30	Top	116.957	-97.881	80.773	-46.975	124.327	-108.017	14.753	-9.317
8	27	Top	102.675	-85.696	70.245	-41.252	109.044	-94.478	13	-8.154
7	24	Top	88.148	-73.311	59.673	-35.399	93.504	-80.75	11.208	-6.97
6	21	Top	73.536	-60.9	49.193	-29.461	77.89	-67.003	9.397	-5.782
5	18	Top	59.04	-48.655	38.975	-23.478	62.43	-53.452	7.592	-4.61
4	15	Top	44.935	-36.829	29.233	-17.716	47.43	-40.382	5.826	-3.481
3	12	Top	31.605	-25.753	20.24	-12.346	33.307	-28.167	4.143	-2.427

2	9	Top	19.594	-15.871	12.34	-7.581	20.625	-17.302	2.607	-1.492
1	6	Top	9.636	-7.759	5.963	-3.694	10.141	-8.424	1.308	-0.728
PARKING	3	Top	2.697	-2.158	1.639	-1.024	2.843	-2.33	0.378	-0.202
Base	0	Top	0	0	0	0	0	0	0	0

Story Response Values- displacement in mm for Combination 1.5 DL + 1.5 Spec Y without ATC and With ATC

			Without ATC				With ATC			
Story	Elevation	Location	X-Dir Max	X-Dir Min	Y-Dir Max	Y-Dir Min	X-Dir Max	X-Dir Min	Y-Dir Max	Y-Dir Min
	m		mm	mm	mm	mm	mm	mm	mm	mm
TERRACE	66	Top	323.133	-154.924	447.968	-273.721	56.569	-30.4	409.865	-345.879
20	63	Top	312.574	-150.564	432.224	-266.092	54.727	-29.555	397.507	-336.058
19	60	Top	301.576	-145.943	416	-258.062	52.857	-28.66	384.622	-325.657
18	57	Top	289.924	-140.945	399.04	-249.436	50.9	-27.693	370.901	-314.453
17	54	Top	277.475	-135.497	381.17	-240.093	48.814	-26.638	356.147	-302.304
16	51	Top	264.15	-129.56	362.283	-229.953	46.575	-25.487	340.233	-289.124
15	48	Top	249.914	-123.118	342.31	-218.962	44.171	-24.235	323.086	-274.865
14	45	Top	234.767	-116.171	321.229	-207.093	41.598	-22.882	304.681	-259.509
13	42	Top	218.736	-108.731	299.055	-194.346	38.857	-21.429	285.029	-243.072
12	39	Top	201.873	-100.822	275.847	-180.753	35.956	-19.88	264.184	-225.6
11	36	Top	184.254	-92.476	251.705	-166.37	32.909	-18.243	242.236	-207.169
10	33	Top	165.981	-83.736	226.772	-151.279	29.731	-16.526	219.311	-187.883
9	30	Top	147.187	-74.659	201.225	-135.581	26.446	-14.742	195.57	-167.875
8	27	Top	128.039	-65.322	175.284	-119.397	23.081	-12.906	171.213	-147.308
7	24	Top	108.752	-55.821	149.208	-102.866	19.674	-11.038	146.486	-126.377
6	21	Top	89.594	-46.284	123.314	-86.154	16.271	-9.162	121.692	-105.327
5	18	Top	70.904	-36.879	97.994	-69.478	12.931	-7.31	97.217	-84.467
4	15	Top	53.101	-27.818	73.755	-53.138	9.729	-5.523	73.569	-64.209
3	12	Top	36.703	-19.372	51.26	-37.575	6.761	-3.854	51.422	-45.116
2	9	Top	22.341	-11.885	31.38	-23.427	4.142	-2.37	31.669	-27.953
1	6	Top	10.783	-5.784	15.229	-11.591	2.018	-1.154	15.473	-13.749
PARKING	3	Top	2.96	-1.601	4.203	-3.256	0.564	-0.32	4.307	-3.851
Base	0	Top	0	0	0	0	0	0	0	0

Model Mass Participation ratios (RCC BUILDING)

		Without ATC				With ATC			
Case	Mode	Period	UX	UY	RZ	Period	UX	UY	RZ
		sec	Unitless	Unitless	Unitless	sec	Unitless	Unitless	Unitless
Modal	1	2.864	0.1757	0.2637	0.2765	3.161	0.6412	0.0805	0.0043
Modal	2	2.812	0.4738	0.2508	0.0025	2.853	0.0826	0.6423	0.0016
Modal	3	1.503	0.0777	0.2131	0.4396	2.494	0.0016	0.0042	0.7584
Modal	4	0.817	0.0479	0.0341	0.0399	0.877	0.1054	0.0112	0.0004
Modal	5	0.804	0.0508	0.0645	0.0009	0.816	0.0114	0.1045	0.0006
Modal	6	0.47	0.0173	0.0174	0.0804	0.719	0.0002	0.0006	0.0979
Modal	7	0.388	0.0373	0.0042	0.0114	0.407	0.0492	0.0026	0.0001
Modal	8	0.382	0.0053	0.046	0.0002	0.389	0.0026	0.0489	0.0004
Modal	9	0.253	0.009	0.0012	0.0421	0.342	0.0002	0.0002	0.0419
Modal	10	0.222	0.0247	0.0001	0.0049	0.231	0.0292	0.0001	0.0001
Modal	11	0.218	4.73E-05	0.0293	2.762E-05	0.223	0.0001	0.0293	0.0001
Modal	12	0.158	0.0047	2.75E-06	0.0253	0.194	0.0003	2.754E-05	0.0246
Total			0.924	0.9245	0.9304		0.9243	0.9245	0.9237

4. Steel Structure Material Methods And Preliminary Data

Exactly same building with all same loadings but with steel columns and beams is considered.

Column size ISMB600 mm and ISMB mm
Beam size ISMB300 mm and ISMB600 mm
ATC column size Dia. 2000mm of 20 mm thickness
Seismic Zone IV
Importance Factor -1.2
Response reduction factor – 5
Basic wind speed 39 m/s
Column to column distance 5 m
Deflection check for load combination – 1.5DL+ 1.5 SPEC X, And 1.5DL+ 1.5 SPEC Y

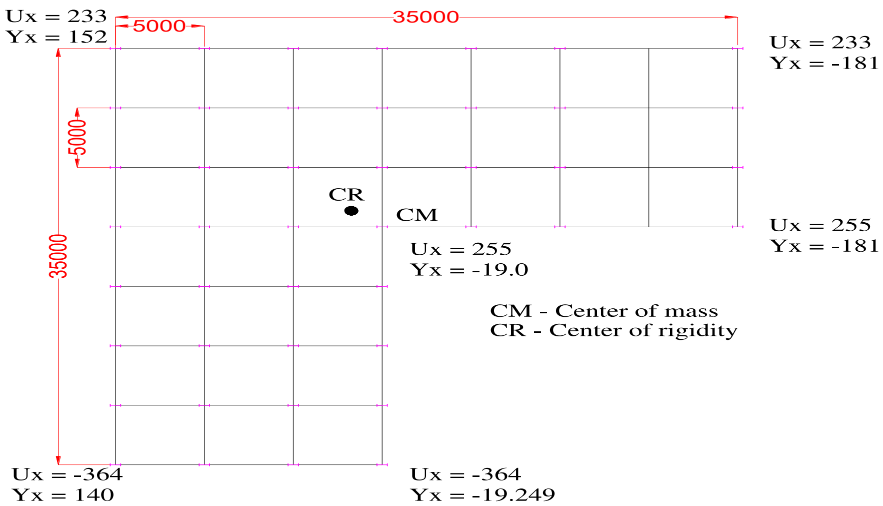


Fig-1. P+20 Building without ATC
Showing displacements (mm) at corner

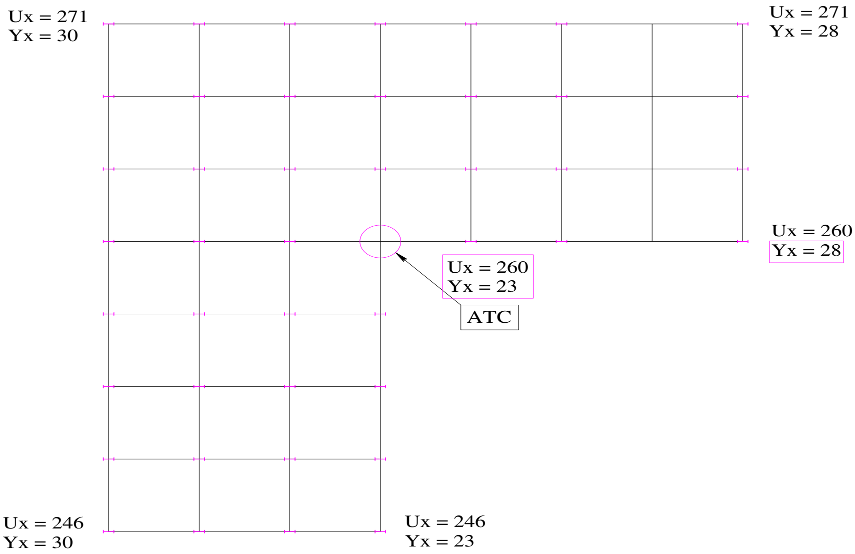
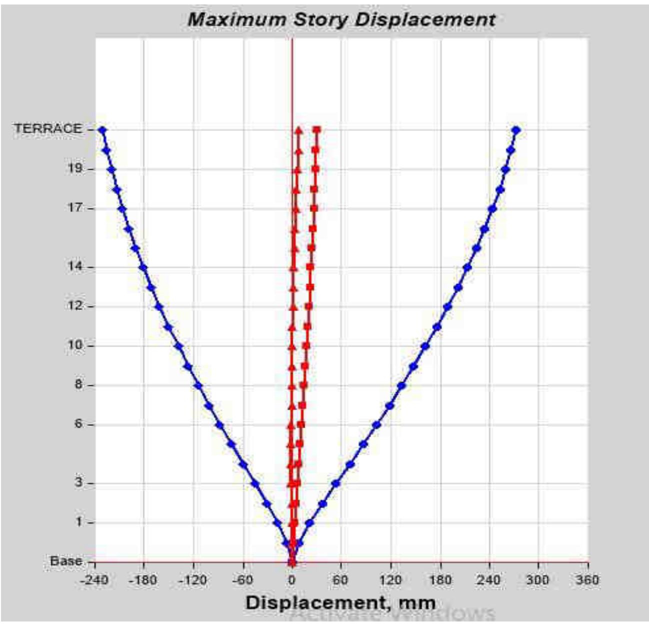
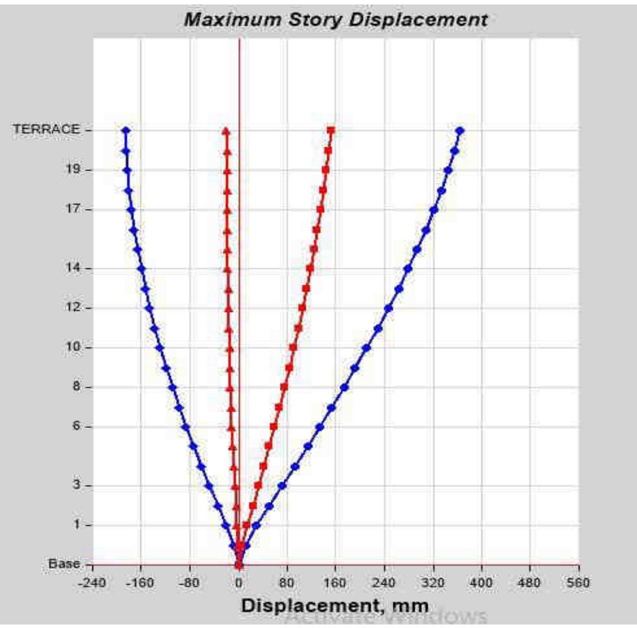


Fig-2. P+20 Building with ATC
Showing displacements (mm) at corner

OBSERVE - DISPLACEMENT IN 'Y' DIRECTION IS VERY LESS AS IN COMPARISION WITH FIG-1

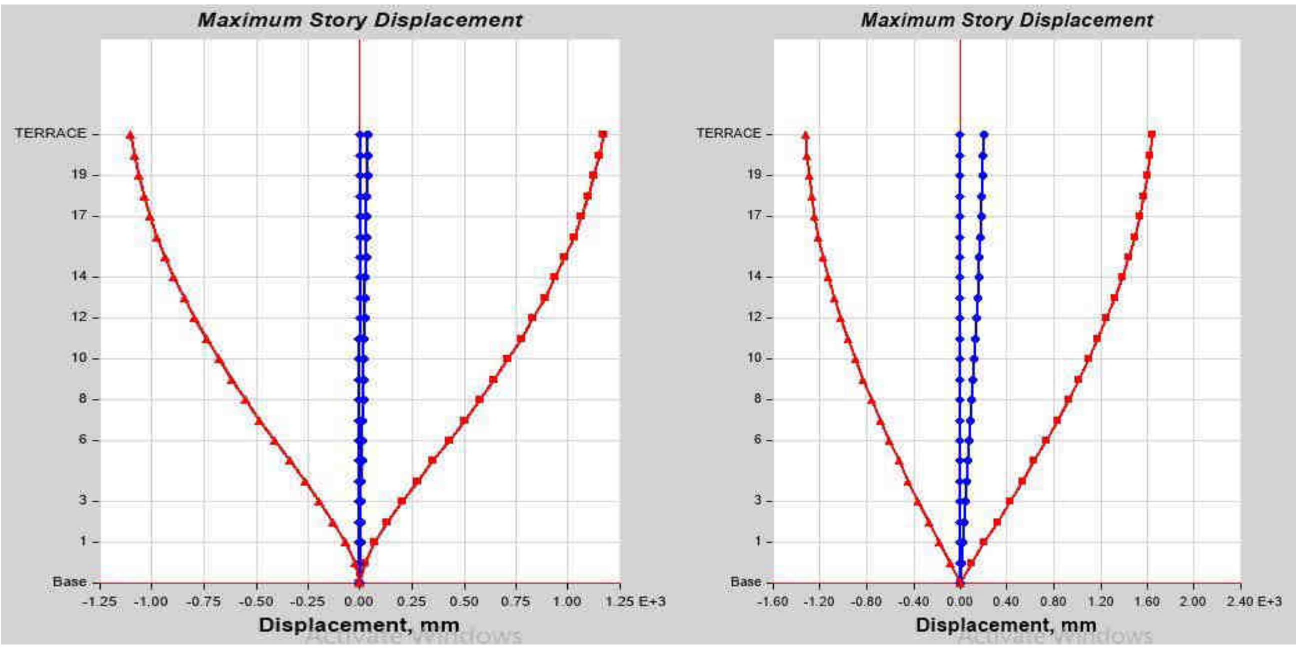
STEEL BUILDING





Displacement Graph with ATC for 1.5DL+Spec X

Displacement Graph without ATC for 1.5DL+Spec X



Displacement Graph with ATC forDisplacement Graph without ATC for
1.5DL+Spec Y 1.5DL+Spec Y

Above two graphs show that displacement due to torsion are reduced at all floors.

Results and Tables (STEEL BUILDING)

Story Response Values –displacement in mm for Combination 1.5 DL + 1.5 Spec XWithout ATC and With ATC

			WITH ATC				WITHOUT ATC			
STORY	ELEVATION	LOCATION	X DIR MASS	X DIR .Max	Y DIR MAX	Y DIR MIN	X DIR MASS	X DIR .Max	Y DIR MAX	Y DIR MIN
	m		mm	mm	mm	mm	mm	mm	mm	mm
TERRACE	66	Top	271.621	30.433	-229.611	8.402	363.188	152.009	-184.672	-19.249
20	63	Top	266.067	29.526	-224.943	7.376	354.729	148.578	-183.855	-19.173
19	60	Top	259.544	28.552	-219.667	6.387	344.963	144.659	-182.099	-19.016
18	57	Top	252.022	27.52	-213.568	5.434	333.859	140.235	-179.365	-18.789
17	54	Top	243.529	26.435	-206.639	4.514	321.543	135.359	-175.706	-18.501
16	51	Top	234.127	25.301	-198.915	3.627	308.161	130.09	-171.186	-18.161
15	48	Top	223.876	24.125	-190.439	2.933	293.831	124.463	-165.857	-17.774
14	45	Top	212.837	22.908	-181.256	2.303	278.637	118.494	-159.759	-17.334
13	42	Top	201.072	21.65	-171.413	1.703	262.64	112.18	-152.918	-16.829
12	39	Top	188.64	20.349	-160.955	1.141	245.892	105.513	-145.357	-16.242
11	36	Top	175.592	18.997	-149.926	0.626	228.458	98.493	-137.102	-15.562
10	33	Top	161.967	17.588	-138.356	0.167	210.415	91.136	-128.186	-14.785
9	30	Top	147.795	16.114	-126.272	-0.226	191.849	83.482	-118.399	-13.908
8	27	Top	133.114	14.575	-113.703	-0.545	172.833	75.572	-108.016	-12.937
7	24	Top	117.969	12.976	-100.679	-0.78	153.415	67.435	-97.09	-11.874
6	21	Top	102.403	11.325	-87.233	-0.925	133.607	59.079	-85.613	-10.717
5	18	Top	86.451	9.631	-73.395	-0.977	113.396	50.501	-73.561	-9.293
4	15	Top	70.147	7.902	-59.212	-0.937	92.776	41.705	-60.924	-7.48
3	12	Top	53.582	6.152	-44.8	-0.814	71.794	32.722	-47.722	-5.675
2	9	Top	37.036	4.408	-30.46	-0.627	50.632	23.616	-34.066	-3.894
1	6	Top	21.198	2.715	-16.893	-0.409	29.81	14.538	-20.297	-2.252
PARKING	3	Top	7.587	1.143	-5.626	-0.191	10.941	5.966	-7.533	-1.032
Base	0	Top	0	0	0	0	0	0	0	0

Story Response Values- displacement in mm for Combination 1.5 DL + 1.5 Spec YWith ATC and without ATC

			WITH ATC				WITHOUT ATC			
STORY	ELEVATION	LOCATION	X DIR MASS	X DIR .Max	Y DIR MAX	Y DIR MIN	X DIR MASS	X DIR .Max	Y DIR MAX	Y DIR MIN
	m		mm	mm	mm	mm	mm	mm	mm	mm
TERRACE	66	Top	38.259	1170.876	3.891	-1105.425	198.081	1639.124	2.693	-1319.996
20	63	Top	36.629	1149.153	3.42	-1086.404	194.438	1624.777	1.99	-1310.959
19	60	Top	34.958	1124.883	2.902	-1064.882	190.061	1602.736	1.307	-1295.432
18	57	Top	33.224	1096.905	2.375	-1039.711	184.921	1573.139	0.668	-1273.63
17	54	Top	31.43	1064.547	1.852	-1010.246	179.035	1536.244	0.077	-1245.785
16	51	Top	29.581	1027.503	1.344	-976.187	172.433	1492.315	-0.464	-1212.11
15	48	Top	27.681	985.7	0.859	-937.465	165.149	1441.639	-0.952	-1172.836
14	45	Top	25.739	939.205	0.517	-894.14	157.222	1384.513	-1.385	-1128.198
13	42	Top	23.762	888.167	0.29	-846.352	148.688	1321.227	-1.759	-1078.428
12	39	Top	21.759	832.796	0.077	-794.298	139.587	1252.085	-2.072	-1023.774
11	36	Top	19.741	773.35	-0.118	-738.222	129.955	1177.414	-2.321	-964.507
10	33	Top	17.716	710.129	-0.294	-678.406	119.836	1097.543	-2.505	-900.895
9	30	Top	15.697	643.475	-0.449	-615.176	109.273	1012.81	-2.624	-833.201
8	27	Top	13.695	573.789	-0.577	-548.916	98.322	923.584	-2.675	-761.708
7	24	Top	11.724	501.549	-0.675	-480.087	87.041	830.265	-2.658	-686.719
6	21	Top	9.797	427.353	-0.735	-409.263	75.492	733.235	-2.568	-608.518
5	18	Top	7.934	352.011	-0.753	-337.227	63.738	632.869	-2.401	-527.379
4	15	Top	6.156	276.666	-0.725	-265.08	51.855	529.603	-2.151	-443.62
3	12	Top	4.492	202.927	-0.644	-194.383	39.933	423.918	-1.814	-357.573
2	9	Top	2.975	133.173	-0.512	-127.45	28.092	316.211	-1.389	-269.441
1	6	Top	1.652	71.202	-0.334	-67.988	16.564	206.884	-0.883	-179.243
PARKING	3	Top	0.597	23.329	-0.138	-22.159	6.121	97.205	-0.346	-86.964
Base	0	Top	0	0	0	0	0	0	0	0

Model Mass Participation ratios (STEEL BUILDING)

		WITHOUT ATC				WITH ATC			
Case	Mode	Period	UX	UY	RZ	Period	UX	UY	RZ
		sec	Unitless	Unitless	Unitless	sec	Unitless	Unitless	Unitless
Modal	1	6.912	0.0002	0.8125	0.0055	5.981	0.0001	0.7663	0.0001
Modal	2	3.629	0.1073	0.0066	0.6781	3.014	0.773	0.0001	0.0014
Modal	3	3.012	0.6785	0.0004	0.0993	1.882	0.0001	0.1026	0.0001
Modal	4	2.299	2.44E-06	0.0956	0.0021	1.507	0.0005	0.0002	0.8153
Modal	5	1.363	0	0.0335	1.54E-06	1.022	3.95E-05	0.0419	4.20E-06
Modal	6	1.185	0.0143	0.0003	0.0905	0.964	0.1116	8.25E-06	0.0003
Modal	7	0.973	3.64E-06	0.0166	0.0001	0.655	0	0.0246	4.14E-06
Modal	8	0.969	0.0959	4.48E-05	0.0211	0.537	0.0353	1.47E-06	0.004
Modal	9	0.758	1.24E-06	0.0099	2.90E-05	0.5	0.0025	4.61E-06	0.0911
Modal	10	0.681	0.0068	0.0002	0.0281	0.456	6.89E-07	0.0164	8.07E-06
Modal	11	0.622	2.64E-05	0.0064	0.0001	0.363	0.0204	0	0.0003
Modal	12	0.541	0.0287	1.27E-05	0.0077	0.337	0	0.0117	1.17E-05
			0.93173	0.98205	0.93263		0.94354	0.96381	0.91262

			4	8	1			4	8

CONCLUSION

By introducing the ATC undesirable displacements due to torsion in a building can be removed easily without compromising utility of building. But more precise study is required using software like ANSYS. Also ATC should be backed by experiments. Special studies are required for stresses in slabs at each floor as these slabs transfer torsion to the ATC

REFERENCE.

[1]IS 1893- 2016, IS 456-2000, IS 800-2007, IS 6700-2017, IS 13920-2016

[2]Zheng-Bo Pia , Meni Sub , Yuan-Yuan Pengc , Yu-Hang Wanga,d,⁎ , Wei Luoe , Yong-Sen Lan Seismic Behavior Of Concrete Filled Steel Tubular Columns With Internal H section Steel Under Pure Torsion And Compression Torsion Loads

[3]Zhe Qu, Feijian Wang, Xiangzhao Chen, Xiaoting Wang, Zhiguang Zhou - Rapid report of seismic damage to hospitals in the 2023 Turkey earthquake sequences.

[4]Effect Of The Torsional Moment On The Shear Strength Of Reinforced Concrete Columns Due To Eccentric Jointing Of Beam To Column Jiandong ZHOU , Masaya HIROSAWA , Tatsuya KONDO And Yasushi SHIMIZU

[5]Study of torsional behavior of reinforced concrete beams strengthened with aramid fiber strips- S. B. Kandekar · R. S. Talikoti

[6]Study of Torsion Effects on Building Structures Having Mass and Stiffness Irregularities - Rajalakshmi K R & Harinarayanan S Sree Narayana Gurukulam College of Engineering, Ernakulam, Kerala, INDIA , Jiji Anna Varughese & Girija K Government Engineering College, Barton Hill, Trivandrum, Kerala, INDIA