ANALYSIS OF HIGH RISE BUILDINGS WITH DIFFRENT SHAPES BY CORNER MODIFICATION & CONSIDERING AERODYNAMICEFFECT.

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ABSTRACT

A literature review process including 5 standard codes & thesis and 40 research papers are conducted to detailed study including the conventional shape of building and Y-shaped building and seismic effect throughout the structure. A total three-issue found throughout the literature review method which is 'Analysis of RC frame and shear wall Structure', 'Non- Linear Time History Analysis of High-Rise Structure' or "Dynamic Analysis of various geometrical shape considering aerodynamic optimization". From all three issues "Dynamic Analysis of various geometrical shapeconsidering aerodynamic optimization"was found suitable for study.The conclusion of the literature review was in the form of key issues. All the research papers under key issues provide a good understanding of seismic analysis of various shapes of building with story drift, story displacement, and torsion under the limitation and condition.For conducting this study, we developed 4 models for square shape and Y-shape building with corner modification. The floor plan of square shape is similar to each other and Y-shape is also similar plan to each other. Material and configuration are also similar to each other. For square model recessed and chamfered corner modification selected but for Y-shaped building, regular corner and chamfered corner modification is used. For all 4 building models, a Non-linear direct integration time history analysis conducted using ETABS software.After conducting Dynamic analysis, obtained results show displacement in X-axis and Y-axis for each building model under the seismic effect. Where this can be seen from obtained outcomes that displacement in both axes of these building depends upon the frequency of input ground motion. Also, the variation of displacement can be seen in all models under the permissible limit as per IS 1893: 2002.due to the dynamic analysis all models represent Non- linearity behavior in Max's story response from 2nd story to top story. These maximum values of the response parameter for these test models depending on the orientation of columns of the building.Between all four models, the same loading in a particular direction shows the superior performance of Y-shape test model comparing among the tall building model.

Keywords: Dynamic Analysis, ETABS

I. INTRODUCTION

Aerodynamics, it is a study of the motion of air gust mainly contact by structures. Once the height of the building rises the effect of air-induced motion also increases. A building or mega-tall structure stands it experience across-wind load and along-wind load which affects the geometry of building or structure.Aerodynamic modification technics aredominant which disturb the mechanism of the vortex shedding phenomenon. The dynamic wave of structures is consisting of sustained, static, and oscillatory motion. Aerodynamic modification is very effective to decrease the wind excitation and the cost of construction.Aerodynamic modification controls the applied forces to high rise structures by various shear layers and disturbing the way of vertex over the height. Outer geometry shape wind load is varying because of the surrounding environment and shape every case is different from each other. The world tallest building Burj Khalifa optimized for wind, to reduce the wind load demand stepping of façade provided. The stepping of structure designed to disturb vortexshedding along the height, due to the dynamic effect of wind on the tower when normal forces are acting on the perpendicular side but when wind act vertexshedding developed. In this context, many research works conducted on aerodynamic optimization but davenport 1971 conduct the pioneer work for high-rise or mid-rise structures.

Non-linear analysis is a process where the deformation of the structure is not linear under the combination of applied load, it is called non-linear analysis. The effect of Non-linear can be originated from geometrical nonlinearity (large deformation) and material nonlinearity. These can cause stiffness of a body under the load application.
Irregular Building**,** As per IS Code 1893:2016 Irregular building are those which stiffness or mass and strength, geometric regularity is not uniform throughout the building. Because of this irregularity buildings have become much lighter as a Applied Loads- Gravity Load: Gravity load includes deal load (Permanent) which is a self-weight of the structure consist of a load of walls, finishes, and floors, live load (Temporary) which is a load of occupants and contents.
Lateral Load: Lateral load might not be a worry for small, low-rise structures then it becomes important when the stories of building increased. Lateral loads such as wind, earth pressure, and water have the potential to b ecome an uplift force.

Common Findings of Issues

- Rectangular structures are further defenceless to the lateral response.
- For across wind excitation, vortex shedding is the most common source.
- If the frequency of vortex shedding reaches nearby to the structure's natural frequency it may lead to vibration in the structure.
- Transverse direction motion can be a severe issue not only for structure fatigue but also for serviceability design.
- Square and rectangular bluff shaped buildings are more unprotected to vigorous vortex shedding induced vibration and rapid oscillation through strong wind.

Objectives, aims, and Method:

- The Objective of this M-Tech Thesis is to analyze the different parameters, codes, and methods used when performing calculations of Tall structure regards to story displacement in the x-axis and-axis.
- The aim of this thesis provides insight into how different ways of modeling a building and its structural system behavior affects the result, especially investigated when comparing vertical and h orizontal loading with different finite element models.

II. METHODOLOGY

- **Dynamic Analysis of RC frame and Shear wall Structure:**

Square shape with recessed and chamfered corner model and Y-shape with similar corner modification structure was analyzed to check the behavior of seismic throughout the entire structure. Non-linear dynamic analysis (Non-linear time history analysis) carried out to obtain the result and compare its behavior of displacement of the same and different configuration. for all four-model story displacement in X-axis and Y-Axis were obtained.

- **Methodol ogy:**

The literature study complete in an earlier chapter specifies that many researchers work in this area and provide us a detailed knowledge with specific reference and different results from numerous studies. The present study contains a detailed and comparative study of optimization of aerodynamic effect and dynamic seismic loading behavior of various building shapes with regular High-rise building analytical model having a concrete floor with reinforced beam Framing system. So, a total of 4 models (one for regular building, one for recessed building, and one for chamfered building) involved in this study to perform analysis and examined behavior, and developed a relationship based on the comparison of the result.

To perform this study total of 4 models were developed. Each other is prepared and analyzed with the E-TABS software. All models are similar to Each other especially the same floor design and same story height except for the geometrical changes (chamfered, recessed corner). Model 1st is a 50-story Square-shape building model with a recessed corner. 2nd model is a 50-story Square-shape building model with a chamfered corner. 3rd model is a 50-story Y-shape building model without corner modification. 4th model is a 50-story Y-shape Chamfered corner model building model without any tapering.All these building models have a similar floor plan except for corner modification. Thesemodel's elevationandfloor plansareapproximately similar.

I. MODELING AND ANALYSIS

Figure 1: OriginalFloor Plan

Table1: MaterialProperties

Name	E (Mpa)	ν	α(1/C)	G (Mpa)	Unit Weight(kN/m³)	Unit Mass(kg/m³)	Fc(Mpa)
M40	25000	0.2	5.50E-06	14731.3	25	2549.29	40

Table 2. Frame Section Detail

Name	Material	Shape	Depth(mm)	Width(mm)
Con_BM900x850	M40	ConcreteRectangular	650	550
Con_Col1650x1450	M40	ConcreteRectangular	1050	950
Name	**Material**	**Shape**	**Thickness(mm)**	**Span(M)**
Shearwall	M40	ConcreteRectangular	304mm	3.65

Table 3. Shell Section Detail

Name	Material	SlabType	ElementType	SlabThickness(mm)
Slab200mm	M40	Uniform	Membrane	200

Table 4. Fixed Support Details

Story	Support LabelName	Support Unique Name	UX	UY	UZ	RX	RY	RZ
Base	As perplan	As perplan	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE

Dimensional models were prepared in E-tabs for Each building design considering theirgeometrical shape with corner modification. Every building model is subjected to real-timehistory loading in a horizontal direction with the principal axis of the building. The principalaxis of the building was assigned by keeping Z-axis upside along the height of the buildingwherethex-axisandy-axisinthehorizontallayoutwiththeperpendicular(90°)toeachother.therefore,wehave4 models foranalysis with differentnames for thebuilding

Model1 –Model T, Model2–ModelC, Model3–Model Y, Model4–Model YC

- ModelTistheconventionortraditionallydesign50-storywithoutanycorner modification.
- ModelCisthe50-storydesignedwithcornermodification(Chamfered Corner)withthesamegeometricalshapeas Model-T. ModelYis50-storeyY-shaped designed withoutanycornermodification
- ModelYCis50-storeydesignedwithCornermodification(Chamferedcorner)withsimilar togeometricalshapeof model-Y.

AssigningDiaphragm to Floors:

Diaphragm is assigning to every floor from ground story to top story (ground floor to 50th floor).Afterdefiningallpropertiesandsectionsinthebuildingmodel.Todefineadiaphragm,firstofall,selectallfloorsofeachstoryandthengototheassignedmenuandshellthenselectthediaphragmsemi-rigid.Afterassigningthediaphragmtoeveryelementonthefloorswillbeact as a single element. The assignment of diaphragm at the roof story of model-T, Model-C,Model-Y,and Model-YC areshown below.

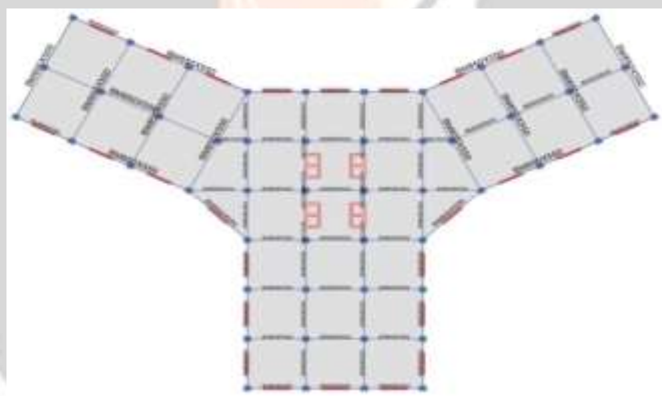

Figure 2. FloorPlanwithBeam andShell Section

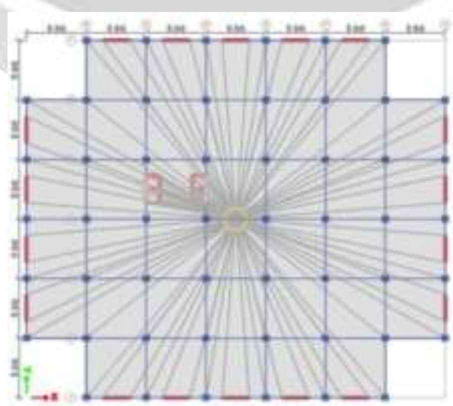

Figure 3. Diaphragm Assigned forModel–TfromETABS

Figure 4.3-D View of Diaphragm Assigned for Model – T from ETABS

Each floor of the model was assumed or act as a semi-rigid diaphragm. The floor wasconsideredamembranetypeofthicknessof200mmwhichwasconnectedtothebeamelementto transfer all loading on the beam. The primary reason for selecting the semi-rigid diaphragmis that rigid diaphragm is based on idealization because it is not possible to construct on theactual construction site. When the structure is subjected to lateral loading, the semi-rigiddiaphragm will generate a more accurate distribution of lateral forces to the lateral loadresistingsystem.Allthefloorsystemsbehavehomogeneouslyasasinglenodeanditwillgivebetter story displacement results. So, all floors of each model are assigned as a semi-rigiddiaphragm,and it is shown in tabularform.

Table 5. Diaphragm detailforEachmodel

Model	Story	FloorLabel	Section	Diaphragm
Model-T	Eachstory	asperplan	Slab200mm	Semi-rigid
Model-C	Eachstory	Asperplan	Slab200mm	Semi-rigid
Model-Y	Eachstory	Asperplan	Slab200mm	Semi-rigid
Model-YC	Eachstory	Asperplan	Slab200mm	Semi-rigid

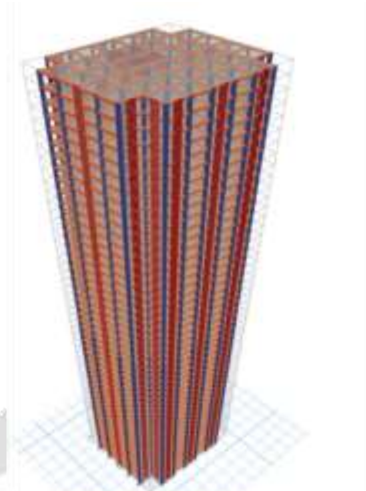

Figure 5. ETABS Model – T – Isometric View

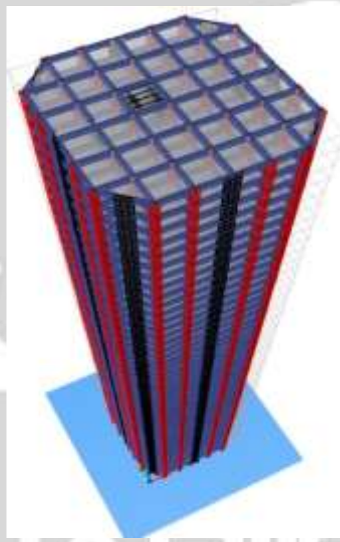

Figure 6. ETABS Model – C – Isometric View

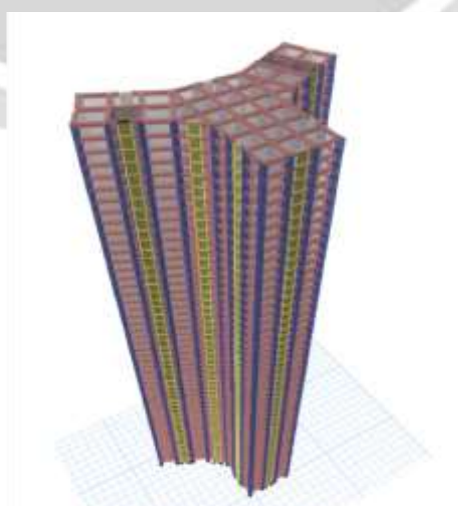

Figure 7. ETABS Model – Y – Isometric View

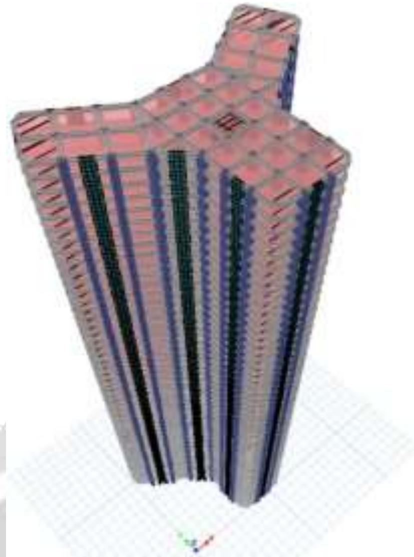

Figure 8. ETABS Model – YC – Isometric View

Table 6. Load Pattern

Name	Type	Self-weightmultiplier	Auto-load
Dead	Dead	1	-
Live	Live	0	-
Masonry	Superimposed Dead Load	1	-
EQX	Seismic	0	IS18932002
EQY	Seismic	0	IS18932002
WLX	Wind	0	IS8751987
WLY	Wind	0	IS8751987

For this building concrete material is taken homogenous and isotropic, for concretes physical properties, E-TABS program can take the values for the calculation of self-weight of the frame member of the structure model. Self-weight is considered a dead load in the program. By default, concrete density is taken as 24.99 KN/ M^3 Also dead load od floor finish is taken 2 KN/M^2 is applied on the floor for every case of the four buildings being considered. A live load of 2 KN/M^2 is applied on every floor excepting on the rooftop story, on the roof a live load of 1.5 KN/M^2 is taken. A uniformly distributed load of 18.5 KN/M on the beam element is considered for all floors. This loading is defined under a super-imposed load type.

Table 7. Time Period for Each model

ModelTypes	**Direction**	**Eccentricity**	**PeriodMethod**	**User-Defined Time Period (inSec)**
Model-T	X+Ecc in X	5	UserSpecified	4.48
	X+Ecc in Y	5	UserSpecified	4.48
Model–C	X+Ecc in X	5	UserSpecified	4.29
	X+Ecc in Y	5	UserSpecified	4.29
Model–Y	X+Ecc in X	5	UserSpecified	4.13
	X+Ecc in Y	5	UserSpecified	4.13
Model-YC	X+Ecc in X	5	UserSpecified	4..05
	X+Ecc in Y	5	UserSpecified	4.05

Seismic Loading: To define seismic load pattern, the structure is expected to be situated in Zone II, the respective zone factor is 0.16, soil condition is assumed to be medium type, important factor is taken as 1, the response reduction factor is taken as 5 as per the Codal provision of IS 1893:2002. In this present study, we have considered only two translational components of earthquake data for bi-directional dynamic analysis.

Table 8. Ground Motion Characteristics

Records(Stations)	Component	Magnitude	Epicentral Distance(inkm)	PGA(incm/sec/sec)	PGV(incm/sec/sec)	PGA/PGV	Frequency ContentClassification
Ahmedabad	180	7.7	8.8	341.69	33.45	10.2149	HIGH
Ahmedabad	270	7.7	8.8	210.14	36.92	5.6971	HIGH

Theearthquakegroundmotionrecords(PGA/PGV)areclassifiedintothreecategories:[35]

- High-Frequency content PGA/PGV>1.2
- Intermediate-Frequencycontent 0.8 <PGA/PGV<1.2
- Low-Frequencycontent PGA/PGV<0.8

After defining load patterns above, we have applied the load case to create the response of the structure like story displacement, story drift, etc., because load pattern it is not able to create response of structure. Whenever we analyze the model, we can select the load case which we have to run or not. Many load cases can be applicable but for this study, we have considered linear static for load defining in load patterns above, but for the dynamic analysis with real recorded ground motion data we have considered non-linear direct indirect time history analysis.

Load cases used for the study are as follows:

Table 9. Linear Static Load Cases

Name	StiffnessFrom	MassSource	Loadtype	Load Name	Scale factor
Dead	Pre-setP-delta	Mass-Source	LoadPattern	Dead	1
Live	Pre-setP-delta	Mass-Source	LoadPattern	Live	1
Masonry	Pre-setP-delta	Mass-Source	LoadPattern	Masonry	1
EQX	Pre-setP-delta	Mass-Source	LoadPattern	EQX	1
EQY	Pre-setP-delta	Mass-Source	LoadPattern	EQY	1

Table10. Non-linearDirectIntegrationTimeHistoryLoadCasesforModel- T

Name	MassSource	LoadType	LoadName	Function	ScaleFactor	Coordinate System	Angle	GeometricNonlinearity	NumberOutputSteps	Step Size
							Deg.			sec
TimeHistory	Mass-Source	Acceleration	UX	Match - X	0.98	Global	0	P-delta	100	0.1
TimeHistory	Mass-Source	Acceleration	UY	Match - Y	0.98	Global	0	P-delta	100	0.1

After assigning member and loading applied on the different models, types were explained. All the four models (Model-T, Model-C, Model-Y, Model-YC), were evaluated with the defined various load patterns and cases as per IS 1893:2002. In this chapter results of analysis performed on various models will be discussed. Each model was processed separately and the results like displacement in X-axis and Y-axis were discussed. The results obtained from the analysis were due to only the time history load combination. The time history with load combination is maximum and minimum in each horizontal direction the maximum time history load combination is a appositive value and it is the maximum of all values of analysis case. The minimum time history load combination is a negative and it is a maximum of negative values of analysis case. So, the response due to each load combination is checked below.

Table 11. Story Displacement under Minimum Time History Load Combination in X-axis forAllmodels

Displacementin X-axis				
TimehistoryMaximum				
Story	**Model-T**	**Model-C**	**Model-Y**	**Model-YC**
	mm	mm	mm	mm
Story50	262.948	262.948	205.131	301.676
Story49	259.853	259.853	203.038	298.832
Story48	256.631	256.631	200.842	295.885
Story47	253.24	253.24	198.513	292.751
Story46	249.659	249.659	196.032	289.391
Story45	245.876	245.876	193.392	285.789
Story44	241.884	241.884	190.588	281.936
Story43	237.683	237.683	187.622	277.832
Story42	233.274	233.274	184.497	273.479
Story41	228.661	228.661	181.215	268.881
Story40	223.848	223.848	177.782	264.045
Story39	218.842	218.842	174.202	258.978
Story38	213.649	213.649	170.481	253.686
Story37	208.278	208.278	166.623	248.179
Story36	202.738	202.738	162.636	242.464
Story35	197.036	197.036	158.525	236.552
Story34	191.185	191.185	154.296	230.451
Story33	185.193	185.193	149.956	224.17
Story32	179.075	179.075	145.513	217.721
Story31	172.842	172.842	140.971	211.112
Story30	166.515	166.515	136.339	204.354
Story29	160.116	160.116	131.624	197.457
Story28	153.675	153.675	126.833	190.431
Story27	147.196	147.196	121.972	183.288
Story26	140.644	140.644	117.05	176.037
Story25	134.094	134.094	112.073	168.689
Story24	127.678	127.678	107.05	161.255
Story23	121.239	121.239	101.988	153.746

Story22	114.765	114.765	96.894	146.174
Story21	108.298	108.298	91.776	138.548
Story20	101.834	101.834	86.642	130.882
Story19	95.382	95.382	81.501	123.186
Story18	88.953	88.953	76.361	115.473
Story17	82.558	82.558	71.23	107.755
Story16	76.209	76.209	66.116	100.044
Story15	69.918	69.918	61.03	92.355
Story14	63.698	63.698	55.981	84.699
Story13	57.565	57.565	50.978	77.094
Story12	51.532	51.532	46.032	69.553
Story11	45.617	45.617	41.154	62.094
Story10	39.838	39.838	36.355	54.737
Story9	34.216	34.216	31.65	47.505
Story8	28.775	28.775	27.052	40.424
Story7	23.546	23.546	22.579	33.531
Story6	18.569	18.569	18.254	26.87
Story5	13.91	13.91	14.107	20.512
Story4	9.643	9.643	10.188	14.559
Story3	5.834	5.834	6.588	9.179
Story2	2.699	2.699	3.455	4.637
Story1	0.552	0.552	1.063	1.354
Base	0	0	0	0

Table 12. Story Displacement under Minimum Time History Load Combination in Y-axis forAllmodel

DisplacementinY-axis				
TimehistoryMaximum				
Story	Model-T	Model-C	Model-Y	Model-YC
	mm	mm	mm	mm
Story50	173.871	173.871	216.482	260.825
Story49	171.065	171.065	214.171	258.143
Story48	168.038	168.038	211.765	255.341
Story47	164.909	164.909	209.223	252.359
Story46	161.7	161.7	206.524	249.177
Story45	158.417	158.417	203.659	245.791
Story44	155.058	155.058	200.628	242.202
Story43	151.616	151.616	197.43	238.413
Story42	148.09	148.09	194.068	234.424
Story41	144.479	144.479	190.547	230.242
Story40	140.783	140.783	186.87	225.868
Story39	137.003	137.003	183.041	221.308
Story38	133.141	133.141	179.067	216.567
Story37	129.201	129.201	174.952	211.652
Story36	125.187	125.187	170.703	206.569
Story35	121.103	121.103	166.325	201.325
Story34	116.955	116.955	161.826	195.928
Story33	112.748	112.748	157.213	190.386
Story32	108.489	108.489	152.491	184.705
Story31	104.185	104.185	147.67	178.896
Story30	99.843	99.843	142.754	172.967
Story29	95.471	95.471	137.753	166.926

Story28	91.079	91.079	132.674	160.783
Story27	86.673	86.673	127.525	154.547
Story26	82.266	82.266	122.312	148.227
Story25	77.88	77.88	117.045	141.834
Story24	73.6	73.6	111.731	135.378
Story23	69.321	69.321	106.379	128.868
Story22	65.064	65.064	100.996	122.314
Story21	60.836	60.836	95.592	115.729
Story20	56.648	56.648	90.174	109.123
Story19	52.508	52.508	84.752	102.506
Story18	48.425	48.425	79.335	95.891
Story17	44.409	44.409	73.933	89.29
Story16	40.47	40.47	68.554	82.715
Story15	36.619	36.619	63.21	76.18
Story14	32.867	32.867	57.911	69.698
Story13	29.227	29.227	52.668	63.283
Story12	25.712	25.712	47.493	56.951
Story11	22.338	22.338	42.398	50.719
Story10	19.118	19.118	37.398	44.605
Story9	16.072	16.072	32.507	38.628
Story8	13.216	13.216	27.741	32.811
Story7	10.572	10.572	23.118	27.178
Story6	8.152	8.152	18.658	21.762
Story5	5.984	5.984	14.392	16.606
Story4	4.077	4.077	10.365	11.782
Story3	2.445	2.445	6.664	7.418
Story2	1.128	1.128	3.455	3.731
Story1	0.249	0.249	1.043	1.079
Base	0	0	0	0
Story	Model-T	Model-C	Model-Y	Model-YC

III. RESULTS AND DISCUSSION

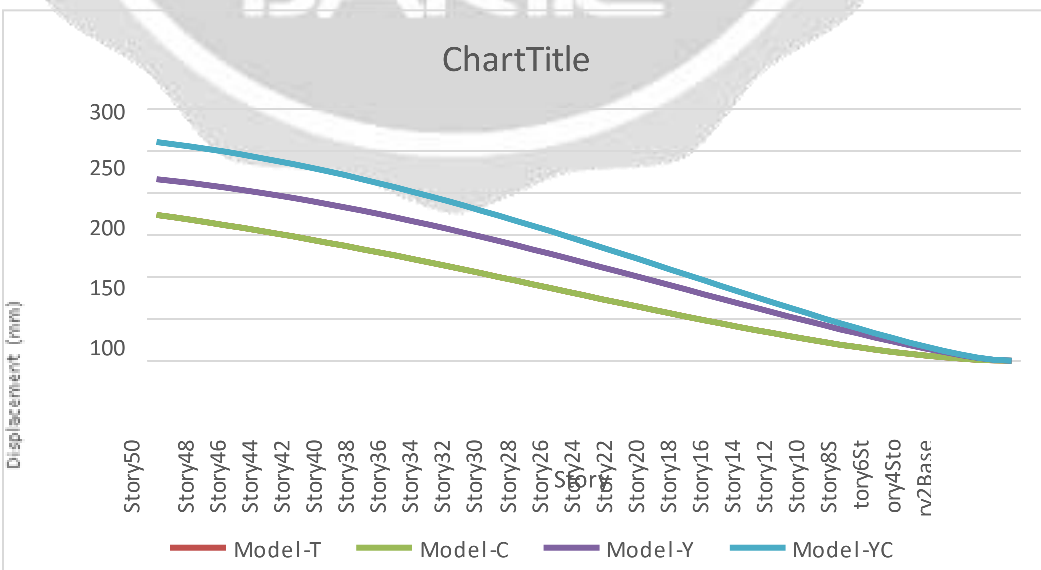

Figure 9.comparison ofmaximumdisplacementinX-axisbetweenfourtestmodes

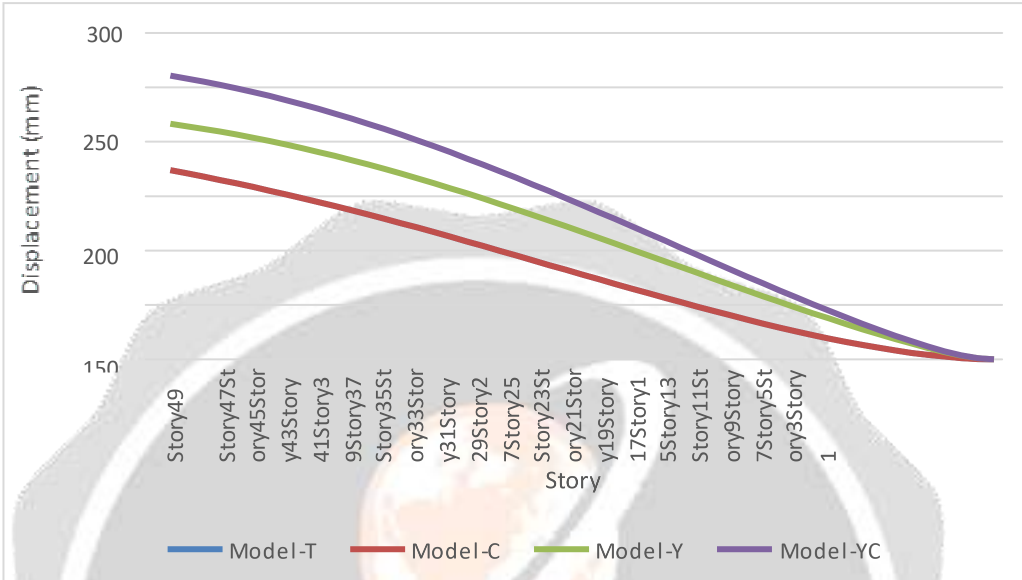

Figure 10.comparisonofmaximumdisplacementin Y-axisbetweenfourtestmodels

IV. CONCLUSION

An in-depth study of various research paper, analysis of the four test models comes to theconcrete conclusion can be made for the comparison and outcome of the research work. Thisstudy was performed on four test model of two square and two Y–shaped models (Model –T,Model–C,Model–Y,andModel–YC)inETABSundertheNon-lineartimehistoryanalysis.For,understanding the behavior ofstory displacement throughout thebuildingheight.

Here the measure conclusions have been conducted after an in-depth comparative analysisofthefour test models:

- Forall4models’maximumdisplacementwasintheX-axisdue tothelowfrequencyof groundmotion of an earthquake.
- For the maximum displacement was occurs on X-axis due to the orientation ofcolumnsforModel– T and Model – C.
- ForModel-YandModelYCthemaximumdisplacementisshowninY-axisduetoitsY-shapegeometrical shape.
- Inthesquaremodelinter-storydriftfoundbetween21to27storiesduetohorizontalforces and y-shape model inter-story drift found 17 to 25 stories due to the axialforces.
- Depending upon the 3-D modeling approach, the variation in displacement willoccurduetothefundamentaltimeperiodofbuildingwhichisextremelydependentonthe geometry of thestructure.
- For all tests, model drift found out in lower stories due to its higher floor height.However, it can be said that the height of the stories governs the parameters of theinter-storydrift.
- In all four models’ models -T and Model -C have similar behavior but model -YandModel – YCshows variation duetoits geometry and cornermodification.
- After looking at all the results, maximum displacement was in model – YC, due toitsY-shapewithachamferedcornerbutModel–Ywashavingtheleastdisplacementvalue on X-axis.

- Lookingatalltheresults,themaximumaffectedmodelwasModel–YCinbothx-axisand y-axis which has Y-shape and chamferedcornermodification.

V. REFERENCES

1. Akhtarpour , A., & Mortezaee , M. (2019, June). Dynamic response of a tall building next to deep excavation considering soil–structure interaction. Asian J Civ Eng(20). doi:https://doi.org/10.1007/s42107-018-0078-4

2. Bobby, S., & Spence, S. .. (2014). Performance-based topology optimization for wind-excited tall building-A framework. Engineering Structures, 74, 242-255. doi:10.1016/j.engstruct.2014.05.043

3. Kim, Y. C., & Kanda, J. (n.d.). Wind pressures on tapered and set-back tall buildings. Journal of Fluids and Structures, 39, 306-321. doi:10.1016/j.jfluidstructs.2013.02.008

4. Li, Y., & Tian , X. (2018, November). Aerodynamic treatments for reduction of wind loads on high-rise buildings. Journal of Wind Engineering & Industrial Aerodynamics, 172, 107-115. doi:10.1016/j.jweia.2017.11.006

5. Lu, Z., & He, X. (2018, March). Performance-based seismic analysis on a super high-rise building with improved viscously damped outrigger system. Struct Control Health Monit. doi:https://doi.org/10.1002/stc.2190

6. Mehmood, T., & Warnitchai, P. (2016, January). Seismic Evaluation of Tall Buildings Using a Simplified but Accurate Analysis Procedure. Journal of Earthquake Engineering, 1-26. doi:10.1080/13632469.2016.1224742

7. Rahnavarda, R., & Fard, F. F. (2018, March). Nonlinear analysis on progressive collapse of tall steel composite. Case Studies in Construction Materials, 8, 359-379. doi:10.1016/j.cscm.2018.03.001

8. Zheng, C., & Liu , Z. (2018, December). Experimental investigation of vortex- induced vibration of a thousand-meter scale mega tall building. Journal of Fluids and Structures, 85, 94-109. doi:10.1016/j.jfluidstructs.2018.12.005