PARAMATRIC STUDY ON PERFORNMANCE OF CYLINDRICAL WATER TANK WITH DIFFERENT STAGING CONFIGURATIONS

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Abstract - *Seismic forces are very harmful to damage or completely destroy RCC water tank. We all are aware about hysterics loading compression and tension which show loop on the graph and these can be effectively resist by horizontal buckling resist braces. For analysis of hysistraces seismic effect and resist capacity of BRBs in staging water tank the behavior of Elavated water tank compare with ordinary water tank. The time history method can be applied to the model. The mode displacement is acquired by modeling the structure in the structure analysis software. The main aim was to compare the modify structure with the ordinary structure. Parameter has help in comparisons of this model. There was significant decrease of time period of EWT with BRBs and Base shear also get decrease this was a good sign for the thesis. To study various literatures available related to Elevated water tank. Guidelines from IS 1893 part-1, IS 1893 Part-2, IS 3370, IS 456, IS 11682, IS 875 will be followed during the procedure. To Study performance of Elevated water tank with different lateral load resisting system. Structural engineering software ETAB will be used to find out the stiffness of the model. Computer program will be prepared for seismic analysis using the MS-Excel. Formulae and values for various parameters will be taken from IS1893 (part 2):2014. Each model will be analyzed for tank full condition, partially filled and tank empty condition. To compare the analysis results in terms of base moment and base shear.18 Lac liter E.S.R cylindrical type of water tank is considered to be situated in BHUJ-Seismic Zone V, water tank is considered to be resting on Medium type soil, water tank is considered as SMRF. Concrete M-25, Steel Fe-415.Total 25 models will be made and each model would be analyzed for full tank, partially filled tank and empty tank condition.*

Key Words: Bhuj , BRB, Base shear, Base moment, Time period, Seismic Zone V, Software ETABS, Time history analysis, Seismic response parameters.

1. INTRODUCTION

Water tank are used to store water for daily requirement of the human being. Water is life line for every kind of creature in this world. These are in turn has led to the increase in the construction of steel towers of various configurations and heights. To the secure constant water supply from longer distance with sufficient static head to desire location under the effect of gravitational force, the elevated water tanks are necessary. The cost and expenditure of steel water tank is more as compare to other material water tanks and so they are infrequently used for water tanks. Now days seismic efficient structure is priority of designing. Elevated water tank is vulnerable earthquake because of behave like an inverted pendulum. Such type of RCC staging water tank has less ductility to resist the inertia force generate to wt. of water tank. The make staging efficient to absorb the seismic load proper system should be used in staging. BRBs might be one of the good element to fix the staging to decrease the base shear, displacement, time history, etc.. Many existing water tank do not meet the seismic strength require for resisting the lateral load. Seismic forces are very harmful to damage and completely collapse the RCC water tank. We are know that the hysteresis loading compression or tension show the graph and these can be efficiently resist by BRBs. The analysis of hysteresis seismic effect or resistance capacity of BRB in staging water tank. The behavior of Elevated water tank with BRB should be compare with ordinary staging water tank. The time history method is good method can be applied to the models. The mode displacement is acquired by modeling the structure analysis software. The main aim to compare the modified structure with ordinary structures. Time history, base shear, etc... Parameters are help in comparison of these models. There are significant decreases of time period of elevated water tank with BRB and base shear also get decrease these are a good sign for the thesis. Steel is tending to buckling effect in brace due to not good performance on compressive load. These are the buckling is not good for these type structure. Various techniques used for seismic strengthening of water tank. BRB are one of the best techniques which can be used in the staging for efficiently control the seismic effect on horizontal member. Somewhere BRB also increase lateral stiffness of elevated water tank. BRB have very good performance in cyclic loading or hysteresis loop the displacement is in control.

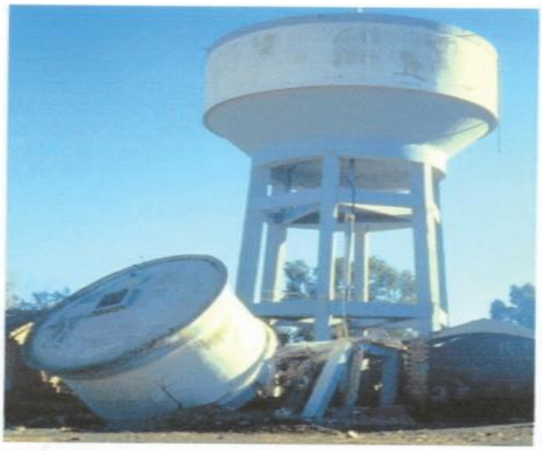


Fig -1: Image of the damaged water tank staging

2. LITERATURE REVIEW

S.C. Duttaa, S.K. Jainb, C.V.R. Murtyb [2000] [1]:

In this Former three of the above mention pattern have greater value of the above mentioned patterns have greater value of co relation of torsion and lateral natural period although the fourth pattern has a lower then when compare with that of primary pattern. The magnitude and direction of eccentricity for elevated water tank is generally unknown pattern base result may be preferred to the standard increased strength design.

T. Takeuchi, J.F.Hajjar, R. Matsui, K. Nishimoto, I.D. Aiken [2012] [2]:

Local buckling failure are observed in specimens possessing rectangular tube with a width to thickness ratio 65 and 76.The initiation of local buckling failure started later as the mortar thickness is increase and the effect of the mortar thickness was observed. The criteria for the local buckling failure of BRBs can be modifying by the mortar thickness and restraint tube shape. The revise criteria improve the ability to predict local buckling failure in BRBs. With circular restraint tube local buckling failure did not occur until the core plate plastic strain amplitude was 3% even for the large diameter to thickness ratios of the tube.

Mr Santosh Rathod, Prof. M. B. Ishwarago [2018] [3]:

The bending moment value has slightly increased due to increase in supporting staging height and wind load on the water tank. The base shear value has in significantly increased due to increase in supporting staging height. It is reviewed that as the height of cylindrical wall reduces and base width increase the value of base shear drastically increase. The value of displacement has highly increased due to reduce height of cylindrical wall and increase in base width.

Hamdy Abou-Elfath, Mostafa Ramadan, Fozeya Omar Alkanai [2016] [4]:

The base shear capacity were increase by 149% which were the same original buckling which shows that BRB is an efficient method to solve the problem of base shear. In the current study an increase in the base shear capacity up to 150%from the base shear capacity of the original RC building has been achieved by the barbs. Storey drift was significantly decrease by the use of BRB. The PGA capacity of brace of S1 S2 S3 was 42 82 147% which was considerable increase than original frame. Bracing of the perimeter frame imposes significant axial force demand on the columns and foundation of the brace bay which requires cross sectional enlargement of columns and strengthening of the foundation.

Soheil Soroushnia, Sh. Tavousi Tafreshi, F. Omidinasab, N. Beheshtian, Sajad Soroushnia [2011] [5]:

It specified that the failure modes of reinforcement concrete elevated tanks with frame staging are shear and bending modes in beams axial modes in columns cracks in joint and torsion mode. It was determine which failures modes of shear force in beams and also find the failure mode of axial force are dominate in the reservoir. The results showed that there is a good implementation of numerical studies with the field studies.

Manish N. Gandhi, Ancy Rajan [2016] [6]:

Parametric study is carried out by using different patterns of bracing in staging of an elevated water tank. Base shear for different bracing pattern is clear that the base shear value reduces for alternate bracing pattern in staging. This is apparent because of the reduction of overall stiffness of the structure.

From the observation made above it can be conclude that cross bracing in staging most effective in reducing displacement due to lateral loading reduce displacement effectively by 81.09% in X direction and 92.98% in Z direction from that of structure without bracing.

From the compare between displacement for different bracing system and displacement for the different alternate bracing. It is conclude that the cross bracing pattern gives the minimum value of displacement.

3. RESEARCH GAP

According to the literature reviewed till now, following research gaps can be noted:

- From the literature review it can be clearly seen that horizontal BRB configuration can give greater structural benefits than vertical bracing configuration.
- From the literature review it can be clearly seen that no work is carried out for horizontal BRB configuration.
- Considering this research gap, present study aims to Study on behavior of Cylindrical Water Tank with Different Lateral Load Resisting Structural Systems.
- The aim is also to study various structural parameters like base shear and base moment.

4. OBJECTIVE

The objective of this work is as follows:

1. To Study the various effect on performance of water tank having Different pattern with BRB under different height using different bracing configuration system.
2. To study the various effects on performance of Elevated water tank with different horizontal BRB configuration of bracing system.
3. To analysis of the performance of bracing in staging in zone5.
4. To observe the base shear of staging with different configuration.
5. To observe the Bhuj earthquake data and apply the time history analysis in ETAB software and note the displacement.
6. To compare the analysis results in terms of time period, base shear and base moment.
7. To Analyze the Stiffness, Story displacement, Base shear, Base moment, Time period and Time history function.
8. Proposing the various configurations which have batter performance.

5. METHODOLOGY

There are three pattern suggest 1) Octagon in Octagon tube 2) Hexagon in Octagon tube 3) Square in Octagon tube.
The staging height is different but earthquake zone are remaining same. The staging height is 1)4.3m 2)5.0m 3)5.5m Calculation of C.G of 3(three) Condition is calculated in excel sheet. Modeling and stiffness will be calculating using ETAB structure software. Core area of BRB will be calculate by story nodal shear force at different level in decreasing order of shear by formula in MS Excel sheet. The comparison between various configurations will be done by calculating base shear, base moment, Time period, Time history function.

6. MODEL DATA

The data for project model is taken as follows:

- Design of Cylindrical tank = 18, 00,000 litres.
- Thickness of top dome = 120mm.
- Thickness of Bottom dome = 200mm.
- Size of Top Ring beam = 230mmX300mm.
- Size of Bottom Ring Beam = 450mmX300mm.
- Density of Concrete = 25KN/m³.
- Diameter of Bottom Dome= 13.865m.
- Diameter of tank (D) =20m. (from calculation)
- Height of cylindrical wall= 6m.

LOAD CALCULATION OF CYLINDRICAL WATER TANK OF CAPACITY 1800000 litres

						Capacity	180000(
1	Dia of Top Dome	(D)	20 m		radii. Of top dom		10
2	Dia of Bottom Dome	(d)	13.86 m		radii. Of bottom dom		6.93
3	Height of Cylindrical wall		6 m				
4	Thickness of Top Dome		0.12 m				
5	Thickness of Bottom Dome		0.2 m				
6	Thickness of Cylindrical Wall		0.2 m				
7	Size of Top Ring Beam		0.23	0.3 m		0.3	
8	Size of Bottom Ring Beam		0.45	0.3 m		0.3	
9	Dome Height		1.5 m				
	Density of Concrete		25 KN/m³				
	Size of Octagone		20 m				
	Radius of Top Dome	(R)	[(r²/dome height)+dome height]/2			34.08333333 m	
	Radius of Bottom Dorr	(r)	[(r²/dome height)+dome height]/2			16.7583 m	

Table-1 Dimension of water tank

B	C	D	E	F	G	H	I	J
SN	Description				Parameter	Value	Unit	Refer
1	Total Mass of Water			Weight	m	17,65,800	kg	2.1
				Volume		1,766	m³	
2	Inner Diameter of Tank at Top				D	20.000	m	definition, P-6
3	Equivalent Height of tank = V / (π D²/4) =				h	5.621	m	Cl.4.2.3, P-10
4	Ratio D / h				D/h	3.558		
					0.866 D/h	3.081		
	Ratio h / D				h/D	0.281	< 0.75	
					3.68 h/D	1.034		
5	IMPULSIVE MASS :				m_i			
a	m_i/m = { 0.23 tanh(3.68 h/D) / (h/D) } =				m_i / m	0.323		Table C-1
	Hence value of impulsive mass m_i =				m_i	5,70,632	kg	
b	Ratio- Height of impulsive mass to Total Ht. h_i/h =0.375 for h/D ≤ 0.75 =0.5 - 0.09375*D/h for h/D > 0.75				h_i / h	0.375		
	(h_i is not used in computing period of vibration,T)				h_i	2.108	m	
c	(h_i* is used for checking overturning moment) hi*/h = (0.866D/h) / {2tanh(0.866D/h)} - 0.125 = 0.45 for h/D > 1.33 (min.value=0.45)				h_i * / h	1.422		
	Hence value of h_i* =				h_i *	7.994	m	
6	CONVECTIVE MASS :							
a	m_c/m = 0.23 * tanh(3.68h/D) / (h/D) -				m_c / m	0.635		Table C-1
	Hence Value of Convective Mass m_c =				m_c	11,20,833	kg	
	Check Sum of Convective Mass & Impulsive Mass =					16,91,465	= 95.79 % of total mass	
b	Ratio of ht. of Convective Mass to Total ht., hc/h= 1-[{cosh(3.68h/D) -1} / {3.68h/D sinh(3.68h/D)}]				h_c / h	0.540		Table C-1
	Value of h_c =				h_c	3.04	m	
c	(h_c* is used for checking overturning moment) hc*/h = 1-[{cosh(3.68h/D)-2.01} / {3.68h/D sinh(3.68h/d)}]				h_i * / h	1.335		Table C-1
	Hence value of hc* =				h_c *	7.504	m	

Selfweight calculation of Members			
1	Top Dome	$2\pi R$*Thickness of Top Dome*Dome height*25	963.195
2	Top Ring Beam	∏D*size of top ring beam*25	107.409195
3	Cylindrical Wall	[πDt]*h*25	1884
4	Bottom Dome	$2\pi r * Thickness\ of\ Bottom\ Dome * dome\ height * 25$	789.31593
5	Bottom Ring Beam	∏D*size of Bottom ring beam*25	212.479875
6	Conical Dome	∏*(D+d)/2*Lc*dome thickness*25	576.78817
		TOTAL SW	4533.18817

Table-2 Self Weight of members

Weight of Water				
Capacity of Tank	1800000	litres	1800	m^3
Density of Water	9.81	KN/m3		
Weight of Water	1800*9.81		**17658**	**KN**
Area of octagone				
Area of octagone	(A)	1931.37	m^2	

Staging Calculations							
		size		height		Vol (m3)	Weight(KN)
1	Column Size	0.6	0.6	27.2	m	9.792	**244.8**
2	Brace (m)	0.3	0.6				

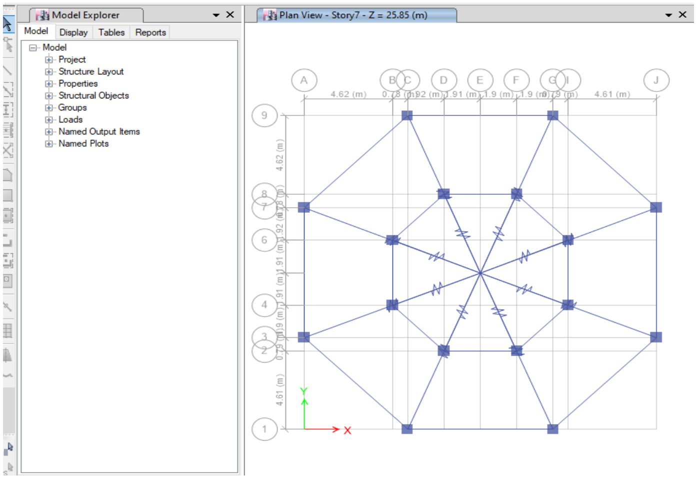
Table-3 Staging calculation

CG of empty container				
		Weight(KN)	height	
1	Top Dome	963.195	9.425	9078.112875
2	Top Ring Beam	107.409	7.95	853.9031003
3	Cylindrical Wall	1884	4.8	9043.2
4	Bottom Dome	789.316	0.95	749.8501335
5	Bottom Ring Beam	212.48	1.65	350.5917938
6	Conical Dome	576.788	1	576.78817
		4533.19		20652.44607
		CG OF EMPTY CONTAINER		4.555832517

Table-4 CG of empty container

CG of full container				
		Weight(KN)	height	
1	Top Dome	963.195	9.425	9078.112875
2	Top Ring Beam	107.409	7.95	853.9031003
3	Cylindrical Wall	1884	4.8	9043.2
4	Bottom Dome	789.316	0.95	749.8501335
5	Bottom Ring Beam	212.48	1.65	350.5917938
6	Conical Dome	576.788	1	576.78817
7	Water	17658	4.65	82109.7
		22191.2		102762.1461
		CG OF FULL CONTAINER		4.630763584

Table-5 CG of Full container



Story Data

Story	Height m	Elevation m
Story7	4.55	25.85
Story6	4.3	21.3
Story5	4.3	17
Story4	4.3	12.7
Story3	4.3	8.4
Story2	4.3	4.1
Story1	2.8	-0.2
Base		-3

Table-6 Dimension of Plan & staging height

I	For octagonal Tube in Tube							
	.							
			No	Weight	Total			
1	Column load		16	244.8	3916.8	KN		
2	Brace							
		size	no	length		TOTAL(KN)		
	i	300X600	40	7.65		1377		
	ii	300X600	40	3.82		687.6		
						2064.6	KN	
			Total			5981.4	KN	
2.4	SEISMIC LOADS :							
2.4.1	SEISMIC MASS at C.G. of Container :							
					Tank Empty		Tank FULL	
1	Self Wt.				453		453	tonnes
2	Water						1,766	tonnes
3	STAGING		Total Load	598				
			Seismic Load = W/3	199	199		199	
					653		2,418	tonnes

Table-7 Octagonal tube & Seismic load calculation

2 STIFFNESS of STAGING :

For evaluating Seismic Forces, it is necessary to evaluate Period of Vibration of the system,

2.4.3 COMPUTATION OF STIFFNESS with the help of FEM Software :

The figure given at Para 2.4.1 above illustrates the model to be generated for purpose of analysis
After generating the geometrical model for shaft or staging in any Software based on Finite

For evaluating stiffness of a structure of given geometry, an arbitrary unit load (Say 100 t) is applied at the

TANK Condition →	FULL	EMPTY	
Horizontal Force applied, W =	100.000	50.845	tonne
Average displacement at Top of Staging δ_1 =	45.300	33.270	mm
rotation θ_1 =	0.001	0.001	radian
distance of C.G. from Top of Trestle, h =	4.580	4.320	m
Average displacement at C.G.of load= $\delta_1 + h\,\theta_1 = \delta_2$ =	49.880	37.590	mm
Stiffness of the structure = W / δ_2 = 'k' =	2,005	1,353	kg/mm
Stiffness of the structure, 'k' =	20,048	13,526	kg/cm
The difference between two values is small, adopt higher value of 'k' =	20,048		kg/cm

4.3m

As the height of different storeys vary, the stiffness of whole trestle is worked out as under.

Storey	Foundn to Brace-1	Brace-1 to Bra	Brace-2 to Bra	Brace-3 to Bra	Brace-4 to Cor	BR5	BR6	br6 to con
Storey Height	7.3	3.7	3.7	3.7	3.7	3.7	3.7	10.15
	730	370	370	370	370	370	370	1015
Column Stiffness, Kc:	8328.68486	6396.4622	63964.622	63964.622	63964.622	63964.622	63964.622	3,098
Storey Stiffness Ks =	199888.4368	153515.093	1535150.93	1535150.93	1535150.93	1535150.93	1535150.93	74,363
Storey Flexibility, Fs	5.00279E-06	6.514E-06	6.514E-07	6.514E-07	6.514E-07	6.514E-07	6.514E-07	1.345E-05
Total Flexibility = S F	2.32185E-05			Overall Stiffness K = 1/SFs=		kg/cm		43,069

Adopting value of K =	43,069	kg/cm	20,048
Period of Vibration, T = 2 p √ (W/Kg) = √ (W) / {√(Kg) / 2p}			
Substituting Value of K =49,009 kg/cm and g = 981 cm/sec², {√ (Kg) / 2π } =			1034.51601
eriod of Vibration, T : √ W / 1034		seconds	

Table -8 Stiffness Calculation with FEM Software

SEISMIC FORCES :					
1	Zone Factor, Z =	0.36	for Zone	V	
2	Importance Factor I =	1.50			Table:6, Part-1
3	Response Reduction Factor, R =	2.50	SMRF		Table:2, Part-2
4	Seismic Coef. α_h = ZI/2R x Sa/g =	0.108	x S_a / g		Cl.6.4.2, Part-1

		Tank Empty	Tank FULL	
1	Equivalent Load at C.G.	624	2,390	tonnes
2	Period of Vibration, T = √ W / 1,104	0.76	1.40	sec.
3	Value of Sa/g from Fig.2 of IS:1893-2002			
	for medium soils, applying formula,	1.78	0.97	ratio
4	Seismic Coef. α_h =	0.192	0.105	
5	Seismic Force = α_h x W =	120.021	250.568	tonnes
6	Level of Force	16.410	16.600	m
7	Lever Arm from C/L of Raft-Beam	18.410	18.600	m
8	Moment on Foundation	2,210	4,661	t-m

Table -9 Seismic force

A	IMPULSIVE MASS :				
	Self Weight of Container, m_1 =	4,53,000	kg		2.1
	1/3 Weight of Staging, m_s =	1,71,000	kg		2.1
	Impulsive mass of water, m_i =	0	kg		2.5.1.5a
	Total Impulsive Mass M_i =	6,24,000	kg		
	Stiffness of Trestle, K =	20,048	kg/cm		2.4.3
	$T_i = 2\pi\sqrt{M_i/K_i}$ =	1.12	seconds		
	Spectral Acc. Coef. from Curve, S_a/g =	1.22			Fig.2, Part-1
	Zone Factor, Z =	0.36	for Zone	V	
	Importance Factor I =	1.50			Table:6, Part-1
	Response Reduction Factor, R =	4.00	SMRF		Table:2,Part-2
	Seismic Coef. α_h = ZI/2R x S_a/g =	0.0675	x S_a / g =	0.0820	Cl.6.4.2,Part-1
	Base-Shear due to Impulsive Load, V_i =	51,183	kg		
B	CONVECTIVE MASS :				
	Convective mass of water, m_c =	11,20,833			
	Time period for conv.mode, T_c =	5.31	seconds		4.1.6.f
	Spectral Acc. Coef. from Curve, S_a/g =	0.26			
	Seismic Coef. α_h = ZI/2R x S_a/g =	0.553	x S_a / g =	0.1417	
	Base-Shear due to Impulsive Load, V_c =	1,58,794	kg		
C	TOTAL BASE-SHEAR :				
	Total Base Shear = $\sqrt{V_i^2 + V_c^2}$ = V =	1,66,839	kg		Cl.4.6.3,P-19

Table 10- Impulsive and convective mass calculation

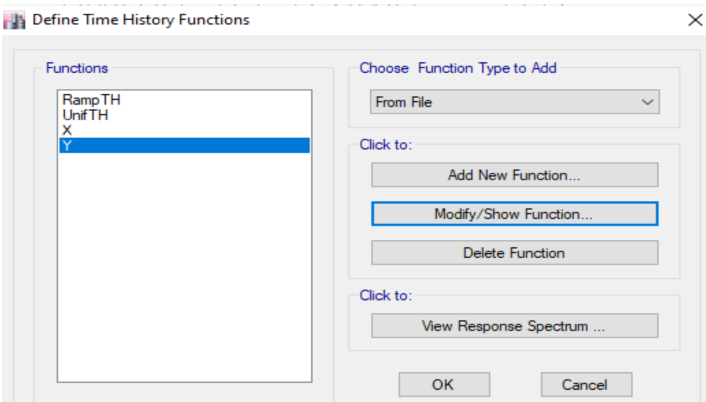


Fig-Time history Function

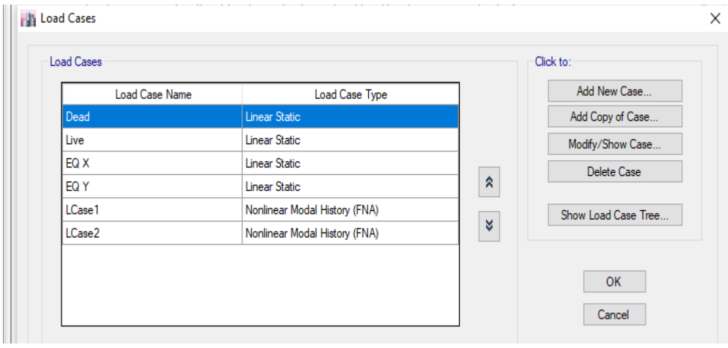


Fig- Time history function Adding on load cases

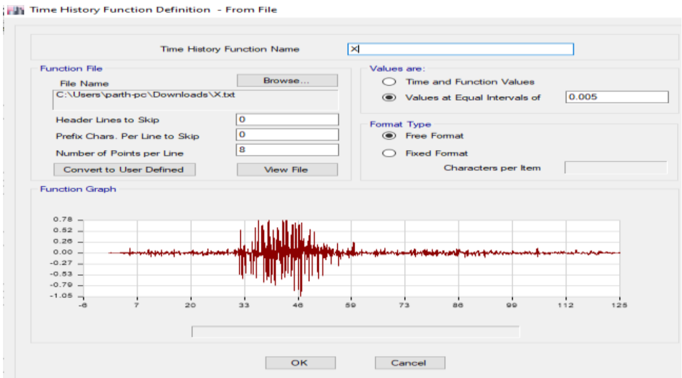


Fig- Time histroy function Graph

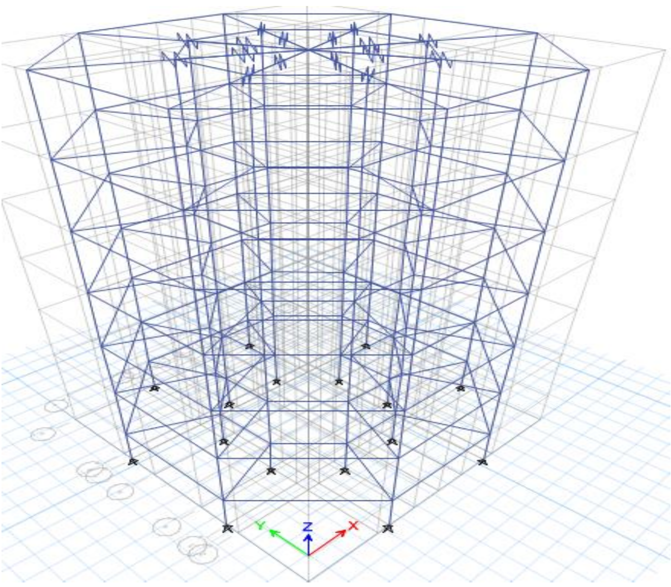


Fig-Perspective view of octagon column and bracing

7.RESULTS

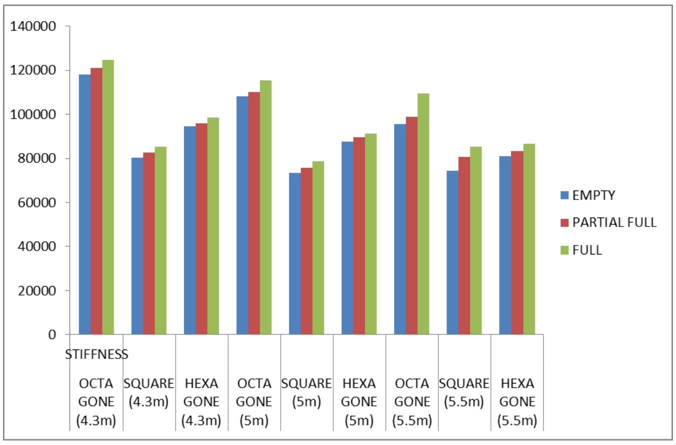


Fig- Stiffness of staging

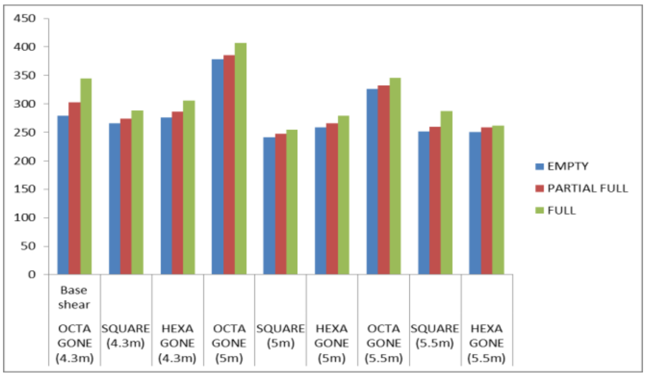


Fig- Chart of Base shear

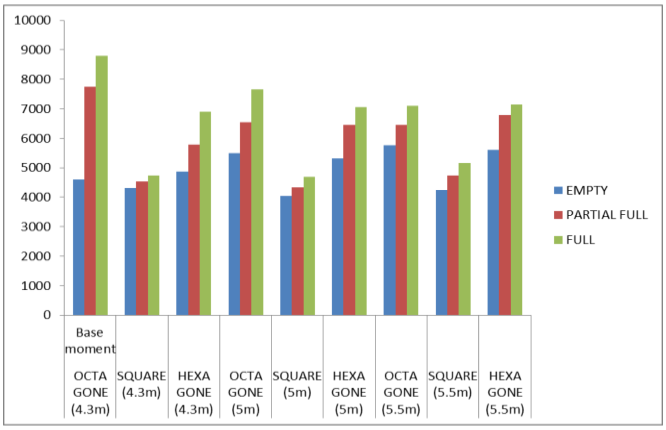


Fig- Chart of Base moment

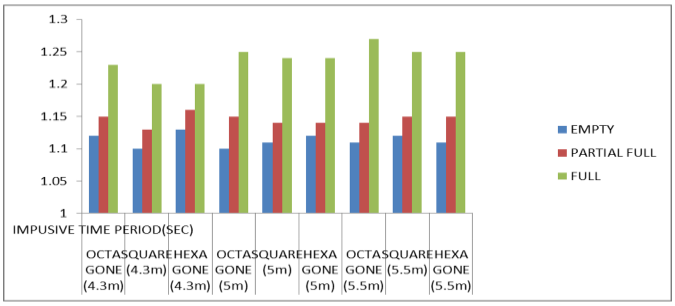


Fig- Impulsive time period (sec)

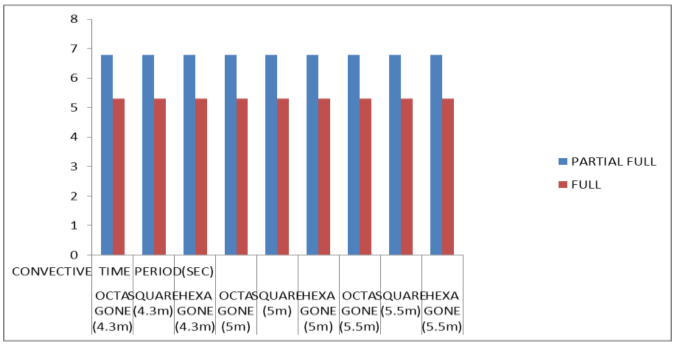


Fig- Convective time period (sec)

8. CONCLUSION

1. As the horizontal BRB height is increase, the stiffness decrease respectively.
2. Maximum Impulsive Time period is of octagonal BRB Configuration.
3. The Base moment is more of tank full condition compare to partial fill and empty condition.
4. Time Base shear is maximum of tank full condition compare to partial fill and empty condition.
5. From the above result it can be noted that octagonal configuration is more stable in terms of the other two as it has less base moment, base shear.
6. Moreover the given structural system is more efficient than horizontal BRB pattern as all the forces are evenly distributed in the system and the base shear and moment is comparatively less.

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