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Sustainability Analysis of Circular Building Over Rectangular Building

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Abstract: *Sustainable development is the practice of using guidelines for environmentally responsible and energy savings to create new world. Sustainable development of a smart city not only depends on planning of transportation system, water supply, waste water management energy efficient but also on better infrastructure. Normally around the world, we observe conventional rectangular shape of building is being followed, these buildings are well planned good in strength but comparatively circular buildings are more durable and better in strength against lateral loads, less embodied energy, energy efficient, better acoustics. The aim of this study is to analyze the benefits of circular shape buildings over rectangular buildings. The main parameters considered in this study to compare circular and rectangle building against lateral loads, energy efficiency and acoustic design.*

Keywords: *Circular building, Energy efficient, E-tabs, Lateral loads, Sustainable development.*

I. Introduction

India is a developing country, and we have to built it smartly. In the series of development, we have seen major problem of our cities is traffic planning, sewage disposal, transportation, proper building planning but have to focus also on building construction. In the ancient time our ancestors used circular shape structures for living for example igloos, Teepees, African mud brick huts, yurts etc. they choose circular shape because they inspired by nature, but in normally around the world, we observe conventional rectangular shape of building is being followed, these buildings are well planned good in strength. This paper shows that if use modern material with ancient shape our buildings are more durable and comfortable. For analysis of two models generated in E-tabs software. For model special moment resistant frame used. In first model rectangular shape of building was analyzed and for second modal circular shape used for analysis. Both shape of buildings was analyzed in same lateral load (earthquake and wind) conditions and results of story deformation, later load distribution, shear force is discussed. This paper also discussed about energy efficiency and acoustics of circular shape if we used that shape in building construction.

II. Analysis of Models in Seismic load

Lateral load analysis was done is E-tabs software. For analysis two models which is in shape of circular and both shape of structure. Geometry and material property detail of rectangular and Circular shape building shows in TABLE1. Special moment resistant frame was used for model. Geometry and material [1] property detail of rectangular and Circular shape building shows in TABLE 1 and TABLE 2.

Area of building	600 m^2
Hight	32.6 m
Size of Beam (M 25)	250 x 500 mm
Size for Column (M 30)	400 x 700 mm
Thickness of Slab (M 20)	150 mm

Table 1

Figure 1

Area of building	615.75 m^2
Hight	32.6 m
Size of Beam (M 25)	250 x 500 mm
Size for Column (M 30)	400 x 700 mm
Thickness of Slab (M 20)	150 mm

Table 2

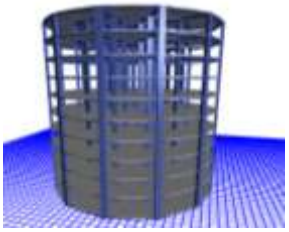


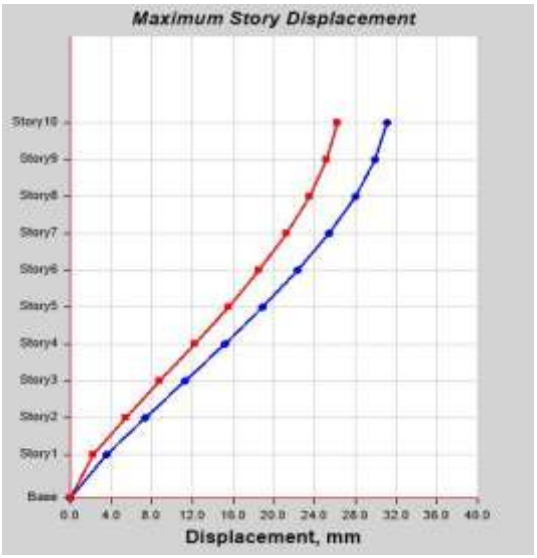
Figure 2

Earthquake condition [2] for both models are zone factor z=0.36 soil type soft importance factor is 1, response reduction factor = 5. Analysis was performed in E-tabs2016 software [3].

Story displacement results for rectangular building

Story	Elevation	X-Dir	Y-Dir
	m	Mm	mm
Story10	32.6	31.045	26.267
Story9	29.4	29.914	25.184
Story8	26.2	27.978	23.49
Story7	23	25.386	21.233
Story6	19.8	22.3	18.529
Story5	16.6	18.851	15.491
Story4	13.4	15.156	12.223
Story3	10.2	11.307	8.827
Story2	7	7.389	5.427
Story1	3.8	3.512	2.276
Base	0	0	0

Table 3

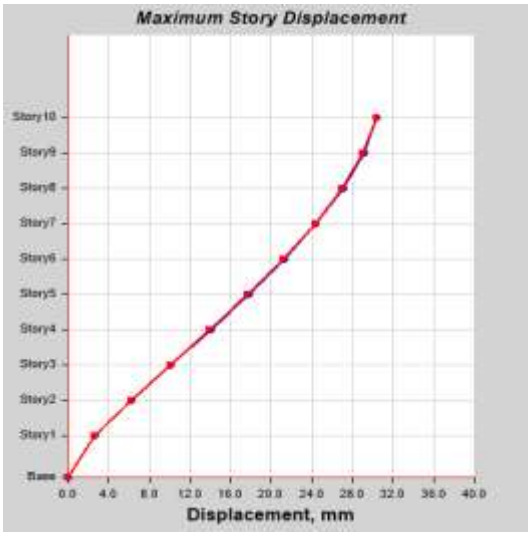


Graph 1

Story displacement results for Circular building

Story	Elevation	X-Dir	Y-Dir
	m	Mm	mm
Story10	32.6	30.01	30.334
Story9	29.4	29.09	29.031
Story8	26.2	27.23	27.017
Story7	23	24.408	24.361
Story6	19.8	21.257	21.215
Story5	16.6	17.751	17.713
Story4	13.4	14.006	13.972
Story3	10.2	10.134	10.103
Story2	7	6.267	6.24
Story1	3.8	2.647	2.627
Base	0	0	0

Table 4



Graph 2

Results of story displacement [4] shows that in X- direction rectangular building had more displacement but in Y- direction circular building had more displacement this is due to dimension of rectangular building.

Lateral load distribution for rectangular and Circular building in X and Y direction

Story	Elevation(m)	X-Dir (KN)	Y-Dir (KN)	X-Dir (KN)	Y-Dir (KN)
		Rectangular Building		Circular Building	
Story10	32.6	333.7005	399.9578	318.0702	318.2188
Story9	29.4	301.0209	360.7895	293.5527	293.6899
Story8	26.2	239.0587	286.5245	233.1276	233.2366
Story7	23	184.2289	220.8081	179.6582	179.7422
Story6	19.8	136.5313	163.6401	133.144	133.2062
Story5	16.6	95.9662	115.0205	93.5853	93.629
Story4	13.4	62.5333	74.9495	60.9819	61.0104
Story3	10.2	36.2328	43.427	35.3339	35.3504
Story2	7	17.0647	20.4529	16.6413	16.6491
Story1	3.8	5.1216	6.1385	5.0133	5.0156
Base	0	0	0	0	0

Table 5

Lateral load distribution [5] on each story shows that in max. load at top story in case of circular building is 318.2188KN but in case of rectangular building its 399.9578KN. It clearly shows that lateral load is more in rectangular building.

Story Shear Distribution

Story	Elevation(m)	Location	X-Dir (KN)	Y-Dir (KN)	X-Dir (KN)	Y-Dir (KN)
			Rectangular Building		Circular Building	
Story10	32.6	Top	-333.7005	-399.9578	-318.0732	-318.2104
		Bottom	-333.7005	-399.9578	-318.0731	-318.2092
Story9	29.4	Top	-634.7214	-760.7473	-611.7974	-611.9933
		Bottom	-634.7214	-760.7473	-611.7973	-611.9909
Story8	26.2	Top	-873.7802	-1047.2718	-844.932	-845.2301
		Bottom	-873.7802	-1047.2718	-844.9314	-845.2259
Story7	23	Top	-1058.009	-1268.0799	-1024.5921	-1024.9706
		Bottom	-1058.009	-1268.0799	-1024.5912	-1024.9656
Story6	19.8	Top	-1194.5404	-1431.7199	-1157.74	-1158.1674
		Bottom	-1194.5404	-1431.7199	-1157.7389	-1158.1606
Story5	16.6	Top	-1290.5066	-1546.7405	-1251.3303	-1251.7953
		Bottom	-1290.5066	-1546.7405	-1251.3289	-1251.7875
Story4	13.4	Top	-1353.0399	-1621.69	-1312.3178	-1312.8114
		Bottom	-1353.0399	-1621.69	-1312.3162	-1312.803
Story3	10.2	Top	-1389.2727	-1665.117	-1347.6534	-1348.1614
		Bottom	-1389.2727	-1665.117	-1347.6517	-1348.1526
Story2	7	Top	-1406.3374	-1685.5699	-1364.2953	-1364.8104
		Bottom	-1406.3374	-1685.5699	-1364.2935	-1364.8014
Story1	3.8	Top	-1411.459	-1691.7084	-1369.3087	-1369.8254
		Bottom	-1411.459	-1691.7084	-1369.307	-1369.8164
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

Table 6

Shear force on in X-direction in rectangular building is maximum 1411.459KN and also maximum in Y-direction. Shear force is also maximum in rectangular building.

III. Analysis of Models in Wind load

Wind load depends on movement along outer surface of building in circular building its smooth but in rectangular building wind create vortex around the corners.

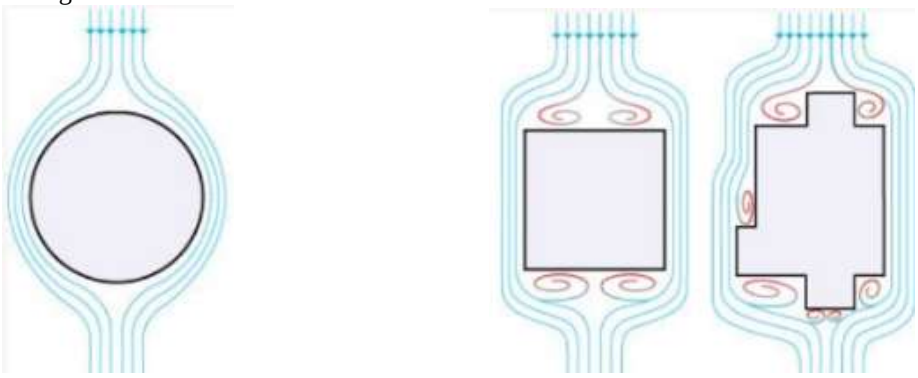


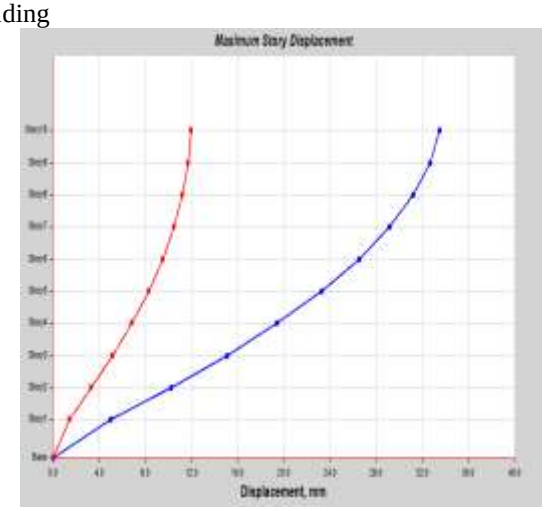
Figure 3

Analysis of circular and rectangular building in case of wind load was done in E-tabs software. For both cases site conditions are same. Wind load conditions [6] for analysis are basic wind speed is 50 m/s, Terrine category-2, Importance factor = 1, Risk coefficient K1 factor = 1, Topographic factor K3 =1, Story height 36.2 m, External pressure coefficient Cpe =1.2. permeability of building is zero.

Story Displacement in X and Y Direction for Rectangular building

Story	Elevation(m)	X-Dir (mm)	Y-Dir (mm)
Story10	32.6	33.499	11.968
Story9	29.4	32.656	11.693
Story8	26.2	31.22	11.21
Story7	23	29.162	10.48
Story6	19.8	26.495	9.499
Story5	16.6	23.238	8.273
Story4	13.4	19.414	6.812
Story3	10.2	15.054	5.138
Story2	7	10.21	3.301
Story1	3.8	5.012	1.445
Base	0	0	0

Table 7

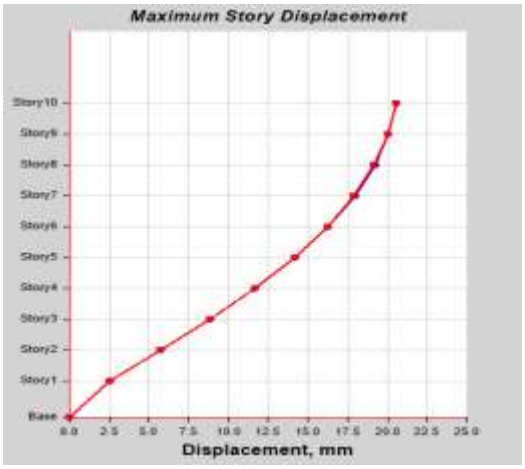


Graph 3

Story Displacement in X and Y Direction for Circular building

Story	Elevation(m)	X-Dir (mm)	Y-Dir (mm)
Story10	32.6	20.529	20.512
Story9	29.4	20.032	20.015
Story8	26.2	19.186	19.169
Story7	23	17.927	17.91
Story6	19.8	16.247	16.23
Story5	16.6	14.158	14.14
Story4	13.4	11.678	11.659
Story3	10.2	8.841	8.822
Story2	7	5.725	5.705
Story1	3.8	2.551	2.534
Base	0	0	0

Table 8



Graph 4

Results of story displacement [7] shows that in X- direction rectangular building had more displacement but in Y- direction circular building had more displacement this is due to dimension of rectangular building same as in case of seismic loading.

Lateral load distribution for rectangular and Circular building in X and Y direction

Story	Elevation(m)	X-Dir (KN)	Y-Dir (KN)	X-Dir (KN)	Y-Dir (KN)
		Rectangular Building		Circular Building	
Story10	32.6	212.253	154.5598	87.2957	87.2957
Story9	29.4	215.3315	107.6649	172.2639	172.2639
Story8	26.2	209.4775	104.7379	167.5807	167.5807
Story7	23	203.4336	101.716	162.7457	162.7457
Story6	19.8	197.713	98.8558	158.1693	158.1693
Story5	16.6	192.7027	96.3506	154.161	154.161
Story4	13.4	184.6346	92.3166	147.7065	147.7065
Story3	10.2	175.0316	87.5151	140.0242	140.0242
Story2	7	172.802	86.4003	138.2405	138.2405
Story1	3.8	189.0016	94.5001	151.2001	151.2001
Base	0	0	0	0	0

Table 9

Lateral load distribution [8] on each story shows that in max. load at top story in case of circular building is 87.2957KN but in case of rectangular building its 212.253KN. It clearly shows that lateral load is more in rectangular building in case of wind load

Story Shear Distribution

Story	Elevation(m)	Location	X-Dir (KN)	Y-Dir (KN)	X-Dir (KN)	Y-Dir (KN)
			Rectangular Building		Circular Building	
Story10	32.6	Top	-212.253	-54.5598	-87.4292	-87.4132
		Bottom	-212.253	-54.5598	-87.4292	-87.4132
Story9	29.4	Top	-427.5845	-162.2247	-259.8289	-259.7811
		Bottom	-427.5845	-162.2247	-259.8289	-259.7811
Story8	26.2	Top	-637.0619	-266.9627	-427.5332	-427.4743
		Bottom	-637.0619	-266.9627	-427.5332	-427.4743
Story7	23	Top	-840.4956	-368.6787	-590.3973	-590.3099
		Bottom	-840.4956	-368.6787	-590.3973	-590.3099
Story6	19.8	Top	-1038.2086	-467.5345	-748.6543	-748.5545
		Bottom	-1038.2086	-467.5345	-748.6543	-748.5545
Story5	16.6	Top	-1230.9114	-563.8851	-902.9092	-902.7649
		Bottom	-1230.9114	-563.8851	-902.9092	-902.7649
Story4	13.4	Top	-1415.5459	-656.2017	-1050.6881	-1050.5238
		Bottom	-1415.5459	-656.2017	-1050.6881	-1050.5238
Story3	10.2	Top	-1590.5775	-743.7169	-1190.7649	-1190.599
		Bottom	-1590.5775	-743.7169	-1190.7649	-1190.599
Story2	7	Top	-1763.3795	-830.1172	-1329.0401	-1328.8604
		Bottom	-1763.3795	-830.1172	-1329.0401	-1328.8604
Story1	3.8	Top	-1952.381	-924.6173	-1480.2523	-1480.0699
		Bottom	-1952.381	-924.6173	-1480.2523	-1480.0699
Base	0	Top	0	0	0	0
		Bottom	0	0	0	0

Table 10

Shear force in rectangular building is maximum 1952.381KN.

IV. Energy Efficiency

If we consider all figures of geometry which is used in building construction, circle is only one which has shortest boundary in term of area. If we compare round house and rectangular house, we see length of wall in round house is very less [9]. So, if length of wall is less material required for construction also less (15 to 20 %), less men work power required.

Figure 4

Figure 4 clearly shows that 34 % more exterior wall required in rectangular building and in circular building we 55 % more floor area than the rectangular building.

Round houses are more energy efficient because it has less dead space. Dead space means corners, in rectangular shape corner are mandatory. In corners of dead space cold air collected due to air circulation of air, it never happened in round shape of rooms. A Round House can capture breezes from all directions, and also ensures an even and constant cross ventilation throughout the room. In round house optimal exposure of walls in day-light can produce maximum solar energy throughout the day, as at all times the sun's rays are perpendicular to the Round House exterior wall.

V. Acoustics

Main consideration in the design of buildings is acoustics, operation and construction of most buildings, and it is very important because its directly effect on health, communication and productivity. The acoustics of a circular space are very good. If use curve ceiling it soften and brighten the sound. The shape also prevents against the noise pollution it provides insulation against the exterior sound. Sound waves dispersed by the shape. Circulation of sound waves is very smooth in round shape.

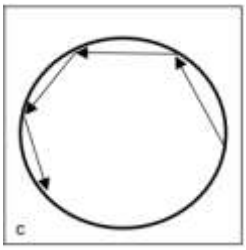


Figure 5

In round shape sound waves reflected by smooth and soft edges but in rectangular shape wave reflected by hard edge. So round house is good in acoustics.

VI. Conclusion

From this study and its outcome, clearly shows that for smart city we have to built a smart structure also. Rectangular buildings are good in strength, durability but circular buildings are more efficient in aspect of lateral load, energy efficiency and acoustics. In lateral load either its earthquake or wind in both cases circular building is stronger. In case of displacement somewhere story displacement is more in circular building but it is in considerable limit but over all in both load case (wind and earthquake) circular building has less displacement. In case of seismic load displacement is 12% less in circular building and in case of wind its 40% less. In case of lateral load distribution in seismic load 3% less in circular and in case of wind its 25% less in circular shape building. Shear force is also less in circular building. In condition of earthquake its 21% more in rectangular building and in case of wind load its 60% more in rectangular building. So, I can say against the lateral load circular shape is stronger than rectangular shape for building. Circular shape is also good for energy efficiency, by using this shape we can use more area but less exterior wall area. Because of shape less material required in construction so less energy required. That shape is also good for insulation point of view it means less energy consumption. India is in developing phase so we have built it smartly by using all unconventional power sources so we can save energy. In that circular shape of building will be very help full.

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