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Analysis and Design of Advanced Bus Stand

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Abstract

A controversial issue in the seismic analysis and design of buildings with multiple underground stories lies in incorporating the effects of these underground stories on the seismic response of these structures. Building codes lack recommendations concerning this controversy; thus, the designers are basing their analysis on approximations, engineering judgment and experience. Some model and analyze the building cropped at the ground floor level, others include a certain number of basement floors, while few include all the underground floors.

Keywords: Seismic zone, Importance factor, Advance bus design, Reduction factor, Response Spectrum method

I. INTRODUCTION

This has been an active area of research throughout the past decade (Dutta and Roy, 2002, Dutta et al., 2004, Shakib, 2004, Naim et al., 2008, El Ganainy and El Naggar, 2009, Raychowdury 2010, Tabatabaeifar and Massumi, 2010). El Ganainy and El Naggar investigated the seismic performance of moment-resisting frame steel buildings with multiple underground stories. Their study was tailored for the governing site conditions in Vancouver, Canada, and the Beam-on-a-Nonlinear Winkler Foundation approach was used to simulate the important aspects of the nonlinear behaviour of the foundation and side soil. Raychowdhury also used a similar approach to study the response of low-rise steel moment resisting frame buildings. Tabatabaiefar and Matssumi (2010) used a 3D finite element model to simulate the effects of soil structure interaction on reinforced concrete moment resisting frames.
Common managerial problems identified in the construction of deep basement:

1) Very expensive and time consuming in nature, often involved huge amount of work resources.
2) Inconsistent and sensitive to the quality of planning and management of individual projects.
3) Works are highly hazardous, both to human operatives working within and the life and properties of third parties that within the vicinity.
4) Works involved a lot of managerial challenges. Such as, in the preparation of a highly efficient working programme, monitoring and rectifying the progress of works in case problems arising, or in resources planning where materials, labours& plant equipment are involved.

There are many methods to construct large-scaled and deep basement

1) Deep basement can be constructed using some traditional ways such as cut & fill or bottom up methods. These methods are relatively economical and effective when dealing with certain jobs which are simpler in nature.
2) On the other hand where basement is going deeper and the surrounding environment getting more complex and sensitive, top-down or combined method may be a more appropriate option to construct.

A. *Design Issues:*

This section examines the key issues and the components to be integrated while designing a BRT stop.
1) *Passenger Amenities*
a) Shelter
The BRT shelter is to be provided at every stop/station. They are to extend along the full length of the platform serving as a weather protection to the passengers. The shelter should be of high quality, prefabricated and modular. The Shelter roofs should be such that rain water is directed away for the vehicle side. The material for constructions should be readily available in the market, easily maintained and durable.
b) Passenger Information
All the stops should be provided with a standard form for presenting passengers information such assignage's, route details and graphics. Specifically they comprise of bold identification signage, transit route maps, neighborhood maps placed at prominent locations. Signage and graphics should readily distinguish the BRTS stations from the regular stops. The stops should also facilitate advertising at specific locations that does not conflict with the other directional and information signage. IT Display could be optionally placed at station entries and on platforms indicating the system wide schedule and delay at each platform.
c) Street Furniture
All the stops and stations should be accommodated with seating for at least 15 waiting passengers. Other necessities include rails for leaning, trash receptacles.

d) Other Amenities and Facilities

Other conveniences for the passengers that form a requirement at the stops are ticket vending counters, bicycle racks, vending stalls for newspaper and public telephones. These are to be placed at locations having least interference with boarding and alighting passengers.

2) *Safety and Security*

Safety and security is essential for the safe operation and public acceptance of the transit system. Security is essential as the BRT stops would be open for extended hours and likely to be unattended. Visibility is also an important criterion to security. Passengers should be able to see the surrounding locations and be seen from the locations outside the station. Security equipment such as closed circuit television for monitoring may be used while upgrading the BRT shelters over a longer period of time. Adequate illumination, especially at nights is necessary.

3) *Barrier Free Design*

The BRT stations should be made accessible to by the physically challenged. The internal layout of the shelter should be barrier free to facilitate easy circulation. Access via ramps need to be provided for stops having high platforms.

4) *BRT Platform Characteristics*

The BRT system presents with itself a unique array of options and requirements for the platform design. Planning the platform for BRT station revolves around design guidelines, berth configurations, platform width and height and vehicle interface issues.

5) *Platform Dimensions*

The Length of the platform depends upon the length of the vehicle and the number of bays required which is in turn dependent upon design bus volumes and service times at any given time. Width of the platform varies from 2.5 M to 5 M. The passengers should be able to clear the station before the arrival of the subsequent bus. The Platforms could be provided either at a low height or at a higher level. The Platform/vehicle interface has a strong influence on the boarding and alighting speeds. Level Boarding is attained through precision docking system at stations having a high platform. High platform stations (as located in Curitiba, Bogotá and Quito) are more expensive and occupy more space due to provision of access ramps. Due to the influx and availability of low floor buses and low cost for construction, low height platforms giving a height of 0.35 M have been more accepted worldwide.

- Access – Access to the high platforms from the pedestrian path needs to be provided through ramps.
- Provision of Bays – Linear and parallel bays are generally preferred for online bus stops.

Fig. 1: Boarding and Alighting platform type for BRT Stations

6) *Climatic Protection*

Protection from weather is a major consideration in the BRT stations. Completely enclosed stops, although preferable due to high concentration of RSPM in the city, would require the provision of air conditioning and ventilator fans. This however escalates the cost involved in the maintenance of the station. Passive solar design and natural cooling techniques could be sought after solutions to overcome climatic extremes.

7) *Aesthetic Design*

Aesthetics and passenger friendliness in addition to a modern appearance together formulate the essential architectural considerations. The design should symbolize an image representing speed in hand with modernity. Over use of advertising displays resulting in a visual clutter needs to be curtailed at bus stops. Locations for concentrated advertising displays need to be specified within and on the external façade of the stop.

8) *Fare Collection*

Fare Collection also forms an important influence on the design of the passenger facilities within the BRT station. Off board fare collection policy reduces the dwell time at bus stations and enables rapid boarding and lighting. The station can be divided into paid areas and free areas. Entry into the paid area of the station can be controlled by introduction of turnstiles or other control devices. Bogotá is one such example of a controlled access station. Since Ahmadabad does not have the high level of passenger traffic that exists in cities like Curitiba, Jakarta and Bogotá, it is not necessary to provide costly infrastructure as ticket vending machines, although provisions could be made for incorporating it while upgrading the system.

II. CASE STUDIES

Central Bus Station (CBS), also called Thampanoor Bus Station, is a bus station in Thiruvananthapuram, Kerala, India. It is located opposite, the Trivandrum Central Railway station at Thampanoor.It has an area of 7.41 acres serving the buses traveling on all routes in Kerala and other inter-state destinations such as Nagercoil, Kanyakumari, Chennai, Bangalore etc.It is also the headquarters of the Kerala State Road Transport Corporation (KSRTC). The work for the new Central Bus Terminal at Thampanoor started by March 2010 and was opened to public on February 3, 2014 by the Chief Minister of Kerala, Shri. Omen Chandy.

III. LITERATURE REVIEW

A. *Srikanth and V. Ramesh (2013)*

His comparative study of seismic response for seismic coefficient and response spectrum methods. In this thesis, the earthquake response of symmetric multi-storied building by two methods are studied. The methods include seismic coefficient method as recommended by IS Code and modal analysis using response spectrum method of IS Code in which the stiffness matrix of the building corresponding to the dynamic degrees of freedom is generated by idealizing the building as shear building. The responses obtained by above methods in two extreme zones as mentioned in IS code i.e. zone II and V are then compared. Test results Base Shears, Lateral Forces and Storey Moments are compared.

B. *Sang-Hyeok Nam, Ha-Won Song, Keun-Joo Byun, Koichi Maekawa (2006)*

Since underground reinforced concrete (RC) structures interact with the surrounding soil medium, the behavior of the interfacial zone betweenthe RC structure and the surrounding medium of the underground RC structure should be considered for accurate seismic analysis. In this paper, an averaged constitutive model of concrete and reinforcing bars for the RC structure and the path-dependent Ohsaki’s model for the soil are applied, and an elasto-plastic interface model which considers the thickness of the interface is proposed for seismic analysis of underground RC structures. A finite element analysis program is developed and verified by predicting both static and dynamic behaviors of underground RC structures. Then, the effects of the interface on the behavior of underground RC structures are analyzed. The effect of stiffness of the RC structure due to different reinforcement ratios of underground RC box structures to the behavior of the structures is also analyzed. Finally, failure mechanisms of underground RC structure under seismic action are simulated through seismic analysis of an underground RC station structure. c 2006 Elsevier Ltd. All rights reserved.

C. *Seth L. Pearlman, P.E., Member, ASCE, Michael P. Walker, P.E.2, Member, ASCE, and Marco D. Boscardin, Ph.D. P.E., Member, Geo-Institute (2004)*

Deep underground basements that are integrated into urban development projects early in the overall project design offer many inherent improvements to the overall quality and value of the project and its surrounding community. Diaphragm walls combine into a single foundation unit the functions of temporary shoring, permanent basement walls, hydraulic cutoff, and vertical support elements/shear walls, and, because of this combination, have proven to be an economical alternative in many circumstances. This paper examines the evolution of deep underground basement construction, identifies considerations associated with diaphragm wall construction, and provides several case history examples to illustrate the resolution of key issues.

D. *S. S. Basarkar, Manish Kumar, B.G. Mohapatro, P.R. Mutgi (2011)*

Infrastructural requirements in urban area make mandatory construction of basements which serve as space for car parking and housing utilities of various kinds. Demand for underground space has increased exponentially and this has triggered several levels of basement. Invariably, majority of such projects are planned on fast track basis wherein, technology of any form that can reduce the construction period is always a preferred choice. In this context, Top-Down construction has been increasingly used in urban areas, particularly for high rise buildings with basements so that the sub-structure and super-structure works can be executed concurrently. Top-down construction is replacing the traditional bottom-up construction technique owing to several advantages this new technique offers. This paper presents details of Top-Down construction technology. Important component of this technique is the Diaphragm wall, which is a specialized slender retaining wall constructed from the ground. Construction intricacies and methodology of execution of such wall also form part of this paper. Two case summaries are reported on Top-down construction executed by principle authors’ firm. One such site comprised multi-level car parking facility in a crowded area of Delhi, while other formed a part of underground metro station at Kolkata. The paper concludes with words of indispensability of such technology for early commissioning of the structures.

IV. Methodology

A. General

An earthquake can be measured in terms of magnitude and intensity. For that seismologists use two fundamentally different but equally important types of scales. The original force or energy of an earthquake is measured on a magnitude scale. The Richter scale is a well-known example of a magnitude scale. The second type of scale measures the intensity of shaking occurring at any given point on the Earth's surface. These scales are referred to as intensity scales. The Mercalli intensity scale, which measures the effects of the seismic waves, is an example of a commonly used intensity scale.

The main objective of this study is to carry out the analysis of g+4 and underground parking bus stand building against earthquake as per Indian standard codes of practice IS 1893(Part 1):2002. The earthquake loads on the building are calculated assuming the building to be located at Nagpur. The member forces are calculated with load combinations for Limit State Method given in IS 456: 2000 and the members are optimized for the most critical member forces among them. The building is subjected to self-weight, dead load, live load as per IS 875(Part 1, Part 2):1987.

B. Methodology

1) Types of seismic analysis

a) Code based Procedure for Seismic Analysis (IS 1893:2002) Equivalent Lateral Force

Seismic analysis of most of the structures is still carried out on the basis of lateral force assumed to be equivalent to the actual loading. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode shape. The base shear is distributed along the height of structures in terms of lateral force according to code formula. This method is conservative for low to medium height buildings with regular conformation.

b) Response Spectrum Analysis

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of Multi-Degree-of-Freedom (MDOF) system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single -degree-of-freedom (SDOF) system, which is then combined to compute total response. Modal analysis leads to the response history of the structure to a specified ground motion; however, the method is usually used in conjunction with a response spectrum. The science of strong ground motion may use some values from the ground response spectrum (calculated from recordings of surface ground motion from seismographs) for correlation with seismic damage. If the input used in calculating a response spectrum is steady-state periodic, then the steady-state result is recorded. Damping must be present, or else the response will be infinite. For transient input (such as seismic ground motion),the peak response is reported. Some level of damping is generally assumed, but a value will be obtained even with no damping. Response spectra can also be used in assessing the response of linear systems with multiple modes of oscillation (multi-degree of freedom systems), although they are only accurate for low levels of damping. Atypical combination method is the square root of the sum of the squares (SRSS) if the modal frequencies are not close. The result is typically different from that which would be calculated directly from an input, since phase information is lost in the process of generating the response spectrum.

V. Modeling

This building has been modeled as 3D Space frame model with six degree of freedom at each node using ETAB 2016 software for stimulation of behavior under gravity and seismic loading. The isometric 3D view and plan of the building model is shown as figure. The support condition is considered as fully fixed.

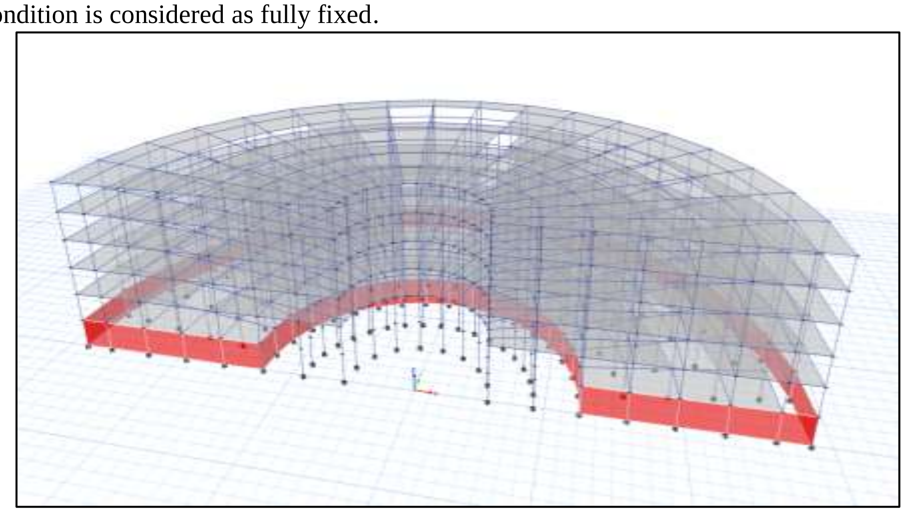

Fig. 2: 3D View of building

Table – 1
Load combination

Name	*Load Case/Combo*	*Scale Factor*	*Type*
1.5 (DL+LL)	*SWT*	*1.5*	*Linear Add*
1.5 (DL+LL)	*BW*	*1.5*	
1.5(DL+LL+LL2)	*SWT*	*1.5*	*Linear Add*
1.5(DL+LL+LL2)	*LL*	*1.5*	
1.5(DL+LL+LL2)	*BW*	*1.5*	
1.5(DL+LL+LL2)	*BLL*	*1.5*	
1.2(DL+LL+EQX)	*SWT*	*1.2*	*Linear Add*
1.2(DL+LL+EQX)	*LL*	*1.2*	
1.2(DL+LL+EQX)	*BW*	*1.2*	
1.2(DL+LL+EQX)	*BLL*	*1.2*	
1.2(DL+LL+EQX)	*EQX*	*1.2*	
1.2(DL+LL-EQX)	*SWT*	*1.2*	*Linear Add*
1.2(DL+LL-EQX)	*LL*	*1.2*	
1.2(DL+LL-EQX)	*BW*	*1.2*	
1.2(DL+LL-EQX)	*BLL*	*1.2*	
1.2(DL+LL-EQX)	*EQX*	*-1.2*	
1.2(DL+LL+EQY)	*SWT*	*1.2*	*Linear Add*
1.2(DL+LL+EQY)	*LL*	*1.2*	
1.2(DL+LL+EQY)	*BW*	*1.2*	
1.2(DL+LL+EQY)	*BLL*	*1.2*	
1.2(DL+LL+EQY)	*EQY*	*1.2*	
1.2(DL+LL-EQY)	*SWT*	*1.2*	*Linear Add*
1.2(DL+LL-EQY)	*LL*	*1.2*	
1.2(DL+LL-EQY)	*BW*	*1.2*	
1.2(DL+LL-EQY)	*BLL*	*1.2*	
1.2(DL+LL-EQY)	*EQY*	*-1.2*	
1.5 (DL+EQX)	*SWT*	*1.5*	*Linear Add*
1.5 (DL+EQX)	*BW*	*1.5*	
1.5 (DL+EQX)	*EQX*	*1.5*	
1.5 (DL- EQX)	*SWT*	*1.5*	*Linear Add*
1.5 (DL- EQX)	*BW*	*1.5*	
1.5 (DL- EQX)	*EQX*	*-1.5*	
1.5 (DL+EQY)	*SWT*	*1.5*	*Linear Add*
1.5 (DL+EQY)	*BW*	*1.5*	
1.5 (DL+EQY)	*EQY*	*1.5*	
1.5 (DL-EQY)	*SWT*	*1.5*	*Linear Add*
1.5 (DL-EQY)	*BW*	*1.5*	

Name	*Load Case/Combo*	*Scale Factor*	*Type*
1.5 (DL-EQY)	*EQY*	*-1.5*	
0.9DL+1.5EQX	*SWT*	*0.9*	*Linear Add*
0.9DL+1.5EQX	*BW*	*0.9*	
0.9DL+1.5EQX	*EQX*	*1.5*	
0.9DL-1.5EQX	*SWT*	*0.9*	*Linear Add*
0.9DL-1.5EQX	*BW*	*0.9*	
0.9DL-1.5EQX	*EQX*	*-1.5*	
0.9DL+1.5EQY	*SWT*	*0.9*	*Linear Add*
0.9DL+1.5EQY	*BW*	*0.9*	
0.9DL+1.5EQY	*EQY*	*1.5*	
0.9DL-1.5EQY	*SWT*	*0.9*	*Linear Add*
0.9DL-1.5EQY	*BW*	*0.9*	
0.9DL-1.5EQY	*EQY*	*-1.5*	
SER DL+LL	*SWT*	*1*	*Linear Add*
SER DL+LL	*BW*	*1*	
SER DL+LL	*RL*	*1*	
SER DL+LL	*LL*	*1*	
SER DL+LL	*EP*	*1*	
SER DL+EQX	*SWT*	*1*	*Linear Add*
SER DL+EQX	*BW*	*1*	
SER DL+EQX	*RL*	*1*	

SER DL+EQX	EQX	1	
SER DL+EQY	SWT	1	Linear Add
SER DL+EQY	BW	1	
SER DL+EQY	RL	1	
SER DL+EQY	EQY	1	
SER DL+0.8LL+0.8EQX	SWT	1	Linear Add
SER DL+0.8LL+0.8EQX	BW	1	
SER DL+0.8LL+0.8EQX	RL	0.8	
SER DL+0.8LL+0.8EQX	EQX	0.8	
SER DL+0.8LL+0.8EQY	SWT	1	Linear Add
SER DL+0.8LL+0.8EQY	BW	1	
SER DL+0.8LL+0.8EQY	RL	0.8	
SER DL+0.8LL+0.8EQY	EQY	0.8	

VI. RESULTS

A. *Story wise Displacement in X,Y,Z direction*

Table - 2
Displacement Ux (mm)

		circular	cross
	RL	mm	mm
ROOF	24	26.444	41.47
4th FLOOR	20	23.613	37.718
3rd FLOOR	16	17.369	27.578
2nd FLOOR	12	9.201	11.5957
1ST FLOOR	8	3.854	4.59939
GL	4	1.043	2.05995
BASEMENT	0	0	0

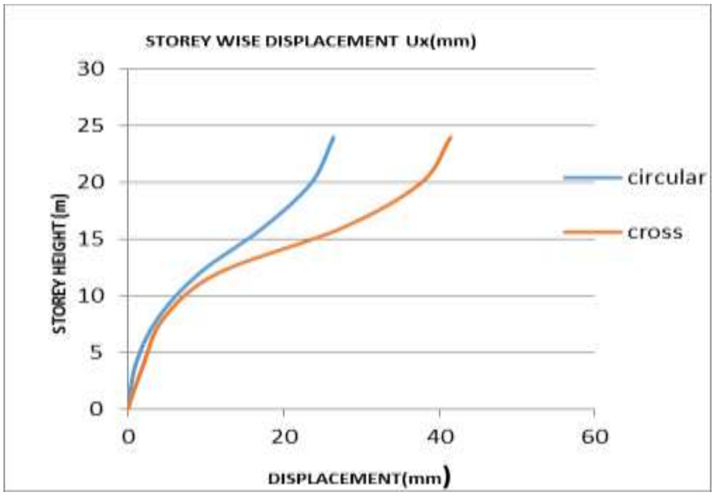

Chart 1: Displacement Ux (mm)

Table – 3
Displacement Uy (mm)

		circular	cross
	RL	mm	mm
ROOF	24	25.74	53.62
4th FLOOR	20	22.887	46.457
3rd FLOOR	16	16.693	33.518
2nd FLOOR	12	9.703	12.0187
1ST FLOOR	8	4.167	5.65539
GL	4	0.782	2.14406
BASEMENT	0	0	0

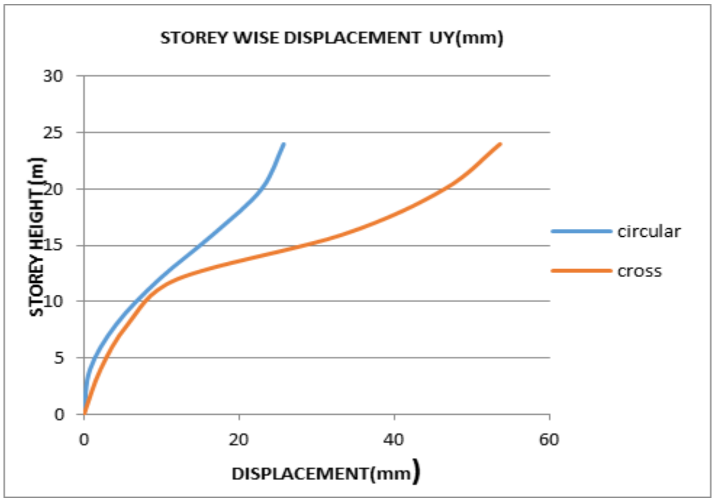

Chart.2: Displacement Uy (mm)

Table - 4
Displacement Uz (mm)

		circular	cross
	RL	mm	mm
ROOF	24	8.469	8.653
4th FLOOR	20	9.083	9.533
3rd FLOOR	16	6.191	7.33
2nd FLOOR	12	4.202	6.434
1ST FLOOR	8	3.097	5.808
GL	4	1.668	2.522
BASEMENT	0	0	0

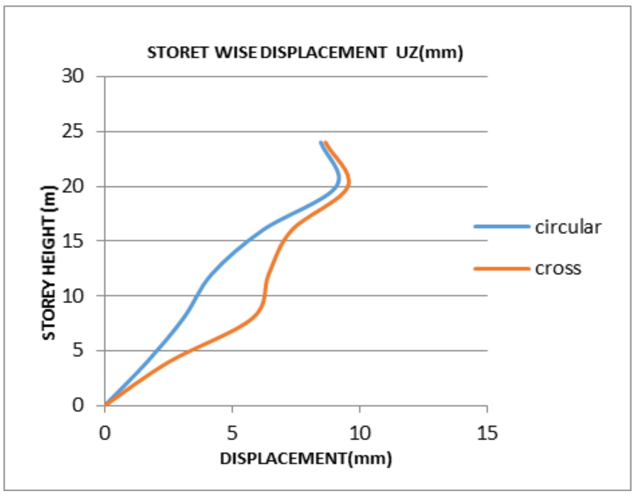

Chart 3: Displacement Uz (mm)

B. Modal Periods and Frequencies

Table – 5
Modal Periods and Frequencies

	CIRCULAR COLUMNS		CROSS COLUMNS	
Mode	Period	Frequency	Period	Frequency
	sec	cyc/sec	sec	cyc/sec
1	1.175	0.851	3.128	0.32
2	1.059	0.944	2.957	0.338
3	1.032	0.969	2.875	0.348
4	0.405	2.471	2.843	0.352
5	0.375	2.667	1.943	0.515
6	0.363	2.754	1.92	0.521

7	0.232	4.317	1.912	0.523
8	0.22	4.537	1.897	0.527
9	0.218	4.593	1.428	0.7
10	0.192	5.204	1.337	0.748
11	0.175	5.703	1.279	0.782
12	0.17	5.886	0.487	2.054

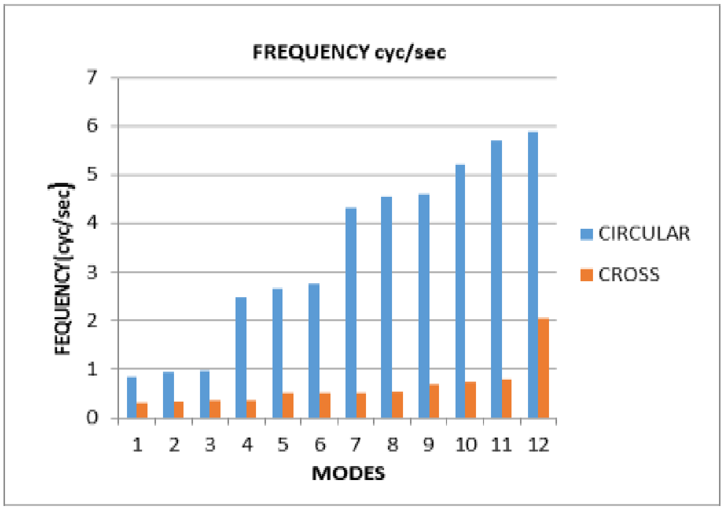

Chart 4: Modal Periods and Frequencies

C. *Beam Forces*

Table - 6
Shear force -V2-(kN)

	CIRCULAR	CROSS
Story	V2	V2
	kN	kN
ROOF	153.9394	210.0671
4th FLOOR	217.9063	194.977
3rd FLOOR	202.5853	190.1491
2nd FLOOR	243.1243	215.0776
1ST FLOOR	264.1248	231.4779
GL	147.4261	142.6728

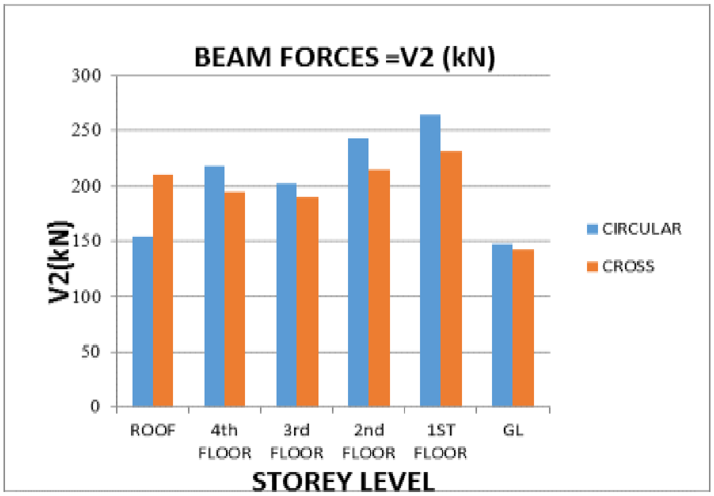

Chart 5: Max. shear force -V2-(kN) in beams

Table - 7
Max. Moment -M3-SAGG (kNm)

	CIRCULAR	CROSS
Story	M3	M3

	kNm	kNm
ROOF	134.6224	156.32
4th FLOOR	135.3749	145.36
3rd FLOOR	134.4837	117.8812
2nd FLOOR	176.7125	171.4165
1St FLOOR	199.2738	238.4126
GL	107.7131	92.9007

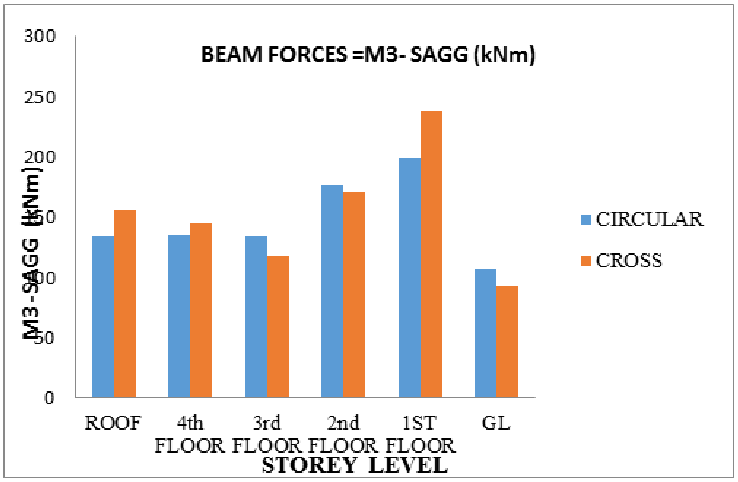

Chart 6: Max. Moment -M3-SAGG (kNm) in beams

Table – 8
Max. Moment M3-Hogg (kNm)

	CIRCULAR	CROSS
Story	M3	M3
	kNm	kNm
ROOF	267.9145	380.62
4th FLOOR	342.4857	360.86
3rd FLOOR	228.7456	177.3848
2nd FLOOR	255.0651	261.012
1ST FLOOR	262.153	306.8295
GL	151.7907	136.0906

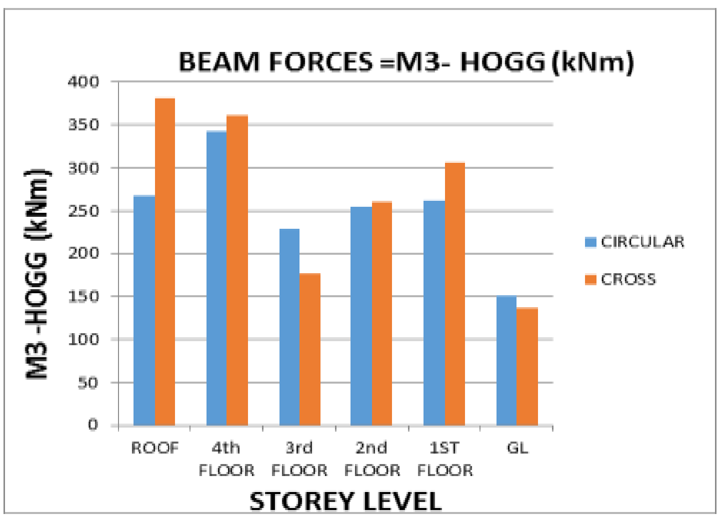

Chart 7: Max. Moment M3-HOGG (kNm)in beams

Table - 9
Max. Axial force -P-(kN)

	CIRCULAR	CROSS
Story	P	P
	kN	kN

ROOF	476.7418	536.0154
4th FLOOR	1414.202	1380.3699
3rd FLOOR	2459.7736	2361.6376
2nd FLOOR	3485.9834	3343.0144
1ST FLOOR	4531.6856	4347.1779
GL	5244.3014	5080.8749

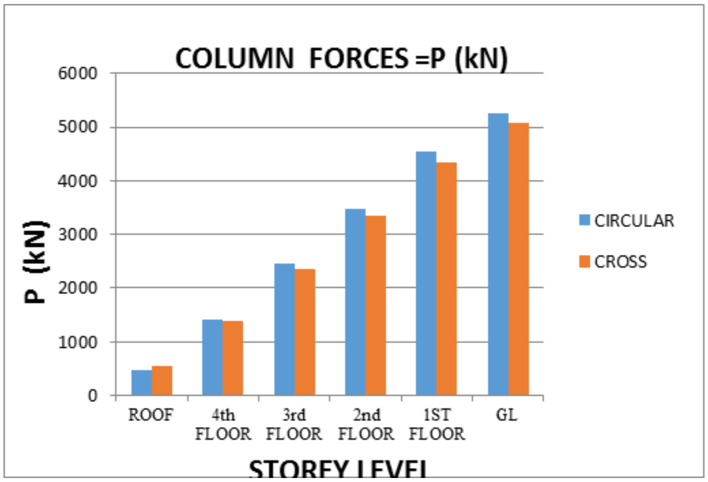

Chart 8: Max. Axial force -P-(kN) in columns

Table – 10
Max. Moment Mx-(kNm)

	CIRCULAR	CROSS
Story	Mx	Mx
	kNm	kNm
ROOF	337.8839	318.6261
4th FLOOR	212.0688	196.1775
3rd FLOOR	272.6879	176.683
2nd FLOOR	338.1155	250.8156
1ST FLOOR	369.9478	277.7302
GL	176.3326	106.0257

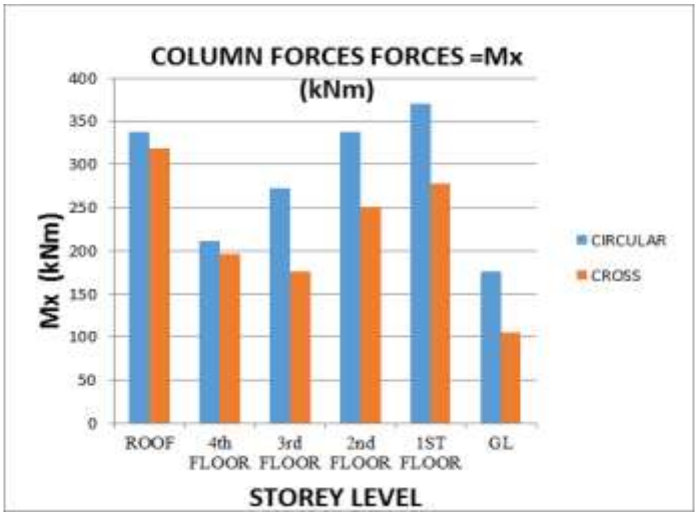

Chart 9: Max. Moment Mx-(kNm) in columns

VII. CONCLUSIONS

1) The beam bending moment (sagging) is found to be less in structure with circular column as compared to cross shaped column.
2) The beam bending moment (hogging) is found to be more in structure with circular column as compared to cross shaped column.

3) The column axial forces are found to be more in structure with circular column as compared to cross shaped column.
4) The column moment (major) is found to be more in structure with circular column as compared to cross shaped column.
5) The column moment (minor) is found to be more in structure with circular column as compared to cross shaped column.
6) The beam reinforcements (comp) are found to be less in structure with circular column as compared to cross shaped column.
7) The beam reinforcements (tensile) is found to be less in structure with circular column as compared to cross shaped column.
8) The beam reinforcement (torsion) is found to be less in structure with circular column as compared to cross shaped column.
9) The beam shear reinforcement (shear) is found to be nearly equal in structure with circular column as compared to cross shaped column.
10) The column reinforcements (long) is found to be less in structure with circular column as compared to cross shaped column
11) The column reinforcements (links) are found to be less in structure with circular column as compared to cross shaped column.
12) The volume of column concrete is found to be more in structure with circular column as compared to cross shaped column
13) The Final conclusion form this case study is that Structure with circular column is found more economical as compared to cross shaped column irrespective of increase in volume of concrete in circular columns.

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