International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 1 ǁ 2022 ǁ PP. 10-20

Response Spectrum Analysis of irregular shaped High Rise Building having Elevated Swimming Pool at Different Positions on the Intermediate Floor.

Akbar Mustafiz Alam[1], Dr Heleena Sengupta[2]
[1]Mtech Student, Structural Engineering, Techno India University,Kolkata, WB, India
[2]HOD, Department of Civil Engineering, Techno India University, Kolkata, WB, India

ABSTRACT:
This project includes the study of irregular shaped High Rise Building having elevated swimming pool at different positions of an Intermediate Floor under dynamic analysis using the STAAD pro. In this project, we have analyzed the G+19 building frame models having swimming pool in the intermediate floors at different positions (along the length, centre position, two different corner positions) by the Response Spectrum Analysis (RSA) in order to develop economic design. In place of simple and regular configuration of the buildings, we have considered irregular building in view of the fact that irregular type of buildings suffers more damage during earthquake. Also, the effect of hydrostatic pressure (water pressure) acting on the plates of swimming pool has been considered in this study. The following are the objective of this study:-

- *To study impact of seismic forces under dynamic loading on irregular shaped high rise building having swimming pool at different positions i.e along one side, near centre position, two different corner positions.*
- *One of the major problems of irregular building having re entrant corner is torsion; hence comparative study of torsion for all model frames is necessary.*
- *To find out the result of other seismic parameters like lateral force, peak story shear, modal periods etc for all four model frame in order to compare safety of these structures.*

KEYWORDS*: High-Rise, Irregular Shaped building, Response Spectrum Analysis, Re-Entrant corners, Dynamic*

Date of Submission: 15-01-2022 Date of acceptance: 30-01-2022

I. INTRODUCTION

Indian economy is developing very fast. The construction industry of this country has been developing rapidly over the past two decades. The Indian construction industry employs over 30 million people and creates assets worth over rupees 200 billion. It contributes 5 percents to the Nation's total GDP. Thousands of high rise buildings have already been constructed in different cities of India and many of them have amenities like skywalks, swimming pools etc. To provide better aesthetics, economic use of land and also to provide adequate natural ventilation, the developers/ architects nowadays preferred irregular shaped buildings in place of regular buildings in order to meet up the requirements of clients/ flat buyers. These types of buildings have many amenities like gymnasium, kids playing area, roof top garden, roof top swimming pools etc. In the recent development, it is observed that many developers are also providing swimming pools at intermediate floors connected to individual flats to attract the aspirant flat buyers. For an example, one proposed Residential tower in Mumbai City has swimming pools in all its floors. Though water masses of swimming pool acts as a mass dampener and help to resist seismic forces, but the loading due to swimming pool is heavy and complicated. Also, the irregular buildings are more vulnerable to seismic damages and undergo larger displacement compare to regular shaped buildings. The present study is an attempt to study the seismic effect on irregular buildings subjected to hydrostatic pressure for having elevated swimming pool on its intermediate floor.

Figure 1: Building having swimming pools on all floors

1.1 Problem Statement

Reinforced concrete moment resisting frame of typical 3.6 meter storey height with geometrical irregularity is considered for this study. The aim of the study is to find out base reactions, modal participation, peak story shears and peak additional torsion due to effect of seismic forces on the irregular RC Model frame subjected to hydrostatic pressure for having swimming pool on its intermediate floors at different positions.

II.METHODOLOGY

In this project, four RCC frame models having swimming pool at different positions on 12th floor (Height 43.2 meter) have been considered. The horizontal dimensions are taken in such way to meet up the standard conditions given for plan irregularities in the table 4 of IS code 1893 (Part 1): 2000. As per IS 1893(Part 1):2016 building having re entrant corners is a type of irregularity. If both the projections of the structure beyond any corner are greater than 15% of its pan dimension in the given direction, it is considered as re entrant corner. In this study, we have considered re entrant corners towards projection of the building plan. The loading of swimming pool in 12th floor (ht 43.3 meter) fulfills the condition for mass irregularity (vertical irregularity) as per IS code 1893 (Part 1): 2016. All the four model frames are 72 meters in height and have equal horizontal dimensions (identical plan irregularity). However, the positions of swimming pool for all model frames are being altered in order to create four different RC frame models. For better understandings, the RC frame models are designated as Model frame 1, Model Frame 2, Model Frame 3 and Model frame 4 according to the position of swimming pool (given in Table 1). All the frame models have been analyzed with the dynamic response spectrum analysis method.

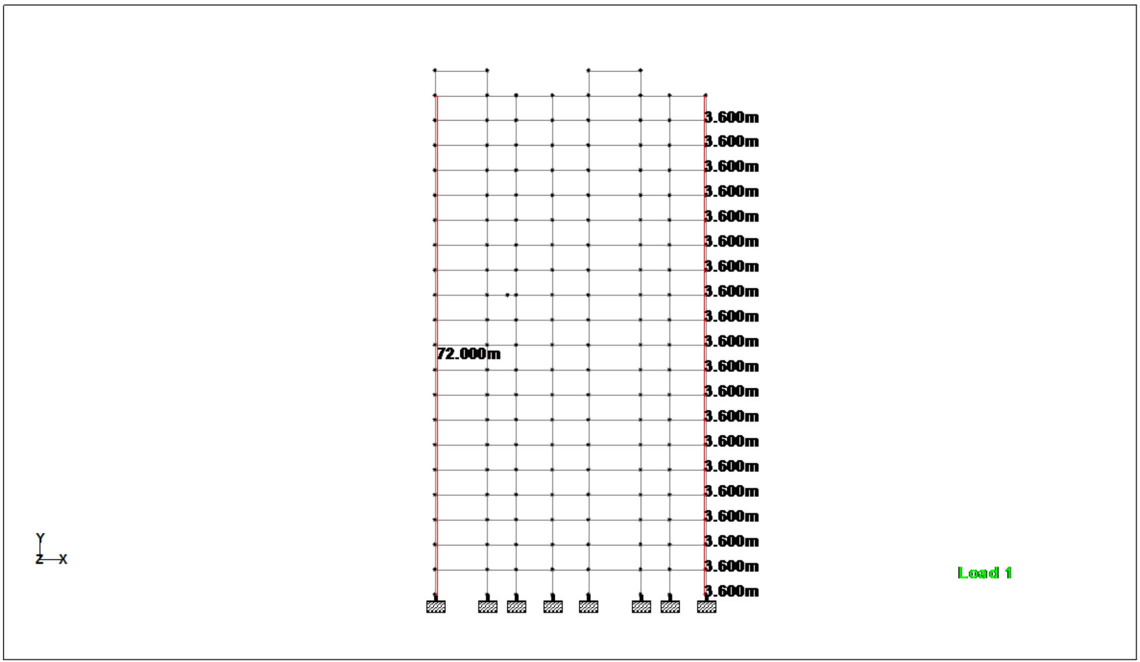

Figure 2.1: Elevation of the Building

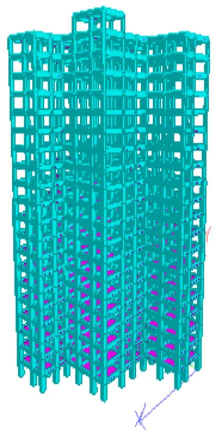

Figure 2.2: 3D view of the Model Frame

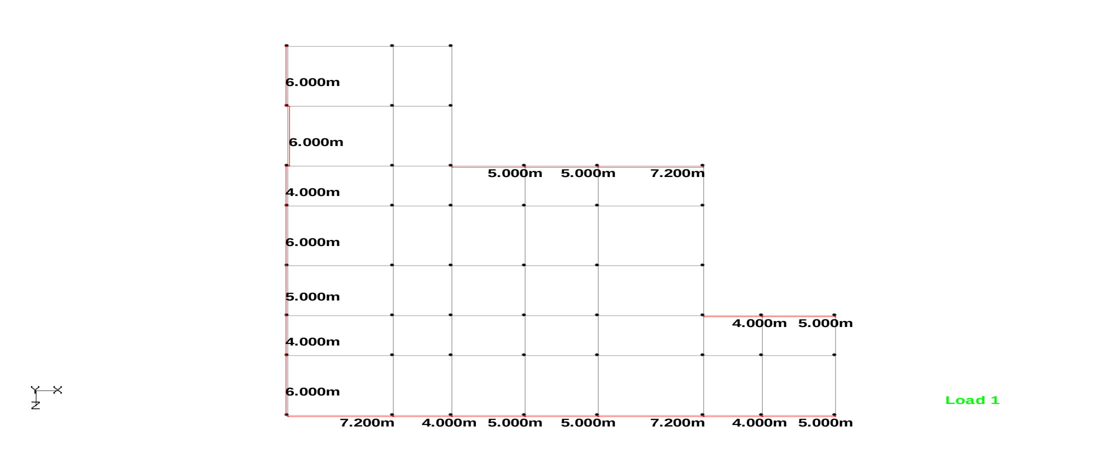

Figure 2.3: Floor plan of the Building

Table 1: General Consideration for the RC Model Frame

Name	**Location of Swimming Pool on 12th Floor**
Model 1 Frame	One sided along its length
Model 2 Frame	Near Centre position
Model 3 Frame	Two Sided at Corner position
Model 4 Frame	Two sided at Re entrant corner towards the projection of the building

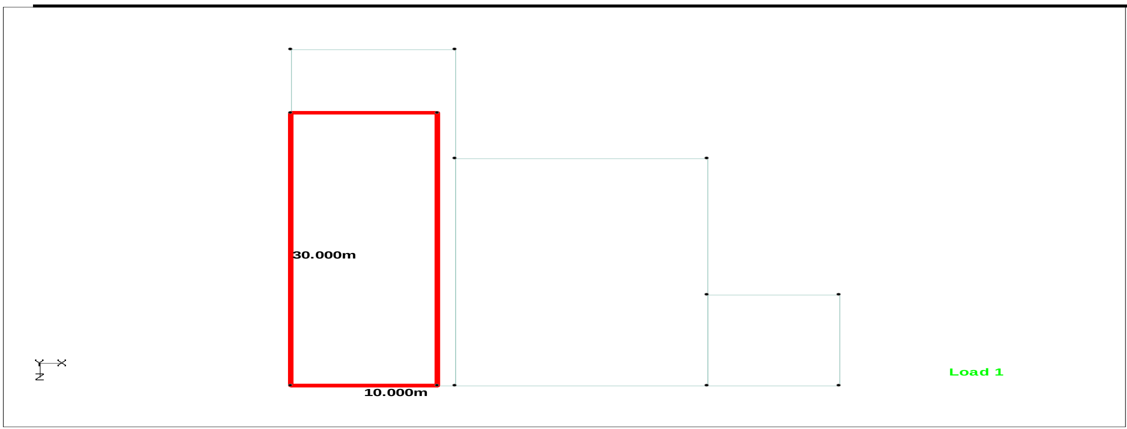

Figure 3.1: Layout plan of Model Frame 1 (SWIMMING POOL –ONE SIDED)

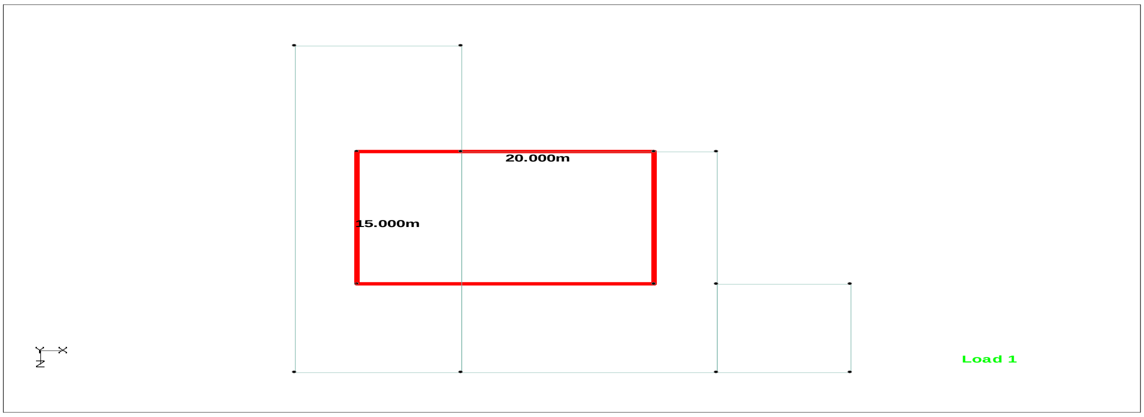

Figure 3.2: Layout plan of Model Frame 2(Swimming pool near centre position)

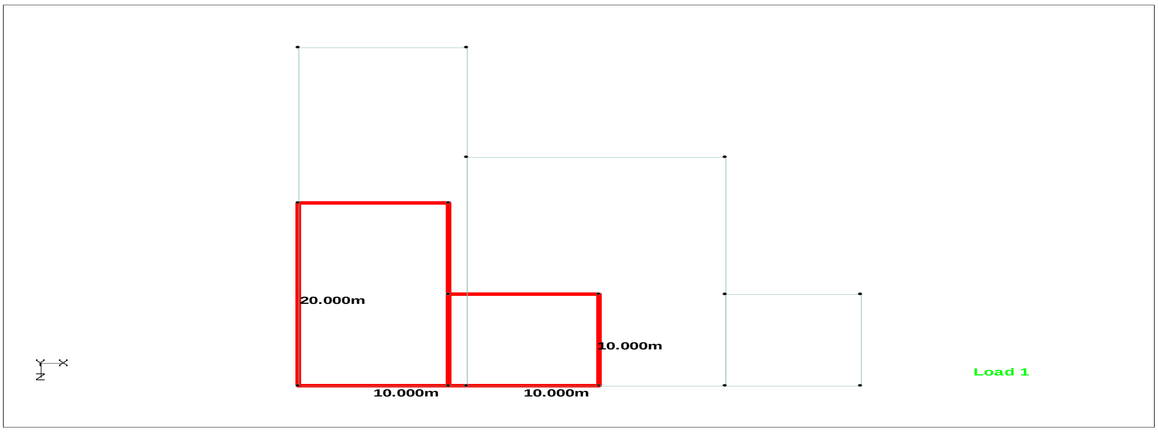

Figure 3.3: Layout plan of Model Frame 3 (Two sided swimming pool at corner)

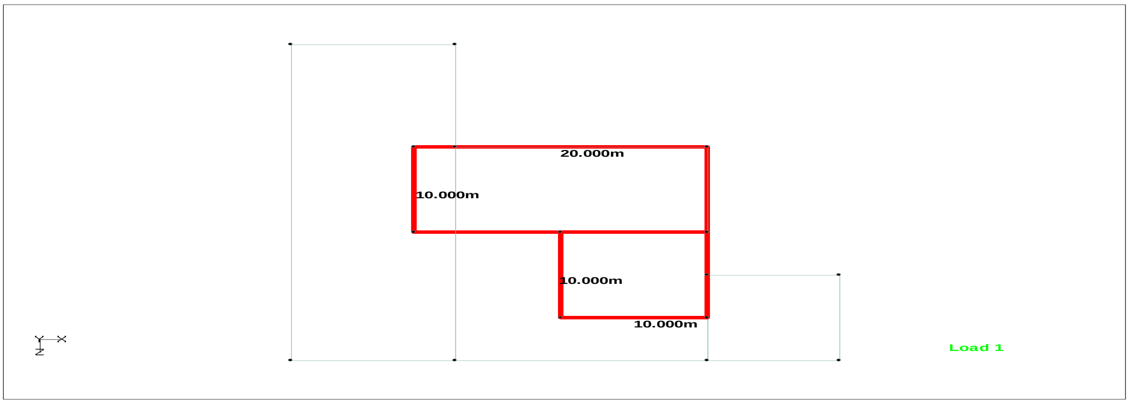

Figure 3.4: Layout plan of Model Frame 4 (Two sided swimming pool at the re entrant corner)

2.1 Structural Properties used for All Models:

The detail description of materials and structural properties used in this study is given in the Table 2. The structural properties and materials of all four model frames are kept identical, except the position of swimming pool on the intermediate floor.

Table 2 Structural Details for all Model Frames

Particular Of Items	Properties
Total Built-Up Area	934.40 sq. meter
Plan Area of Swimming Pool	300 sq. meter
Number of Stories	G+19
Column size upto 11^{th} floor	1200mm X 1200mm
Column size from 12 th floor to 19^{th} floor	750mm X 750 Mm
Height of Column	3.6 meter
Depth of Swimming Pool (At 11^{th} Storey)	1.5 meter
Beam Size	1000mm X 500mm
Slab Thickness	150 mm
Swimming Pool Plate Thickness	150 mm

2.2 Property Reduction factor/Stiffness modifiers:
As per clause no 6.4.3.1 of IS 1893 (part 1):2016, 70 percent of gross moments of inertia for columns and 35% of gross moment of inertia for beams have been taken for analysis of beams and columns.
2.3Definition of Load Cases, Load Case Specification & Load Calculation for All Frames Models:
For the response spectrum analysis, first of all, the seismic parameters are to be defined in the STAAD Pro software as per the standard practice codes of the respective country. Subsequently, the primary load cases have been considered according to the type of loading. After consideration of all primary load cases, load combinations of the primary load cases are generated in accordance with latest consideration of IS Code 1893(part 1) 2016. In this study, the total number of load cases as well as load combinations and magnitude of loading are kept identical for all model frames. Table 3 shows the seismic parameters used in the analysis and the Table 4 shows all the primary load cases.

Table 3 Seismic Parameters used in All Frame Models

PARTICULARS	DETAILS
Seismic Zone	Zone –III (CITY KOLKATA)
Seismic Intensity	Moderate
Zone Factor Z	0.16
Building Frame System	Special RC Moment Resisting Frame (SMRF)
Response Reduction Factor R	5.0
Importance Factor I	All General Buildings (I =1.5)
Rock/Soil Type	Medium Soil (Value = 2)
Structure Type	RC Frame Building (Value = 1)
Damping Ratio	5% (Value = 0.05)

Table 4: Load Cases

Load Case Number	Name	Load Type
1	EQ+X	Seismic load + X direction
2	EQ-X	Seismic Load -X direction
3	EQ+Z	Seismic Load + Z direction
4	EQ -Z	Seismic load- Z direction
5	DEAD LOAD	Self weight, Floor loads, hydrostatic pressure and member loadings
6	LIVE LOAD	Live Load

2.4 Load Case 1,2,3 & 4 [Earthquake or Seismic Load):
Seismic or Earthquake loads are indicated as EQ+X, EQ-X, EX+Z and EX-Z according to the direction of action. The total seismic weight of each floor is its full dead load plus appropriate amount of Imposed load , as specified in table 8 of IS 1893 (part 1) 2016. For calculating seismic forces of the structure, the imposed load on roof need not be considered. The floor live load is considered as 2 KN/M². As per clause 7.3.1 and table 8 of IS 1893, combination of dead load plus 25 % of live load is used to determine the reference joint loads which are required for RSA.

2.5 Load Case 5 (DEAD LOAD):
The dead load is designated as Load Case Number 5 in this analysis. Dead Load includes self weight of the RCC frame comprises slabs, beams, columns and the plate elements used for swimming pool. The unit weight of RCC is considered as 25 KN/m^3 as per IS 456: 2000.
Self Weight: The self weight for slabs, beam, columns and plate element is applied in Y direction (vertical) with a load factor -1.
Dead load of Slabs: Slab weight under the category of Dead load is considered as Floor load. The thickness of slabs are considered as 150mm, hence floor load is applied as (25x.15)= 3.75 KN/m^2.
Member loads: The weight of outer walls, partition wall and swimming pool walls are considered as member loading and considered as uniform force in Y direction.
Hydrostatic pressure: Hydrostatic pressure is the term for the force that water exerts upon other objects when it is not in motion. Water within the pool exerts hydrostatic pressure on the base as well as wall of swimming pool. The depth of swimming pool is considered as 1.5 m. Hence, pressure on the base on swimming pool is 15 KN/m^2 and the magnitude of hydrostatic pressure on the wall is in the range of -5 to -15 KN/m^2 in the direction depends on the orientation of plate element and it is distributed in horizontal shape**.**

2.6 Load Case 6 (LIVE LOAD)
The live load is referred herein as load case number 6. Live load includes imposed load for all the floors and considered under the category residential building as given in IS 875 Part -2.
Live load for all the floors = 2 KN/m^2

2.7 Combinations of load cases:
In this study, the load combination are being considered according to the IS code 1893;2016, clause no 6.3.2.2:

{1}.EARTHQUAKE LOAD COMBINATION: (DL+LL+EQ)*1.2
{2}.EARTHQUAKE LOAD COMBINATION: (DL+LL-EQ)*1.2
{3}.EARTHQUAKE LOAD COMBINATION: (DL+EQ)*1.5
{4}.EARTHQUAKE LOAD COMBINATION: (DL-EQ)*1.5
{5}.EARTHQUAKE LOAD COMBINATION: (0.9DL+1.5EQ)
{6}.EARTHQUAKE LOAD COMBINATION: (0.9DL+1.5EQ)

2.8 Design Parameter Considered for All RCC Frame Cases
The design of all building frames has been done in STAAD pro according to Indian code for reinforced concrete i.e. IS 456:2000.The design considerations for all model frames are kept identical. The following parameters are considered for concrete design:

Table 5 Design Parameter

PARTICULARS	DETAILS
Design Code	IS 456: 2000
Grade of Concrete	M35
Grade of Main Reinforcement	Fe500
Grade of Secondary Reinforcement	Fe500
Max. Percentage Of Longitudinal Reinforcement Allowed	6%
Max percentage of reinforcement allowed for beams	4%
Clear cover for beams	25mm
Clear cover for columns	40 mm

III. RESULTS & DISCUSSIONS

3.1 Comparison of Base Shear:
Base shear is an estimate of maximum expected lateral force on the base of the structure due to seismic activity. The maximum value of lateral force due to applied dynamic seismic activity is observed in Model Frame 3(swimming pool at corner position), whereas model Frame 2 (swimming pool near centre) exhibits less magnitude of lateral forces. The lateral forces for Model Frame 1(swimming pool one sided) and Model frame 4 (swimming pool at re entrant corner) is almost similar and Model Frame 4 shows slightly better results than Model Frame 1. It emerges, that the Model frame 2(swimming pool at centre) is much safer in terms of lateral forces and model 3 is most vulnerable.

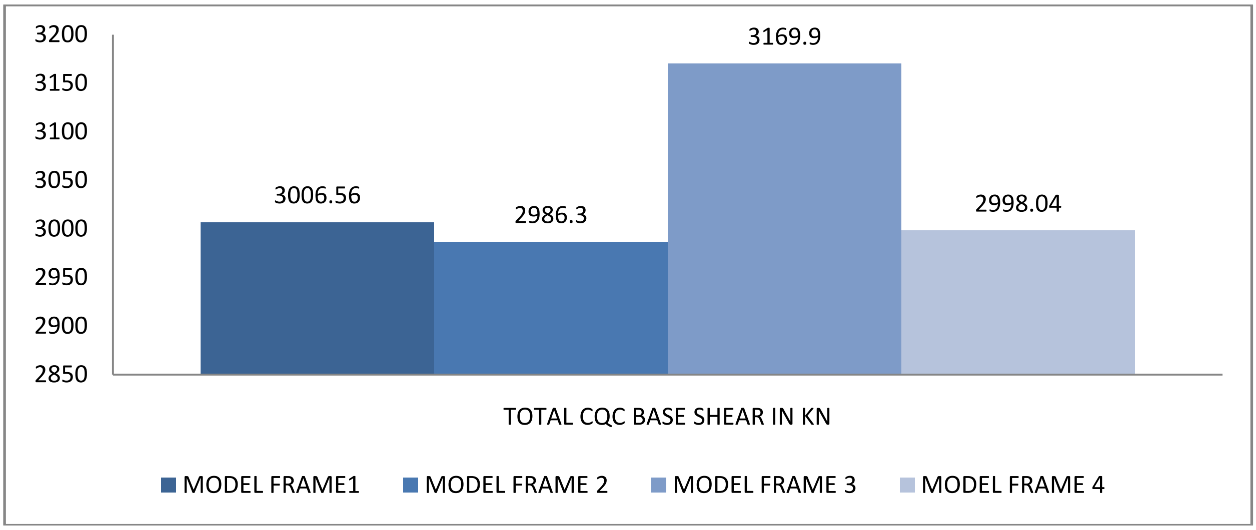

Figure 4: Total CQC Base Shear in KN

3.2 Comparison of Peak Additional Torsion:

The results of Peak Additional Torsion from RSA are imperative since torsion is a problem for irregular structures. The experimental value of Torsion in X and Z direction are graphically represented below. The results show that there is a significant increase in torsion at 12^{th} floor due to the existence of swimming pool. The increase in torsion for Model Frame 1 (swimming pool one sided) is much higher compare to other Model frames, whereas the increase is least for Model No 2 (swimming pool near centre).It may be concluded that Model Frame 1 (swimming pool one sided) is more susceptible to torsion due to applied seismic forces. On the other hand, Model No 2 (swimming pool at centre) shows better results than all other Model Frames.

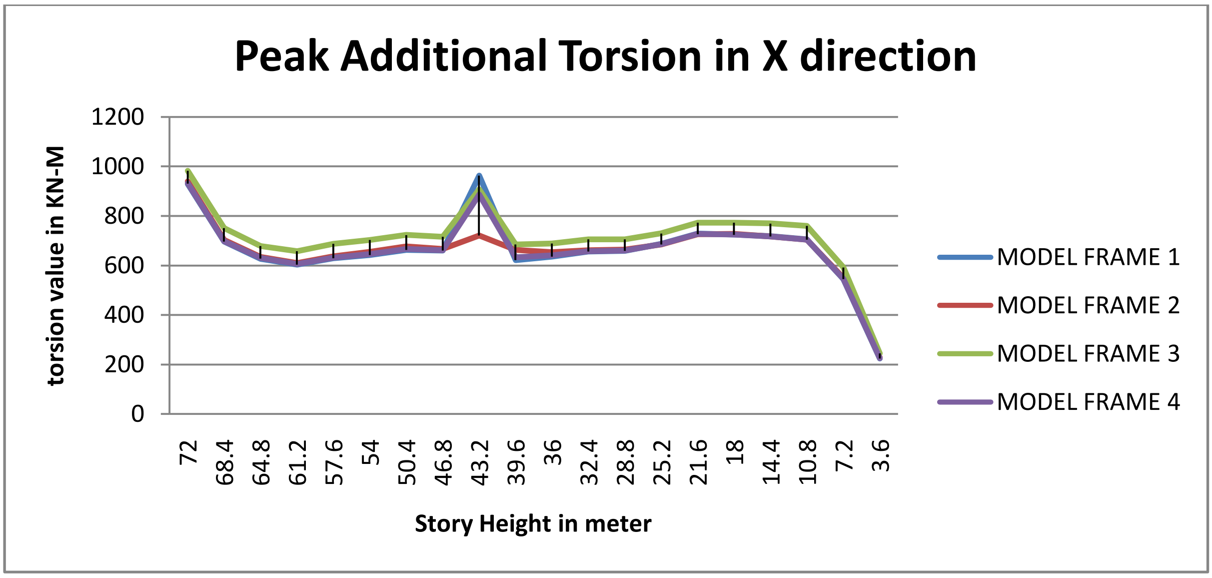

Figure 5.1: Peak Additional Torsion in X direction

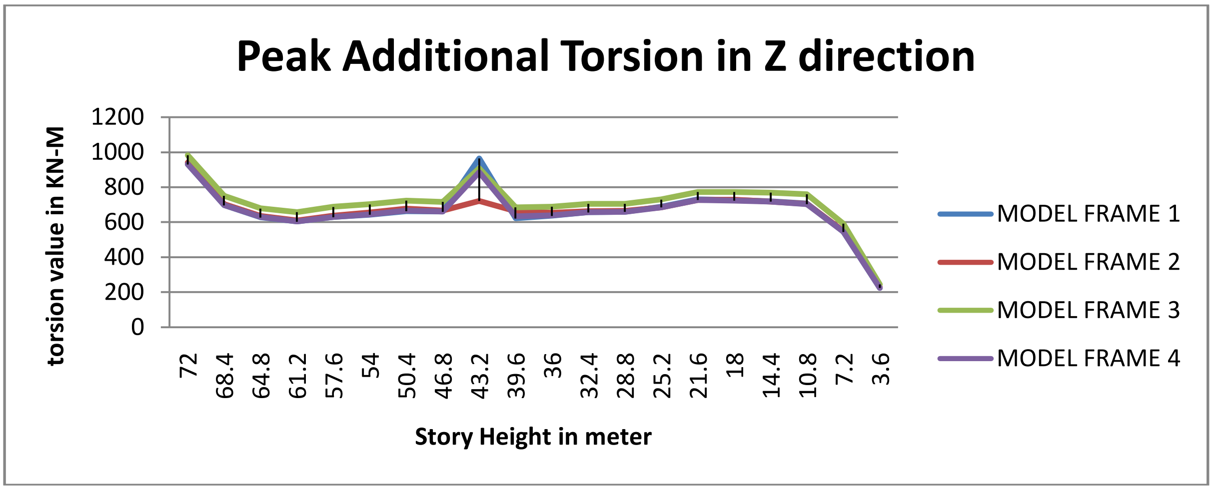

Figure 5.2: Peak Additional Torsion in Z direction

3.3 Comparison of Story Shear:

The results peak story shear in the RSA shows the lateral load acting per story. As long as we go lower, the value of story shear is greater. The results of peak story shear from RSA are graphically represented. The results of RSA indicate that Model Frame 2 is practically much safer compare to other models. The results of model frame 1 and Model frame 4 are almost identical, whereas Model frame 3 is more vulnerable to collapse due to peak story shear.

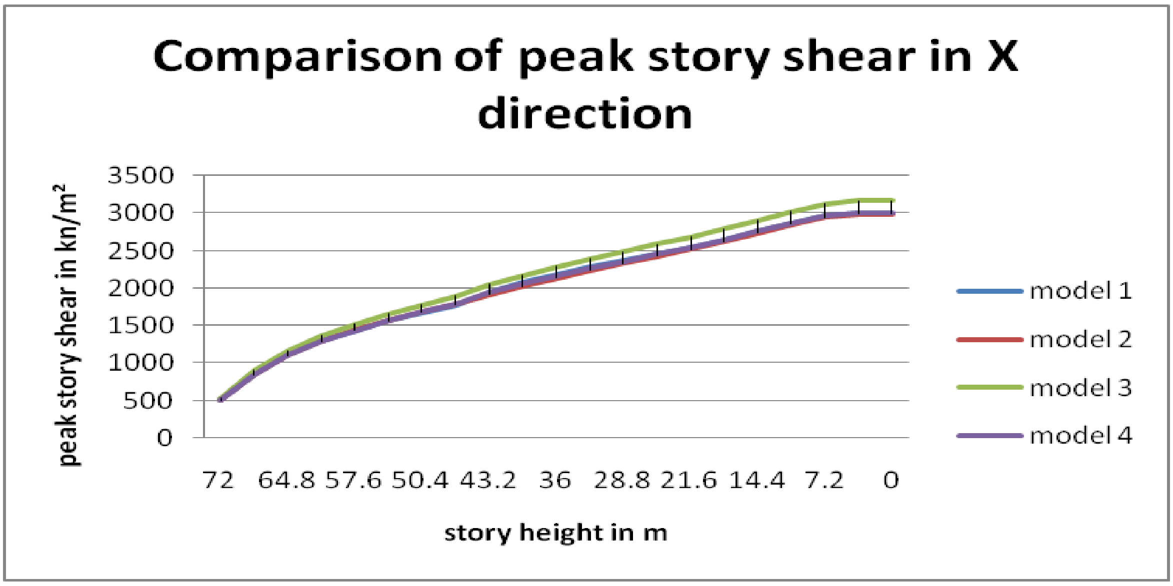

Figure 6.1: Peak Story Shear in X direction

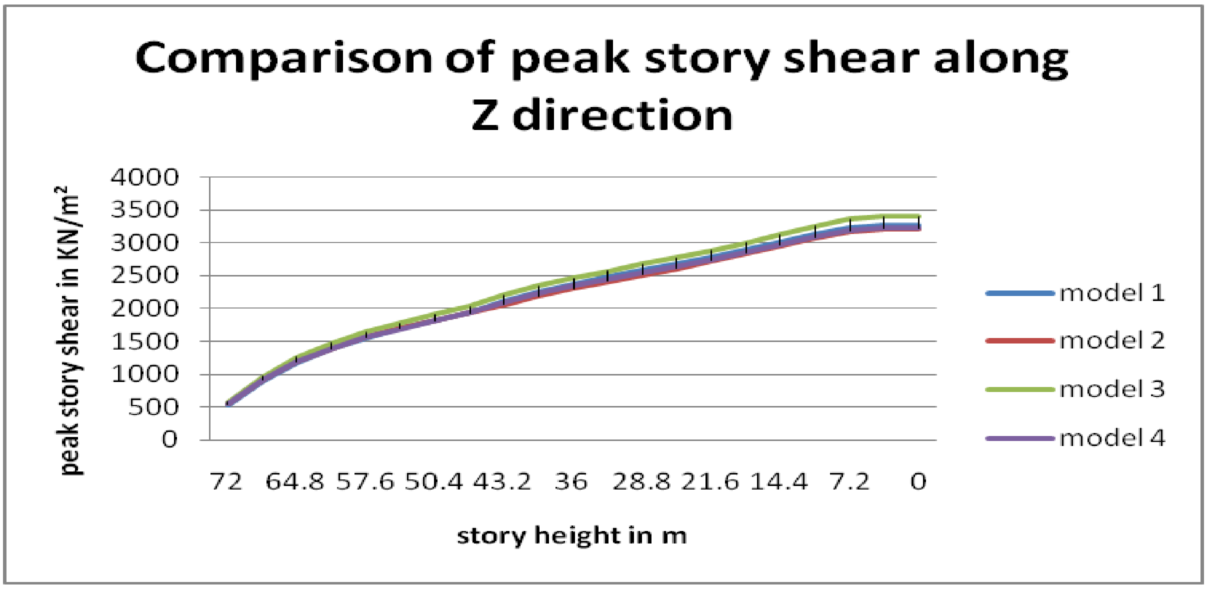

Figure 6.2: Peak Story Shear in Z direction

3.4 Comparison Report of MODAL PERIODS:

Modal periods of seismic analysis depend on the building stiffness and its seismic weight. At least 90% mass participation factor is considered to determine the total number of mode to be used in the analysis. The modal period of Model Frame no 3 is higher compare to other Model Frame. It emerges, that the Model frame 3 exhibits better resistance to earthquake with period of higher order.

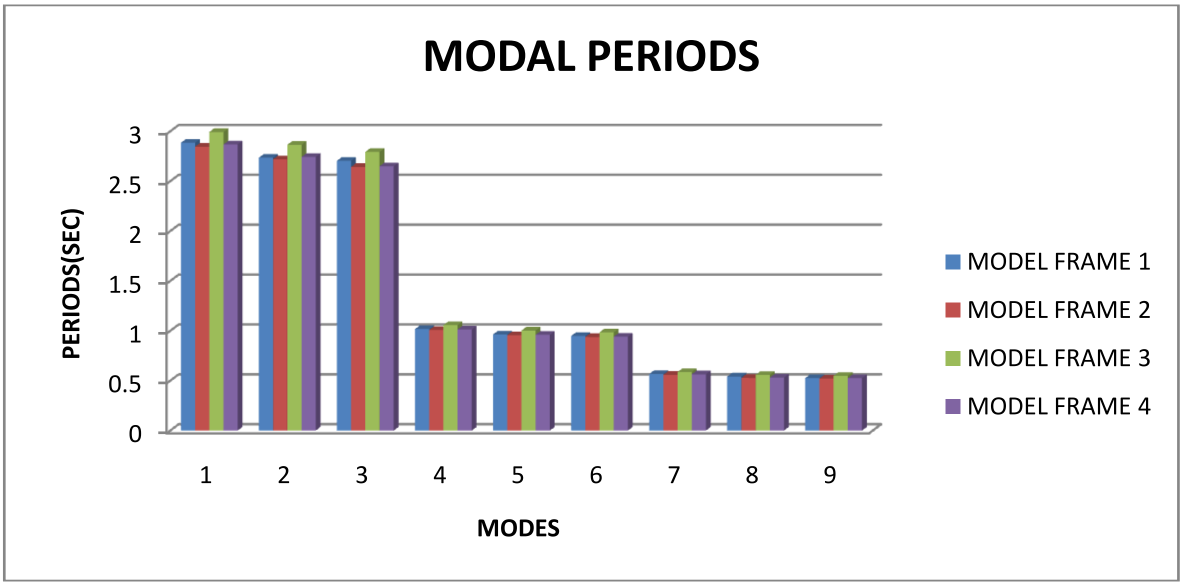

Figure 7: Modal Periods

IV. CONCLUSION & SCOPE

The present study is an attempt to compare the results of seismic forces on irregular shape building having irregularity in both horizontal and vertical direction and also subjected to hydrostatic pressure at intermediate levels. Based on the results of response spectra analysis the following points are concluded:

i. The hydrostatic pressure due to swimming on any floor of High Rise Buildings plays important role for increase in peak additional torsion. The magnitude of torsion varies significantly according to the position of the swimming pool on that particular floor.

ii. There is a significant increase in peak story torsion in 12th floor due to existence of heavy weight of swimming pool. However, the increase in peak story torsion for model frame 2 is much lower compare to other models. Increase in torsion in the 12th floor is highest for Model Frame 1; the values are 54% and 52% more in X and Z directions respectively compare to the next floor (11th floor) of the building. It is concluded that Model frame 1 (having one sided swimming pool) is much susceptible in terms of torsion compare to other Model frames. Model frame 2 (swimming pool near centre position) exhibits better results.

iii. The results of Peak story shears shows that in both X and Y direction, the Model Frame No 3(swimming pool at corner) is very much vulnerable and Model frame no 2 (swimming pool near centre) is practically much safer.

iv. In terms of effect of lateral forces at ground level due to seismic action, the Model Frame 2 (swimming pool near centre) demonstrates better performance, Model Frame 3(swimming pool at corner) is most susceptible and results of Model no 1 and Model No 4 are almost similar.

v. It appears that the results of Modal periods are completely different from other seismic parameters and it exhibits that the performance of Model 3 (swimming pool at corner) is better in terms of resistance to earthquake with period of higher order.

vi. Based on the analysis results, it has been concluded that the centre position of swimming pool is practically much safer in irregular building since it exhibits better results in term of resistance to different parameter of earthquake force except the modal periods. It also emerges that the corner position of swimming pool is most vulnerable in irregular buildings and the designers need to pay special attention for placing swimming pool at corners.

REFERENCES

[1]. Shreyasvi.C, B Shivakumarswamy, " A case Study on Seismic Response of Buildings with Re Entrant Corners" IJERT: 2278-0181

[2]. Akash Agrawal, Anurag Wahane," Analysis of Elevated Swimming Pool with Different Positions on the terrace of RCC Frames using STAAD Pro"IRJET e-ISSN2395-0056, p-ISSN:2395-0072, VOLUME 07 Issue:09|Sep 2020

[3]. S.R Kangle, D.S Yerudkar," Response Spectrum Analysis for Regular Multistory Structure in Seismic Zone III", IJERT ISSN 2278-0181 Vol 09, September-2020

[4]. Davidson Shilpa Sara, Kumar Aswathy S , "Study on the Effect of Swimming Pool as Tuned Mass Damper", International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Volume 6, Issue 06 , Special Issue – 2018.

[5]. IS: 875 (Part I) – 1987, "Code of Practice for Design Loads (Other than Earthquake) For Buildings and Structures", Part 1 Dead Loads - Unit Weights Of Building Materials And Stored Materials, Second Revision, September 2003.

[6]. IS: 875 (Part 2) – 1987, "Code Of Practice For Design Loads (Other Than Earthquake) For Buildings And Structures", Part 2 Imposed Loads, Second Revision and June 1998.

[7]. IS 1893 (Part 1):2002/2016, "Criteria for Earthquake Resistant Design of Structures", Part 1 General Provisions and Buildings.

[8]. IS 456:2000, "Plain and Reinforced Concrete - Code of Practice", Fourth Revision,2000.

[9]. Chopra A.K."”Dyamics of Structure"", 3rd edition, Prentice hall of india,2007

[10]. S K Duggal, "Earthquake Resistant Design of Structures", Published by Oxford Higher Education, Second Edition, 2002.

[11]. N. Krishna Raju, "Design of Reinforced Concrete Structures", CBS Publishers & Distributors Pvt. Ltd., Fourth Edition, 2010.