"Analysis of Elevated Swimming Pool with Different Positions on the Terrace of RCC Frames using STAAD Pro."

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ABSTRACT:

This project work symbolizes ***the study of behavior of swimming pool as per the considered position of pool at the terrace floor of the high rise regular building under Dynamic Response Spectrum Analysis (RSA) Using STAAD Pro.*** RCC frame Building with different position of swimming pool ***(i.e. One-Side, Two-Side, Three-Side, Centre)*** were taken for the study. The Walls/ Plates of pool is subjected to hydrostatic pressure due to water present along with the base of the swimming pool. The research also includes the study of seismic action on the surface plates of swim pool due to plate stress behavior *(Ref. Fig. 5.1-5.4)*. The main target is to achieve the efficient swimming pool position which can be applied in the high-rise building. The following are the objectives of this study are as follows-

- ❖ To model the RCC frames having Swimming Pool on the terrace of the each frames i.e. with different position varying as One-Side, Two-Side, Three-Side & Center Position Swimming Pool using Dynamic Seismic Analysis Method;
- ❖ To check the efficiency by analyzing the quantity of material of different case study;
- ❖ Comparison between the Model 1,2 ,3 & 4 frame with the respective different Case on the parameters i.e. Displacement, Compressive Stress, Lateral Load, Storey Shear

Keywords: High-Rise, Swimming Pool, RSA, Dynamic

1. INTRODUCTION

The trend of RCC high rise structures has increased nowadays in India. Many different amenities like swimming pool, garden etc. have been provided in high story building which is very attractive from an aesthetical point of view but it is dangerous from a structural point of view. The swimming pool is a heavy weight and the detailing is complicated, but it is not much different than other structural loads. If the pool were to break for some reason and all the water rushed out, it would destroy some interior and possibly some windows. But otherwise, it wouldn't level the building. In fact, in most cases, the extra water mass will help the building resist earthquakes by acting as a liquid mass dampener.

1.1 General Shapes of the swimming pool

Understanding the different pool shapes that are available can help you in making the decision to buy a pool. Many people don't understand what the possibilities are for different kinds of pools in their backyard. The shape you pick can be helpful or detrimental to the type of experience you are looking for. This post will outline the basics of what each shape does for your home. To make a decision on a pool shape you need to keep in mind the location where the pool will be built. The shape should be well accommodated to the place. It should also accommodate the activities you expect to take place. Which are- **Oval Pools, Kidney Pools, Figure 8 Pools, Rectangular Pools, Lazy L Pool, Circular Pools, Free Form Pools, and Geometric Pools.**

1.2 Basic Requirements in Swimming Pool Construction

1. It is necessary to have a pool shell i.e. the pool floors and the walls to be structurally sound.

2. The pool shell must be designed and constructed so that they have good water tightness. This condition must be followed when the pool is fully or partially filled. Some of the swimming pools due to the area of the construction may be constructed below water table. This demands for higher water tight pool shell in order to resist the penetration and the infiltration of the ground water. This condition can exist even if the pool is filled with water or vacant.

3. The floor and the wall surface in the interior of the swimming pool must be properly finished with a smooth, reasonably impervious and an attractive material. This must enable easy cleaning of the surface. The water within the pool must be of proper standard of clarity and purity.

4. The pool must have a walkway that surrounds the perimeter of the pool. The width of the walkway must be 1.5m in minimum value. This walkway must be finished with a non-slip material that can be easily cleaned and highly durable.

5. For pools that are used by young children and non – swimmers, there must be provision for safety steps all around the walls. The location of the steps must not be greater than 900mm below the water level.

6. The provision for diving board is based on the swimming association of the region. This varies if the pool is installed for diving competitions.

1.3 Effects of Earthquake Accelerations to Rooftop Pool

From past earthquake experiences, it was found that the water of a pool can move out of the pool during moderate or strong earthquake. For example, during recent Nepal's earthquake, water can splash out of the pool easily, even for on the ground swimming pool. The effects will be greater for roof top swimming pool, especially the continuous type. Because the floor acceleration at top of building will be larger than the ground acceleration, a study is needed to find the effects of horizontal and vertical accelerations on water in rooftop swimming pool during earthquake

Fig 1.1 Effect of Earthquake to a Swimming Pool on ground level

Fig 1.2 Earthquakes Impact In Pools Flooring

2. LITERATURE REVIEW

Chokshi Shreya H., Dalal S.P. (2015) has studied that buildings are essential in all populated cities. To increase value in certain buildings there are associated risks that we take like providing swimming pool at each floor level. Water carrying structures are more important that must remain functional following disasters such as earthquake. Most of the failures of structures after earthquakes are suspected to have resulted from the dynamic buckling caused by overturning moments of seismically induced liquid inertia and surface slosh waves. This paper investigates the hydrostatic and the hydrodynamic behavior of water in the swimming pool when subjected to earthquake forces. The main object of this paper is 1). To compare the static and dynamic analysis of the building. 2) The study of hydrodynamic effects.

Suja Gayathri, Dr. Subha K (2016), has studied in their paper that - most swimming pools in multistoried buildings are constructed without considering the consequences that might occur during the event of an earthquake. The sloshing and overtopping of the large volume of water can lead to additional damages. The objective of this study is to model a swimming pool and the sloshing movement of the water retained in it using ANSYS 16. The swimming pool will be modelled as a rectangular flat bottom constant depth concrete water tank. A comparison between the stresses developed when water is modelled as a static body and the stresses developed when sloshing is permitted is also carried out. The effect of variation in positioning the pool at various storey of the building on the magnitude of stresses developed is also studied.

3. METHODOLOGY

3.1 General Considerations for the Analysis of All RCC Frames

In this project response spectrum method of seismic analysis is used to compare the seismic performance of four RCC frames of 32 meter height provided with swimming pool at different location on the top storey. For simple understanding, the frame models are abbreviated in terms of model numbers from one to four and their detail description is given in the table 1.

Table 1 General Consideration for the Frame Study

Designation	Location of Swimming Pool
Model 1 Frame	One sided
Model 2 Frame	Two sided
Model 3 Frame	Three sided
Model 4 Frame	Centered location

3.2 Detail of the Structural Properties Used for All Models

The detail description of physical structural properties and material properties of all four RCC frame used in the study are given below in the table 2. Except the location of the swimming pool, all parameter are kept same for all four models.

Table 2 Structural Properties Used for all Model Frames

Particular Of Items	Properties
Total Built-Up Area	375 sq. meter
Plan Area of Swimming Pool	135 sq. meter
Number of Stories	G+9
Height of Column (For 1st To 10th Storey)	3.2 meter
Depth of Swimming Pool (At 10th Storey)	2.1 meter
Beam Size	400mm X 400mm
Column Size	600mm X 500mm
Slab Thickness	150 mm
Swimming Pool Plate Thickness	300 mm

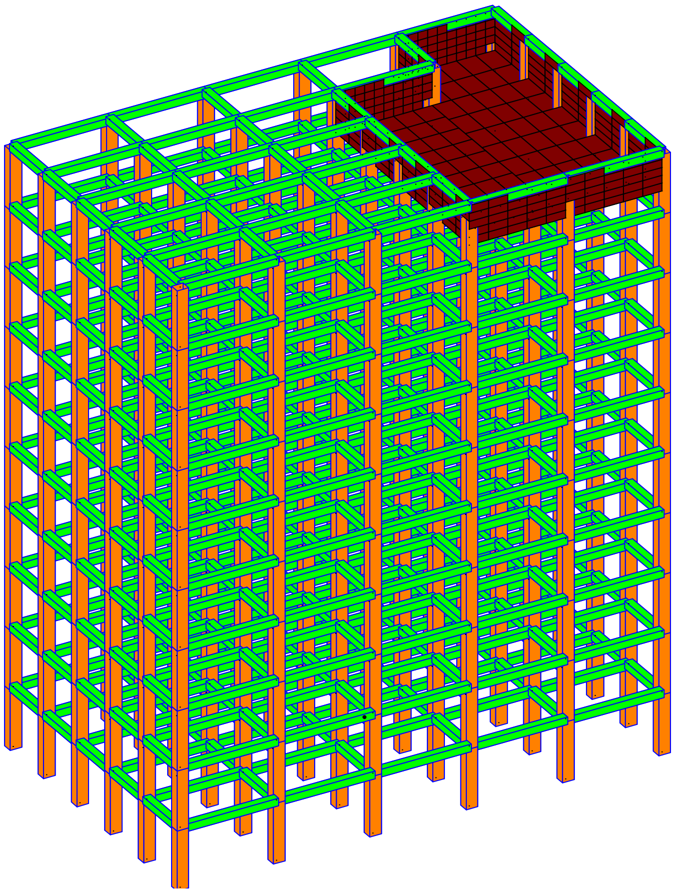


Fig. 3.1 Isometric View of the Model 1 Frame

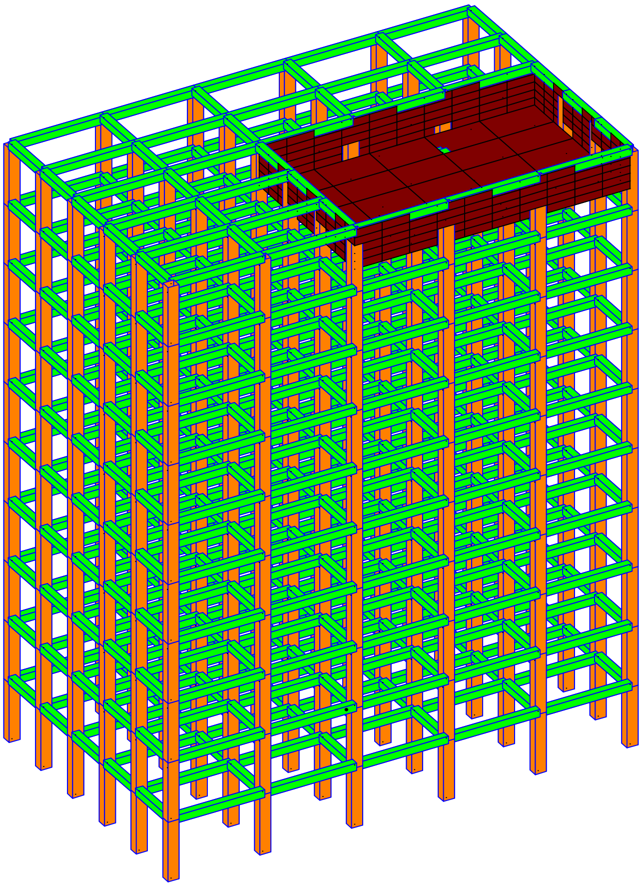


Fig. 3.2 Isometric View of the Model 2 Frame

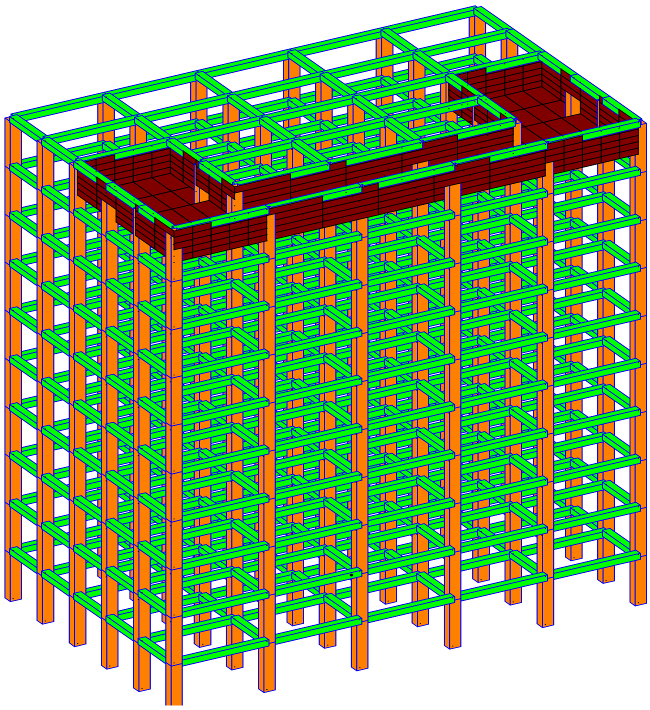


Fig. 3.3 Isometric View of the Model 3 Frame

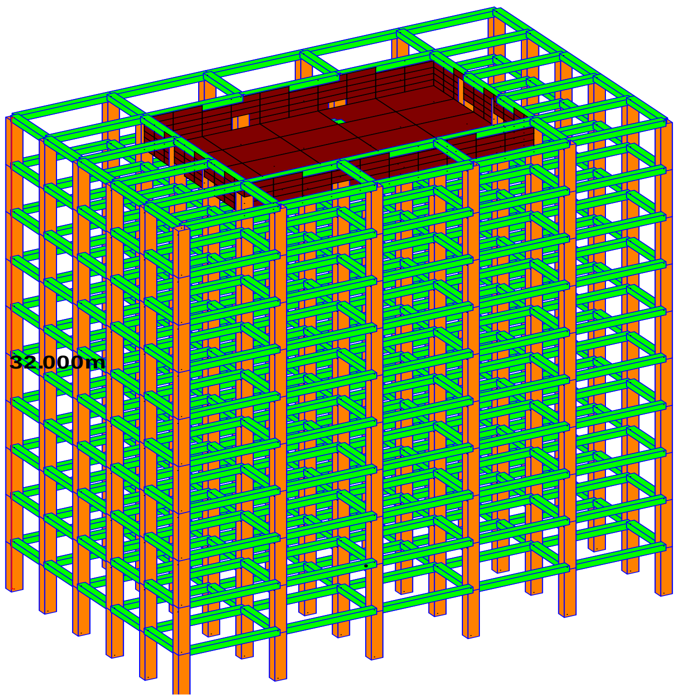


Fig. 3.4 Isometric View of the Model 4 Frame

3.3 Load Case Specification & Load Calculation for All Frames Models –

3.3.1 Primary Loads Considered for Analysis -

In STAAD Pro Software., the loads which are acts on the structure are considered in the form of primary load cases and after that load combinations of primary load cases is considered. The total number of load cases, magnitude of loads and load combinations used is same for all the four model frames. Table 3 shows the five primary load cases with their loading type, load case numbers and designated name which have been used in analysis of the frame models in Staad Pro software -

Table 3 Primary Load Cases

Load Case Number	Name	Load Type
1	DEAD LOAD	Dead Load
2	LIVE LOAD	Live Load
3	ROOF LIVE LOAD	Roof Live Load
4	DX	Seismic Load
5	DZ	Seismic Load

3.3.2 Calculation of Loads Used for All Frame Models -

The detailed calculation of the load acting on the structures of dead load, floor live load, roof live load are given below.

3.3.2.1 Load Case 1 (DEAD LOAD)

The dead load acting on a building includes self-weight of the RCC used in slab, columns, beams and hydrostatic load of water for swimming pool. Total dead load of any component depends upon its dimension and unit weight of the material used. The unit weight of the reinforced cement concrete is considered as 25 KN/m^3 according to the IS code 875 part-1. The dead load is load Case Number 1 and designated as 'DEAD LOAD' in software for all the frame models.

- **Dead Load of the Beam, Column and Surface Element for Swimming Pool -** The dead load of the frame structure containing beam, column and surface element of the swimming pool is applied to the structure by assigning self-weight load in Y direction with load factor -1.
- **Dead Load of the Slab Element-** The self-weight of slab load is applied under the category of the floor load in software, hence the calculated load is in unit KN/m^2.
  Self-Weight of Slab/Plate = (unit weight of reinforced concrete X thickness of the slab)
  = 25X 0.15
  = 3.75 KN/m²
- **Water Pressure on Base of The Swimming Pool**
  Pressure on Base of Swimming Pool= (Unit Weight of Water X Height of Swimming Pool)
  = (10 X 2.1)
  =21 KN/m2
- **Water Pressure on Wall of The Swimming Pool-** Pressure exerted on the wall of the swimming pool is assigned to wall hydrostatic type of plate load of magnitude 21 KN/m^2 assigned with to wall plate in appropriate direction depend upon the orientation of the individual plate in all four models. Distribution of the wall pressure is of trapezoidal in shape.

3.3.2.2 Load Case 2 (LIVE LOAD)

Live load includes imposed load for all the floors and considered under the category of commercial building as given in IS 875 Part -2. The live load is load case number 2 and designated as 'LIVE LOAD' in software for all the frame models.

Live load for all the floors = 4 KN/m²

3.3.2.3 Load Case 3 (ROOF LIVE LOAD)

Roof Live load is also provided according to the IS 875 Part- 2. The roof is considered flat and access is provided. The roof live load is load case no. 3 and designated as 'ROOF LIVE LOAD' in the Staad pro software for analysis of all the frame models.

Live load for roof (at Terrace) = 1.5 KN/m²

3.3.2.4 Load Case 4 & 5 [Earthquake or Seismic Load (DX & DZ)] -

Seismic or Earthquake Load is designated as DX & DZ where "D" stands for Dynamic load and X & Z represents their respective direction of action. As per IS 1893:2016, Article 7.3.1 the total seismic load is calculated by adding total dead load of the structure and appropriate percentage of floor live load. The percentage of live load to be added depends upon its magnitude as given in table 8 in IS 1893:2016. For uniformly distributed floor live load of magnitude 4 KN/m² the percentage of live load to be taken is 50%. As per the IS 1893:2016 article 7.3.2 the roof live load need not be considered while calculating the design seismic loads.

3.3.2.5 Load Combinations Used For Analysis of All Case Frames

As per IS 1893:2016, article 6.3.1.2 while designing the RCC and Prestressed concrete structure by limit state method, the following load combinations of the primary loads shall be accounted for-

- 1.5 (DL+LL)
- 1.2 (DL+LL±EL)
- 1.5 (DL±EL)
- 0.9 DL± 1.5EL

In this study Load combinations, provided in the software are defined under load case number 6 to 14 for all frame models.

3.4 Seismic Specifications Taken for the Study

Table 4 Seismic Parameters used in All Frame Models

PARTICULARS	DETAILS
Seismic Zone	Zone –IV
Seismic Intensity	Severe
Zone Factor Z	0.24
Building Frame System	Ordinary Moment Resisting Frame (OMRF)
Response Reduction Factor R	3.0
Importance Factor I	All General Buildings (I =1)
Rock/Soil Type	Medium Soil (Value = 2)
Structure Type	RC Frame Building (Value = 1)
Damping Ratio	5% (Value = 0.05)

3.5 Design Parameter Provided to All RCC Frame Cases-

The detail concrete design of all frame models is done in Staad. Pro. Software. The design parameter provide in software are kept same for all frames. Details of the provided design parameter are given the table no. 4.5

Table 5 Design Parameter Provided to All Frame Models

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%

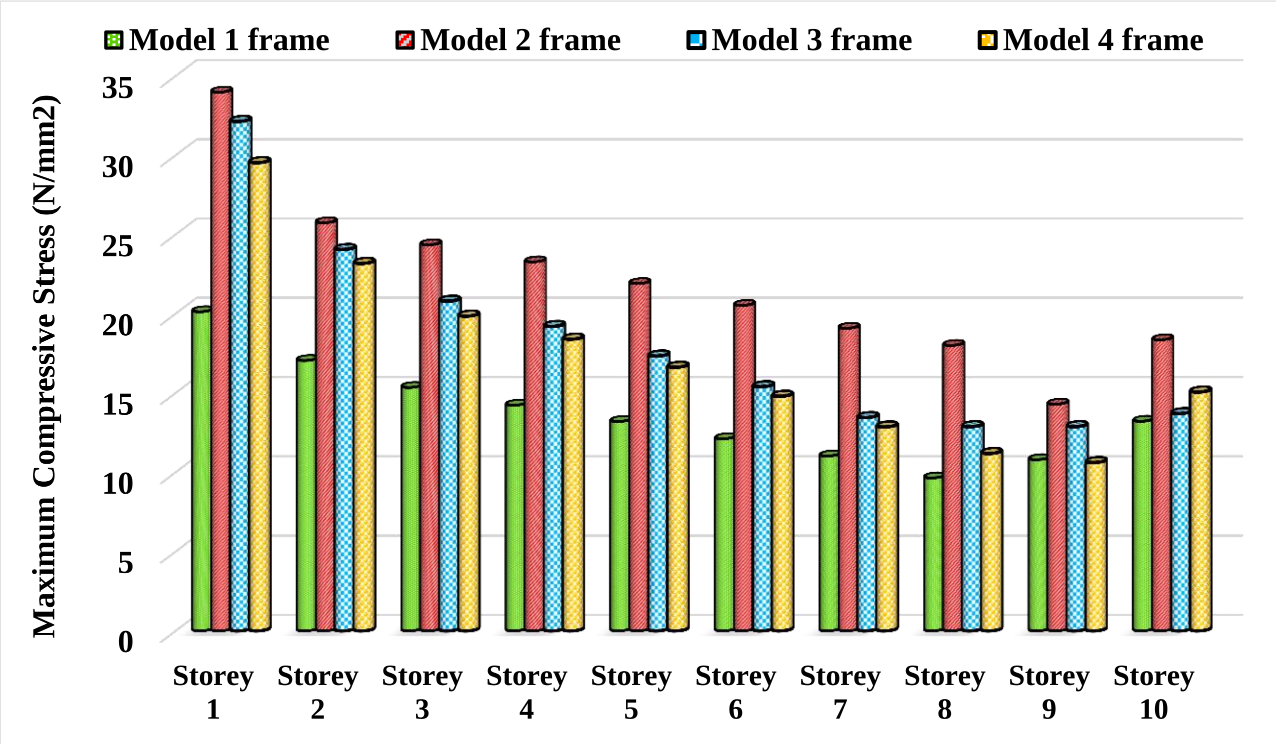
4. Results & Discussions

4.2 Comparison report

The comparison all four model frame is done on the basis of different parameters as described in 5.1. The reports of all these parameters are obtained by analyzing all five frame cases in Staad pro. V8i software

4.2.1 Comparison Report of Compressive Stress

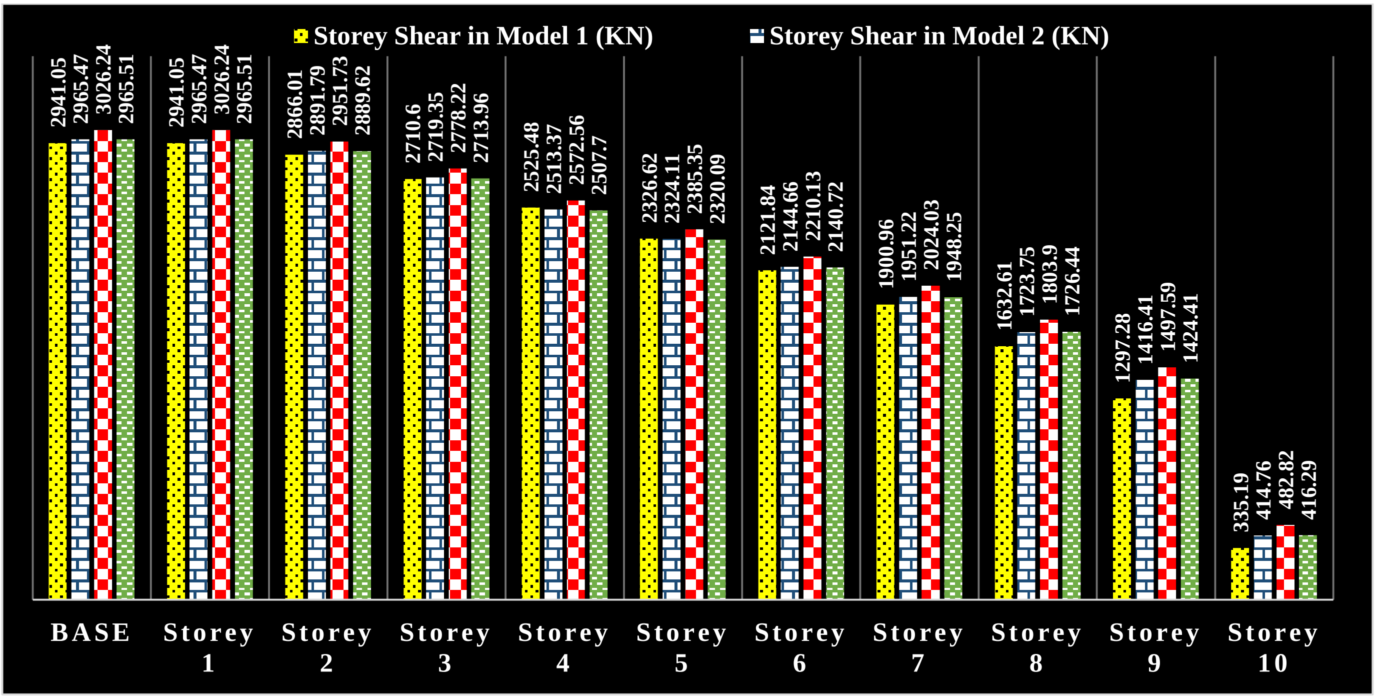
The comparison of compressive stress is shown in Table 5.21 & Graph 5.21. In this four different cases, the value of compressive stress is given by i.e. ***20.12 N/mm² (for 1-Side Swim Pool) < 29.525 N/mm² (for Center Position Swim Pool) < 32.13 N/mm² (for 3-Side Swim Pool) < 33.97 N/mm² (for 2-Side Swim Pool)*** respectively. It is very clear that the minimum value of compressive stress is shown by Model 1 frame & Model 4 frame as compare to maximum value by Model 2 & Model 3 Frame. Thus, 1-side & Center positon swim pool shows much better results in terms of compressive stress with respect to 2-Side & 3-Side Swim pool.



Graph 4.1 Comparison Report for Compressive Stress

4.2.2 Comparison of Storey Shear –

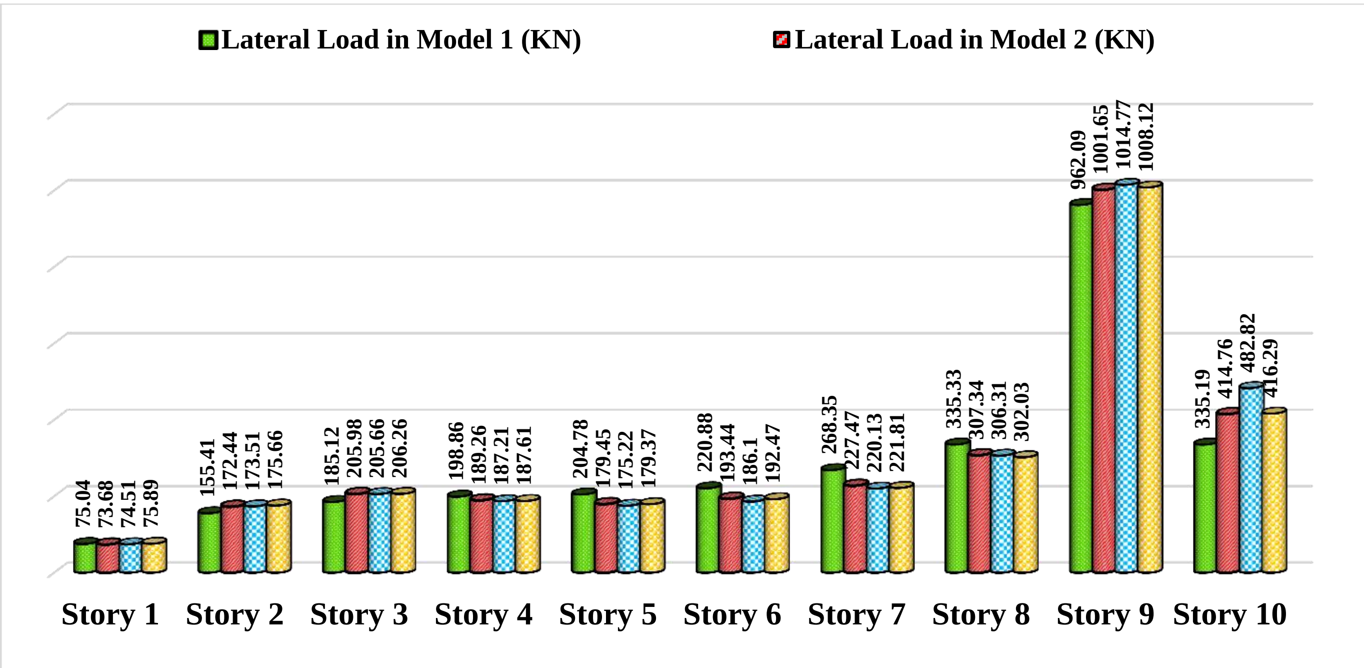
The Comparison report of Storey Shear is shown in Table 5.22 and Graph 5.22.The maximum value of Storey shear i.e. ***1297.28 KN (for 1-Side Swim Pool) < 1416.41 KN (for 2-Side Swim Pool) < 1424.41 KN (for Center Position Swim Pool) < 1497.59 KN (for 3-Side Swim Pool)*** respectively .Thus, here Model 1 frame is practically safer whereas Model 2 & 4 frames shows similar results and are better when compared with the least efficient Model 3 frame.



Graph 4.2 Comparison Report for Storey Shear

4.2.3 Comparison Report of Lateral Load

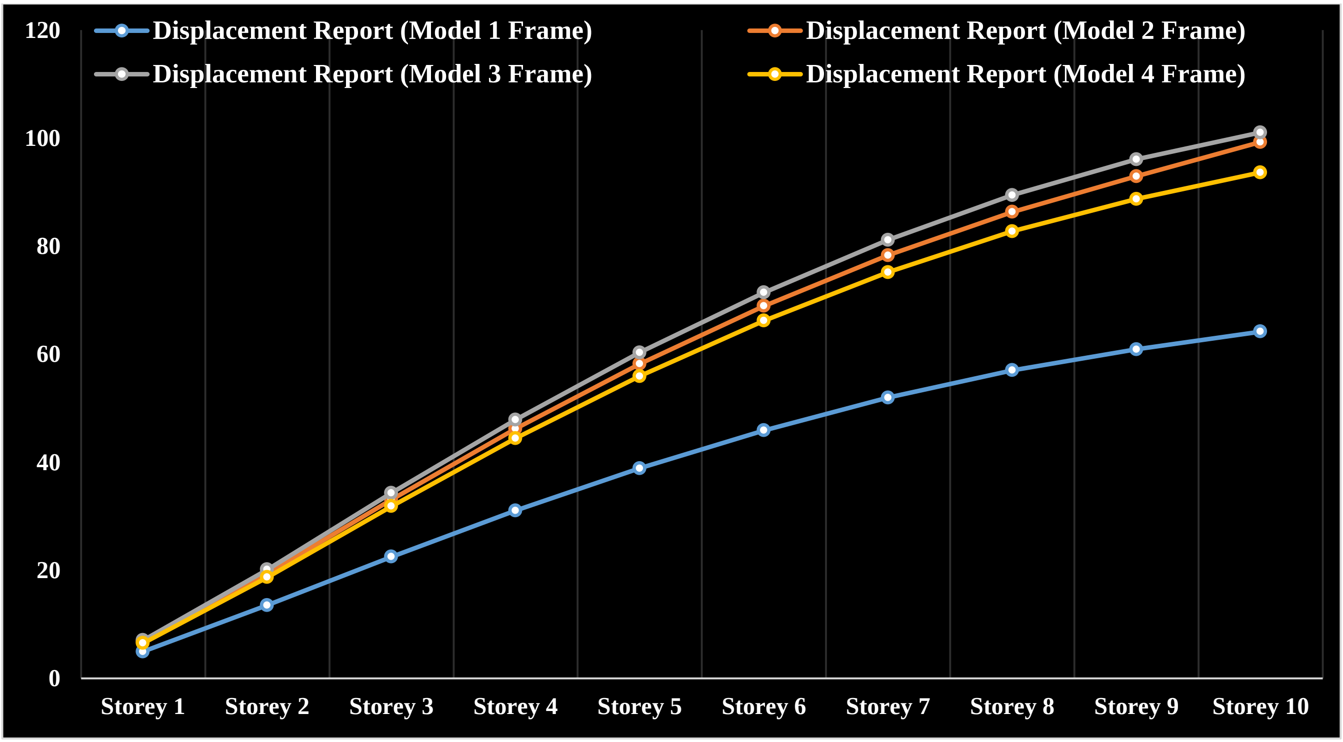
The maximum value of lateral load for the different cases are as follows ***-962.09 KN (for 1-Side Swim Pool) < 1001.65 KN (for 2-Side Swim Pool) < 1008.12 KN (for Center Position Swim Pool) < 1014.77 KN (for 3-Side Swim Pool)*** respectively. It is concluded that at ground floor, there is minimum value of lateral load due to seismic load applied is at ground floor only. Therefore, this Model 3 frame should be given special attention while designing practically and the minimum lateral load is shown by 1-Side Swim Pool. Thus, Model 1 frame is better in terms of lateral load whereas Model 2 & 4 frame are showing similar results and the vulnerable frame is Model 3 frame i.e. 3-Side Swim Pool.



Graph 4.3 Comparison Report for Lateral Load

4.2.4 Comparison Report of Storey Displacement

The report of maximum value of Storey displacement for the different cases are as follows- ***64.19 mm (Model 1 Frame) < 99.29 mm (Model 2 Frame) < 101.06 mm (Model 3 Frame) increasing continuously*** but for the case of Model 4 i.e. Center positon swim pool, the displacement value decreases ***up to 93.67 mm*** making the center swim pool very much stable as compare to 2-Side & 3-Side swim pool. ***When the swim pool Sides on the frames increases, there is increase in the displacement also increases both shows not much difference between 1-Side & Center positon swim pool thus concluding this both frames are practically safer***.



Graph 4.4 Comparison Report for Storey Displacement

5. CONCLUSION & SCOPE

The following conclusions were made after analysis of all Model frames-

1) It is been concluded that the displacement in One-Side Swimming Pool Building (64.19 mm) ***is approximately 31% less*** than Center-Position Swimming Pool Building (93.67 mm) whereas ***35 % less* than** Two-Side Swimming Pool Building (99.29 mm) & ***37 % less than*** Three-Side Swimming Pool Building (101.06 mm).It concludes that as ***the position of swimming pool changes, there is change in displacement. One-side Swimming pool Building shows better results whereas the other Case Model shows less variation when compared with each other. (****Ref. Graph 4.4)*
2) The analysis demonstrates that the lateral load in Model 1 frame shows best performance and the second best results were shown by Model 2 & 4 frame i.e. (two side & center position pool). Hence, concludes as ***the Sides of Pool increases, there is increase in Lateral Load for Model 1, Model 2 & Model 4 frames. The Vulnerable Building with respect to Lateral load is Model 3 frame*** which has to given special attention while designing practically. ***(****Ref. Graph 4.3)*
3) As from the results observed, the maximum compressive stress is in the bottom most storey on each model case. But as per the comparative analysis of different cases frames, the stess in One-Side Swimming Pool Building (20.12 N/mm^2) ***is approximately 41% less than*** Two-Side Swimming Pool Building (33.978 N/mm^2) , ***whereas 37% less than*** Three-Side Swimming Pool Building (32.13 N/mm^2) & ***approximately 31% less than*** Center-Position Swimming Pool Building (29.525 N/mm^2).Hence, the Model 1 & 4 shows lesser stress as compared to Model 2& 3 Frames. Making Model 1 frame much practically safer.

4) According to the report analysis , the maximum Storey shear in One-Side , Two-Side & Center-Position Swimming Pool Building shows very much similar results which are ***approximately 2% less than*** three-Side Swimming Pool Building . Overall Model 3 frame is vulnerable in terms of Storey shear and cases i.e. Model 1, 2 & 4 are practically safer.
5) After all analysis, We can say that there is a much variation in results as the ***positon of swimming pool in elevation plays an important role*** in the designing of the building and here it's been concluded that the single side or center positon pool comprises the best position for the regular buildings.

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