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# "Dynamic Analysis of Rigid Frame having Elevated Swimming Pool at Different Location of Roof Storey"

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***ABSTRACT -*** High-Rise Building are considered between 23 m to 150 m high. Buildings giant than 150 m are considered as Skyscrapers. Hence, the utmost critical issue for the structural engineer is the height of the building. As the high-rise structures has many technical issues but the most susceptible issues are considered to be seismic and wind forces acting in lateral directions. This project work symbolizes the study of behavior of swimming pool as per the considered position of pool at the terrace floor under Dynamic Response Spectrum Analysis (RSA) Using ETABS. 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. The main target is to achieve the effective position of swimming pool which can be applied in the high-rise building.

***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. 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.

### 1.1 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 Effect of Earthquake to a Swimming Pool on ground level*

*Fig 2 Earthquakes Impact In Pools Flooring*

**2. Reviews**

**Chokshi Shreya H., Dalal S.P. (2015)** has investigated the hydrostatic and the hydrodynamic behavior of water in the swimming pool when subjected to earthquake forces. The main object of this paper is to compare the static and dynamic analysis of the building and the study of hydrodynamic effects.

**More Amol R., Prof. Kale R.S. (2017)** has investigated the effects of various Mass and column stiffness Irregularity on the seismic response of a structure. The objective of the project is to carry out Response spectrum analysis (RSA) of vertically Mass and column stiffness Irregular RC building frames. Comparison of the results of analysis of irregular structures with regular structure will be done. Comparison of mass irregular buildings having different column stiffness will also be done. The scope of the project also includes the evaluation of response of structures for axial force, base shear, time period, bending moments, storey drift and storey displacement.

**Mr. Khan Pathan Irfan, Dr.Dhamge N.R (2016)** has studied that multistoried buildings are designed as per Earthquake code IS: 1893-1984. Earthquake causes different shaking intensities at different locations and the damage induced in buildings at these locations is also different. There is necessary to construct a structure which is earthquake resistance at a particular level of intensity of shaking a structure. But during Bhuj earthquake, in Ahmedabad two buildings which were designed as per IS:1893-1984 and were found to be seriously damaged due to mass irregularity as a swimming pool was located at the 10th floor. Here excess mass leads to increase in lateral inertia forces, reduced ductility of vertical load resisting elements and increased propensity towards collapse. Excess mass on higher floors produce more unfavorable effects than those at lower floors. Vertical Mass irregularity is an important factor which is to be considered while designing multistoried building. This paper highlights the effect of mass irregularity on different floor in RCC buildings with as RSA analysis using STAAD-Pro V8i software. In this project work seismic analysis of RCC buildings with mass irregularity at different floor level are carried out. The Model Considered was of G+10 having swimming pool on 3rd, 6th and 9th Floor. Maximum Base Shear along X and Z directions is also calculated. Lateral Displacements & Storey Drift is also evaluated for X and Z directions. Axial Forces, Torsion & Bending Moment are calculated for six different columns.

**Davidson Shilpa Sara, Kumar Aswathy S (2018)**, has studied that the ever-increasing height of the high-rise structure poses considerable challenges for structural engineers and researchers. Among the many difficult technical problems involved in design, the effects of wind and earthquakes on these structures are definitely the most critical issues. The control of structural vibrations produced by earthquake or wind can be done by various means. Tuned mass dampers (TMD) have been widely used for vibration control in mechanical engineering systems. This paper presents the study carried out to find the feasibility of implementing swimming pool as passive TMD using SAP2000. Multi-storey concrete structures without swimming pool and with swimming pool were taken for the study. The swimming pool was placed at the roof. The mass and frequency of the swimming pool including its water were tuned to the optimized values. The behavior of the pool was studied under various conditions, such as different shape. The results show if the pool is tuned properly it can reduce the peak response of structures subjected to seismic forces.

**Reddy V. Mallikharjuna, S. Kumar Raja Ravindra (2018)** has studied that Water tank is a structure used to store water for supplying to households as drinking purpose, for industries as a coolant and irrigational water for agricultural farming in some areas. Water tanks are classified on bases of their shapes and position of structure. Elevated water tanks are constructed in order to provide required head so that the water will flow under the influence of gravity the construction practice of water tanks is as old as civilized man. The water tanks project have a great priority as it serves drinking water for huge population from major metropolitan cities to the small population living in towns and villages. This project is an application economy of the tank as an objective function with the properties of that optimization method to the structural Analysis and design of circular tank, water depth, and unit weight of water and tank floor slab thickness, as design elevated water tanks, considering the total tank that are tank capacity, width and length. To considering dead load, live load, seismic load a computer program has been developed to solve numerical examples. The project is strictly in accordance with IS 456:2000 (plain and reinforced concrete), SP 16 (Design Aids for Reinforced Concrete), IS 801 (Design of cold formed steel) load calculations are done using STAAD Pro and Manual calculations are done through known data. The aim of the project is to apply seismic loading for different zones - II III, IV, and V and assess the varying steel and concrete in seismic zones.

### 2.2 Objective of this Study

The following below are objectives for the seismic analysis. Firstly, to model the RCC frames having Swimming Pool on the terrace of each frame i.e., with different position. To analyze and investigate model frame on the basis of different location of swimming pool.

## 3. Methodology

### 3.1 General Considerations for the Analysis of All RCC Frames

In this paper, response spectrum method of seismic analysis is used to investigate the responses to quantify the mass irregularity factor and stiffness coefficient factor for the RCC frames of 16.5-meter height provided with different location of rectangular swimming pool at terrace.

***Table 1 General Consideration for the Frame Study***

| Description of Swimming Pool | Annotations |
|---|---|
| **Building without elevated Swimming Pool** | **WSP** |
| **Building with swimming pool at the center of the terrace** | **SW1** |
| **Building with swimming pool at the right upper corner of the terrace** | **SW2** |
| **Building with swimming pool at the eccentric point having lower left coordinate (5,24)** | **SW3** |
| **Building with swimming pool at the eccentric point having lower left coordinate (25,28)** | **SW4** |
| **Building with Multi-Swimming pool** | **SW5** |

### 3.2 Detail of the Structural Properties Used for All Models

The detail description of physical structural properties and material properties of all RCC frame used in the study are given below in the table 2.

*Table 2 Structural Properties Used for all Model Frames*

| Particular Of Items | Properties |
|---|---|
| Total Built-Up Area of frame | 1600 sq. meter |
| Plan Area of Swimming Pool | 80 sq. meter |
| Number of Stories | 5 |
| Floor Height | 3.3 m, 4.3 m |
| Depth of Swimming Pool | 3.3 meter |
| Beam Size | 230 mm X 550 mm |
| Column Size | 450 mm X 450 mm |
| Slab Thickness | 150 mm |
| Swimming Pool Slab Thickness | 150 mm |
| Swimming Pool Vertical Wall Thickness | 250 mm |

### 3.2.1 Building Models in the Study

Figure 3 shows the plan view of the model without swimming pool. The plan area of the swimming pool is 80 sq. meter height of the pool is 3.3 meter.

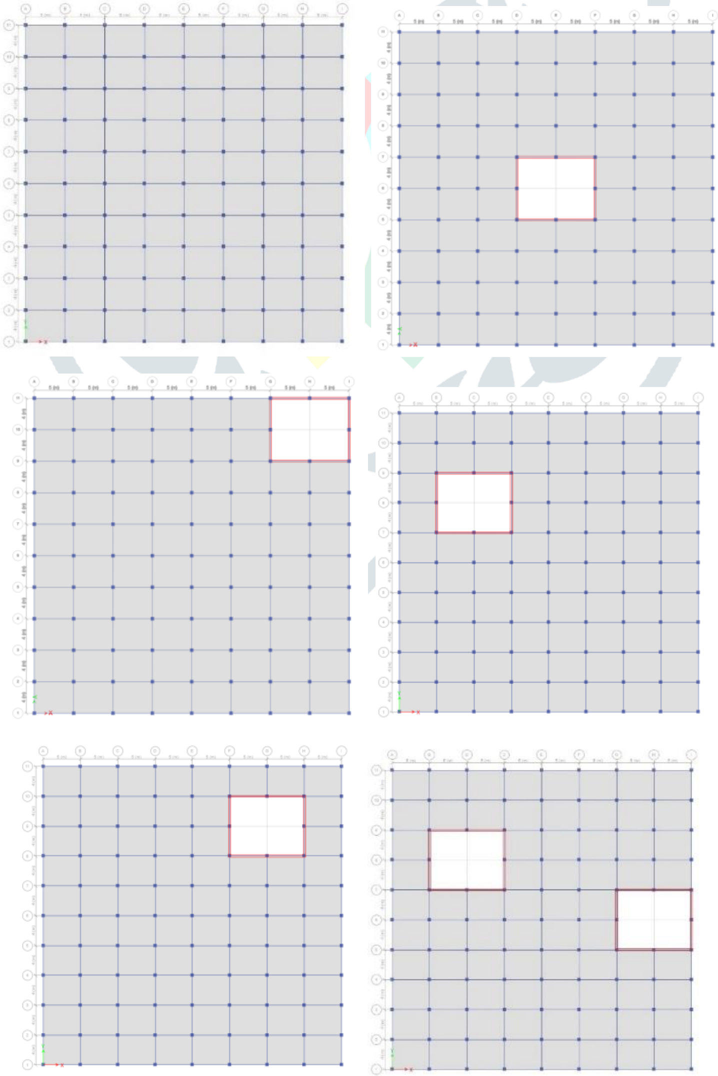


*Fig 3 Plan View of Building Models*

Total capacity of the swimming pool is 264 cubic meters. Figure 3 shows the view of all model frame. Columns are of square shape of size 450 X 450 mm, is kept same in the entire height of the building. Figure 3 shows the plan of Building with swimming pool at the eccentric distance having coordinate ((5,24,16.5), (15,32,16.5)) from the origin denoted as SW3 model and the figure 3 shows the plan of Building with swimming pool at the eccentric distance having coordinate ((25,28,16.5), (35,36,16.5)) from the origin denoted as SW4 model having similar plan area of the swimming pool i.e., 80 $m^2$. Figure 3 shows the plan of Building with swimming pool at the eccentric distance having one pool at coordinate ((5,24,16.5), (15,32,16.5)) from the origin and the other pool is located at ((30,16,16.5), (40,24,16.5)) coordinate denoted by SW5 model.

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

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

#### 3.3.1 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 material grade and the sectional property to the building elements.
- **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/$m^2$***

- **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 3.3)*

*=**33 KN/m2***

- **Water Pressure on Wall of the Swimming Pool**

Distribution of the wall pressure is of trapezoidal in shape. Water Pressure exerted in a tank of height 3.3 m. Also, assumed that the water is filled in the tank to the brim. The density of water is 1000 Kg/m3. The acceleration due to gravity (g) = 9.8 m/sec2. Hence, the *Pressure at the bottom of the vertical wall* = 1000 * 9.8* 3.3 = 32340 Kg/m/sec2 = 32340 N/m2 = 32.34 KN/m2.

#### 3.3.2 Live Load

The Live load for all the floors is 4 KN/$m^2$. Live load for roof (at Terrace) = 1.5 KN/$m^2$

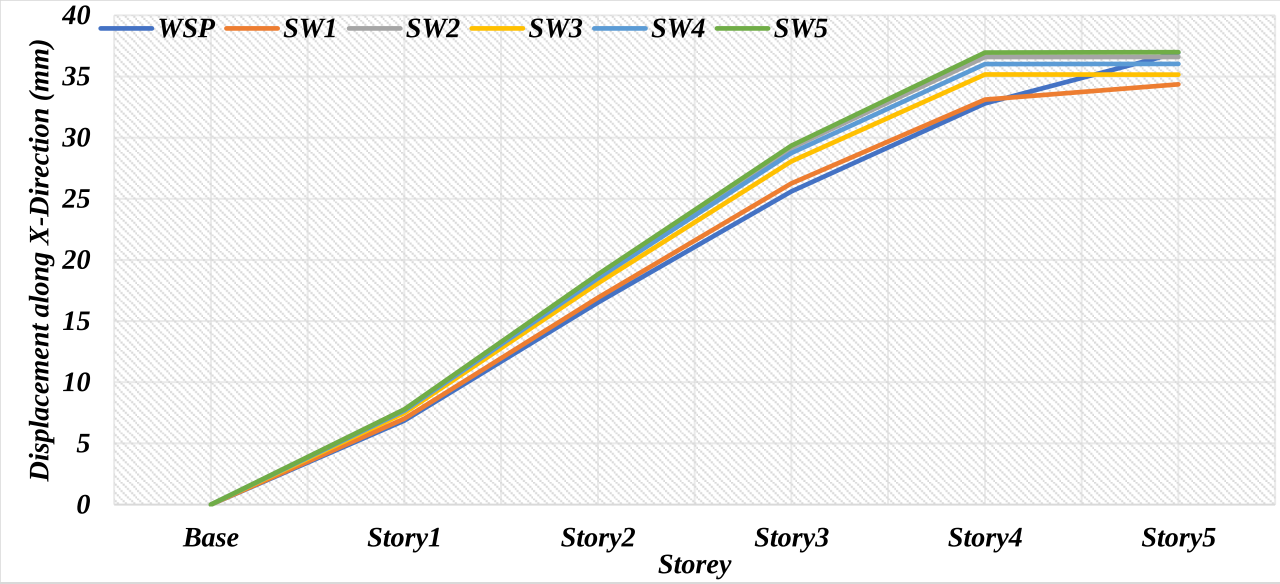
***Table 3 Seismic Parameters used in All Frame Models***

| PARTICULARS | DETAILS |
|---|---|
| Seismic Zone | Zone –V |
| Seismic Intensity | Severe |
| Zone Factor Z | 0.36 |
| 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)** |

**4.1 Comparison Report of Storey Displacement**

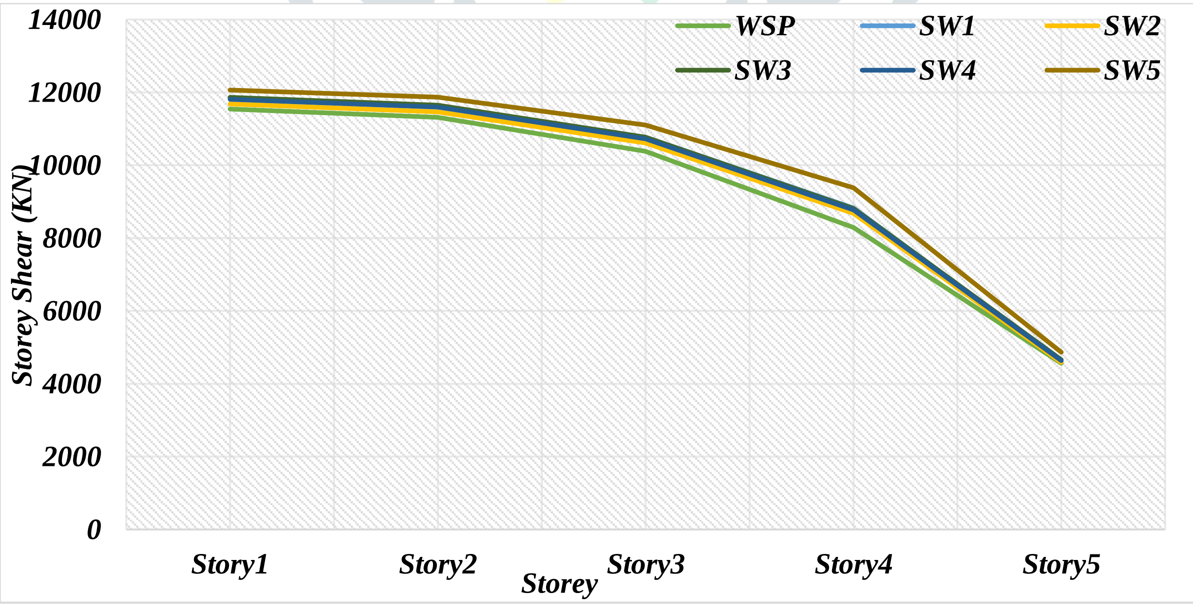
The report of maximum value of Storey displacement along x-axis for the different cases are as follows- ***34.35 mm (SW1 Frame) < 35.15 mm (SW3 Frame) < 36.02 mm (SW4 Frame) < 36.59 mm (SW2 Frame) < 36.95 mm (WSP Frame) < 36.99 mm (SW5 Frame) increasing continuously*** but it is least for the SW1 model frame which concludes that ***the swim pool location play major role in the lateral stability of the frames increases.***




***Graph 1 Comparison Report for Displacement along X-Axis (All Values in mm)***

**4.2 Comparison of Storey Shear**

The maximum value of Storey shear i.e., ***12064 KN (SW5 Frame) < 11863 KN (SW3 Frame) < 11846 KN (SW1 Frame) < 11809 KN (SW4 Frame) < 11681 KN (SW2 Frame) < 11543 KN (WSP Frame)*** respectively. Thus, here WSP frame is practically safer and are better when compared with the least efficient SW3 frame.




***Graph 2 Comparison Report for Storey Shear along Y-Axis (All Values in KN)***

**5. Conclusions**

*1)* It is been concluded that the displacement in building with Swimming pool at the center ***is approximately 7% less*** than the building with no swimming pool at the terrace. Displacement in Building with multi-swimming pool (36.989 mm) is showing similar with the building with SP at the eccentric distance. It concludes that as ***the position of swimming pool changes, there***

***is change in displacement. SW1 shows better results whereas the other Case Models. There is no variation when swimming pool placed along the height of the building in both principal axes.***

2) According to the report analysis, the maximum Storey shear is seen in SW5 which are ***approximately 22.4% less than*** WSP model. Overall SW5 need special attention while designing in terms of Storey shear.

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