IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"Investigation of Rigid Frame having Elevated Swimming Pool at Different Height of Building"

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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 and identification of the existence of stiffness irregularity if swimming pool is positioned at different height of Building Using ETABS. 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, Stiffness, 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. 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.

1.2 Methods of Seismic Analysis

The method of seismic analysis to analyze the structure are classified on the basis the external loading action, the behavior of structural material and type of structural modal selected. In bureau of Indian Standards, these four methods of analysis are defined-

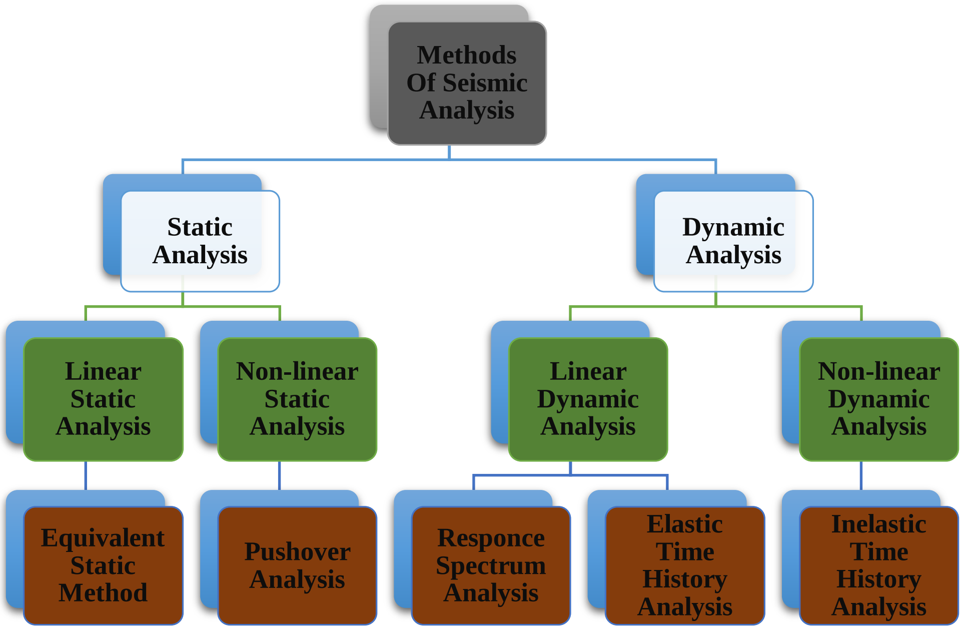


Fig.1 Flow Chart of Classification of Methods Seismic Analysis

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. 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

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 along the height of building. To validate the presence of stiffness irregularity.

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 1st storey	**SW6**
Building with Swimming Pool at the center of 2nd storey	**SW7**
Building with Swimming Pool at the center of 3rd storey	**SW8**

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.

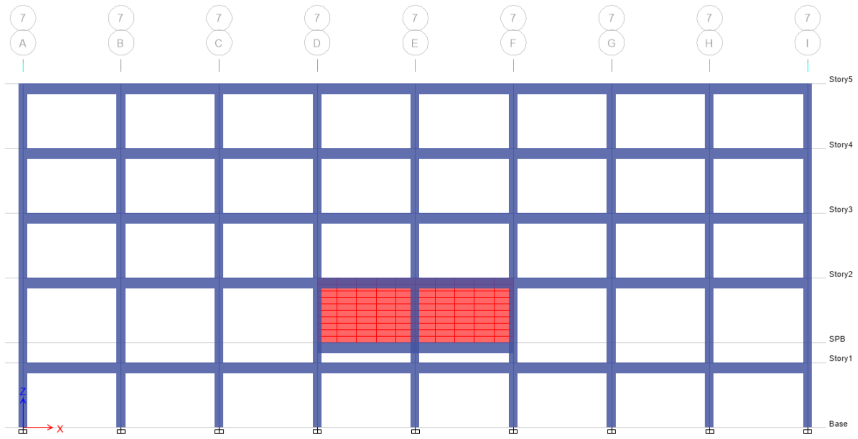
Table 2 Structural Properties Used for all Model Frames

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**

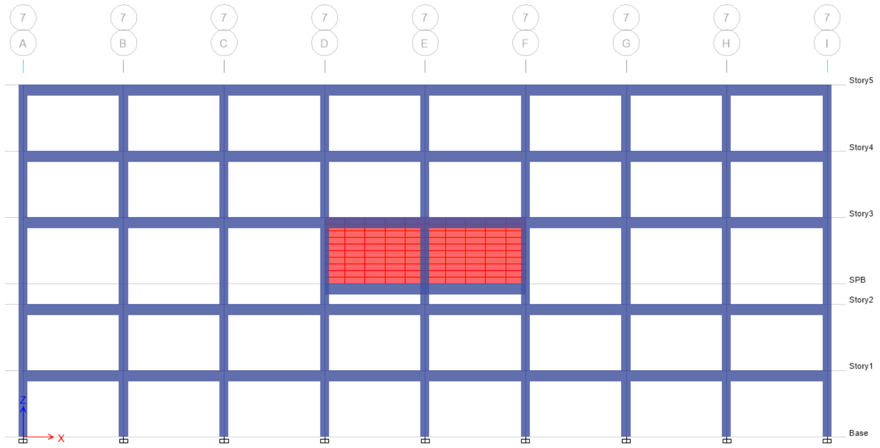
Slab Thickness	**150 mm**
Swimming Pool Slab Thickness	**150 mm**
Swimming Pool Vertical Wall Thickness	**250 mm**

3.3 Building Model Varying with location of swimming pool along the height

In this category three models with elevated swimming pool placed at 1st , 2nd and 3rd storey need to be examined for the mass irregularity factor. Figure 2 (a) shows the elevation of Building with swimming pool placed at 3.3 m height denoted by SW6. Figure 2 (b) shows the elevation of Building with swimming pool placed at 6.6 m height denoted by SW7. Figure 2 (c) shows the elevation of Building with swimming pool placed at 9.9 m height denoted by SW8.

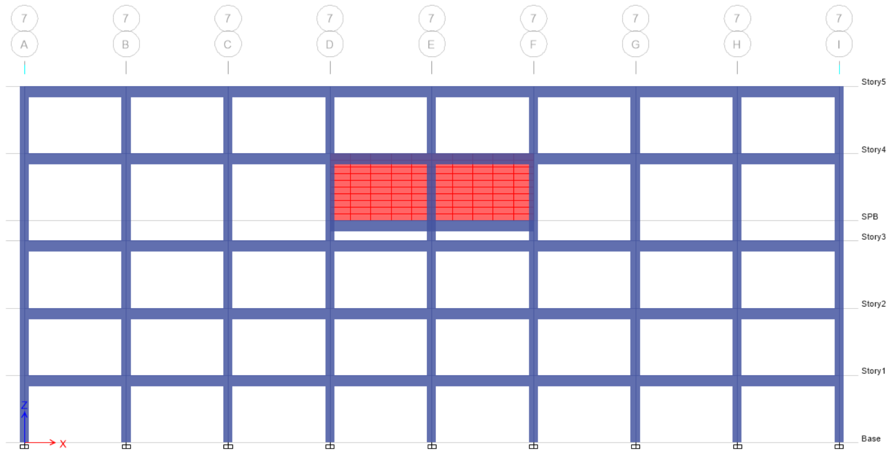


(a)



(b)

The red color shown in the figure 2 is the vertical wall of swimming pool which is of thickness 250 mm using material of M30 grade and Fe500 grade steel.



(c)

Fig. 2 Different Cases of Models (a) At 1st Storey (b) At 2nd Storey (c) At 3rd Storey

3.4 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.

3.4.1 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. 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/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 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.

3.4.2 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 Stiffness

The stiffness along X-axis is higher for multi-swimming pool case where it is least for WSP model frame.

Table 4 Comparison Report for Stiffness along X-Axis (All Values in KN/m)

Story	Story1	Story2	Story3	Story4	Story5
Output Case	RSAX	RSAX	RSAX	RSAX	RSAX
WSP	1745699.42	1206646.87	1165685.27	1159029.71	1075002.64
SW1	1745555.95	1206973.04	1174911.12	1284903.64	3746484.10
SW2	1615070.6	1116798.99	1087320.456	1222999.85	18280399.3
SW3	1685585.8	1166059.161	1136665.436	1277526.426	37137041.15
SW4	1659889.1	1148510.209	1119805.028	1258758.745	25324271.8
SW5	1662532.3	1149420.037	1121914.445	1290558.325	125276954
SW6	2379444.9	119163406	1549299.265	1218578.114	1095992.956
SW7	1792559.4	1485608.767	106726663	1683827.961	1141450.804
SW8	1736944.8	1216744.168	1372965.188	94864604.87	1849720.599

4.2 Evaluation of Stiffness or Soft Storey Irregularity

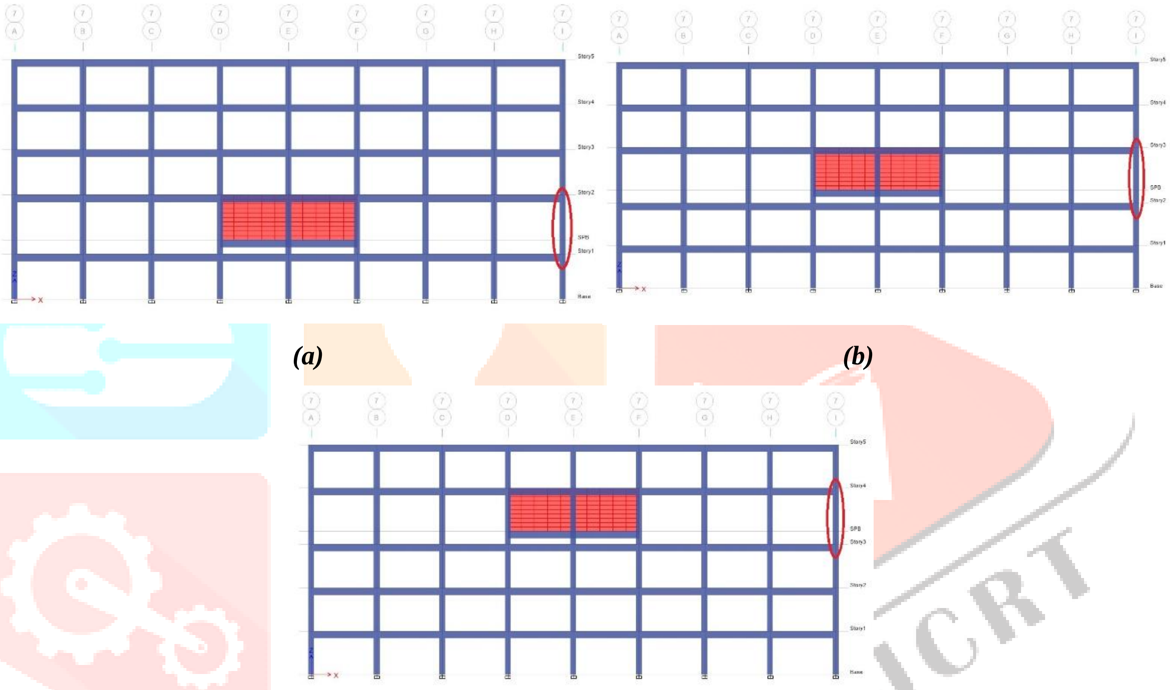
As per IS1893:2002/2016, the stiffness irregularity exists when the lateral stiffness at any storey is less than 70 % than the storey below. As there are cases in which swimming pool is along the height of building hence there is chances of stiffness irregularity which is need to be investigated for avoid future vulnerability.

i.e., Stiffness Irregularity, if $K_i/K_{i+1} < 0.7$

Table 5 Check for Stiffness Irregularity factor

Story	K_i/K_{i+1} for WSP	K_i/K_{i+1} for SW1	K_i/K_{i+1} for SW2	K_i/K_{i+1} for SW3	K_i/K_{i+1} for SW4	K_i/K_{i+1} for SW5	K_i/K_{i+1} for SW6	K_i/K_{i+1} for SW7	K_i/K_{i+1} for SW8
Story5	-	-	-	-	-	-	-	-	-
Story4	1.08	0.34	0.69	0.62	0.59	0.65	1.11	1.83	1.44
Story3	1.01	0.91	0.89	0.89	0.89	0.87	1.63	1.32	0.46
Story2	1.04	1.03	1.03	1.03	1.03	1.02	1.40	0.50	0.94
Story1	1.45	1.45	1.45	1.45	1.45	1.45	0.76	1.31	1.43

WSP, SW6 model frames are only cases which are not having stiffness irregularity whereas rest all cases are under stiffness or soft storey irregularity as the ratio is below 0.7 as per IS 1893:2002/2016. All the red marking in the table shows the stiffness irregularity.



(a) ***(b)*** ***(c)***

Fig. 3 Factor Responsible for Stiffness Irregularity (a) 1st storey (b) 2nd Storey (c) 3rd Storey

The red marking in figure above along with the tabulation result shows that due to increase in length of vertical element from 3.3 m to 4.3 m , thus there is a decrease in stiffness.

5. Conclusions

The trial cases are also evaluated for stiffness irregularity. The model cases WSP model is showing the ratio of stiffness as above 0.70 whereas the model such as SW1, SW2, SW3, SW4, SW5, SW6, SW7, SW8 are having stiffness factor below 0.70. This concludes that those cases whose stiffness is below 0.70 need careful analysis and designing.

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