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Soil Structure Interaction of R.C. Building with Basement Resting on Pile Raft Foundation

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Abstract: Historically, Basements or underground stories were built in a castle to use as a dunged on oar store room. However, in modern construction, the restrain to go deeper below the grade level in term so basements which can be utilized for parking, shopping mall or combination of both.

In such cases, dynamic soil properties have a significant effect of activating dynamic soil structure interaction phenomena on during earthquake. Here in present study an effort is made to study the behavior of a building by varying number so basements considering dynamic soil structure interaction. Issues like considering higher frequency modes, influence zone to be considered for dynamic soil structure interaction, behavior of building with basements under different water level conditions for two different types of layered soil and their comparison with fixed based structure is deal with. It is observed that dynamic soil structure interaction can significant change the behavior of the building and hence it is recommended to perform dynamic soil structure interaction for building with multiple basements. In addition, some important recommendations are provided at the end to serve as a guide for researchers and practicing engineers.

Keywords: soil structure interaction, multiple underground stories, basements, Non-linear direct integration time history, layered soil, clayey soil

I. INTRODUCTION

A. Present Scenario

In present scenario, there is a trend to go deeper below the grade level in terms of basements which can be utilized for parking, shopping malls or a combination of both. In such cases, the response of soil influences the motion of the structure and response of the structure influences motion of the soil which is known as soil structure interaction. As the structure and the soil are prevented to behave independently by the interaction, the convention a non-interaction analysis considering the base of the superstructure as fixed and the substructure designed to resist the seismic earth pressure in addition to seismic base shear and momentum and from the super structure results in either costly run safe design.

B. Need of the study

Under the Earthquake, in addition to the inertial interaction, building with basement may create kinematic interaction which needs to be evaluated. The behavior of high rise building with backstay effect may be different in presence and absence of soil which needs to be incorporated. Present methodology does not consider the resistance of side soil which seems logical but not considering the effect caused by shear wave in absence of soil resistance may prove dangerous under seismic event.

The performance of high rise building with basement resting on pile - raft foundation under seismic excitation considering soil structure interaction.

C. Aim of the study

To study behaviour of High Rise building with basements considering soil structure interaction.

D. Objective of the study

To study the behavior of 30 story RC moment frame structural wall system building by varying basements based on IS 1893-2016 and IS 16700-2017.

To evaluate the dynamic soil properties, soil structure interactions performed by direct method for soft soil and medium soil.

II. LITERATURE REVIEW

A. Overview

In this chapter, review of literature is presented for following:
Study the seismic behavior of underground structures.
Study the effect of concrete diaphragm wall founder ground structures.
Study the soil structure interaction phenomenon.
Study the seismic performance of buildings with basements.

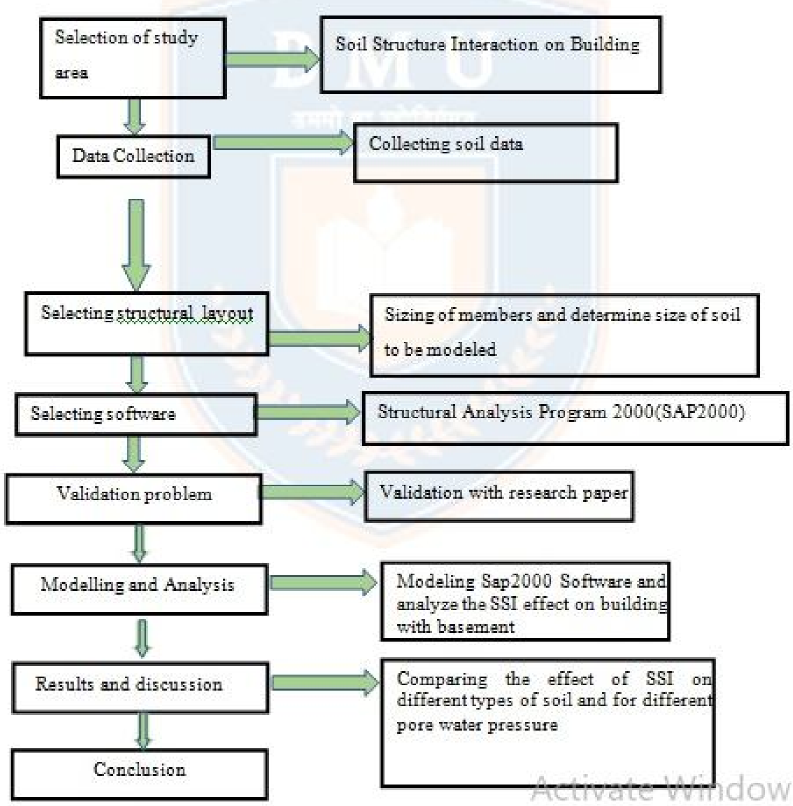
(1)Title: A study on the effects of piled-raft foundations on the seismic response of a high rise building resting on clayey soil,Soil Dynamics and Earthquake Engineering Publication Year:21 March 2021
Author: Hamid Reza Bolouri Bazz, Ali Akhtarpour, Abbas Karamodin Main aim of this journal is to find the behavior of a super structure with pile raft foundation in different cases which shows a deficiency in the general belief of the response of the structure.

(2)Title: Soil–basement interaction effects on the seismic response of tall buildings with basement Levels Publication Journal: Engineering Structures Publication Year:25 May 2022
Author: Francisco J. Pinto, Christian Ledezma, Jose A. Abell, Rodrigo Astroza, Shideh Dashti
The need to build tall buildings has been increasing worldwide, creating new challenges in Earthquake engineering and design. Many of the current analysis methods cannot be extrapolated beyond the definition under which they were established. Prior studies and existing seismic design guidelines have indicated that the current fixed-base hypothesis for evaluating the seismic response of structures is not sufficient to properly represent the boundary conditions and behaviour of tall buildings with basement levels. Studies of soil-structure interaction (SSI) for tall buildings have, however, typically been inconclusive.

III.METHODOLOGY

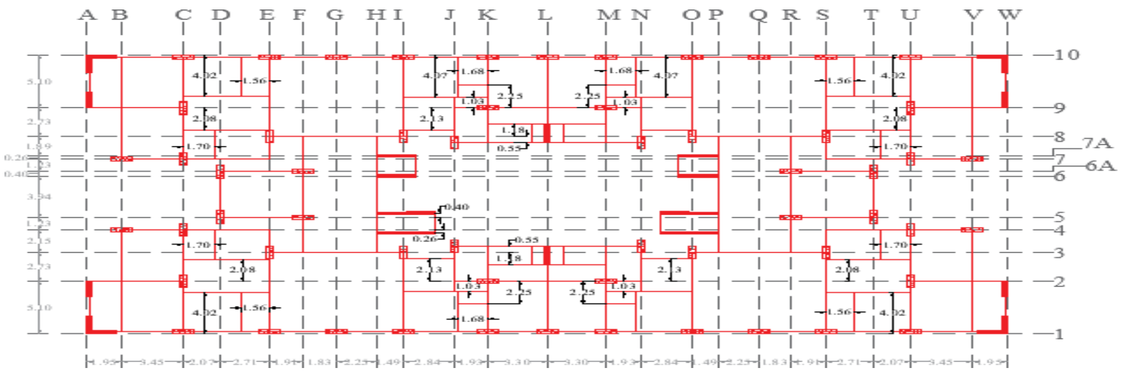
A. Flow Chart

This chapter discusses the flow of whole dissertation work. The work shows in different steps, starting from creating the geometry and ending with the results. The flowchart which illustrates these steps

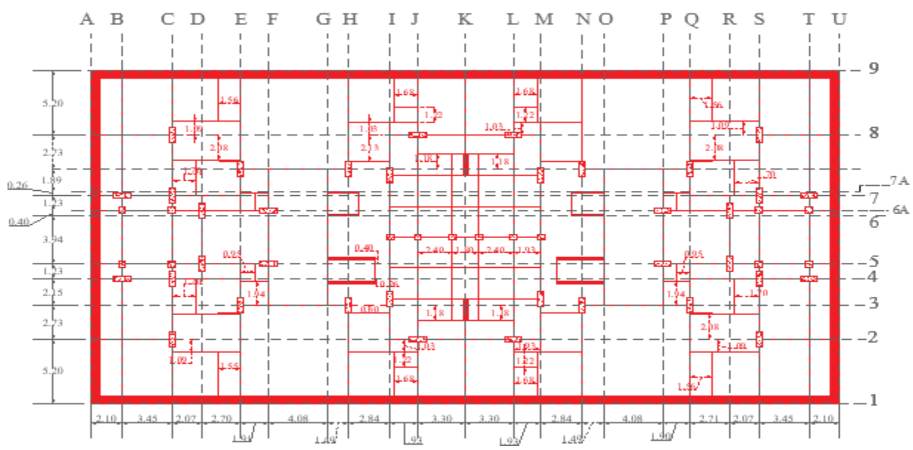


B. Structural Layout

A G+30 storey building having total height of 91m having structural layout as showing figure 3.4 is considered for study



Structural layout (a) typical stories



Structural layout (b) Basement floor

IV. VALIDATION

The validation of SAP 2000 software is carried out with the research conducted by B.R.Jayalekshmi & H.K.Chinmayion “Effect of soil stiffness on seismic response of reinforced concrete buildings with shear walls” using LS-DYNA software. The software is validated for fixed base condition and as well as for soil structure interaction by linear time history analysis.

A. Plan of Building Frame

The building withG+3 story of the plan shown below is validated

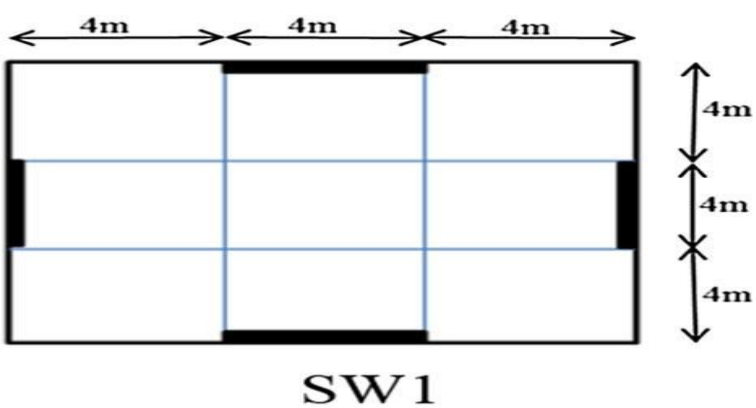


Figure 4.1 Plan of building frame

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1) Dimensions of components of building frame

Table 4.1 Dimensions of components of building frame

Columns(m)	Beams(m)	Shear wall thickness(m)	Floors lab(m)	Raft foundation Slab (m)
0.32 x 0.32	0.23 x 0.23	0.15	0.15	0.3

2) Details of soil parameter

Table 4.2 Details of soil parameter

Soil type	Shear wave velocity (Vs)(m/s)	Poisson's ratio	Unit weight (KN/m3)
Rock	1200	0.3	22

3) Details of soil to be modelled

Table 4.3Details of soil to be modelled

Width of soil mass beyond raft	Depth of soil below the raft	Projection of Raft
1.5 x B	2 x B	1m on all sides
Where B is the width of Raft		

4) Modelling of structure as fixed base

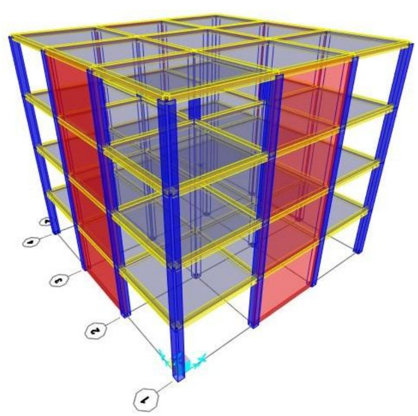


Figure 4.2 Fixed base model for validation

5) Defining time history function

The artificial time history as defined in the research paper is defined in SAP 2000

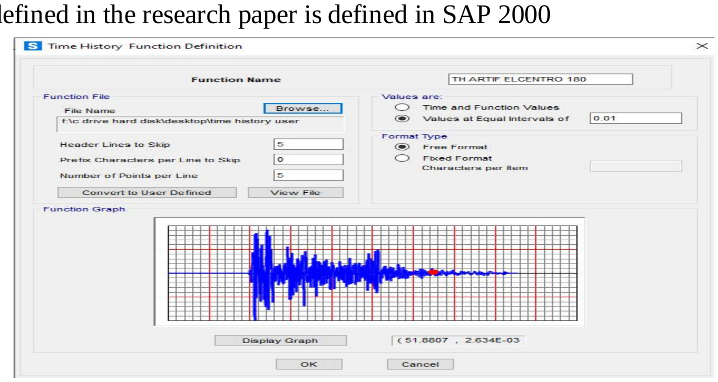


Figure 4.3 Time history function.

6) Result comparison

Table 4.4 Result comparison

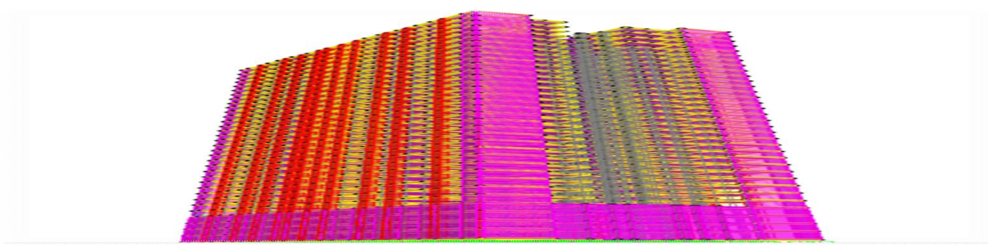
Data Type	Software LS-DYNA		Software SAP2000		Percentage Error (%)
	Fixed base	SSI	Fixed base	SSI	
Natural period (seconds)	0.2 to 0.25	0.2 to 0.25	0.214	0.223	0.8
Roof deflection (m)	0.03 to 0.032	0.032 to 0.035	0.0318	0.033	1.5
Base shear/weight	0.15	0.025 to 0.03	0.15	0.03	9

According to the results summarized in tables above, the natural period in LS-DYNA Software
For Fixed base is in between 0.2 to 0.25 and for SSI is in between 0.2 to 0.25 there for percentage
Error is 0.8% For Roof deflection percentage error is 1.5 % and For Base shear/weight is 9%.
Hence, The Validation Comparison Results is approximately equal For LS-AYNA and SAP2000 Software.

V. MODELLING

Modeling for soil structure interaction is carried out for 3 and 4 basement floors using general purpose finite element software SAP 2000. The results of soil structure interaction are compared with fixed base model.

A. *Modeling for fix base*



(Figure 5.1.1) 3DModeling in SAP2000

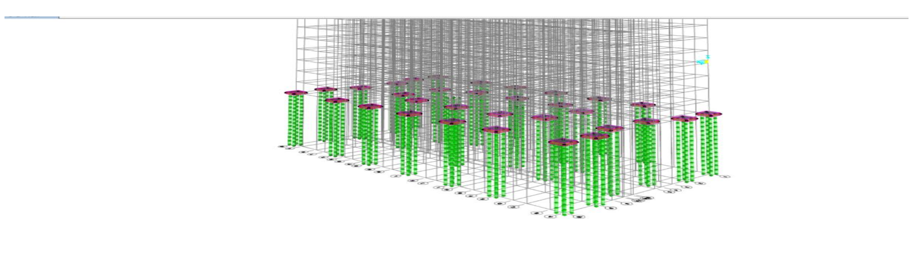


Figure 5.1.2 Pile Raft foundation in SAP2000

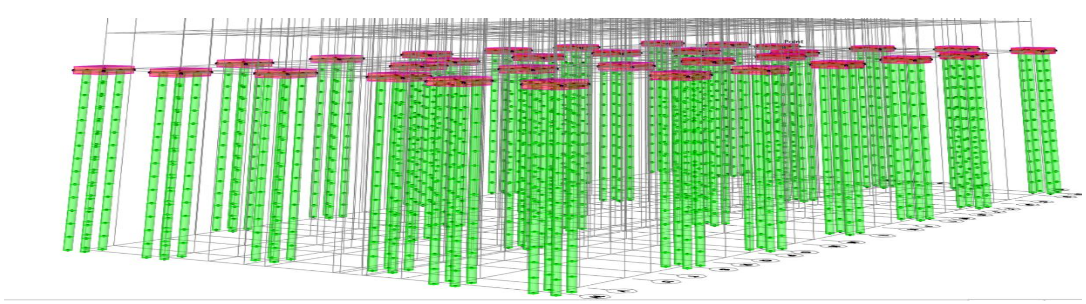


Figure 5.1.3 Pile Raft Foundation in SAP2000

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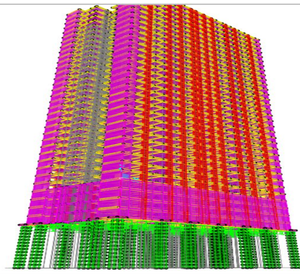

Figure5.1.4 3D modelled of Building with pile raft foundation in SAP2000

B. Modelling parameters

The modeling parameters like grade of materials, section properties, stiffness modifiers, loading is shown from table1 to table 3.

Table 5.1 Grade of materials

<table>
<tr><td colspan="5">Characteristic compressive strength of concrete (N/mm2)</td></tr>
<tr><td>Columns</td><td>Beams</td><td>Slabs</td><td>Shear walls</td><td>Basement walls</td></tr>
<tr><td>30</td><td>25</td><td>20</td><td>30</td><td>30</td></tr>
<tr><td colspan="5">Yield strength of rebar (N/mm2)</td></tr>
<tr><td colspan="5">415</td></tr>
</table>

<table>
<tr><td colspan="2">Columns(mm)</td><td>Beams(mm)</td><td>Slab(mm)</td><td colspan="2">Shear wall(mm)</td><td>Basement wall thickness(mm)</td></tr>
<tr><td>Perimeter column only founder ground stories</td><td>600x1200</td><td rowspan="3">300 x600</td><td rowspan="3">125</td><td>Core walls</td><td>200</td><td rowspan="3">600</td></tr>
<tr><td>all square columns</td><td>500 x500</td><td>Remaining walls</td><td>300</td></tr>
<tr><td>Remaining columns</td><td>400x1200</td><td></td><td></td></tr>
<tr><td colspan="7">Notes:
1. Slab is modeled for membrane behavior while shear wall sand basement wall sari modeled for shell thin behavior.
2. Stiffness modifiers are applied as per IS16700:2017
3. No stiffness modifiers are applied for basement walls</td></tr>
</table>

Pile cap (Raft)	Shell thin behavior	2 m x 2m (32 pile cap)
Piles	Circular shape	0.45 m (diameter) (128 piles) each raft four piles

Table5.2 Section properties

VI. ANALYSIS, RESULTS AND DISCUSSION

A. Assumptions

The following assumptions are made for performing analysis:

The Diaphragm wall and main building structure is provided with tied connection rather than slipping connections of that the diaphragm wall and main building structure behave as one unit.

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It is assumed that both the material soil and structure behave in linear lactic manner as this assumption is justified for general building structures. However, for important building, nonlinear behavior of soil is preferable.
It is assumed that the effect of adjacent structures on the main building structure is negligible. As in the case of tall building surrounded by low to mid-rise structures. This assumption is justified from the research carried out by

B. Analysis

In the present study, nonlinear time history analysis is performed under major component to Bhuj earthquake applied in two orthogonal directions. The time history of Bhuj earthquake is in cm/s2 unit and therefore the scale factor 1/100 is applied to convert it in to m/s2unit.

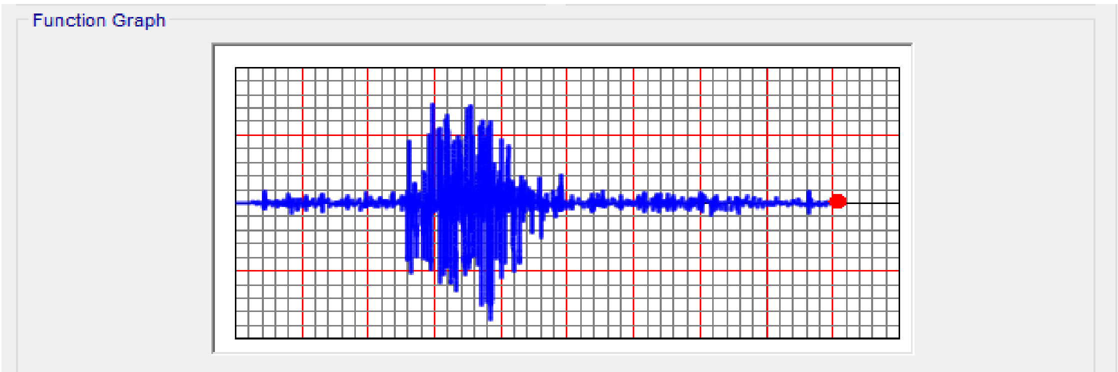

Figure 6.1 Time history function of 180˚ component of Bhuj Earthquake

C. Issues which Required Attention

When the underground structure becomes much more rigid than the above ground structure, the seismic mass associated with it does not excite and hence it is difficult to analyze by Eigen vector analysis. Therefore, how to satisfy IS 1893:2016 criteria that number of modes considered in the analysis should be such that at least 90% mass participation is obtained?
While modeling soil by solid elements, how much influencing zone to be considered?
Dynamic soil structure interaction on building with basements

D. Results for basements (Medium to Hard soil)

a) Displacement X direction, Y direction, Z direction
Fixed base structure: -

Table 6.7 Displacement Fixed base structure

	FIXED BASE		
	DIS COMB: GRAVITY+THX/THY		
STOREY	U1 (X)	U2 (Y)	U3 (-Z)
30	130.00	515.2	23.7
29	124.7	470.8	22.8
28	123.3	440	21.1
27	121.1	410.2	19.3
26	117.9	388.6	18.5
25	114.4	365.01	17.01
24	112.9	333.9	16.03
23	111.6	300.2	15.4
22	109.2	289.2	14.01
21	106.4	250.7	13.7
20	103.8	234	12.6

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19	101	200.1	11.4
18	99.7	180.3	10.2
17	97.1	159.4	9.1
16	95.04	137.1	8.96
15	93.07	162.5	9.01
14	88.4	150.14	9.06
13	84.2	132.62	9.06
12	80.3	118.1	8.99
11	76.2	99.5	8.9
10	65.1	81.2	8.56
9	60.4	63.2	7.87
8	55.5	49.5	7.45
7	48.52	38.2	7.2
6	40.3	29.14	6.5
5	32.3	21.8	6.2
4	24.4	15.6	5.7
3	17.3	10.24	5
2	10.3	5.8	4.25
1	4.35	2.5	3.4
0	0.9	0.6	2.2
-1	0.5	-0.16	1.73
-2	0.51	-0.14	1.6
-3	0.4	-0.13	1.17
-4	0.302	-0.9	0.8

6.6.1 Comparison of displacement for different soil structure interaction conditions with fixed base condition

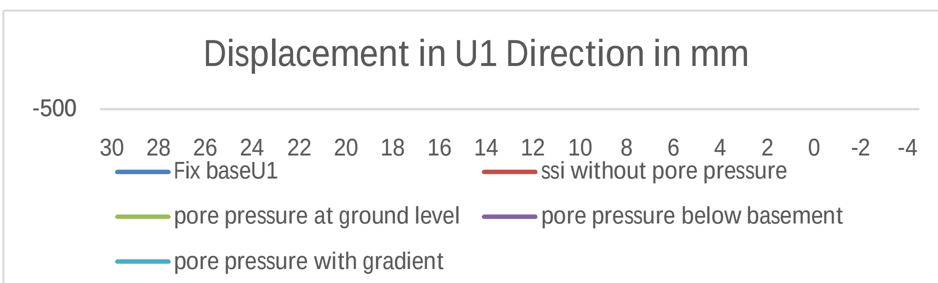

Figure6.7 Comparison of displacement in X direction for different soil structure interaction conditions with fixed base condition

VII. CONCLUSIONS

In present study, SSI of RC building with basement resting on pile raft foundation is investigated. The three-dimensional analysis is performed for a 30 story RC moment frame-structural wall system having four and three basements. The buildings were assumed to be on two types of layered soil namely medium to hard and soft to medium soil. The dynamic analysis is performed in SAP 2000 by using nonlinear direction generation time history analysis under Bhuj earthquake. Upon studying several general cases like dynamic soil structure interaction without pore pressure, dynamic soil structure interaction with water level at ground level, water level below basement, water level having gradient around the structure and comparing their results with fixed base structure following major conclusion sare drawn: -

Influence zone for performing dynamic soil structure interaction can be taken as five times the width of building in the direction considered. However, the depth of influence zone is to be decided by performing sensitivity analysis in a way that time period of entire soil structure system gets constant after that particular depth.

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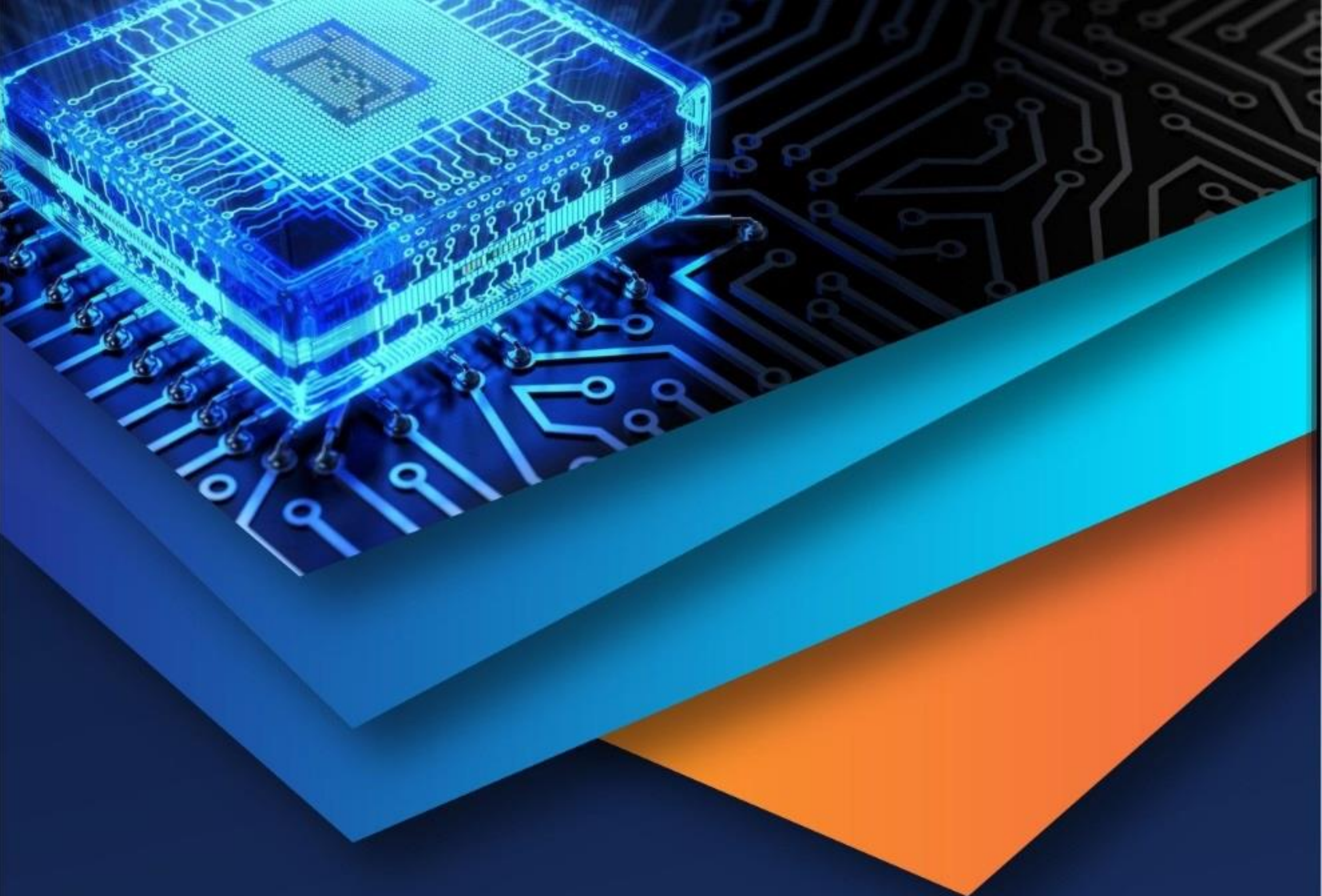

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