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SOIL LIQUEFACTION AND ITS IMPACT ON PILE FOUNDATIONS

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ABSTRACT

This study examines the impact of soil liquefaction on buildings supported by piles driven into the ground, focusing on the structural response and potential consequences when the ground temporarily loses its strength and becomes unstable during seismic loading, such as earthquakes. To enhance safety and mitigate the risks associated with soil liquefaction, proactive measures are being considered, such as conducting thorough ground investigations before construction, implementing ground improvement techniques, and employing meticulous engineering and design practices when planning buildings supported by piles in regions prone to ground weakness during seismic events. This research is essential for advancing our comprehension of the impact of soil liquefaction on pile-supported buildings and for developing strategies to enhance structural stability in regions prone to liquefaction, providing valuable insights for engineers and builders committed to creating earthquake-resistant structures and ensuring the safety of communities in seismic-prone areas.

Keywords: Soil Liquefaction, Pile Foundation, Static And Dynamic Conditions, MIDAS GTX NX.

I. INTRODUCTION

During an earthquake, soil liquefaction can transform solid ground into a temporarily unstable, liquid-like state, causing structural instability, potential building damage, and harm to various infrastructures. A pile raft system combines the benefits of both raft and pile foundations, utilizing a network of piles to provide sufficient bearing capacity while effectively reducing excessive settlement in deep foundation applications.

Many scientists and engineers have studied how buildings and bridges with foundation piles can withstand earthquakes and other challenges. [1] Found that denser soil is better for piles, and special pile shapes and stiffness make them stronger against buckling. They also came up with an easy way to estimate the load a pile can handle before buckling. [2] Analysed on a building that tilted during an earthquake due to soft soil. It highlights the importance of understanding soil conditions and designing structures to be safe in earthquake-prone areas. [3] Suggested the need to update building codes to address the risk of pile buckling on his analysis done on shaky soil. [4] Introduced a new model to predict how pile foundations respond to earthquakes. It accounts for various factors, including soil properties, to improve the accuracy of predictions. [5] Used computer modelling to analyse how a group of piles would perform under static and earthquake conditions for an oil tank. It provided valuable data for designing stable foundations. [6] assessed how anti-slide pile-reinforced bridge foundations perform during landslides and earthquakes. It showed that these piles can effectively reduce the impact of earthquakes on bridge foundations. [7] Introduced a simplified method to analyse the performance of pile foundations during earthquakes, offering an alternative to complex models. [8] This research compared the seismic behaviour of piled rafts and pile groups. It found that piled rafts can offer advantages in terms of stability and reduced settlement during earthquakes. [9] Summarized the common damage patterns and causes of bridge pile foundation failures during earthquakes. It emphasized the importance of seismic design measures. [10] Investigated the lateral forces induced by liquefaction on piles during seismic events. It challenged conventional methods and suggested improvements for predicting pile behaviour. [11] focuses on the behaviour of soft clay during earthquakes and its interaction with pile foundations. It highlighted the importance of non-linear analysis in predicting pile responses. [12] analysed soil stiffness on the response of piled raft foundations under earthquake loading, he examined how different soil stiffness affects the performance of piled raft foundations during earthquakes, with practical implications for design. [13] provided insights into the risk of liquefaction during earthquakes in Mumbai and how to design strong foundations for tall buildings in such conditions. It has been noticed that areas are prone to liquefaction at moderate earthquake of magnitude 6.0 and above. [14] Used computer simulations to understand how piles react during earthquakes in soft ground, highlighting the importance of considering various factors in pile design. [15] clay deposit when reinforced with OBD stone column influences its bearing capacity.

In essence, these studies contribute to making buildings and infrastructure more resilient to earthquakes and other seismic challenges by improving our understanding of how piles and foundations behave in different soil conditions and under seismic forces.

II. METHODOLOGY

Finite Element Analysis (FEA)

Finite Element Analysis (FEA) is a powerful computational method in engineering and science. It dissects complex structures into small, well-defined elements and uses mathematical equations to predict their response to various physical conditions, aiding in design optimization. Finite Element Analysis (FEA) empowers engineers and scientists to simulate, analyse, and optimize complex structures. It minimizes the reliance on physical prototypes, saving time and resources, and allows exploration of numerous design scenarios and alternatives.

By modelling this diverse soil profile in MIDAS and taken all data from it, the aim to perform various geotechnical analyses to assess the structural response and foundation design considerations. This includes evaluating factors such as bearing capacity, settlement predictions, and the potential impact of liquefaction-induced ground motion on the projects as shown in fig. 1. Similarly material properties are shown in table 1,2and 3 respectively.

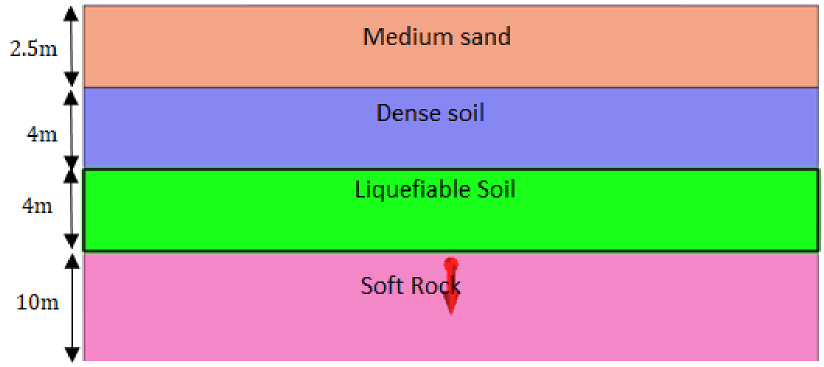

Figure 1: Soil profile

Table 1. Material Properties

Name	Medium Sand	Liquefiable Sand	Dense sand	Soft Rock
Model Type	Mohr-Coulomb	Modified UBCSAND	Mohr-Coulomb	Mohr-Coulomb
Material	Isotropic	Isotropic	Isotropic	Isotropic
General				
Elastic Modulus (E)(KN/m^2)	50000	60000	100000	100000
Poisson's Ratio (v)	0.3	0.02	0.3	0.3
Unit Weight(Y) (KN/m^2)	20	20	20	24
Damping Ratio (For Dynamic)	0.05	0.05	0.05	0.05
Porous				
Saturated Unit Weight (KN/m^2)	21	21	21	25
Initial Void Ratio	0.5	0.5	0.5	0.5
Non - Liner				
Cohesion (c) (KN/m^2)	35	1	35	150
Friction Angle(ϕ∘)	33	35.5	33	37

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Piles of length 20m and radius 0.3m have been modelled of under mentioned characteristics.

Table 2. Pile Element

Pile Interface	Ultimate Shear force	Shear Stiffness modulus	Normal Stiffness Modulus
Modal type Pile	250	50000 (kN/m^2)	200000(kN/m^2)

A Raft of dimension 30 x 15x 1.5m has been modelled of under mentioned characteristics.

Table 3. Structure

Name	Material	Elastic Modulus (E)	Poisson's Ratio (v)	Unit Weight (Y)
Raft Grade C3500	Elastic	23503000	0.2	23.5631

III. MODELING AND ANALYSIS

Modelling

The model, as depicted below, illustrates the arrangement and dimensions of the piles, pile caps (footings), and the surrounding soil and structure are shown in fig. 2 ,3 and 4 respectively These piles serve a dual function, acting as both friction and end-bearing piles, supporting a raft foundation measuring 30 meters in length, 15 meters in breadth, and 1.5 meters in thickness, with an imposed dead load of 200 kN/m^2.

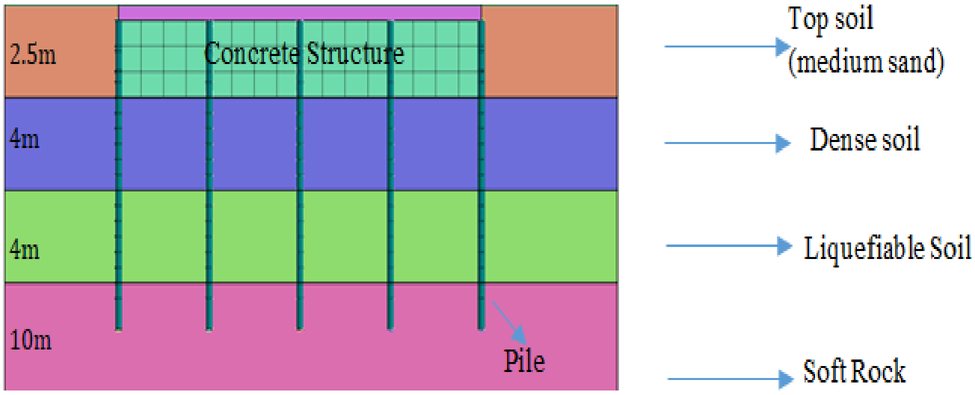

Figure 2: cross section of soil profile with pile and pile cap

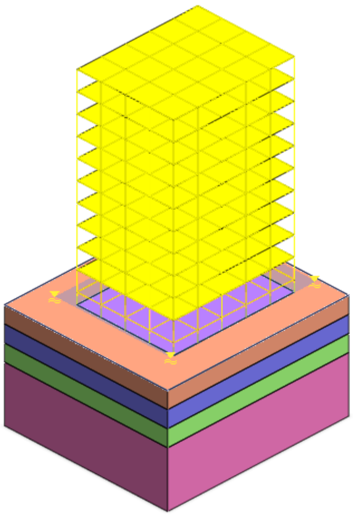

Figure 3: 3D view of building

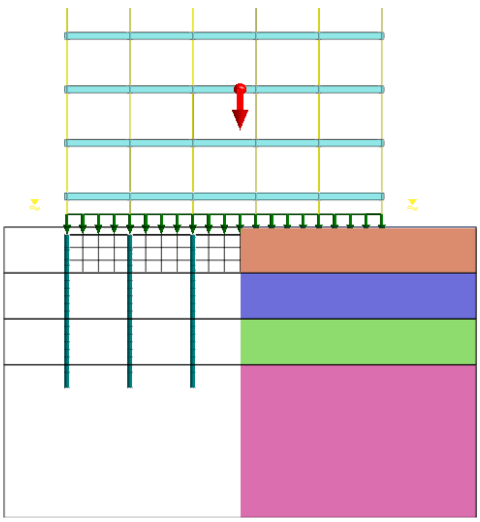

Figure 4: Cross section of the building with load

Analysis

Understanding the characteristics of seismic wave propagation in a semi-infinite medium is crucial for conducting comprehensive dynamic analysis of seismic events. Boundary conditions that inadvertently reflect outward-propagating waves back into the model can lead to undesirable and inaccurate results in dynamic modeling. To mitigate seismic wave reflections and effectively damp them at model boundaries, infinite elements are typically employed alongside finite elements, enhancing the accuracy of dynamic analyses. Figure 5 shows Infinite elements around the model. Following the modeling process, the analysis of total displacement and time-variant displacement under seismic loading (zone-II, zone-III) provides crucial insights into the structure's response to seismic events.

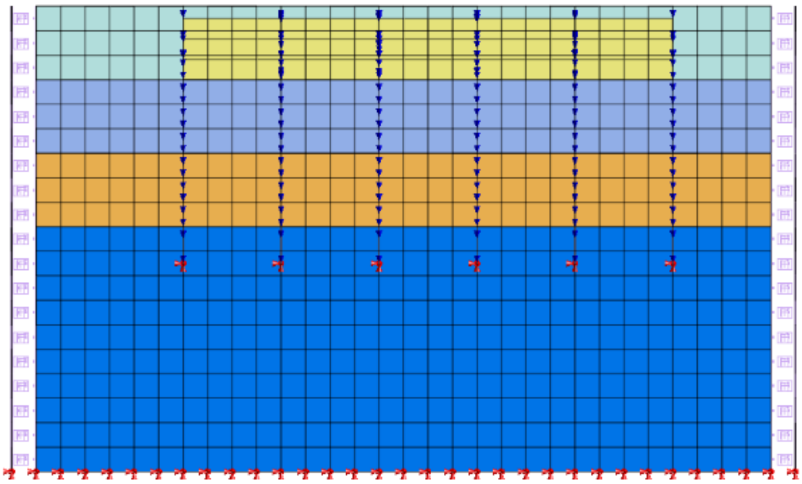

Figure 5: Infinite elements around the model

IV. RESULTS AND DISCUSSION

Total Displacement and Acceleration of Piles under seismic load:

In seismic analysis of piles or pile foundations, a displacement and acceleration graph (movement) are shown in fig. 7 and 8. Bending of piles due to seismic wave varies with time during an earthquake or seismic event which are shown in fig 6. This graph is a fundamental tool in assessing the behaviour and performance of piles under seismic loading conditions.

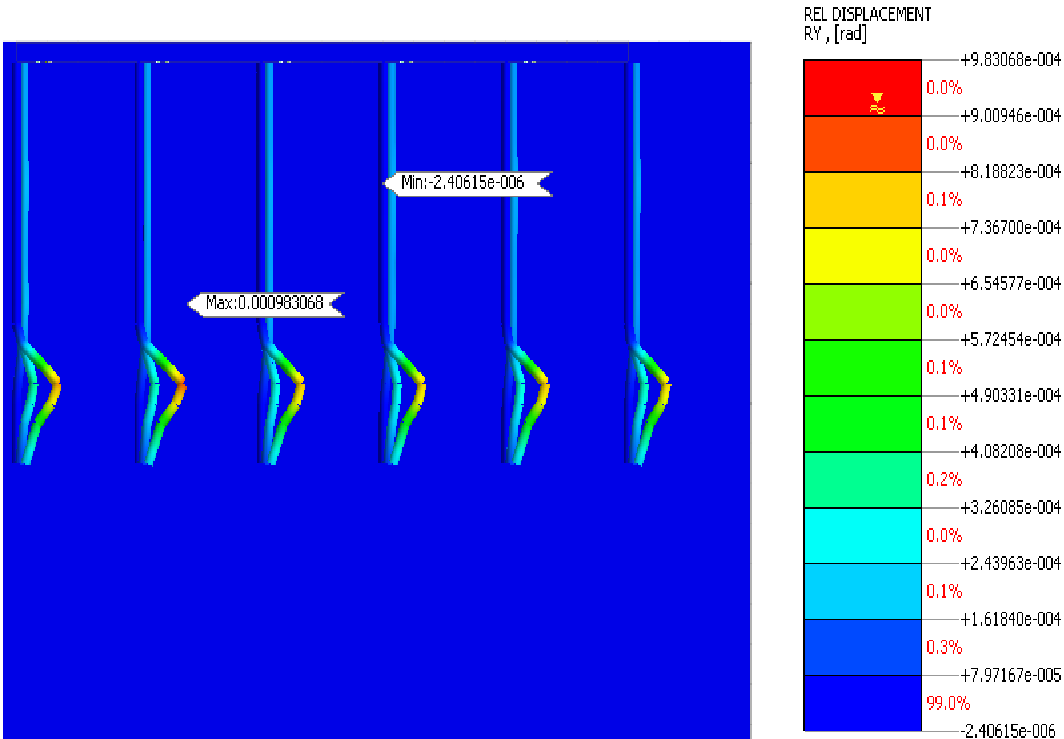

Figure 6: Bending of piles due to seismic wave

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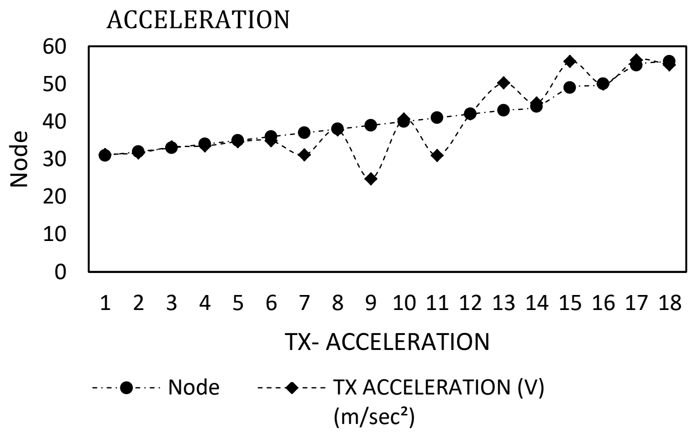

Figure 7: Acceleration under earthquake

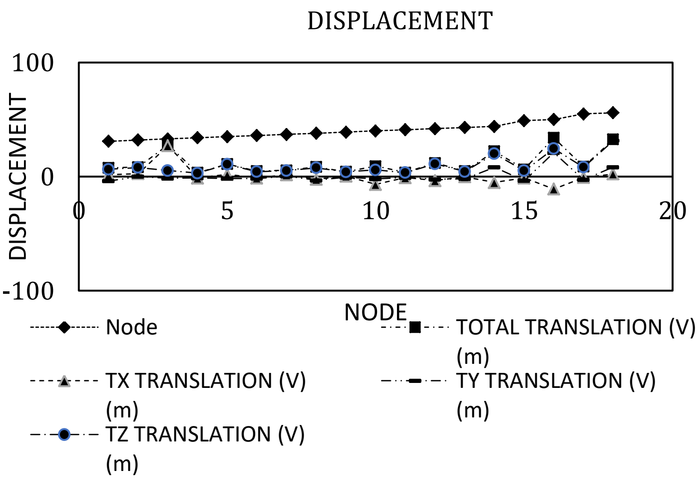

Figure 8: Displacement of piles due to seismic load wave

V. CONCLUSION

By integrating insights gained from this research, engineers can develop more resilient and earthquake-resistant structures that prioritize soil-structure interaction, optimized pile design, and the utilization of sophisticated computer simulations to enhance earthquake analysis and design, ultimately safeguarding lives and minimizing seismic risks.

Seismic waves can induce substantial displacements in piles and result in excessive buckling when they encounter liquefied soil layers, causing significant settlement or potential structural failure; thus, proactive measures are imperative to mitigate the liquefaction-induced risks during seismic events.

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