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Abstract

This paper uses a simpler approach, i.e., static equivalent approach, to estimate the response of piles resting on liquefied soil. For this, the pile head response under a three-storey reinforced concrete frame structure founded on liquified soil which is sandwiched between two non-liquefied crust layers is investigated using a synthetic accelerogram. Liquefaction degrades the soil stiffness around the pile, increasing pile response. For the single-layered soil profile, the maximum pile head deflection increases 3.66 times of that when liquefaction does not occur. It is also estimated that a non-liquefied crust layer directly over a liquefied soil generates lateral load on the pile, which largens the pile head displacement and intensifies the damaging effect further in addition to axial load. It is estimated that maximum pile head displacement are almost 2 times of that of without crust layer.

Keywords: Static equivalent model, crust layer, SAP2000v14, Liquefaction, lateral spreading.

ANALYSIS OF PILE DEFORMATION UNDER MULTYLAYERED LIQUEFIED SOIL USING STATIC EQUIVALENT MODEL

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***Abstract*— This paper uses a simpler approach, i.e., static equivalent approach, to estimate the response of piles resting on liquefied soil. For this, the pile head response under a three-storey reinforced concrete frame structure founded on liquified soil which is sandwiched between two non-liquefied crust layers is investigated using a synthetic accelerogram. Liquefaction degrades the soil stiffness around the pile, increasing pile response. For the single-layered soil profile, the maximum pile head deflection increases 3.66 times of that when liquefaction does not occur. It is also estimated that a non-liquefied crust layer directly over a liquefied soil generates lateral load on the pile, which largens the pile head displacement and intensifies the damaging effect further in addition to axial load. It is estimated that maximum pile head displacement are almost 2 times of that of without crust layer.**

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I. INTRODUCTION

Seismically well-designed structures fail during earthquakes due to the abrupt change of soil conditions due to earthquake-induced liquefaction and lateral spreading. The failure of structures often occurs due to excessive deformation of piles which are generally used under large buildings and bridges to carry a substantial axial load [1]. During a possible earthquake, the piles and surrounding soil are subjected to dynamic loads. Simultaneously, there is a significant reduction of soil strength and stiffness due to the non-linear behaviour of soil and pore water pressure generation. Due to excessive pore water pressure soil behaves as liquid with no shear strength and starts flowing laterally. If there is some inclination at the surface of the liquefied soil layer, then the flow is excessive. This phenomenon is called the lateral spreading of soil. The resistance to lateral deformation of a pile is significant in shallow depths as the deformation of laterally loaded piles near the ground surface is generally higher. This is because liquefaction potential at a greater depth is higher than shallow depth due to higher overburden pressure [2-5] at greater depth.

Though the results obtained from all these previous studies closely match the field case histories, experimental studies require a large laboratory setup. For this, some researchers introduced numerical formulations and modeling to analyse pile foundations [6-11]. Use of different computer software in the numerical analysis of pile foundations in liquefiable soil, is increasing through the past decades.

Piles in liquefied soil sandwiched between the non-liquefied crust layer and the base layer at the bottom [12, 13] experience additional stresses due to the lateral movement of the non-liquefied crust above the liquefied layer. Dutta and Nanda [14] made an attempt to evaluate the pile response in liquefied soil sandwiched under non-liquefied crust layer. They found that the effect of crust layer has a significant role on soil-pile interaction. During the lateral spread, the upper non-liquefied crust layer is displaced laterally along with the underlying liquefied soil leading to further enhancement of lateral displacement and lateral force from the surface crust layer.

The above studies show that the seismic response of structures with deep foundations in layered soil are significantly affected by soil–pile interaction and this interaction is more complex in the presence of liquefied soils. Pile response analysis due to liquefaction required a large laboratory equipment setup or can be accurately predicted numerically. In this paper, a simpler approach for design engineers, i.e., static equivalent approach [15] is used to estimate the response of piles resting on liquefied soil and liquified soil sand-witched between non-liquified crust layers**.** Pile response is predicted using a synthetic accelerogram for maximum considered earthquake in the most severe Indian seismic zone (ISZ-V). Method accuracy was demonstrated by comparing the experimental observation reported by Zahmatkesh, 2019 [16], where a scaled accelerogram of Kobe earthquake is used.

II. STATIC EQUIVALENT APPROACH TO EVALUATE PILE RESPONSE

In static equivalent approach to assess dynamic response in pile foundation, first, the effect of dynamic forces (vibration) on the soil is evaluated in terms of free field motion. Then, the motion is converted to the stiffness of soil to model the soil as grounded spring with equivalent spring stiffness which is applied on the pile equivalently, considering soil dragging effect.

The pile and soil-pile interaction are modeled using SAP2000v14 [17] software, considering soil as a spring