International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 5 ǁ 2022 ǁ PP. 44-47

A Review on Soil Structure Interaction of FRP RCC Pile under Cyclic Load

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Abstract
In areas where the soil strata below the superstructure is weak or highly compressible the pile foundation is used. Piles are mainly used to support structures under lateral and vertical loads. Vertical load-bearing capacity of piles depends mainly on site conditions, soil properties, pile material properties, pile dimensions, and method of pile installation. Pile foundations resist significant lateral forces induced by earthquakes, winds, waves, earth pressures and ship impacts. It is important to strengthen/retrofit the foundation structure to resist the increased lateral loads due to changes in the use of the structure. In recent years, strengthening/retrofitting the existing deficient piles by using Fibre Reinforced Polymer (FRP) jacketing is becoming more popular. FRPs are lightweight, corrosion resistant and have high strength. The engineering application of FRP may present competitive alternatives to conventional pile materials, due to the accelerated degradation of these conventional materials in aggressive environments.

Keywords: *strengthening, RC piles, glass fibre reinforeced polymer, GFRP, Cyclic Loads.*

Date of Submission: 04-05-2022 Date of acceptance: 18-05-2022

I. INTRODUCTION

Pile foundations have been used for many years, for carrying and transferring of loads to soil considered to be weak in structure due to the soil conditions. Pile foundations are often necessary to support large structures when the surface soil conditions are not strong enough to support the structure with shallow foundations. Pile foundation can be founded in dense sand layers at depth, and also provide additional frictional support along their length to resist vertical loads. Lateral loads, however, are just as important as vertical loads in designing pile foundations and are often more complicated. More powerful lateral loads occur as a result of unpredicted events such as heavy wind, earthquakes, slope failure and lateral spread induced by liquefaction. In recent years, strengthening/retrofitting the existing deficient piles by using Fibre Reinforced Polymer (FRP) jacketing is becoming more popular. FRPs are lightweight, corrosion resistant and have high strength. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as SOIL STRUCTURE INTERACTION (SSI). The study of laterally loaded pile requires a proper assessment of soil-structure interaction phenomenon involving the interaction between pile surface and the surrounding soil.

II. LITERATURE REVIEW

RJ Jardine., (2012) studied that Cyclic loading can degrade pile capacity and stiffness markedly and its effects should both be researched further and addressed more routinely when designing foundations that carry a high proportion of variable environmental loading.

Hang Zhou et al., (2019) performed a general analytical solution for lateral soil response of non-circular cross-sectional pile segment. The elastic response for the two dimensionally laterally loaded pile is obtained. The analysis present in this paper based on the theory of complex variable elasticity. Since no analytical solution for the non-circular cross-sectional pile, the present analysis serves the important purpose of providing a set of benchmark results that could underpin further more sophisticated analysis, such as nonlinearities of soil.

Shiping Zhang et al., (2019) studied a coupled vibration of an interaction system including saturated soils, pile group and superstructure under the vertical motion of bedrocks, based on Boer's poroelastic theory. Based on the developed model and relevant analytical solutions, the effect of pile-soil parameters on the dynamic amplification factors of the interaction system are also investigated. In addition, the developed model

and proposed analytical solution can be conveniently reduced to investigate the coupled vibration for the interaction system of structures with pile group embedded in single phase soils.

Ahmad Dehghanpoor et al., (2019) studied a soil-pile-superstructure interaction effects in seismically isolated bridges under combined vertical and horizontal strong ground motions. The influence of elastomeric bearing on SSI reduction was investigated by comparing the relative response of the superstructure, Free-Field and Foundation Input Motion at the pile head in the frequency domain. This paper explored the effects of coupled VC and HC of ground motion on seismic isolation bridges including CFB, CERB to determine and compare critical damage parameters in the structural elements with or without VCs. The beneficial effect of elastomeric bearing on decreasing bending moments under VCs is significant.

Juntao Wu et al., (2019) studied a dynamic soil reaction around pile-fictitious soil pile coupled model and its application on parallel seismic method. The PS method is a non-destructive test technique for evaluating pile integrity, which has a wide range of applications for detection of reinforced concrete pile length and defects. The developed solutions are then employed to investigate the effects of pile soil properties and technical aspects of PS method on the dynamic response of surrounding soil. Once the radial distance and hole depth are determined, the points spacing should be considered as a combination to optimize the test workload.

Jifei Cui et al., (2019) studied a long-term time-dependent load settlement characteristic of a driven pile in clay. The evaluation of the soil behaviour due to aging is incorporated in a skin friction softening model, which is used in the load transfer method to predict the bearing capacity evaluation of the driven pile. Both the proposed method and the experimental data show that the bearing capacity of the test piles increases 30-50% due to aging effect. A nonlinear softening model was used to simulate the degradation behaviour of the load transfer curve for the pile-soil interaction. The traditional load-transfer method is adopted to determine the load-settlement response for the static load test of a single pile.

Balasubramanian et al., (2012) investigated the effect of the cyclic loading on the characteristics of the retrofitted beam-column joints with FRP materials such as FRP strips, FRP sheets, MS flats and embedded additional reinforcement. This study exclusively depicts the various methods of strengthening RC beam – column joints.

Dagui Tong et al., (2019) performed a wave-monopile-seabed interaction considering nonlinear pile-soil contact. This study developed an integrated numerical model to simulate the wave-monopile-seabed interaction considering a nonlinear contact at the pile-soil interface. Coulomb friction contact is adopted to simulate the pile-soil interaction. The results reveal that the pile-soil sliding takes place under dynamic wave loading. The effects of the nonlinear pile-soil contact on pore pressure response is insignificant, whereas the seabed displacement and pile behaviour are remarkably influenced in comparison with the canoed pile-soil interface model. The contact pressure and shaft friction on the pile-soil interface fluctuate with the wave propagation simultaneously. The magnitude of shaft friction is greater than the contact pressure due to high magnitude of coherent sliding resistance.

Rajesh R Rele et al., (2019) studied seismic behaviour of rocking bridge pier supported by elastomeric pads on pile foundation. The effect of pile soil interaction along with ground response analysis is also incorporated in the full bridge model adopted for the study. The pier bending moments of the proposed bridge remained in elastic range as the moments were below the yield moments. The pile moments in the rocking bridge are also decreased by approximately 12-15% when compared to the target bridge. The distribution of ductility demand was uniform in the rocking bridge and the piers of the same was twice more ductile than the conventional pier adopted in current practice of bridge substructure design.

Abtin Farshi Homayoun Rooz and Amir Hamidi., (2019) performed a numerical model for continuous impact pile driving using ALE adaptive mesh method. Pile installation through consecutive hammer impact is called impact driving which has increasingly exploited as the most efficient method, through the generated ground vibrations have great potential to undermine its surrounding structures. The results were verified with field measurements which indicate a remarkably better match compared to the previous numerical studies. The surface-to-surface contact approach of the pile and the soil as well as master-slave technique improved the pile-soil interaction, and thereby, it resulted in a better simulation of the field results.

Jiale Li et al., (2019) performed a vertical bearing capacity of the pile foundation with restriction plate via centrifuge modelling, which institutes an innovative strategy over traditional pile foundation to achieve higher axial bearing capacity. This is achieved by adding restriction plates inside the pile to help from the soil plug. The pile diameter and shapes of the restriction plates on the soil plug behaviour and pile load carrying capacity are analysed. A bearing capacity equation is obtained by normalizing the ultimate bearing capacity with the pile diameters for different restriction plates. The ultimate bearing capacities of models under different gradational levels of centrifuge experiments are normalized and compared. The ultimate bearing resistance has a power law relationship with pipe pile diameter.

Sampath Rao et al., (2012) carried out experiments to determine the effect of environmental conditions on the strength aspects of GFRP laminates. The results from the experiments showed that the effect

of the environmental condition on the GFRP affects the young‟s modulus and the flexural modulus of the specimens abruptly.

Piyush jain., (2017) studied the experimental study on retrofitting of RC beam using basalt fibers. The beam was wrapped with basalt fiber sheet in single u-type layering, double u-type layering along the different strength of the beam. The result have been analysed.

E. J. Prakash Arul Jose ., (2018) studied the experimental study on PFRP confined RC driven piles subjected to vertical loads. To find the performance of PFRP confined RC pile subjected to vertical load. The shear strength at the interface increases with the increase in surface roughness of the specimen.

Mingbo Yao and Jingpei Li., (2019) studied effect of the degradation of concrete friction piles exposed to external sulphate attack on the pile bearing capacity. A chemo-mechanics model is established to compute expansion based on the consideration of the pore filling. Furthermore, the effect of concrete expansion on pile-lateral-soil effective stress is analysed. The degradation of concrete friction piles leads to loss of friction, resulting in the bearing capacity of the pile decline. The effect of different soil properties the on pile bearing capacity is different. The expansion increases with time. The relative compaction effect occurs, which leads to the increase of effective stress of the soil around a pile. The decreasing of the effective radius and the modulus of a pile leads to decrease the skin friction. The increase of skin friction is not obvious when the soil stress increases. The skin friction decreases due to external sulphate attack, which leads pile a larger settlement in a sulphate rich environment.

Fayun Liang et al., (2019) studied transverse response of pile group foundations supporting a long-span cable-stayed bridge under uniform and non uniform excitation. An elaborate bridge model was fabricated according to an assumed bridge with a total length of 2672m and a geometric similarity ratio 1/70. The influence of the wave passage effect on the seismic response of the pile groups is detectable when the bridge model is excited longitudinally, while the influence is undetectable when the bridge model is excited transversely. The wave passage effect has little effect on the seismic response of pile groups when the studied integral bridge model is model is excited in the transverse direction, which is different from the results when the model is excited longitudinally.

Qiang Li et al., (2019) studied a vertical vibration of a single pile embedded in a frozen saturated soil layer. The theories of elasticity and a composite solid-phase saturated porous medium were employed to investigate vertical vibration of an end-bearing pile embedded in a frozen saturated soil layer from three-dimensional axisymmetric analysis. The results showed that the maintaining freezing status technology was still valid for pile vibration in permafrost over a larger frequency range; however, it might be invalid in a very low frequency due to the ice skeleton formed below the frozen temperature of the soil. The soil porosity and the shear modulus of the unfrozen soil also have an influence on the dynamic response of the pile top. The results deepened the understanding of the common mechanism of pile-soil interaction in frozen saturated porous media.

Meijuan Xu et al., (2019) performed a physical and numerical modelling of axially loaded bored piles with debris at the piles tip. For bored piles a careful cleaning work must be implemented to minimize the tapered debris in the drilled hole; otherwise the presence of debris can result in soft to effect, influencing the axial resistance. Numerical simulation is further performed to simulate the behaviour for a bored pile with debris in a destructive field test. The load shared by different component shows that skin friction is dominated initially, which decreases with the applied load. Load transfer occurs in the soil pile system that pile tip resistance is gradually mobilized with the compression of debris. It is not reasonable to discard a bored pile with debris directly; instead, settlement can be allowed to eliminate the debris, after which the axial resistance of bored pile is regained.

Stylianos Chrisopoulos and Jakob Vogeslsang., (2019) studied a finite element benchmark based on experimental modelling of vibratory pile driving in saturated sand. A hypo plastic constitutive model with intergranular strain has been selected to describe the mechanical behaviour of the soil. These motion quantities are modelled satisfactorily with deviations mostly in the range of 10-20%. The evaluation and comparison of incremental soil displacements around the vibrating pile allow the identification of typical displacement patterns in the soil corresponding to characteristic phases of pile penetration. The results show that the deformation process in the soil realistically modelled in the simulations.

Lei Su et al., (2019) studied a seismic fragility assessment of large-scale pile supported wharf structures considering soil-pile interaction. Soil-pile interaction is found to have a significant impact on seismic performance of pile supported structures. For distinct damage states, the effect of SPI on the seismic fragilities of different piles can be totally different. SPI can have either negative or positive impact on the seismic fragilities for different structural components and different damage states.

Doaa A.El Molla ., (2019) conducted a seepage through homogeneous earth dams provided with a vertical sheet pile and formed on impervious foundation. This aims to determine the effect of existence of sheet pile as well as its height and location on the total seepage discharge and velocities through the dam's cross section. Increasing the sheet pile's height decreases the total seepage discharge by a ratio up to 34.4% of its

value without sheet pile. The maximum velocity was detected at the sheet piles upper end; and its value is directly proportional to the height of the vertical sheet pile.

II. CONCLUSION

1 The GFRP wrapped piles cyclic capacity is significantly higher than the conventional pile of the same depth and diameter. The GFRP wrapped piles depth of fixity is about 60% to 70% higher than conventional concrete piles. It shows that the moment carrying capacity of GFRP wrapped piles are much more than the conventional concrete piles.

2 GFRP piles with fibre orientation along the length of the pile indicated about 41% more lateral strength than unconfined pile. However, the increment in the cyclic load carrying capacity was only about 15% for fibres oriented in circumferential direction. The percentage increase in cyclic strength of pile strengthened with bidirectional GFRP mat was 26% than unconfined pile. This clearly indicates that the GFRP strengthening is an effective method for strengthening of existing

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