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Pile Group Effect Analysis of a Group of 12 Conductors in an Offshore Jacket Platform

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Abstract. The conductor is the outermost casing of an offshore well which protects a borehole below seafloor, facilitates safe drilling and acts as the initial foundation of the well. An offshore jacket platform installed for production of hydrocarbon, generally contains multiple wells. Conductors are made of open-ended steel tubes and driven below the seafloor to a designed depth. Unlike the piles which support offshore jacket platforms permanently, the conductor pipes are not designed to carry axial load from the platform structure. Conductors are kept free for relative axial movement with respect to the jacket structure. They are laterally restrained by the jacket structure and can resist lateral load of the structure to some extent. But, during the initial design of platforms their contribution in resisting lateral load is not considered. However, international code API RP 2SIM (2014), widely followed by the offshore industry, recommends that conductors can be considered for resisting lateral load of the structure while analysing an existing platform to assess the safety of structure and foundation. In this paper, 'group effect' with respect to lateral load for a 12-conductor group is presented. The study pertains to an existing platform where conductors were also considered for sharing lateral load.

Keywords: Lateral loading, Conductor group, Offshore platform.

1 Introduction

Open-ended steel tubular piles are, generally, the permanent foundation for supporting fixed jacket type offshore platforms. On "well" platforms, which are built to facilitate drilling of wells and produce hydrocarbon, generally, there are multiple wells. The conductor, which is also an open-ended steel pipe, is the outermost casing of an offshore well which facilitates safe drilling and acts as the initial foundation of the well. Generally, in the western Indian offshore, outer diameter of conductors are in the range of 0.66 m to 0.76 m (26-30 inches) and they are driven to a maximum depth of 70 m or refusal (whichever is shallower) below the seafloor. As such, conductors are similar to driven piles; but lesser in diameter compared to the piles which support the platforms for all kinds of loads. Conductors do not carry axial load of the platform as they are driven through guide frames with a gap existing between the guides and the outer surface of the conductor pipes. They are also not designed to share lateral load in the initial design of platforms. But, their lateral resistance to movement of platforms is permitted to be accounted for, while analysing an existing platform to assess the safety of structure and foundation as recommended by API [1].

When piles are in close proximity to each other, the average lateral load carrying capacity of individual piles in a group is generally less when compared to the pile acting as an isolated or single pile. This reduction in capacity of pile is due to the interaction of piles in a group or 'group effect'. The international code [2] recommends that the 'group effect' is to be considered when the spacing between two piles in a group is less than 8 times the outer diameter of a pile. In the present case, the group of 12 conductors is analysed to examine the 'group effect' with respect to lateral load-displacement behaviour and effect on sharing of lateral load from the structure. The group of conductors was considered for sharing the lateral load of the jacket platform in structural integrity assessment of an old platform.

2 Soil Condition and Layout of the Conductors

Relevant soil data for the analysis are presented in Fig. 1. The soil condition is predominantly clayey for the depths which matter in the analysis of lateral loading of

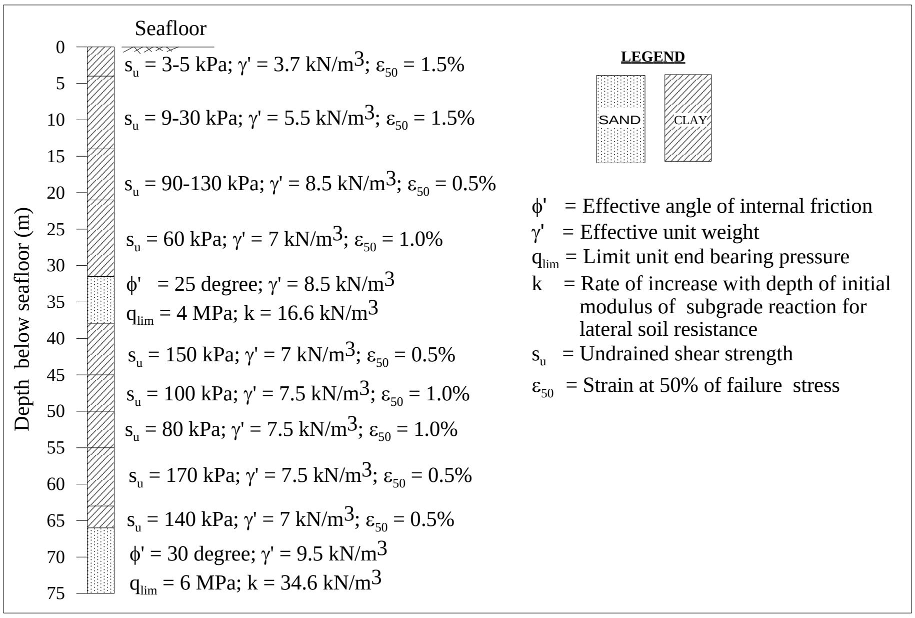

Fig. 1. Soil condition at the location

conductors, with clay occurring in very soft condition near the seafloor. It is worth mentioning that, for lateral load-displacement analysis of piles (or conductors) the soil condition near the seafloor is important. After certain depth below the seafloor, which depends on the pile diameter, soil condition, load level and restraint of pile head, the pile's lateral movement is negligibly small and the influence of soil condition at greater depths becomes insignificant for lateral load-displacement analysis. However, the soil data are presented up to the depth slightly exceeding the depth of the conductors below seafloor.

The layout of the conductors at the seafloor level is presented in Fig. 2. The outer diameter of all the conductors is 0.762 m having wall thickness of 25 mm.

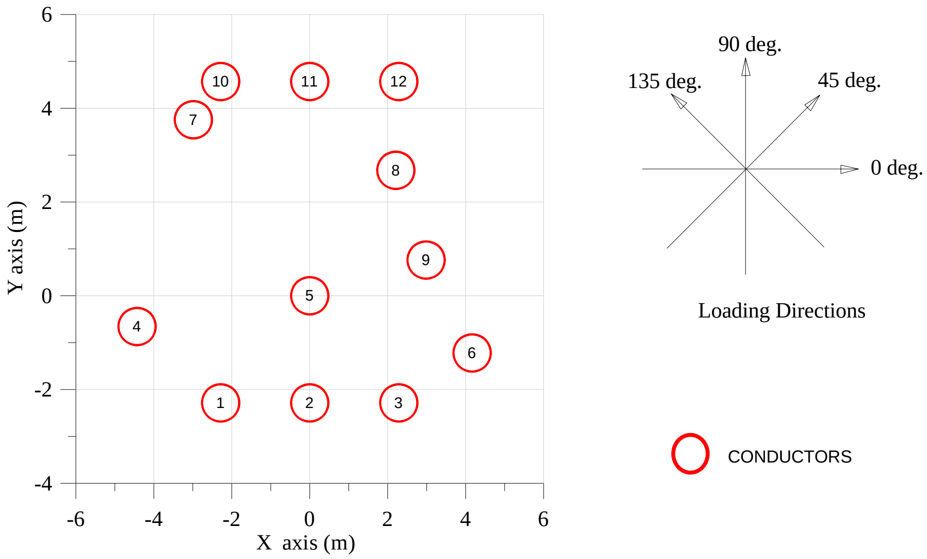

Fig. 2. Relative positions of the conductors at seafloor level**.**

It may be noted that some of the conductors in the group are having mild slope with the vertical. But, for calculating the group interaction effect, all the conductors are considered as vertical below the seafloor.

3 Analysis

For offshore piles, the lateral load-displacement analysis is generally carried out using the 'subgrade reaction' approach using 'p-y' data (lateral load-displacement behaviour of soil with respect to lateral movement of pile). Non-linear p-y data were derived using the procedure [3] given by Matlock (1970) for clay layers and O'Neill and Murchison (1983) for the sand layer [4] following recommendation of API [2]. In the presented case, static p-y curves were used to define lateral resistance of soil. Data of p-y were defined at every metre depth along the conductor depth. Since the conductors are closely spaced, group interaction factors with respect to lateral loading were assessed.

This paper focuses on derivation of the applicable group factors ('P' and 'Y' multipliers for 'p-y' data of individual piles) for considering group interaction of the conductors in the soil-foundation-structure interactive analysis. Further, the changes in load-displacement behaviour of individual conductor as well as reduction of conductor's load carrying capacity due to 'group effect' are also analysed and presented.

3.1 Method used for assessment of group interaction factors

To determine the applicable group interaction factors, the method [5] given by Hariharan and Kumarasamy (1982) was used. This method was used in many cases for the assessment of 'group effect' with respect to lateral loading for offshore piles groups. According to the method, the lateral group interaction requires the application of 'P' and 'Y' factors (multipliers) with the 'p-y' data used for the pile-soil-structure interaction analysis. For details of the method, the work of the developers of the method may be referred to [5]. It is briefly explained below.

The method prescribes that equations (1) and (2) should be used to determine the 'P' and 'Y' factors. Equation (1) shows the stress ratio due to the stress influence from the other piles on one pile, in a group of N nos. of piles. Similarly the eq. (2) shows the ratio of displacement of the pile which is larger than unity due to group action.

$$P_i = \sigma_{x0} / \left(\sigma_{x0} + \sum_{\substack{j=1 \\ i \neq i}}^{N} \sigma_{xij} \right) \quad (1)$$

$$Y_i = \left(d + \sum_{\substack{j=1 \\ i \neq i}}^{N} x_{ij} \right) / d \quad (2)$$

where d= incremental displacement of pile; σ_{x0} = stress at periphery of pile in x direction; σ_{xij} and x_{ij} are interactive stresses and displacements; N = no. of piles in the group.

As shown in equations (1) and (2), 'P' and 'Y' multipliers are calculated on the basis of displacement and stress (as per elastic theory) in a horizontal layer of soil that occurs due to movement of a laterally loaded pile. The P factor is less than 1 and Y factor is more than 1 when there is group interaction for a group of piles or conductors.

For analysis of foundation in case of existing platforms, environmental loading from different directions are considered and the most onerous direction is that in which the safety factor is the least. It is customary to consider 8 (eight) loading directions for the environmental loading for a symmetric, rectangular or square platform. In the present case also, 8 directions (at intervals of 45 degrees) are considered to find the applicable 'P' and 'Y' factors. It may be noted that for calculation of the group interaction factors, application of loading from four directions 0, 45, 90 and 135 produces the required results for all the eight directions. This is because of geometrical similarity. For example, if the distance between any set of two conductors is 's' and if the angle between a particular loading direction and the line connecting the two conductors is 'θ', the interaction factors for these conductors will remain the same for the corresponding angle 'θ + 180' also. Thus, loading from directions 0 and 180 degrees on the group produces the same ‘P’ and ‘Y’ factors for the group; similarly, any loading directions ‘α' and ‘180 + α' produce the same result.

The equations (1) and (2) produce the ‘P’ and ‘Y’ factors when group influence on one pile (from all other remaining piles) is considered. To determine the applicable ‘P’ and ‘Y’ factor for loading on the group of conductors from a particular direction, ‘P’ and ‘Y’ factors are determined for all individual conductors and an average value is calculated. This average value is considered as the applicable value for the group for that particular direction of loading. Thus, average values for all the 4 directions are calculated separately in the similar way.

To carry out soil-foundation interactive analysis of the group of conductors with only one pair of factors ‘P’ and ‘Y’, the most onerous pair of the factors is considered. This pair is applied (as multipliers) with the ‘p-y’ data for individual conductors. Generally, the most onerous pair of factors is the one where the value of the ‘Y’ factor is the maximum. For this pair, the ‘P’ factor is, generally, found to be the minimum. In cases, where this is not the case, i.e. the ‘P’ factor is not the minimum, it is suggested that the pair which produces the maximum group effect should be selected for the analysis. Otherwise, pairs applicable for different directions as shown in Table 1 may be applied for corresponding loading directions in the interactive analysis.

To examine the comparative lateral load-displacement behaviour of individual conductors in the presented case, analyses with and without application of group interaction factors were carried out.

4 Group Interaction Factors and Comparative Results

As already discussed, 4 different loading directions i.e. 0, 45, 90 and 135 degree were analysed to examine the group factors. The directions of loading with respect to the group were shown in Fig.1. The result of calculation of the group factors for these 4 directions of loading is presented in Table 1. It can be observed that the factors with respect to the directions of loading are not significantly different from each other. However, the most onerous ‘P’ and ‘Y’ factors are given by the loading direction of 135 degrees. So, the ‘P’ and ‘Y’ factors were considered as 0.5 and 3.22 respectively while accounting for the ‘group effect’ of the conductor group.

Table 1. Group interaction factors corresponding to the loading directions.

Loading direction (deg.)	‘P’ factor	‘Y’ factor
0	0.51	3.19
45	0.50	3.15
90	0.50	3.17
135	0.50	3.22

The comparative load-displacement behaviour of a conductor was examined by carrying out soil-conductor interactive analysis with and without considering the group effect. The load-displacement result is graphically presented in Fig. 3. Further, comparative plots for bending moment and displacement of a conductor are presented in Fig.4 where the parameters with and without consideration of 'group-

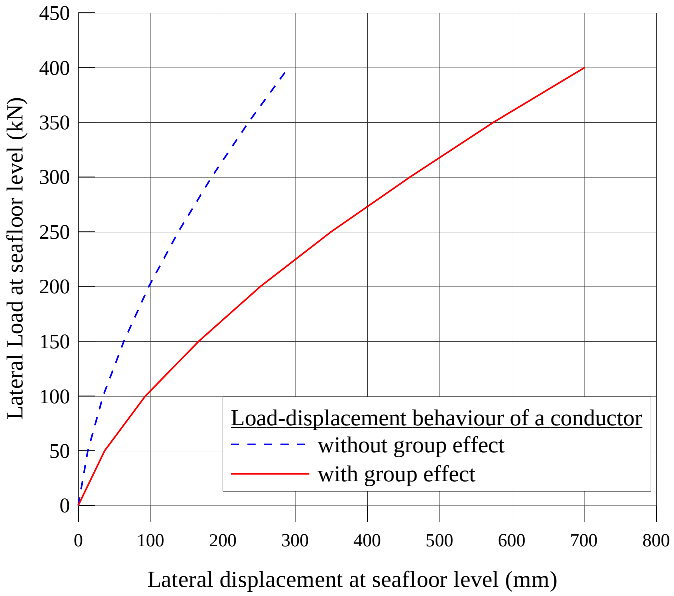

Fig. 3. Lateral load-displacement behaviour of a conductor in the group

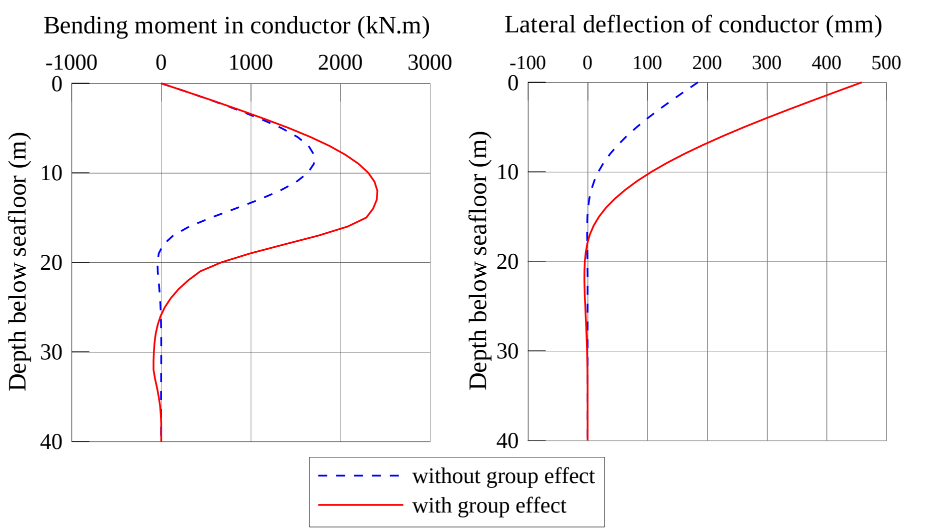

Fig. 4. Bending moment and lateral displacement of a conductor within the 12-conductor group for lateral load of 300 kN at pilehead.

effect' are shown for a typical lateral load of 300 kN, applied at seafloor level to a conductor. It may be noted that there are some simplified assumptions in the analysis. One such assumption is that the part of the conductor above the seafloor does not have any influence on the load sharing of the conductors. Pure lateral load was considered neglecting any influence of axial load or applied moment on the conductors. Further, there may be a small gap, generally, up to 50 mm, between the guide frame and the conductor which was neglected in view of comparatively much larger lateral displacement that occurs for piles and conductors of jacket platforms in response to design environmental / applied load, when the soil condition near seafloor is soft clay, as in the present case.

It is observed that the lateral load shared by a conductor may be, relatively, a small fraction of the load shared by a pile of the platform since conductors are free-headed and their diameter is smaller in comparison to the piles of the platform which are generally highly restrained also (against rotation) at seafloor. However, consideration of sharing of lateral load by conductors can be important in meeting the requirement of safety of the foundation and structure of an existing platform, especially, when the number of conductors in the platform is large and piles alone are not sufficient to resist the lateral forces for meeting the required safety limits of existing platforms.

5 Conclusions

The methodology for incorporation of group analysis of conductors, when conductors are included as lateral load sharing members of the foundation in assessment of structural integrity of an existing offshore jacket platform, is described and demonstrated with an example. Further, analytical results of laterally loaded conductor with and without consideration of 'group effect' are presented. It is observed that the 'group effect' may significantly reduce the load-sharing capacity of the conductors as found from the results of analysis. Main observations are as follows:

1. The group interaction factors (multipliers) 'P' and 'Y' to be applied with 'p-y' data for the analysis of the group of 12 conductors was assessed as 0.5 and 3.22 respectively.
2. The average load shared by a conductor was found to be significantly reduced due to 'group effect'. In the presented case, it was reduced by about 55% compared to results when 'group effect' is not considered.
3. When 'group effect' was considered, the lateral displacement of conductor at seafloor level corresponding to lateral load was found to be 2.4-2.8 times the displacement for an individual conductor without consideration of 'group effect'. In other words, load-sharing by a conductor will be significantly reduced for any lateral displacement of the structure due to the 'group effect'.

In spite of certain simplifications, authors are of the opinion that the result of the analysis and the corresponding conclusions are not likely to deviate much from the reality. Similar soil conditions, as mentioned in the current case, are found near seafloor in many offshore locations. As such, the analysis presented in the paper may be useful in estimating the results expected for similar condition of soil and conductor groups when conductors are also considered for sharing lateral load in the structural integrity analysis of existing offshore jacket platforms.

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References

1. American Petroleum Institute: Structural Integrity Management of Fixed Offshore Structures, API RP 2SIM. 1st edn. API, Washington, DC (2014).
2. American Petroleum Institute: Geotechnical and Foundation design Considerations, ANSI/API RP 2GEO. 1st edn. API, Washington, DC (2011, Addendum 1, 2014).
3. Matlock, H.: Correlations for design of laterally loaded piles in soft clay. In: Proceedings of the Offshore Technology Conference, pp 577-594. OTC Paper No.124 (1970).
4. O'Neill, M.W. and Murchison, J.M. : An Evaluation of p-y Relationships in Sands, prepared for the American Petroleum Institute, Report PRAC 82-41-1. Houston, University of Houston (1983)
5. Hariharan, M. and Kumarasamy, K.: Analysis of pile groups subjected to lateral loads, Proceedings, 3rd International Conference on Behaviour of Offshore Structures, Vol. 2, Hemisphere Publishing Corp., pp. 383-390, Washington, D. C. (1982).