



## Seismic Analysis of Pile Group with Different Variations in Dimensions and Parameters

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### Abstract

As per demand of current construction many projects are running such as metro construction, bridges, tall building, and industries, etc. In such type of construction where the soil bearing capacity (SBC) is very low it is necessary to provide pile foundation. Conduction of dynamic analysis is for different pile group for earthquake. The stress resting action increases with the group action of piles. Present study describes about pile group, modeling of four piles and eight pile groups taking space between them as 2.5D and 3D, where D is the diameter of the pile. Diameter of four pile group is 0.6 and diameter of eight pile group is 0.4, shape chosen to arrange the pile group are Rectangle, Square, Diamond and Staggered. The analysis of different shape pile groups has been done using the response spectrum method based using STAAD Pro. Parameters such as displacement, shear force (SF) and bending moment (BM) were taken in consideration for pile group analysis. Pile cap is analyzed for bending moment in 'y' and 'z' direction.

**Keywords** – Pile, Pile Cap, Laterally Loaded Piles, SBC

### 1. Introduction

Seismic analysis is related to computation of the response of a building or other structure under earthquakes [1-4]. It is a part of the process of structural design which includes earthquake engineering or structural assessment and retrofit in regions where earthquakes are prevalent. During earthquake many of the buildings collapse due to lack of understanding of the inelastic behavior of structure [6-8]. Elastic analysis gives only elastic capacity of the structure and indicates where the first yielding occurs [9-10]. This is applicable for wind analysis too [11-13]. However, it cannot give any information about redistribution of forces and moments as well as failure mechanism [14-18]. For study of inelastic behavior of structure nonlinear analysis is necessary and structures used in transportation such as box culvert, inelastic behavior changes slightly and it gives optimum results [19-21]. The development of rational methodology that is

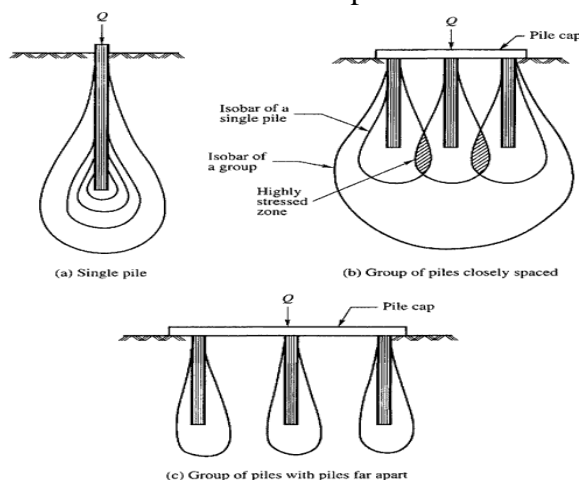
applicable to the seismic design of new structures using available ground motion [22-24], information and engineering knowledge, and yet is flexible enough to permit the incorporation of new technology as it becomes available has been supported for sometimes now [1, 25-26]. The major focus of several major research and development has contributed efforts throughout the world while in majority of cases nonlinear analysis is used.

Earthquake or seismic analysis is a subset of structural analysis which involves the calculation of the response of a structure subjected to earthquake excitation. Major seismic input includes, ground acceleration, velocity/displacement data, magnitude of earthquake, peak ground parameters, and duration etc. [27-28]. Pile foundation falls under the category of deep foundation where pile group is a combination of pile having pile cap that is normally in contact

with soil. Load applied on pile cap is distributed to individual pile. The ultimate capacity of pile group is the addition of the individual capacity of piles [29]. A pile foundation can be constructed using different materials such as timber, concrete or steel [29]. Pile foundations are mainly used transfer to the column and its foundation mostly used that places, where weak layer of the soil for example marshy area, tall building, offshore platform, defense structure, dams and lock structures, transmission towers etc. exist. The pile foundation proves advantageous in reducing permeability, shrinkage, consolidation, swelling, swelling pressure, and improve soil bearing capacity [30]. The pile foundation causes lateral forces in wind action, wave action, traffic and wind movement, water pressure, with stand blasts, lateral pressure, ground movements, earthquakes.

### 1.1 Group Action of Pile

Load acting on a pile is of higher magnitude than instead of providing single pile when group of pile are used. Fig.(a) showing load acting on single pile with stress bulb. Fig. (b) showing load acting on group of piles and a combined stress bulb is formed which is summation of individual pile stress bulb.



**Fig.1 Group action of piles with stress zone effect (Ref. abuildersengineer.com)**

Now the combined action of piles is termed as Group action of pile used in different diameter pile to determine the group action of pile [31]. The results are summarized from different result for the Staad Pro analysis by FEM methods of pile group [32] so the arrangement also emphasis on the group action of piles. [33] referred the other software like FLAC and the data are to be get with the help of P-Y curves for influence of pile. The effects of pile cap with variation of thickness are discussed in it and deal with lateral and vertical loads on it with cohesive and non-cohesive soil types in it [34]. The group action of pile is based on different arrangement, method, different dimensions, soil types, analysis method on which the different researchers deals with group action of pile and pile cap.

### 1.2 Pile Group Analysis

In the present study, pile and pile group were studied which based on use of different software such Staad pro and different parameters which are described below:

The pile group arranged in series of 2 piles, 3 piles, and 4 piles at a spacing of 2D, 3D, 4D, 5D and 6D, D (diameter) for analysis cohesion less soil is taken. The authors made use of finite element method using software STAAD pro. Parameters taken for analysis are deflection, axial force (AF), shear force (SF) and bending moment (BM) for pile in group [31]. The behavior of pile foundation for a bridge pier in a cohesion less soil, piles arranged in group of 3 and 4. The shape of pile cap consist of triangular and square for 3 and 4 respectively. The pile systems are subjected to lateral loads. The piles are arranged in series and non-series and comparison is carried out between the two. The parameters of study are axial force, shear force and bending moment analyzed

on Staad Pro using finite element method. It is concluded that maximum value of taken parameters are obtained for series arrangement [32]. The analysis on pile foundation in black cotton soil. As black cotton soil shows anonymous behavior with temperature variations. It has a tendency to shrink during summers and expands a lot during monsoon which affects the super structure. In this paper authors have designed a foundation which will protect the structure from ill effects of black cotton soil. For study G+ 2 storeys is chosen and analysis is done by both software and manually [35]. Pile modeled on G+5 building in a clay and sandy soil taking live, dead load and weight of structure. Using Staad pro modeling and foundation design is done. The support reactions derived from Staad pro is applied in. It was concluded from their research that sandy soil possesses more bearing capacity than clayey soil. Also, in clayey soil the vertical settlement in isolated footing is more than embedded pile. Pile foundation of sandy soil shows more vertical settlement as compared to isolated footing [36]. Various methods to analyze the vertical and horizontal loads applied on structure. To calculate vertical load-Y curve and Vesic's method are used taking cohesion less and cohesive soil. Piles are considered as linear elements and soil interaction effect is taken assuming Winkler soil spring. Using IS code 2911 lateral and vertical sub grade modulus is derived. Using finite element method in Staad pro lateral load is derived; also, L-pile software and Brom's method are used [26]. The examined pile subjected to lateral and vertical loads subjected to deflection using finite element method. The vertical loads in piles are distributed in two parts, namely skin friction and end bearing at the base. Using static analysis on  $c-\phi$  values, ultimate bearing

capacity of vertical load in pile is determined for cohesive and cohesion less soil. The deflection occurred in pile is checked using Staad pro software. Calculations for Lateral load carrying capacity, depth of fixity and maximum moment in pile are done using IS Code 2911(Part I/Sec2) [37]. This includes a simple experiment on B+G+4 building modeling and analysis on Staad pro software using a pile foundation. For calculating dead and live load IS:875 (Part I)- 1987, IS: 875 (Part II)-1987 are referred respectively. The structural components are beam column staircase, slab, shear wall, retaining wall [38]. With the use of FLAC-3D software, 3D-Lagrangious analysis is performed in which concrete piles and different cap size as well as length subjected to lateral load are investigated using numerical simulations. With the P-Y curve drawn and analysis of influence of piles on these curves suggested that with increase in pile cap, soil resistance increases [33]. The working on raft foundation analysis taking into account the pile-soil-pile and pile-soil-cap interaction [28]. The group enlighten about the combined piled raft foundation by calculating relative proportions of load taken by raft & piles, the effect of piles on total and differential settlement. The article dealt with the analysis of CPRF by simplified methods and finite element analysis using the Software PLAXIS [28].

### **1.3 Group Action of Pile Based on P-Y Curve**

A series of P-Y curves for single pile was used. The newly placed P-Y curves were compared with old P-Y curves to determine the soil pile interaction. For different relative density, soil-pile reaction was increased by 40-95% for smooth pile [39] and discussed about the waves generated by

seismic forces through the soil suggesting with these waves kinematic effects are introduced on pile foundation. For this a research group used lumped –mass parameter models to get the value of kinematic response of pile from obtained P-Y curves to affirm the approaches theoretical and experimental comparisons [40]. Devi et al. [29] conducted three-dimensional analysis on cohesionless type of soil strata comprising dry sand in two pile groups composed of two and three piles each. Considering foundation head displacement at the top and bending moment of the pile as responses, the group observed that parameters such as pile spacing, pile size and configuration of the pile group can significantly influence the behavior of the pile group. The damage to pile supported structure in a liquefiable soil due to Earthquake is reviewed by Bhattacharya et al. [41] and discussed two important theories of pile failure namely flexural mechanism and buckling Instability to extract information and compare the better performance of pile foundation. A full-scale lateral spreading experiments was conducted on a pile foundation of the port of Tokachi, Hokkaido, Island, Japan, and single pile use in its foundation [42] with group of four pile and nine pile groups using P-Y analysis method for pile response during lateral spreading.

## 2. Need of The Study

The main scope of research work is to study the behavior of group action of pile under seismic load. For this different arraignment are taken by varying the basic parameters such as spacing between the piles, dia. of pile, dimensions ex. 2D, 3D, (L, 2L), length spacing (S, 2S) & thickness (T, 2T), soil types, seismic zone types, patterns of pile group (square, rectangular, diamond, staggered). Also, pile is analyzed along with

super structure. Since with change in topography there is change in soil and also a change in its bearing capacity. The SBC may be low at some place and may be high at other thus making application of pile group desirable at low SBC geography. Seismic analysis of pile group will be studied by different method such as time history analysis, response spectrum, Pushover analysis and equivalent static analysis.

## Conclusions

As per the study of different research on pile group by different researches which are mentioned above. It is concluded as the following points.

- It is compulsory to analyze the seismic effects on pile before construction.
- The circular shape of pile proved most effective.
- Low bearing capacity of soil. Make it necessary requirement of pile.
- Piles can be used in different shapes, size and spacing between them

## Conflict of interest

The author declares no conflict of interest.

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