COMPARISON OF VERTICAL AND BATTERED PILES SUBJECTED TO LATERAL LOADS

Dr D.K. Maharaj[1],Deepak Kumar[2],DrSanjeev Gill[3]
[1]Director and Principal ,[2]Assistant Professor,
GNIT Mullana ,Ambala ,Haryana
[3] HODDepartment of Civil Engineering,JBIT,dehradun

Abstract : Pile foundations are provided to transfer the vertical and horizontal loads ofsuperstructure like high rise buildings, bridges, offshore structures etc. to the deep strata in the soil. These vertical and horizontal loads are due to the loads coming from the superstructure and wind, water thrust, earthquake, earth pressure respectively. In a pile foundation, piles are used in groups. Vertical piles in a group of piles are more efficient to take vertical loads as compared to horizontal loads and when the horizontal load per pile exceeds the bearing capacity of the vertical piles in that case batter piles are used with vertical piles because batter piles can take more lateral loads than vertical piles. This paper presents the comparison of lateral load resisting capacity of vertical and battered piles. A model study was conducted using mild steel piles having outer diameter of 19 mm and wall thickness of 1.6 mm. The length of vertical piles used were 80 cm for all the tests and the battered pile had a vertical projection of 80 cm. The angle of battered pile with vertical was kept as 25° for all the tests. The soil used in the model testing was fine sand having specific gravity of 2.63 and the tests were conducted at an average density of 16.06 KN/m^3. Piles were spaced at 2.5d (d= diameter of pile) to each other. Tests were performed on pile groups having different arrangements as 1) four vertical pile group2) four negative battered pile group 3) four positive battered pile group 4) three vertical, one positive battered pile group and 5) three vertical ,one negative battered pile group. Load versus deformation curves has also been plotted. From the model study it has been found that pile groups having negative battered piles are more resistive to negative loads.

Keywords: Cohesionless soil, lateral loads, positive & negative battered piles, vertical piles.

Introduction: Generally , whenever a soil of bearing capacity extends to a considerable depth, piles are used to transmit vertical and lateral loads to surrounding soil media .Piles or piles group may be subjected to static, dynamic and as well as repetitive loading. Till now most of research work has been directed towards the response of individual to lateral load However, piles are more frequently used in group and so far a little information is available on the effect of lateral load on pile group.Piles are frequently subjected to lateral forces and moments viz .Quay and harbor structures in which horizontal forces are generated due to the impact of ships during berthing and wave action ,Offshore structure subjected to wind and wave action, Tall structure like chimneys, transmission tower subjected to wind load,In structure in earthquake prone areas.In design of such pile foundation , not only the ultimate loads shall be worked out to ensure that serviceable limits are satisfied .Matlock and Reese (1990) presented a generalized iterative solutions method for rigid and flexible laterally loading piles embedded in soil with forms of varying modulus with depth. The Ultimate lateral resistance of rigid piles based on earth pressure theory was developed by Hansen(1961) and is applicable for short piles. Davisson and Gill (1963) investigate the case of laterally loaded pile embedded in laterally soil system with different modulus of subgrade reaction in each layer. Madhavetal. (1971) have employed an elasto- plastic model for obtaining the response of laterally loaded piles. Broms (1964a,b) method is also based on earth pressure theory with simplifying assumptions for distribution of ultimate soil resistance along the pile length and this method is applicable for both short piles and long piles . This method for computing ground surface deflection of rigid and flexible fixed and head piles was based on modulus of subgrade reaction as suggested by Terzaghi (1955). Jamilokowski and Garassino (1977) and provided a state-of-the-art discussion on soil modulus and ultimate soil resistance for laterally loaded piles. Randolph (1981) studied the problem of flexible piles under lateral loading and proposed algebraic expression for pile head displacement and rotation Karthigeyanetal.(2006) had investigated the influence of vertical load on behavior of a single piles in elastic –plastic soil for single as well as double layers of both sand and clay and generated p-y curves. Zarmri et al. (2009) have carried out the lateral load behavior under combined vertical and lateral loads considering variation of water table at different elevations.

MODEL PILES:

Mild steel piles having an outer diameter of 19 mm and wall thickness of 1.6 mm (with EI of pipe section = $4.64*10^8$ N-mm^2) were used for experiment work. The length of vertical piles are chosen to be 80 cm for all the test and the battered pile had a vertical protection of 80 cm . This enable the pile to be consider as long pile in order to simulate the field condition to greater extent.

TYPE OF SOIL AND METHOD OF FILLING:

The soil used in model testing was fined sand. For filling the tank rainfall technique of sand filling was used. Its provided uniform and required density throughout the fill .The test were conducted at an average density 16.06 KN/m^3 .The sand density for the entire test was kept constant . The sand used was dry and uniform .The grain size distribution curve has been depicated in fig. The soil properties were as follows:

TABLE 1

PROPERTIES OF FINE SAND

Soil type	SP
Effective size (D_{10}) in mm	0.175
Uniformity coefficient (C_u)	2.00
Coefficient of curvature (C_c)	3.84
Specific gravity (G_S)	2.63
Minimum dry unity weight (γd, min) in KN/m^3	13.54
Maximum dry unity weight (γd, max) in KN/m^3	16.06
Max void ratio, e_{max}	0.84
Min void ratio, e_{min}	0.63

Test Procedure: The testing tank was filled up to a height of 80 cm by rainfall technique for getting the uniform density of 1.6 gm/cc. After that piles were driven vertical or inclined according to the group in the sand at 2.5d (d=diameter of pile) spacing. The embedded length of pile was 70 cm. Pile cap was placed over piles surface and adjusted horizontally. Then free end of the wire was attached gently to hook of the piles cap and by passing it over the pulley attached other end with hanger. A dial gauge was attached to the bottom of the hanger to note down the horizontal deflection of the piles group. After doing this, load was applied in steps (2kg every time) and increment of the load was done up to the point till total horizontal deflection exceeded 10-15 mm. After this, load was brought back to zero in same steps corresponding reading of dial gauge were noted.

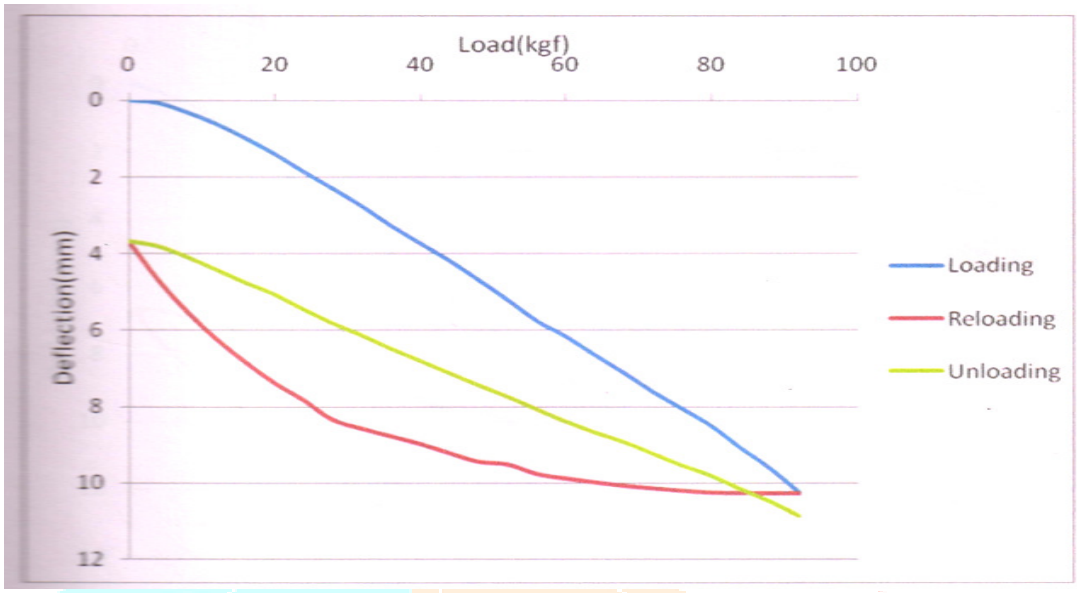

Figure 1

LOAD DEFLECTION CURVE FOR 4V PILE

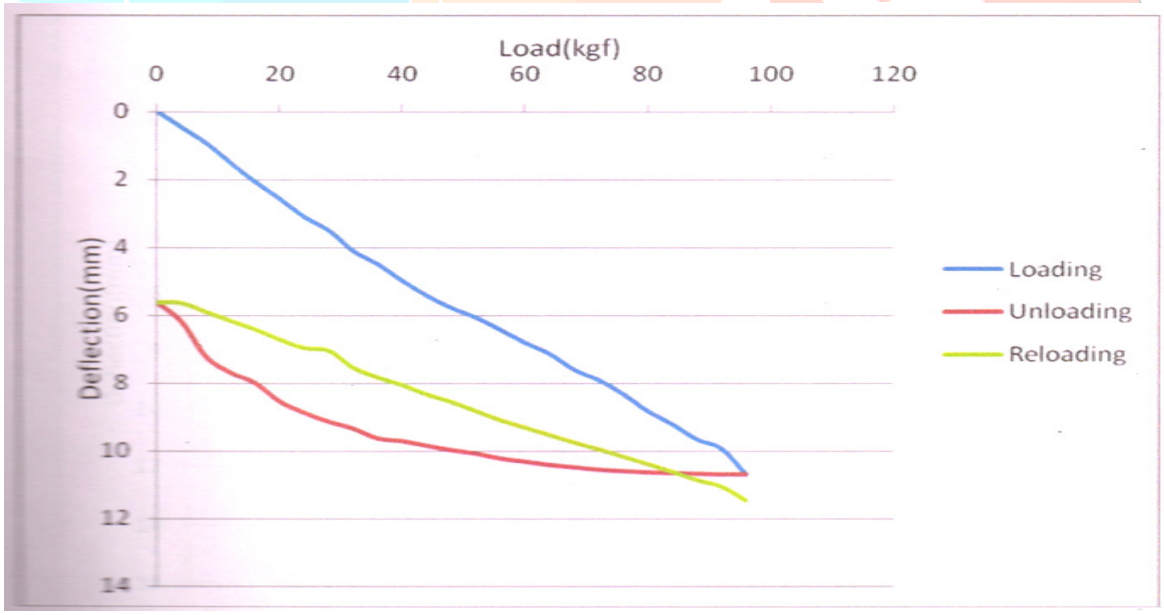

Figure 2

LOAD DEFLECTION CURVE FOR -4B PILE

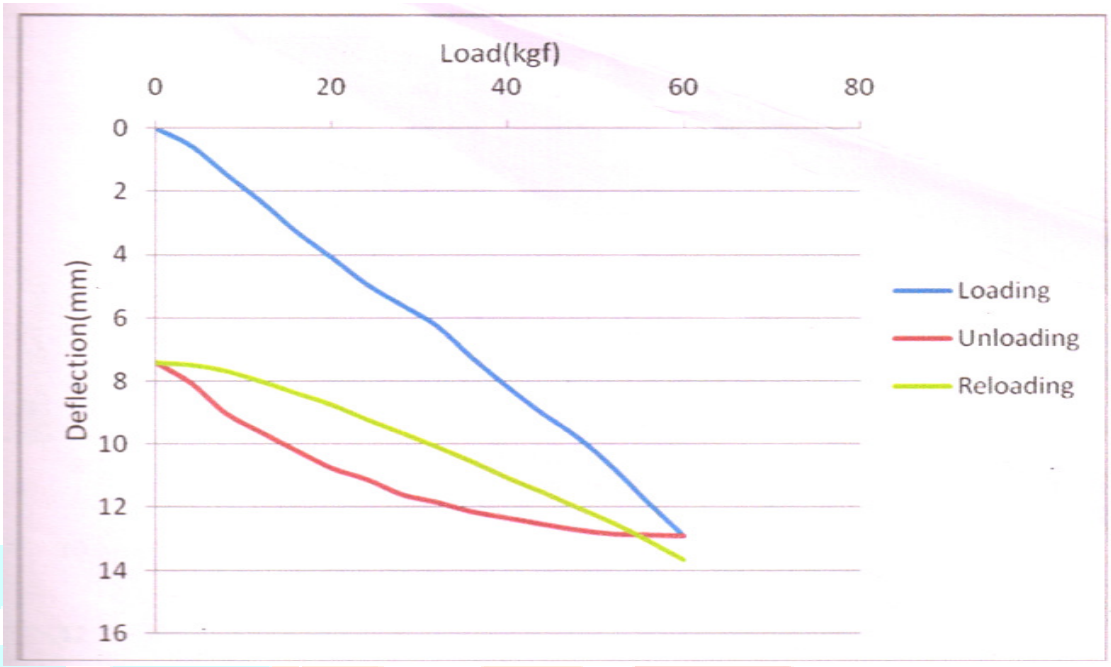

Figure 3

LOAD DEFLECTION CURVE FOR +4B PILE

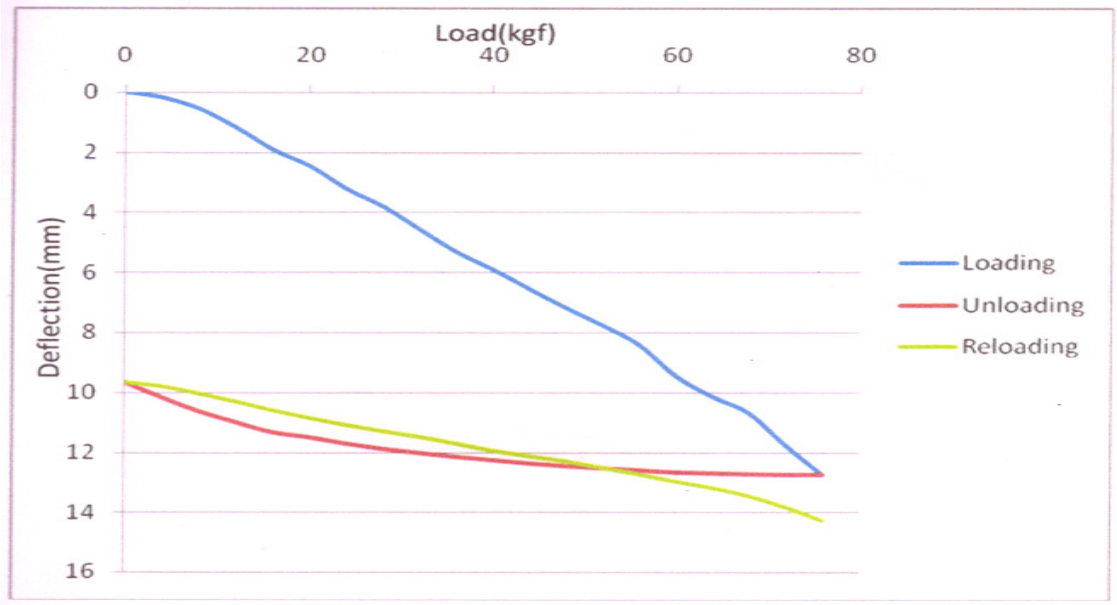

Figure 4

LOAD DEFLECTION CURVE FOR 3V,+1B PILE

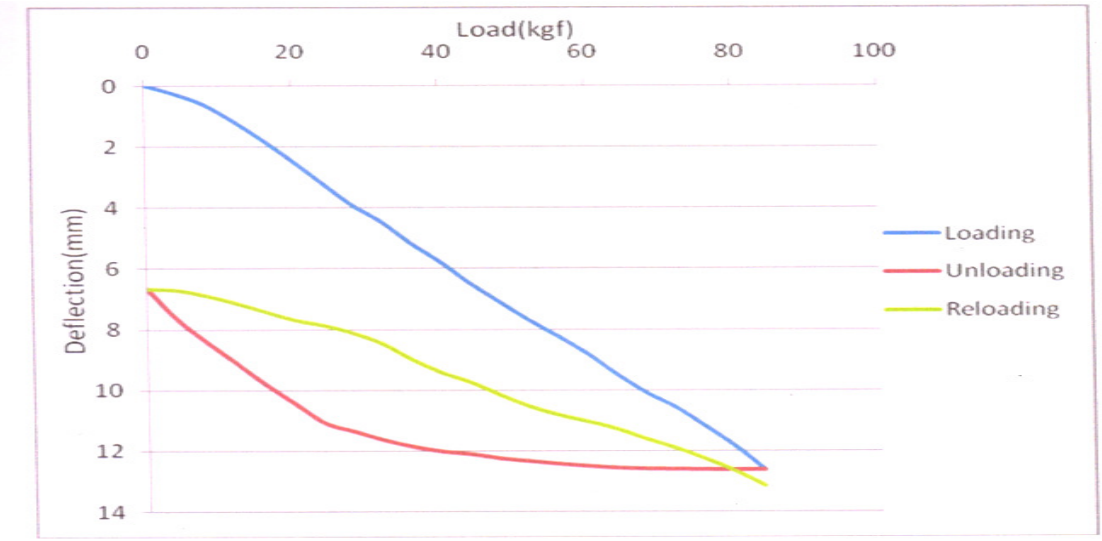

Figure 5

LOAD DEFLECTION CURVE FOR 3V,-1B PILE

CONCLUSIONS

1. The battered pile inclined in the direction of load are more resistant to lateral load than vertical pile and than that of lateral shows less resistance to lateral load than that of vertical pile.

2. The deflection get increased when number of cylces is increased, as quite clear from load deflection curves.

3.If the pile are spaced at sufficient distance apart , the group capacity can be taken as the sum of individual capacity safely

4. Its is clear that the behavior of pile groups contains batter pile in the ground and all types of batter piles in the group, that is whether the load is applied in the direction of batter or against the batter.

5. Piles groups having both batter and vertical piles are more resistant to lateral load , either in the direction of batter or against the batter than pile group containing Vertical piles only

6. Piles groups having a negative batter piles are more reistant than a pile group having a similar positive .

7. Model studies have indicated larger defection as compared to theoretical analysis.

REFRENCES

[1] A. Brown , C. Morrison, C. Reese , Lateral load behavior of pile groups in sand ,J.

[2] Broms , B. (1946a) .The Lateral Resistance of piles in cohesive soils . *Journal of The Soil* Mechanics & Foundation Division ,*ASCE* ,90 (SM2) ,27-63.

[3] Broms ,B. (164b) . The Lateral Resistance of pile in cohesive soils . *Journal of The Soil* Mechanics Foundation Division ,ASCE ,90 (SM2) ,123-156.

[4] Cheng-Der Wang Tzen-Chin Lee , Ming –Tang Chen,(2008) : “Vertical stress

Distribution around better piles driven in cross –anisotropic media" Journal Analytical Methods in Geomechanics Volume 33, No. 8, Page 993 -. 1011.

[5] Comodromos ,E . M .(2003).Response prediction for horizontallyloaded pile Groups . Journal of Geotechnical Engineering of Southeast Asian Geotechnical Society ,123-133.

[6] Das, B. M. (2004) ." *Principles of Foundation Engineering"* ,5th Edition , 2nd Reprint .

[7] G. Poulos , Behavior of laterally loaded piles ,J .Soil Mech. Found .Div., ASCE 97 (5) (1971) 711-731.

[8] Giannakou ,A., Gerolymos , N. , gazetas , G., Tazoh , T., and Anastasopoulos , I., (2010) : "Seiesmic Behavior of Better Piles : Elastic Response " Canadian Geotech Journal Div , ASCE , Vol. 139 No.9, Page 1187-1199

[9] Hernnik of (1950): "Analysis of Pile Foundation with Batter Piies" Trans. ASCE, vol.115, Page351-381.

[10] Jamiolkowski, M., and Garassino, A.(1977). Soil modulus for laterlly loaded plies. Proc., 9th9 Int. Conf. Soil Mechanics Foundation Engineering, Tokyo, 87-92.

[11] J. Kent Hsinao,(2012): "Staticl Analysis of Pile Groups Containg Batter Piles", Jouranl of Structural Elgileering Div. EJSE, Page, 74-81.

[12] K. Gaaver, Behavior of laterally loaded piles in cohesion less soil, in: The Tenth East Asia-Pacific Conference on Structural Engineering & Construction, 2006

[13] Lv Fan – ran , Yin Ji – ming and Jin Yao- hua ,(2011) :"Study on Experiments '' Journal on Soil Mechanics and Foundation Div., ICETCE, Page 6888 -6891.