Behaviour of Prestressed Belled Wedge Pile Under Pullout

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Abstract- *Belled wedge pile is a special shaped pile which has advantages of both belled and wedge pile. These are mainly used in soft viscous soils such as sand and clay. The belled wedge pile can improve the friction of pile shaft, tip resistance and reduce negative skin friction. The wedge shape can reduce the development of negative skin friction when the surrounding soils are deforming under the applied surcharge loads. Relative density, Stiffness of the soil, Surcharge load, Type of pile (BWP, Belled pile, uniform section pile), Angle of inclination of pullout load, Embedment length of pile, Soil layer thickness and soil type, are considered as the parameter of this study. Comparative study between pre stressed and non pre stressed piles reveals the effect of prestressing on the load carrying capacity of concrete pile*

Keywords- Belled Wedge Pile, Pre-stressing, Pre-tensioning Wedge Pile

I. INTRODUCTION

The design of foundations like transmission line towers, radio tower, television tower, radar tower has to incorporate with their self-weight and high ambitious structures like silos, overhead water tank and tall chimneys are not only concerned about transmission of large compressive load in sub-soil profile but uplift loads too. More over water front structures and off-shore structures in hostile environment are subjected to wave action, wind gust and thrust from floating vessels result in tension in foundation. In such cases the piles with enlarged base may be an acceptable option for geotechnical engineers; because its enlarged base can offer more pile capacity and in contrast higher load carrying capacity during uplift; as large volume of breakout soil within slip surface tends to move upward under tension and offers passive resistance. The pile capacity can be improved by increasing pile diameters or pile length. Belled pile (which enlarge the pile tip), and tapered pile (which top cross-section is larger than tip cross-section) are two good methods to improve tip resistance, and side friction, respectively.

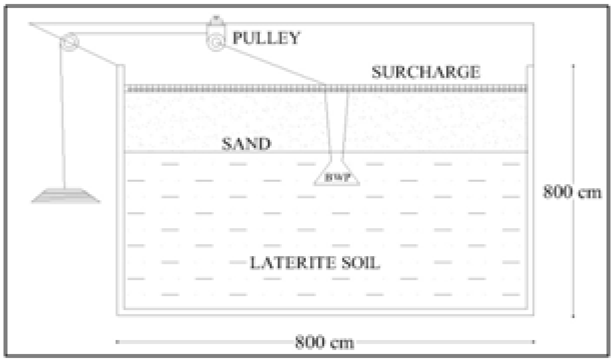
II. OBJECTIVES

- To determine uplift capacity of the pre-stressed BWP in different soil conditions
- To determine the effect of surcharge load, angle of inclination of load and belled angle on the uplift capacity of pile
- To compare the results of uplift capacity of pile with and without pre-stressing

Comparison between prestressed pile and non prestressed pile will reveal the effect of pre stressing in load carrying capacity of concrete structure. Optimum dense condition, belled angle, pile type, angle of inclination of pullout load, embedment length of pile and suitable soil type in uniform soil and layer thickness in layered soil will be determine

III. MATERIALS AND METHODOLOGY

Collection of materials include the collection of sand, laterite for tank filling and cement, aggregate, steel reinforcement for pile casting. M25 mix and Fe 415 steel is used for casting. Determine both engineering and index properties of the each collected material. The soil layers were prepared in a model test tank with inside dimensions of 800mm x 1000mm x 800 mm size. The predetermined weight of soil was spread uniformly in the tank, leveled and compacted to achieve the desire density at each layer. The model pile placed in the tank. The soil filled and compacted with the help of tamping rod to achieved desire density. The hook provided at the end of the pile was then connected to the cable, which was passed over a pulley attached rigidly to the loading frame. The loads were used to hang over the plate tied at one end of the cable and the piles are connected at the other end. Gradual incremental load is then applied to the one end of the rope pulley system so as to move the model piles upward with in the soil in to which it was embedded. Then load is adjusted to get accurate value at the ultimate point of failure condition. Corresponding axial deflection to each load increment was noted using dial gauge fixed in the system. The mould of BWP, BP and conventional pile is made with GI sheet. The tapered angle, bulb shape, soil layer height and the length of pile are the constant parameters in this study. The relative density of sand (30%, 50%, 70%), modulus ratio of pile, stiffness of the soil, surcharge load (100 kpa, 150 kpa,200 kpa, 250kpa and 300 kpa), type of pile (BWP, belled pile, uniform section pile), angle of inclination of pullout load (30̊ ,45̊ ,60̊, 90̊), embedment length of pile, soil layer thickness are the varying parameters. The piles allowing for pre stressing by means of pre-tensioning method as shown in figure given below



Experimental Set Up.

IV. RESULT AND DISCUSSION

The tests for index properties and engineering properties of sand and laterite soil were determined by conducting series of laboratory experiments. Properties of sand and laterite were tabulated in table 4.1 and 4.2.

Table 4.1 Properties of Sand

Properties	Value	IS Codes
Effective Particle Size		
D10 (mm)	0.22	IS:2720 (Part 4) - 1985
D30 (mm)	0.32	
D60 (mm)	0.57	
Uniform coefficient , C_u	2.4	
Coefficient of curvature,	0.77	
Gradation of sand	SP	
Specific gravity	2.65	IS 2720-PART III-
Max. dry density (g/cc)	1.819	IS 2720 PART IV-1983
Min. dry density (g/cc)	1.777	
Sand density (Dr -30%)	1.777	
(Dr -50%)	1.789	
(Dr -70%)	1.819	
Permeability(cm/sec)	$7.24 X10^{-4}$	IS:2720 (Part3 / Section2) - 1980

To record the deflection for each increment of load applied, one sensitive dial gauges of least count of 0.01mm were used. The deflection was noted for each increment of load.

Table 4.2 Properties of Laterite Soil

PROPERTIES	VALUES
Specific gravity	2.656
Sieve analysis, Cu	3.30
Liquid limit	42%
Flow index	31%
Plasticity index	17%
Toughness index	54.8%
Consistency index	247.05
Shrinkage index	0.146
Maximum dry density(g/cc)	1.84

Laboratory tests were conducted by varying parameters like surcharge loading and density of the soil. Figure 4.1 shows the behaviour of uplift over different relative densities of sand ie,30%, 50%, 70%. Pullout capacity of BWP has more in dense sand condition. In medium dense and loose condition pile has less strength. In loose condition the failure load is 4.5 kN at 6 mm deflection. In dense condition it is nearly two times than the loose state.

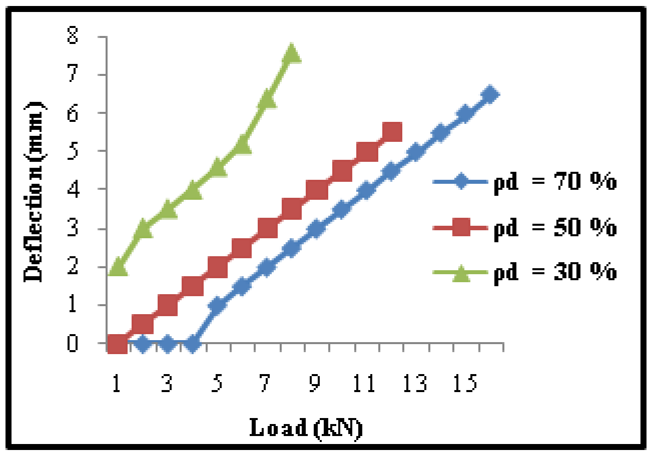


Fig 4.1. Load Deflection Curve for BWP at 30%, 50%, 70% Relative Density

Figure 4.2 shows the comparison of pullout capacity of BWP, BP, WP and CP. Comparative study reveals the better resistance of BWP under pullout than over types. The conventional square pile fails at 6.5 kN load with a deflection of 5.5 mm.BP has a deflection of 3 mm on 4 kN failure load WP fails at load of 5 kN with deflection of 3.5 mm. WP has more uplift resistance than BP but both have less uplift than BWP. So BWP has uplift resistance three times than the other types of piles.

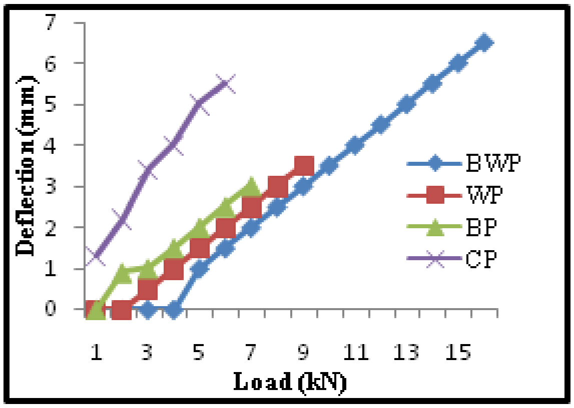


Fig 4.2 Comparison of Uplift Capacity of Piles

Figure 4.3 shows the effect of prestressing on the uplift capacity of piles. Here, the prestressing is provided by means of pre- tensioning method. Prestressed piles have more pullout resistance than the non prestressed piles.

Prestressing provided for the reinforcement before concreting and after providing a horizontal load, concrete poured in to the mould. And at the time of hardening cement prestressing force released.

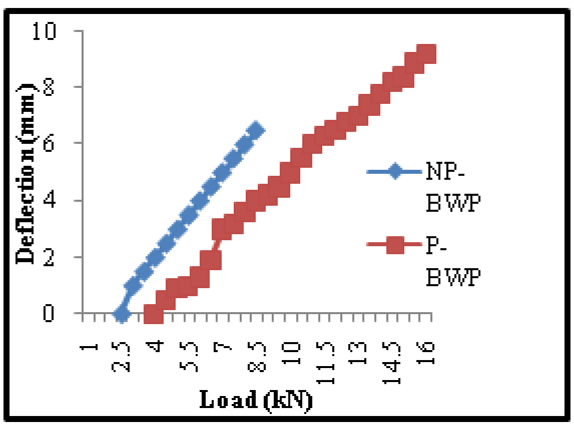


Fig 4.3 Effect of Prestressing over Uplift

Figure 4.4 shows the uplift capacity of BWP under different surcharge load. 100 kPa, 200 kPa, 300 kPa, and 400 kPa were the surcharges provided to soil as overburden soil. Graph shows that the pullout resistance of BWP is increases with increasing surcharge. At 400 kPa the failure load of BWP is 13 kN with 10.2 mm deflection. And at 100 kPa it is 11 mm deflection for 4 kN load. Means, the pullout resistance of BWP is increases gradually with the increasing of surcharge load. Prestressing is provided to the reinforcement by pretensioning method. Pretensioning governs by providing horizontal load using horizontal tendons.

Figure 4.5 shows the comparison of uplift behaviour of different types of piles at 400 kPa. The BP and WP has more uplift resistance than the conventional pile but it is less than the BWP.

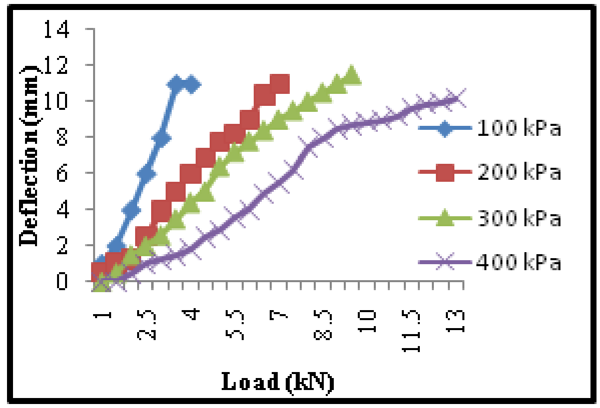


Fig 4.4 Uplift Capacity of BWP at Different Surcharge Loads

The failure load of BWP is 13 kN with 10.2 mm whereas for belled and wedge pile it is 10.4 mm at 9 kN load. Conventional pile fails at a load of 6 kN with a deflection of 8mm.

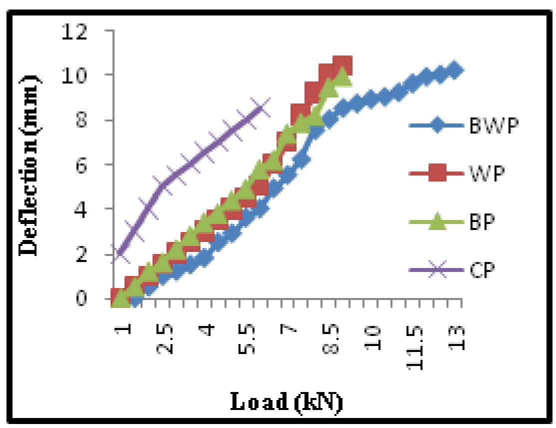


Fig 4.5 Comparison of Uplift Capacity of Piles at 400 Kpa Surcharge Load

Figure 4.6 shows the effect of pre-stressing under surcharge. With surcharge increasing the pullout resistance of the pile is also increasing.

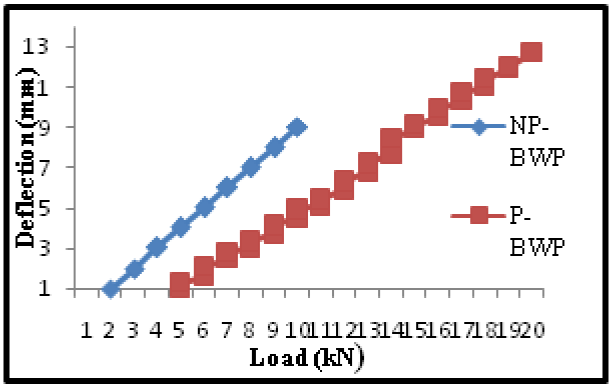


Fig 4.6 Effect of Pre-Stressing under Surcharge

V. CONCLUSIONS

The conclusions made from the study are the following,

- The distribution of BWP along pile depth has both the characteristics of belled pile and wedge pile
- BWP has more uplift resistance in dense sand condition
- It is two times greater than the conventional pile
- The uplift capacity of belled pile and wedge pile is less than the BWP
- Pre-stressed BWP has strength three times greater than the non-pressed piles
- BWP is one of the cost effective pile, which can improve bearing capacities effectively
- Compare to the other pile types, the uplift load of BWP is larger than that of belled and wedge pile.
- The uplift capacity of BWP is increases with pile-surrounding soil modulus ratios increasing and with soil strength increasing
- With increasing the surcharge load the pile soil interaction and uplift resistance increases and modifies the load deflection curves of piles
- Down drag of belled wedge pile is smallest among all the pile shapes evaluated
- Down drag of BWP decrease with increasing stiffness of the pile and surrounding soil, bearing sand and overburden soil and with decreasing in taper angle

REFERENCES

[1] A. I. Dhatrak, Maithily Ghawd & S.W. Thakare "Experimental study on belled wedge pile for different loadings in cohesionless soil " ,(IGC) 2018

[2] Gangqiang Kong,H anlong Liu,Qing Yang, Robert Y. Liang,and Hang Zhou "Mathematical Model and Analysis of Negative Skin Friction of Pile Group in Consolidating Soil", IJERT, 2013

[3] Wenjuan Yao, Yimin Liu, and Jun Chen "Characteristics of Negative Skin Friction for Superlong Piles under Surcharge Loading" ,ASCE 2012

[4] Song- Lin WEN "Failure behaviour of belled pile under combined loads "ASCE 2014

[5] Jaw-Guei Lin, Shih-Yu Hsu, and San-Shyan Lin"The new method to evaluate the Uplift capacity of belled piles in Sandy soil " (JMST) 2014

[6] KONG Gang-qiang ,ZHOU Hang,LIU Han-long DING Xuan-ming,LIANG Robert"A simplified approach for negative skin friction calculation of special-shaped pile considering pile-soil interaction under surcharge" *J. Cent. South Univ. (2014)*

[7] Gang Qiang Konga, Qing Yangb, Han Long Liua & Robert Y. Liangc **"**Numerical study of a new belled wedge pile type under different loading modes" *European Journal of Environmental and Civil Engineering (oct 2013)*

[8] Gangqiang KONG,Xianliang TAN,Zongwei DENGand Zhiren Jin "Comparative analysis of single belled wedge pile with conventional piles under lateral load" *Advanced Materials Research Vols. 594-597 (2012) pp 50-55*

[9] Gangqiang KONG "Performances of Compressive Capacity for Belled Wedge Pile Group" *Advanced Materials Research Vols 261-263 (2011)*

[10] Hamed Niroumand, Khairul Anuar Kassim, Amin Ghafooripour, Ramli Nazir "Uplift Capacity of Enlarged Base Piles in Sand" EJGE 2012

[11] M. Hesham El Naggar and Jin Qi Wei Axial capacity of tapered piles established from model tests Research Gate 2011

[12] KONG Gang-qiang, YANG Qing, ZHENG Peng-yi, LUAN Mao-tian "Evaluation of group effect of pile group under dragload embedded in clay" Research Gate 2009

[13] KONG Gang-qiang, YANG Qing, ZHENG Peng-yi, LUAN Mao-tian "Evaluation of group effect of pile group under dragload embedded in clay" Research Gate 2009

[14] Dr. S. S. Pusadkar, Sachin Ghormode "Uplift capacity of piles subjected to inclined load in Two layered soil" IGC 2015

[15] Suman Manandhar, Noriyuki Yasufuku, Kiyoshi Omine, and Taizo Kobayashi " Response of tapered piles in cohesionless soil based on model tests" NGJS 2010

[16] Tanayan Deb, Sujit Kumar Pal "2D model study on slip surface around belled anchor pile under uplift in cohesionless soil" IGS 2015

[17] Jasim M. Abbas, Zamri Chik, Mohd Raihan Taha "Modelling and Assessment of a Single Pile Subjected to Lateral Load" SCEINDO 2018

[18] Balu E. George, Hari G "Numerical investigation of under reamed piles" (IGC) 2015

[19] M. Hesham El Naggar and Jin Qi Wei Axial capacity of tapered piles established from model tests Research Gate 2011

[20] Ataollah Sanaei Farokhi , Hamid Alielahi , Zahra Mardani "Optimizing the Performance of Under-reamed Piles in Clay using Numerical Method" Research Gate 2015

[21] Tanuja Christopher, Binil Gopinath "Parametric Study of Under-Reamed Piles in Sand" IJERT 2016

[22] Zhijian Yang, Guochang Li, Wenjin Wang, and Yajun Lv "Study on the Flexural Performance of Prestressed High Strength Concrete Pile"ASCE 2013