Predictability of the International Geotechnical Codes for Estimating Ultimate Bearing Capacity of Large Diameter Bored Piles

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1 INTRODUCTION

This paper introduces an analytical and a comparative study between some of the widely used international geotechnical codes for pile foundations design. The implemented codes of design in this work are: Egyptian geotechnical design code (2001), German bored piling code (DIN 4014, 1990), Japan Road Assoc. code (JRA, 2002), and the AASHTO (2007). Consequently, assessment of the predictability of these design codes to the ultimate capacities of large-diameter bored piles is discussed through this comparison.

Figure 1 shows the pile capacity components. The total ultimate load Q_u is expressed as the sum of those two loads, i.e.,:

$$Q_u = Q_{su} + Q_{bu} - W_p \tag{1a}$$

$$Q_u = \sum q_{(su)i} A_{si} + q_{bu} A_p \tag{1b}$$

where: q_{bu} = ultimate end-bearing resistance, A_p = bearing area of pile base, A_{si} = nominal surface area of pile shaft in layer no. (i), $(q_{su})_i$ = ultimate skin friction resistance per unit area of the pile shaft in layer no. (i), and W_p = weight of pile (neglected).

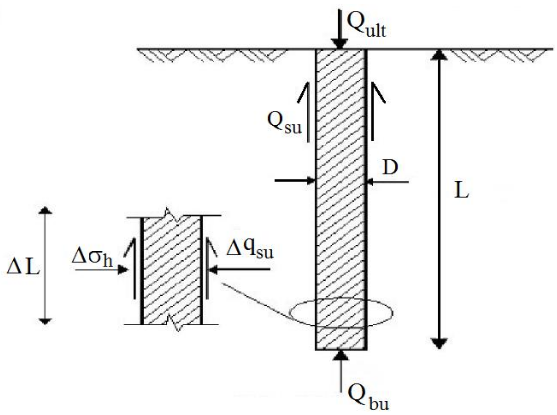

Fig.1 Pile resistance components generated due to external applied vertical load.

2 CASE STUDIES AND SOIL CHARACTERIZATION

Figure 2 depicts the dimensions of the piles (L and D), and the number of databases (pile-loading tests) used in the current study. Fifty-eight pile load-settlement tests, collected from many locations in Egypt were used in the study. The ultimate bearing capacities of the piles were predicted from the pile load tests results using the Chin extrapolation method.

According to the Egyptian geotechnical code (2001), the soil formations in Egypt can be classified into two main deposits: alluvial and desert soil deposits (Figure 3).

An extensive geotechnical investigation program was carried out in the field and in the laboratory, including over 200 boreholes with depths of 25m to 80m from the ground level. Additionally, Standard Penetration Test (SPT) and unconfined compression tests have been conducted continuously for sandy and clayey soil layers, respectively, during the boring of each borehole.

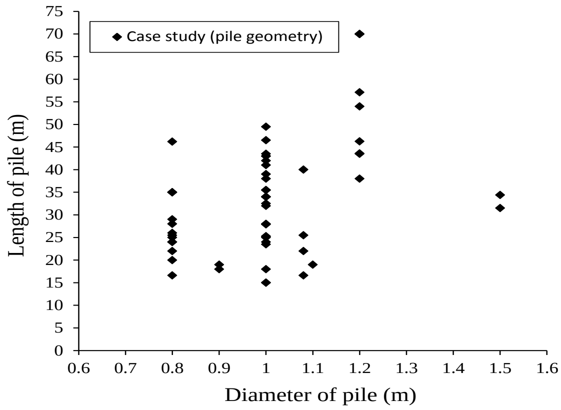

Fig. 2 Dimensions of the piles and number of databases used in the study.

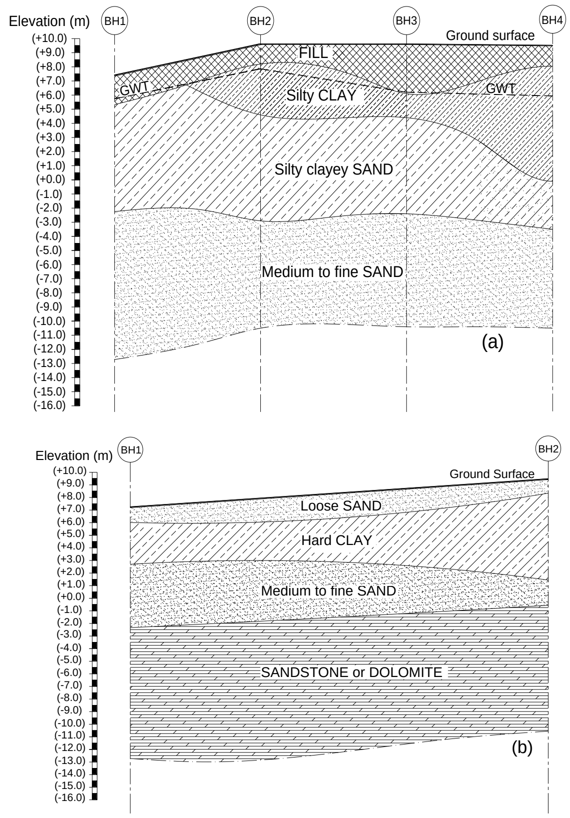

Fig. 3 Typical longitudinal cross-section of the predominant soil deposits in Egypt: (a) alluvial, and (b) desert.

Keywords: Bored piles, end-bearing resistance, skin friction resistance, single pile, settlement.
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3 ANALYSIS OF RESULTS

3.1. Percentage of average error

The error percentage can be calculated using Eq. (2). The negative sign of average error indicates that this code of design under-predicts the values of ultimate pile capacity, which means that it is a conservative design method.

$$\text{Error}\,(\%) = \frac{\left[(Q_u)_p - (Q_u)_m\right]}{(Q_u)_m} * 100 \qquad (2)$$

where: $(Q_u)_p$ = ultimate predicted pile capacity, and $(Q_u)_m$ = ultimate measured pile capacity.

It can be seen that the JRA (2002) yields the lowest average error percentage of 11.8% compared to those values resulting from other codes of design. It is an over-predicting design method; this can be attributed to the slightly high design values adopted by the JRA (2002) for calculating both skin friction and end-bearing resistance of pile.

Table 3 Results of average errors obtained from the codes of design.

Code of design	Average error percentage for 58 case studies
Egyptian code (2001)	-41%
DIN 4014 (1990)	-13.1%
Japan Road Assoc. (2002)	11.8%
AASHTO (2007)	-31.3%

3.2. Statistical analysis

An evaluation scheme using four criteria was considered in ranking those codes of design, as follows:

- The equation of best fit line of predicted versus measured pile capacity, $(Q_u)_p/(Q_u)_m$, with corresponding coefficient of correlation, r, referred to as (R_1).
- Determination of $(Q_u)_p/(Q_u)_m$ at 50% and 90% cumulative probability, referred to as (R_2).
- The 20% accuracy obtained from log-normal distribution of $(Q_u)_p/(Q_u)_m$, referred to as (R_3).
- The arithmetic mean and coefficient of variation for $(Q_u)_p/(Q_u)_m$, referred to as (R_4).

An overall rank index (RI) is defined as the sum of ranking values obtained from the four criteria $(RI=R_1+R_2+R_3+R_4)$. The lower the ranking index, the better the performance of the design method, i.e., in accuracy and predictability.

4 CONCLUSION

The following conclusions can be drawn:

1. JRA code (2002) and DIN 4014 (1990) have revealed well predictability and accuracy for estimating ultimate pile capacity, $(Q_u)_p$, compared to the other international codes of design. As a result, they were ranked in the first and second order, respectively.
2. For economic purposes, re-evaluating the design factors and parameters adopted by the Egyptian code of (2001) is recommended to improve its predictability and reliability. For example, this code does not consider the effect of soil strength parameters around the pile tip for estimating q_{bu}. Introducing reasonable design values is one of the possible solutions.

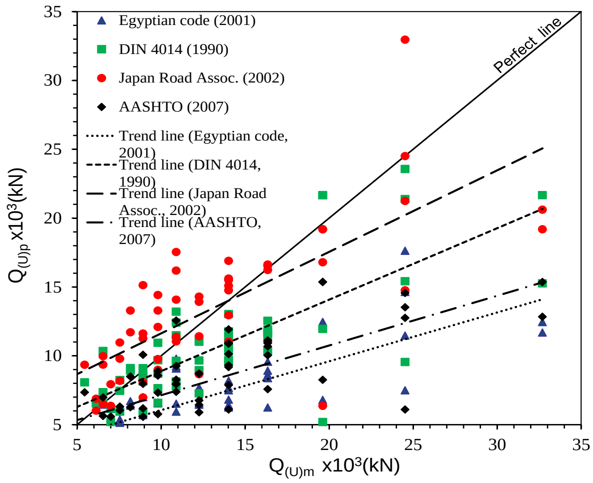

Fig. 4 Correlation between measured and predicted ultimate load for each code.

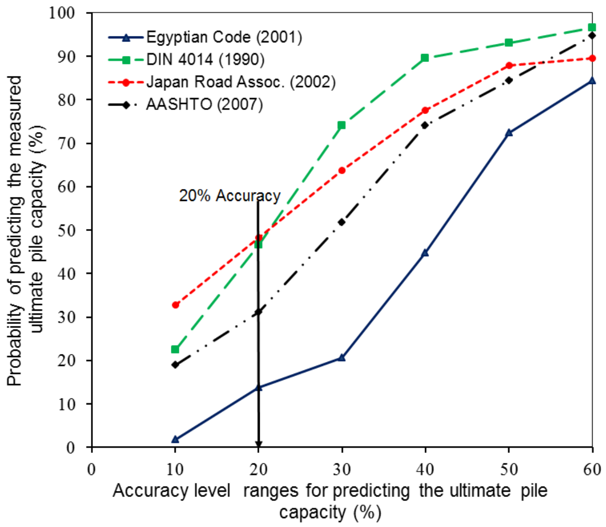

Fig. 5 Relationships between accuracy level and probability of occurrence for the codes of design used in the study.

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