Information Systems and Artificial Intelligence Technology Applied in Numerical Design Stage of Deep Foundation Systems

E.B. Pancar¹, M. V. Akpinar²
¹Ondokuz Mayis University, Samsun/Turkey, erhanpancar@hotmail.com
²Karadeniz Technical University, Trabzon/Turkey, mvakpinar@yahoo.com

Abstract—In this paper, the main objective is to show how to obtain precise pile design by using an information system and artificial intelligence (ISAI) applied in the numerical design stage of a deep foundation system. In this system, real parameters of soil layers are used and axial effect coming into the pile is taken into account.

In this paper, a numerical solution is determined according to the principles of pile design by using an electronic interior control subsystem. In this deterministic approach, intelligent object (IO) with a dz thickness moves forward through the soil layers. Diameter, length and steel ratio are determined by the system through numerical solution. As a result, a precise solution for pile diameter, pile length and steel ratio can be determined directly.

The system incorporates ISAI technology.

Keywords—Deep foundation, pile design, Information Systems and Artificial Intelligence Technology

I. INTRODUCTION

One of the most rudimentary and confounding challenges of construction is constructing the deep foundation, which in turn depends on pile design. Deep foundations are often constructed in difficult ground conditions such as liquefiable soil, collapsible soil, swelling soil, soft and highly compressible soil, landslide areas and underground caves.

In pile design, there are three main information processing options:

a) Manual information processing: Pile length and pile dimensions are approximated. If there is any inconsistency the calculations are repeated. However, even with repetition the exact value cannot be obtained. Therefore, loading experiments must be done to confirm reliability of the pile design.

b) Computer aided information processing: Manual information processing is replaced by a computational program executed via computer. The result is an increase in processing speed. However, loading experiments are still necessary.

c) Electronic information processing by ISAI application: The advantage to this approach is that a precise design solution can be achieved quickly. This paper shows how to obtain this design solution using ISAI.

A controlling objective of pile design is to get a precise solution quickly, delivering an economical and safe result.

Traditionally, pile design has been accomplished by manual information processing or computer aided information processing, both of which have serious limitations. This paper describes a third approach: electronic information processing by ISAI application, by which a precise pile design is determined. In this approach a numerical solution is achieved by moving an intelligent object forward through the soil layers and applying ISAI technology to derive the optimum pile design.

II. AXIALLY LOADED PILE

For the prediction of the axial pile bearing capacity, there are many approaches. Each method has its benefits and drawbacks and none is universally accepted. Therefore designers often use more than one method and base the final design on a synthesis of the results. At the present time, the question about solution uniqueness still remains unresolved.

The approaches to estimate the axial load pile capacity are generally grouped into three broad categories:

(a) Full-scale load tests.

(b) Analysis based on soil properties obtained from laboratory or in-situ tests. These are known as static methods.

(c) Analysis based on pile driving dynamics, known as the dynamic method [1].

Some investigators suggested ANN as a model for the prediction of the behavior of axially loaded piles, using dynamic stress-wave data [2-3]. Some researchs presented a neural network to predict the friction capacity of piles in clays [4-5].

To obtain a solution by neural networks, an input-output pattern is given to the network and the network is trained to find the relation between the input and output data. Analyses are made for various values of input data for the preparation of data for the ANN model [6]. To get a reliable solution, networks with different transfer functions must be set up and trained.

The difference between ISAI technology explained in this paper and ANN modeling is, system does the numerical analyses itself by just giving input parameters to the system and there is no need to set up networks like in ANN. There is an interior control subsystem in numerical analysis in ISAI...
Information Systems and Artificial Intelligence Technology Applied in Numerical Design Stage of Deep Foundation Systems

technology and system computes optimum numerical solution. This is called deterministic approach.

III. DETERMINISTIC APPROACH IN ARTIFICIAL INTELLIGENCE

In designing the ISAI to be used in this application, both deterministic and statistical methods can be suitably used to achieve the numerical solutions. This paper explains the use of a deterministic approach to using ISAI in the numerical design stage of a pile.

An ISAI approach differs from classical pile design in the following ways:

1) The beginning dimensions and steel ratio are set at the minimum of standards used in design. The system determines optimum design dimensions from this starting point.

2) Pile length and other dimensions are determined by using soil layer parameters and electronic interior controls as the intelligent object passes through all the soil layers.

3) Pile length is obtained when the IO, which includes parametric properties of the pile system, goes forward from the soil surface in small differential steps. The system checks length, diameter and steel ratio by numerical analysis at each step. The object and calculation stop when the effects are balanced. The factor of safety in the system is determined by the designer and affects the point at which balance is achieved.

4) This approach is deterministic and depends on the precision of soil parameters.

IV. NUMERICAL SOLUTION

The optimal solution is obtained for a pile under axial effect on the system. The numerical solution is achieved by considering this effect as an IO moves forward through different soil layers (Fig.1.) [7].

Effect is balanced with friction between pile surface and soil, tip effect and factor of safety by forming a numerical solution [8-9-10-11] and an interior control sub system and by using an information system application. Solution susceptibility is dependent on data validity and limit values. Data includes the geotechnical properties of the soil layers and construction material information, effects and design limits. Due to the complexity of this approach, an analogous solution cannot be obtained by manual information processing or computer aided information processing.

In Figure 1., IO moves forward through different soil layers under the axial load denoted by an arrow 3. Equations to compute the surface friction between pile and soil and tip resistance of the pile are:

- lateral earth pressure (py)=zba*k*dz

- lateral earth pressure at the top of the IO (pytu)=∑fpy(zba,fi,c,z)

- lateral earth pressure at the bottom of the IO (pyta)=∑fpy(zba,fi,c,z+dz)

- lateral force for unit length at the mid point of the IO (pyb)=0.5*dz*(pytu+pyta)

- surface resistance of the pile due to skin friction (pks)=fpks(dk,pi,sk,pyb)

- tip resistance of the pile (pka)=fpka(dk,pi,pyta)

- ultimate resistance (pk)=pks+pka;

- Pile length for every movement of IO (z)=z+dz

where,
* zba=unit weight of a soil
* pi=coefficient (3.14159265)
* c=cohesion coefficient of the soil
* fi=friction angle of the soil
* k=lateral earth pressure coefficient. It is computed as ka (active) or kp (passive) according to the direction of the effect on the pile.
* dz=increment of the pile length (intelligent object thickness)
* z=depth at the top of the intelligent object
* cv=perimeter of the pile
* ac=cross-sectional area of the pile
* sk=friction coefficient
* dk=beginning diameter of a pile
* emk=factor of safety
* p=axial load

Input parameters are: zba, c, fi, sk, emk, dz, p values.
When one of the methods in Part 2 (a-c) for axially loaded pile is used in ISAI applied design analysis, the alternatives are used as an interior control subsystem.

Standard Penetration Test (SPT) values can be used as an interior control subsystem. But, SPT values are precise for sandy soils. For sandy soils ka and kp values obtained by real soil parameters must match with ka and kp values obtained by SPT.

\[ ka = f_{ka}(SPT); \quad kp = f_{kp}(SPT) \]

In this way, the system is optimized.

V. PROGRAM DESIGN

To design the program, which is based on an ISAI application, modular and systematic design techniques are essential. The knowledge-base structure consists of program files and data files. Certain information clusters are present in the system. Each program module comes to the kernel memory as needed, then flies away. As a result, all the programs and their modules that constitute the system are not in the kernel memory at the same time. The program operating system controls the relations of the programs in the system and the relation between the data on the knowledge base and the programs. This approach creates a platform independent of the other operating systems (Windows, Mac OS, Unix). This approach is also independent of the coding systems and languages used in programs. For example, some programs and their modules can be designed in different coding systems and languages to increase efficiency. When a program or its module is coded by C++, another module may be coded by Fortran or Pascal. The program management system described in this paper can run and manage all modules as if they are coded in one language. The coding explained in this paper is in C++ because of its efficiency and structural properties.

VI. APPLICATION OF ISAI TECHNOLOGY

In this ISAI solution, the system reads the soil, material and effect information and the intelligent object moves downward through the soil layers. During that time, if the steel ratio exceeds the upper limit while the system is computing buckling, the pile diameter will increase. As a result, the pile length, pile diameter and steel ratio will be optimized. The intelligent object stops moving when the effects are balanced.

Pile design examples are shown in Figure 2 and Figure 3. The first example in Figure 2 considers an axial effect of 75 t and the second example in Figure 3 considers an axial effect of 350 t under same soil conditions with Figure 2 by using information system and artificial intelligence technology.

In Figure 2 and Figure 3,

- “w/w” is an unit weight of a soil, “ε” is a cohesion coefficient, “sa” is a friction angle of the soil, “Nspt” is a Standard Penetration Test result.
- “Ps” is a surface resistance of the pile due to skin friction, “Pe” is a tip resistance of the pile, “Pp” is an ultimate resistance of the pile, “Dp” is a pile diameter, “as” is the steel area in cross-sectional area of the pile.

In the system intelligent object which is symbolized as arrows goes forward through different soil layers and stops when it balances the axial load with a factor of safety.

In Figure 2, axial load is 75 t and factor of safety is 2. Intelligent object starts to move downward with an increment of 0.5 m and stops at 13 m where axial effect is balanced. Pile length is found as 13 m and pile diameter is 65 cm with a 33.17 cm² steel area.
Figure 2: Example with an axial effect of 75 t

Figure 3: Example with an axial effect of 350 t
In Figure 3, axial load is 350 t and factor of safety is 2. Intelligent object starts to move downward through the same type of soil with Figure 3 and stops at 21 m where axial effect is balanced. Pile length is found as 21 m and pile diameter is 80 cm with a 50.24 cm² steel area.

VII. CONCLUSION

1- Information systems and artificial intelligence technology is a new alternative to manual information processing or computer aided information processing. Pile dimensions are determined by the system. This offers the advantage of delivering an optimized result obtained quickly by a deterministic approach.

2- Solution precision is limited by the experimental soil parameters given to the system.

3- In traditional solutions, pile length and pile diameter are estimated first and then confirmed by numerical solutions. In this solution, an intelligent differential object is moved downward through the soil layers. Diameter, length and steel ratio are determined by the system through numerical solution. As a result, a precise solution for pile diameter, pile length and steel ratio can be determined directly.

By using information systems and artificial intelligence applied for engineering design stages, optimal solutions can be obtained which are not possible to achieve using traditional methods. In this method, the system gives a precise result by using an interior control subsystem. This numerical solution shows that there is a benefit to solving engineering problems by using information systems and artificial intelligence technology effectively.

REFERENCES


