International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Special Issue 23 (July 2015), PP. 33-38

OPTIMIZATION OF ANCHORED DIAPHRAGM RCC WALL IN C-Φ SOIL USING GENETIC ALGORITHM

Radhika Bhandary[1], Asha U Rao[2], Narayan Sabahith[3], Nischitha.P.R[4]
[1]AssistantProfessor,
, [2]Associate Professor- senior scale,
[3]Professor,
[4]Post Graduate Student,
Manipal Institute of Technology, Manipal, Karnataka, India
[1]radhika.st@manipal.edu
[2]asha.prabhu@manipal.edu
[3]sabha4@rediffmail.com
[4]nischitha.pr@gmail.com

***Abstract*— In the current study, an anchored diaphragm wall design in C-Φ soil condition is optimized using genetic algorithm. Fixed earth support method is implemented for the design of the wall. The depth of the embedment and the magnitude of tensile force at anchor are determined. The design problem is formulated as a non-linear mathematical programming problem using FORTRAN 95. The analysis and design is carried out by varying the positions of the anchor rod. The anchor position is randomly chosen during the computation to obtain and optimize the total cost. Genetic Algorithm (GA) is employed to obtain the optimum position of the anchor based on minimum cost. The influence of different GA parameters (population size, number of generations, crossover probability and mutation probability) on the solution is studied and the results are tabulated**

***Index Terms*— Anchored Diaphragm Wall, Fixed Earth Support Method, Genetic Algorithm, FORTRAN 95, GA Parameters**

I. INTRODUCTION

Diaphragm wall is a sheet pile wall whose thickness is relatively smaller compared to its depth. They are generally adopted to resist the horizontal pressures due to soil and water. These walls derive their stability from the horizontal resistance of the ground into which they are driven and also from the horizontal support provided by anchors, struts or ties placed at a higher level. Primarily, diaphragm wall acts as an immediate support to ground as the excavation proceeds. They are employed as bulkheads in piers, docks and wharves, in sea walls, breakwaters and other shore protection construction.

The design of sheet pile retaining walls requires several successive operations: (a) evaluation of the forces and lateral pressures that act on the wall, (b) determination of the required depth of piling penetration, (c) computation of the maximum bending moments in the piling, (d) computation of the stresses in the wall and selection of the appropriate piling section and (e) the design of the waling and anchorage system.

The design of diaphragm wall consists of determination of length of embedment, the magnitude of tensile force at anchor, design of the section of diaphragm wall. The forces on the diaphragm wall are determined and the embedment depth is calculated using conventional methods available.

Hwang et al [1] studied the performance of diaphragm walls used in the excavation of Shandao Temple Station of Taipei Metro by using the concept of wall deflection path which is a plot of maximum wall deflections vs. depth of excavation. Finite element analysis was conducted using PLAXIS and parametric studies which influence wall deflections were prepared. The maximum depth of excavation was 18.5m and diaphragm walls of 1m thickness were used to retain the pit. The summary of the study is as follows. In order to quantify the effects of various factors in causing wall movements, a baseline wall deflection path has to be established. Baseline wall deflection paths are defined as the idealized wall deflection paths for excavations of 20m in width with diaphragm walls of 1m thickness carried out in green field by using the bottom-up method of construction. It was suggested to implement Young's Modulus of E=500 x Su, where Su=undrained shearing strength for clayey soil and E=2N (MPa) where N= blow counts in standard penetration test for sandy soil along with Mohr-Coulomb model to obtain realistic outcomes for wall deflections [1]. Bilgin [2] compared the conventional method and finite element analysis(FEM) for the design of anchored sheet pile wall based on lateral earth pressures and anchor forces. The conventional method ignores the stress concentration at the level of anchorage and assumes that the earth pressure linearly increases with depth. The comparative study using FEM for a single level anchored sheet pile walls in cohesionless soils indicated that there is an increase in active pressure and decrease in passive pressure near the pile tip. The wall bending moments were approximately 50% more in conventional methods and anchor forces were nearly 40% lesser in comparison with FEM. The underestimation of anchor forces will result in unsafe design. A coefficient of 0.76 for passive pressure and 1.392 for anchor forces can be used to design a single level anchored sheet pile wall for a safe and realistic design [2].Bhandary [7] used sequential unconstrained minimization technique to optimize the cost of anchored diaphragm wall by varying the position of anchor rod downwards towards the dredge line. The minimum cost was obtained at an anchor level of 7.6m from ground level with 14.5m being the height of the wall. The embedment depth reduced significantly for anchors placed between dredge line and ground level. An increase in anchor force was observed as the distance of the anchor increases from ground level. The area of main steel was found to be the least at the optimum anchor position [7].Kim and Kim [3] suggests a preliminary cost estimation model for the early stages of a bridge construction project with limited availability of data using case-based reasoning (CBR) and genetic algorithm (GA). Other approaches earlier used such as gradient search, fuzzy numbers and analytic hierarchy process were limited in facilitating optimal solutions. Here, a GA-based approach was implemented for a weight generation method and the efficacy of this method was tested by applying it to an actual bridge. In addition, they discovered that a CBR and GA-based construction cost estimation model improved the accuracy when compared to the conventional model in the earlier stages. Therefore, the weight generation method given in this paper will be available for a variety of facilities and it will be useful in designing a more reliable construction cost estimation model for the early stage of a project [4].

A. Anchored Diaphragm Wall

An anchored diaphragm wall receives its lateral support from penetration into the foundation soil and from an anchoring system near the top of the wall. The distribution of stresses from the backfill will depend strongly on the manner in which the wall is constructed, relative stiffness of piling, the depth of penetration, relative compressibility of the soil, the amount of anchor yield etc. Furthermore, the magnitude of maximum bending moment in the wall is influenced greatly by the distribution of stresses against that part of the wall which is embedded, and the stress conditions in this zone are quite complex. This effect cannot be predicted on the basis of simple theory. The design and analysis of bulkheads is a rather complicated subject. Usually, the experimental data and field experience are used as a basis for design. The conventional methods for anchored diaphragm walls may be divided into two broad groups, depending on the relative amount of penetration of the wall below the dredge line. The anchored diaphragm walls shall be designed for the shears and bending moment which thus develop. The anchor system shall be designed to take the lateral forces required to support the walls.

An anchored diaphragm wall maybe subjected to the following forces, namely;

1. Earth pressures-Active and passive
2. Unbalanced water pressure and seepage pressure
3. Mooring pull, ship impact, earthquake force, wave pressure etc.

B. 3. Fixed Earth Support Method

In this case, the piling has a greater depth of penetration below the dredge line and as a result it is assumed that the piling is fixed at the bottom. The wall is then effectively equivalent to a vertical propped beam fixed at the lower end. Due to fixity at bottom, the deflected shape of pile changes its curvature at the point of contra flexure. The diaphragm wall acts as a built up beam subjected to both positive and negative moments unlike in free earth support method where the beam is deflected in one direction only and also only positive bending moment exists.

An anchored sheet pile wall with fixed earth support method may be solved by two methods namely, elastic line method and equivalent beam method. The elastic method is quite complicated and time consuming. Equivalent beam method is generally used with the following assumptions.

1. The soil pressure may be computed by classical Rankine or Coulomb theory.
2. The sheet pile is free to rotate but not permitted to lateral movement at the level of tie rod.
3. The point of inflection (y_i) is equal to the point of contraflexure (y_o).
4. The passive resistance is simplified as a triangular pressure diagram and a concentrated reaction.

While a wall in a given site and soil conditions can generally be designed either for free or fixed earth support, experience has shown that overall economy results from fixed earth support method. Though longer piles are needed, the required section modulus or bending strength of the piles is less, and anchor loads tend to be lower.

C. Analysis of Anchored Diaphragm Wall

A case is considered as shown in figure 1 to find the variation of the embedment depth, bending moment and the cost of diaphragm wall by changing the anchor rod position with all other parameters being the same. The analysis is done using fixed earth support method and the design using working stress method.

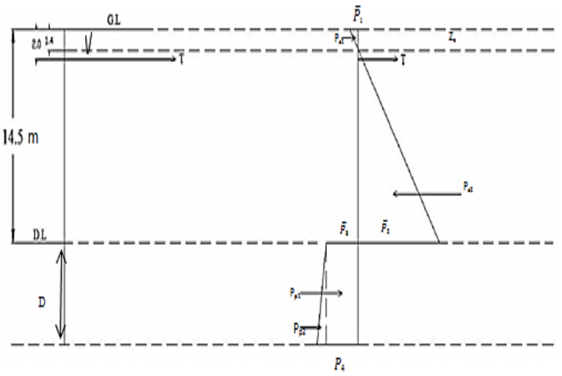

Figure 1: Anchored Wall and Soil Pressure Diagram

Rankine active earth pressure coefficient,

$$Ka = \frac{1-\sin\phi}{1+\sin\phi} \quad (1)$$

Rankine passive earth pressure coefficient,

$$Kp = \frac{1+\sin\phi}{1-\sin\phi} \quad (2)$$

Tschebotarioff (1951) using the information obtained from sheet piling tests performed at Princeton, has proposed that the point of contraflexure for sheet piling be taken at dredge line.

Tensile crack depth, $Z_c = \frac{2 \times c}{\gamma \times \sqrt{Ka}}$ (3)

The anchor should always be placed away from the tensile crack zone.

The pressures $\overline{P}_1$, $\overline{P}_2$, $\overline{P}_3$ and $\overline{P}_4$ shown in figure 1 are calculated using the following equations.

$$\overline{P}_1 = (2 \times c \times \sqrt{K_a}) \quad (4)$$

$$\overline{P}_2 = (K_a \times \gamma \times H) - (2 \times c \times \sqrt{K_a}) \quad (5)$$

$$\overline{P}_3 = (2 \times c \times \sqrt{K_p}) \quad (6)$$

$$\overline{P}_4 = (\gamma \times D \times K_p) + (2 \times c \times \sqrt{K_p}) \quad (7)$$

The active earth pressures P_{a1}, P_{a2} and passive earth pressures P_{p1}, P_{p2} are then determined.

By taking the moments of all the forces about the anchor rod level, the depth of penetration D is attained.

By summation of horizontal forces to zero, the reaction $R_c = P_{p1} + P_{p2} - R_1$ (8)

Maximum bending moments and in beam OA and OB are obtained as well as the maximum shear force.

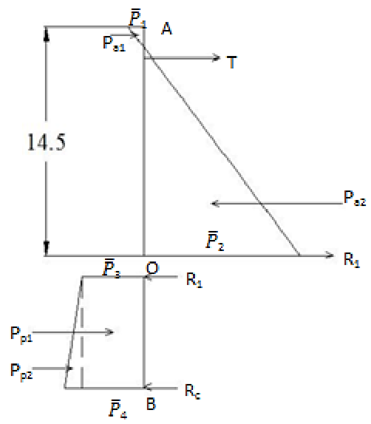

Figure 2: Pressure Diagram

D. . Design of Anchored Diaphragm Wall

The anchor block thickness and width is assumed as 0.3m and 1m respectively.

Cost of diaphragm wall:

Total cost of the diaphragm wall is found using the following equation.

$T_{cost} = C_{grab} + C_{conc} + C_{steel} + C_{ar} + C_{ab}$ (9)

Where, C_{grab}=cost of grabbing

C_{conc}=cost of concrete

C_{steel}=cost of steel

C_{ar}=cost of anchor rod

C_{ab}=cost of anchor block

E. Problem Formulation

Genetic algorithm developed by Goldberg[8] was inspired by Darwin's theory of evolution which states that the survival of an organism is affected by rule "the strongest species that survives". Darwin also stated that the survival of an organism can be maintained through the process of reproduction, crossover and mutation. Darwin's concept of evolution is then adapted to computational algorithm to find solution to a problem called objective function in natural fashion. A solution generated by genetic algorithm is called a chromosome, while collection of chromosome is referred as a population. A chromosome is composed from genes and its value can be either numerical, binary, symbols or characters depending on the problem want to be solved. These chromosomes will undergo a process called fitness function to measure the suitability of solution generated by GA with problem. Some chromosomes in population will mate through process called crossover thus producing new chromosomes named offspring which its genes composition are the combination of their parent. In a generation, a few chromosomes will also mutation in their gene. The number of chromosomes which will undergo crossover and mutation is controlled by crossover rate and mutation rate value. Chromosome in the population that will maintain for the next generation will be selected based on Darwinian evolution rule, the chromosome which has higher fitness value will have greater probability of being selected again in the next generation. After several generations, the chromosome value will converges to a certain value which is the best solution for the problem.

The optimum cost of anchored diaphragm wall in C-Φ soil by varying the position of anchor rod has been formulated as a constrained minimization problem. The problem is formulated as a mathematical programming problem using FORTRAN 95. The total cost is minimized by applying suitable constraints using Genetic Algorithm.

The objective of the study is to find the minimum cost of the wall corresponding to the position of the anchor rod. Hence, the total cost of the anchored wall will be the objective function and the position of anchor rod from the ground level represents the design variable.

In order to ascertain the minimum cost of the anchored diaphragm wall some constraints need to be employed. In the present study, the check for stability number (SN) is used as a constraint.

$SN \geq 0.3$

The expression for stability number is,

$$SN = \frac{c}{\gamma H} \qquad (10)$$

where, c→cohesion of the soil

γ→unit weight of the soil

H→height of the wall from ground level to dredge line

Originally, GA was developed for solving unconstrained optimization problems. However, most of the practical problems are constrained one. Hence, one must transform the constrained problem into an unconstrained one by using a suitable penalty function. The selection of the penalty function is critical. Many researchers believe that penalty functions should be harsh, so that the GA will avoid the forbidden spaces. If the penalty is too large, the design process may converge too quickly, not allowing the GA to exploit various combinations of strings. If the penalty is too small, the convergence process may be too slow and the computational costs could be high. In this study, penalty function suggested by Rajeev and Krishnamoorthy (1992) is used. i.e.

$$\phi(x) = F(1 + KC) \qquad (11)$$

where, parameter 'K' has to be judiciously selected depending on the required influence of a violated individual; for the problems considered in this study, the value of K = 100 is found to be most suitable. 'C' is the constraint violation function and is computed in the following manner,

$$c = \sum_{j=1}^{m} C_j \qquad (12)$$

Where, m = number of constraint equations

In the above equation C_j is calculated in the following manner.

If the constraint is violated, then C_j=100

If the constraint is not violated, then C_j=0

F. Results and Discussions

In order to study the sensitivity of GA parameters on the results, a parametric study has been carried out. These parameters include population size, generation number, crossover probability and mutation probability. While studying the effect of these parameters on the results, the random seed is kept constant as 0.123.

Problem specifications are as follows.

Unit weight of soil, γ=17.7kN/m^3

Unit weight of water, γ_w=10kN/m^3

Cohesion, C=10.5kPa

Angle of internal friction, Φ=10°

Bulk unit weight, γ_b=7.89kN/m^3

Height of the wall from G.L to dredge level, H=14.5m

Concrete used – M30

Grade of steel – Fe415

The following parameters are used in optimization using GA.

Number of parameters = 1

Total string length = 20

Population range = 12-14

Generation number = 5, 20, 50, 100, 150, 200, 250, 300, 350

Variable – Anchor position (AH)

Lower and upper bound for the variable = 2m to (3/4) H

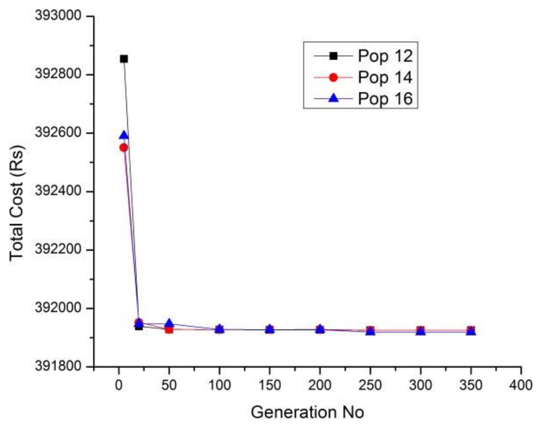

Figure 3: Plot of Total Cost (Rs) Vs Generation Number

Figure 3 shows the variation of total cost of anchored diaphragm wall with the generation number for population sizes 12, 14 and 16. The crossover and mutation probabilities are kept constant as 0.8 and 0.01 respectively. As generation number increases the cost decreases for all population size. At generation number 250, the total cost obtained for population size 12, 14 and 16 are respectively Rs.391925.59, Rs.391925.17 and Rs.391919.06 indicating a marginal influence of population size on

the convergence rate. The total cost obtained for population size 16 is the minimum. However, further increase in population size does not affect the value of total cost significantly. Hence, a population size of 16 is used in this study.

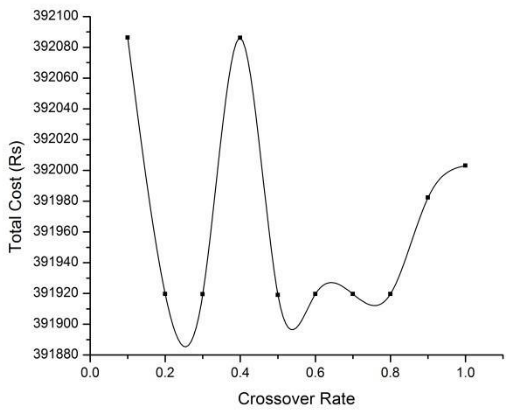

Figure 4: Plot of Total Cost (Rs) Vs Crossover Probability

Figure 4 shows the variation of total cost with the crossover probabilities varying from 0.1 to 1.0. It can be observed that the variation between total cost and crossover probability for population size 16 has no definite trend. However, it can be concluded that the crossover probability 0.5 for provides the minimum cost. Hence, crossover probability of value 0.5 is kept constant for further studies.

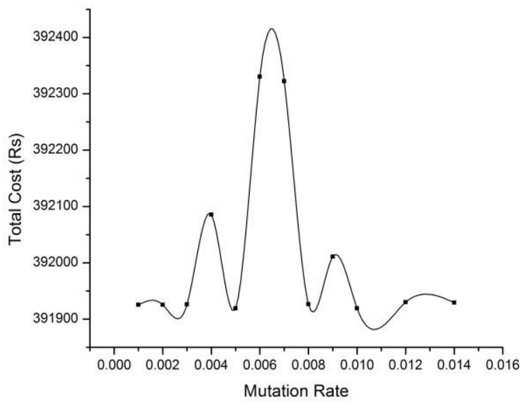

Figure 5: Plot of Total Cost (Rs) Vs Mutation

Figure 5 shows the variation of total cost for the values of mutation probability varying from 0.001 to 0.014. It can be observed from graph that there is no specific trend in the variation. However, mutation probability of 0.01 gives the lowest cost for population size 16.

Therefore, from the above results we can conclude that the population size of 16, generation number 250, crossover probability 0.5 and a mutation of 0.01 gives the best optimized cost of Rs.391919.06 for an anchor position of 3.736m.

G. . Conclusions

The following are the observations from present study.

- For the problem of anchored diaphragm wall analyzed with C – Φ soil varying the anchor position, the best optimized cost of Rs.391919.06 for an anchor position of 3.736m from ground level was obtained.
- For the above case, the population size of 16, generation number 250, crossover probability 0.5 and a mutation of 0.01 gave the optimized cost.
- Genetic Algorithm is most suited for optimizing an anchored diaphragm wall designed using fixed earth support method.

. ACKNOWLEDGMENT

The authors would like to express their sincere thanks to The Director, and H.O.D, Civil engineering, Manipal Institute of Technology, Manipal for providing necessary facilities required for the present studyFigure 5: Plot of Total Cost (Rs) Vs Mutation

Figure 5 shows the variation of total cost for the values of mutation probability varying from 0.001 to 0.014. It can be observed from graph that there is no specific trend in the variation. However, mutation probability of 0.01 gives the lowest cost for population size 16.

Therefore, from the above results we can conclude that the population size of 16, generation number 250, crossover probability 0.5 and a mutation of 0.01 gives the best optimized cost of Rs.391919.06 for an anchor position of 3.736m.

7. Conclusions

The following are the observations from present study.. • For the problem of anchored diaphragm wall analyzed with C – Φ soil varying the anchor position, the best optimized cost of Rs.391919.06 for an anchor position of 3.736m from ground level was obtained.

• For the above case, the population size of 16, generation number 250, crossover probability 0.5 and a mutation of 0.01 gave the optimized cost.

• Genetic Algorithm is most suited for optimizing an anchored diaphragm wall designed using fixed earth support method.

REFERENCES

Journal Articles

[1] Hwang. N.R, Lee. T.Y, Chou. C.R and Su T.C, 2012, "Evaluation of Performance of Diaphragm Walls by Wall Deflection Paths" Journal of GeoEngineering, 7(1), 1-12.

[2] Bilgin.O, 2012, "Lateral Earth Pressure Coefficients for Anchored Sheet Pile Walls" International Journal of Geomechanics, 12 (5), 584-595.

[3] Kim K.J. and Kim K, 2010, "Preliminary Cost Estimation Model Using Case-Based Reasoning and Genetic Algorithms" Journal of Computing in Civil Engineering, 24(6), 499-505.

Books

[4] IS: 9527(Part 3), 1983, Indian Standard Code Of Practice For Design And Construction Of Port And Harbour Structures, Bureau of Indian Standards, New Delhi.

[5] Bowles J.E, "Foundation analysis and design", third edition.

[6] .Rao A.U, 2010, "Role Of Erosion Of Lithomargic Soil In Instability Of Excavated Slopes In Laterite Soils", Ph.D thesis, Dept of civil engineering, MIT, Manipal.

[7] Bhandary R, "Optimization of anchored diaphragm wall using SUMT", MTech thesis, NITK Surathkal.