Stress Analysis of the Shore Pile of a Braced Cut Using Finite Element Method

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Abstract:This paper deals with the finite element analysis (FEA) of the Shore pile of earth retaining structure i.e. Braced Cut. Forces acting on the Braced Cut were investigated. An RCC section of adequate capacity was considered based on apparent earth pressure. Shore pile of Braced Cut was analysed by using a conventional theory of mechanics and finite element software (ANSYS.11). The stresses obtained from the FEA and analytical methods were compared. The conclusion was drawn, basically mentioning that the FEA was compared well with the analytical method and may be used as a tool for designing complex structures.

Keywords: *FEM, ANSYS, Braced Cut, Shore Pile*

1. Introduction

Reduction of soil load occurs in the case of underground construction and it is becoming popular with civil engineers. The challenge of such construction is the design of earth retaining structure. To adopt underground construction where there are neighbouring high rise structures, engineers are using braced cut. Braced cut consists of shore pile, wale, and strut, which are mainly products of concrete and steel. For the economic use of concrete in structures mechanical properties of the constituent materials need to be examined upon application of design load based on equilibrium laws. To determine the safety of a structure an accurate determination of the ultimate load is required and the relation of load and deformation in elastic and inelastic response is desirable. Analytical models or solutions for RCC structures are required as concrete behaves like a nonlinear material even for a small scale of loading. Moreover, embedded rebar in concrete interacts in a complicated manner in terms of slippage and interlock. These criteria compelled designers to depend on the empirically-based formulation, derived from a huge number of lab tests. In this era of modern technology, through the use of high-speed computers, FEM software gives analytical solutions and reduces the requirements of a large number of lab tests. In this paper is an analysis of shore pile under static loads was conducted as an attempt to find the suitability of FEM analysis in this regard.

2. Related Works

The bending moment was taken as input for obtaining a design section with suitable reinforcement. The actual pressure distribution is a function of the construction sequence and the relative flexibility of the wall [5]. Concrete properties of cement were based on ACI manual for Concrete Practice [6]. Stress in various components of structure causes a change in the volume of the members. Like as reactions force of an elongated spring, strain causes stress stresses [7]. Viscous stress counteracts the changes caused by slowly developed time-dependent stress [8].

3. Section Properties

Original Shore pile is a flexural member that remains directly in the contact of soil. It opposes the failure of soil and falling to the cut. It is provided continuously along the length of the entire excavation.

3.1 Section Properties

The length and diameter of the Shore pile were 10000 mm and 508mm respectively. Eight 16 mm bars were provided uniformly over the section maintaining 50mm clear cover. 6.5 mm tie bars were provided in a circular pattern at 135mm intervalsrounding the longitudinal bars. Reinforcing bars were provided at the nodes after meshing so that the deflection of reinforcing bars were ensured in case of deflection of concrete portion.

3.2 Support Conditions

100mm by 100 mm steel sectionswere used as supports. Supportswere provided at 2.0m, 5.15m and 8.0m height from the bottom of the excavation. For an actual representation of support SOLID45 element with properties of steel was used.

4. Materials used for Shore Pile

4.1 Concrete

Stress-strain relation of concrete controls the behaviour of structures. As concrete takes compression in most cases, stress-strain relation is of primary interest. Stress-strain relation exhibits linearity to about 30.00 % of the ultimate strength of concrete in compression. The properties of concrete considered are as shown in Table 1.

Table 1 Concrete Properties of Shore Pile

Name of property	Property
Modulus of Elasticity	20700MPa
Poisson's Ratio	0.2
Open shear transfer co-efficient	0.3
Close shear transfer co-efficient	1.0
Uniaxial cracking stress	4.2MPa
Uniaxial crushing stress	27.6 MPa

4.2 Reinforcing Steel

Rebar of the shore piles are passively fixed firmly in the concrete and is placed before concrete sets. Steel barswere designed to counteracttensile stresses in the tensile zone of the structures.The properties of steel considered are shown in Table 2.

Table 2 Properties of steel used in ShorePile

Name of property	Property
Poisson's Ratio	0.3
Young modulus	2.007e5 MPa
Yield stress	414 MPa
Modulus of Elasticity	2.07e5 MPa

5. Analysis of Braced Cut by Conventional Method

Excavation was done in sandy soil. Considering dry density of soil, $\gamma = 16.18$ kN/m^{3}and angle of internal friction, $\phi =$ 32^o.Considered, water table at 4.0m below ground level and total depth of excavationas10.0m.As maximum deflection will occurs in the bottom, Rankine's theory will not be directly applied. Earth pressure will be calculated from Rankine's earth pressure theory.

By Peck, for sandy soil Sand, $P = 0.65\gamma HKa$

$= 31.5513 KN/m^2$

This pressure value is increased by 15 percent for water and other uncertainties, and for surcharge load increase by 20kN/m^2 pressure to 56.28KN/m

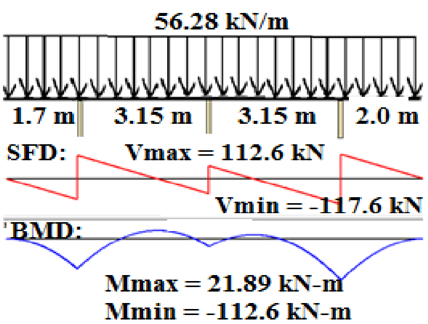

Fig. 1*. SFD and BMD of Shore Pile obtained from Moment Distribution Method.*

Minimum stress, f_{min}= My/I =0.84MPa

Maximum stress, f_{max}= My/I =4.42MPa

6. Finite Element Analysis of Shore Pile

As RC section, concrete was represented by SOLID65 and reinforcement by BEAM188 elements. As deflection is small, solution control was not used and results were read from the first sub-step from ANSYS by default setup.

6.1 Modelling and Meshing of Shore Pile

Modelling was done using the graphical users' interface (GUI). The meshing of the volume was done following the results obtained from the convergence test.The concrete material was modelled as statistically homogeneous with tensile and compressive behavior. As failure pattern was not considered and stress in considered along the only principal axis, biaxial crushing stress was left zero.

6.1.1 Creating volume for Shore Pile: Shore pile is created by volume option keeping elements attributes to SOLID65 as shown in Fig. 2.

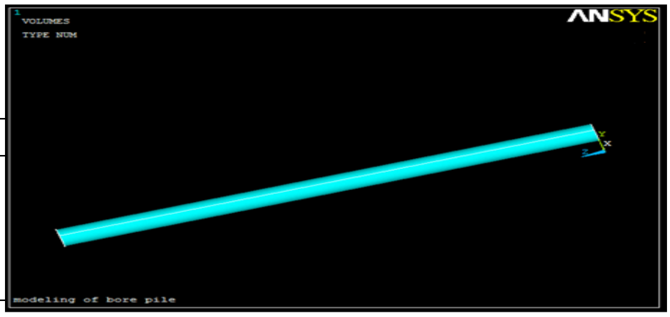

Fig.2.*Volume creation of Shore Pile.*

61.2 Convergence Test: Mesh density is the prime work in the proper modelling of the structure, and this is achieved with the selection of a suitable number of elements having very slight effects on the results. The optimum mesh was checked for an elastic analysis subject to constant load from the plot of maximum deflection versusthe number of elements produced by meshing. From the convergence test, as shown in Fig. 3, it was clear that the 8500 number of elements showeda reasonably accurate result.

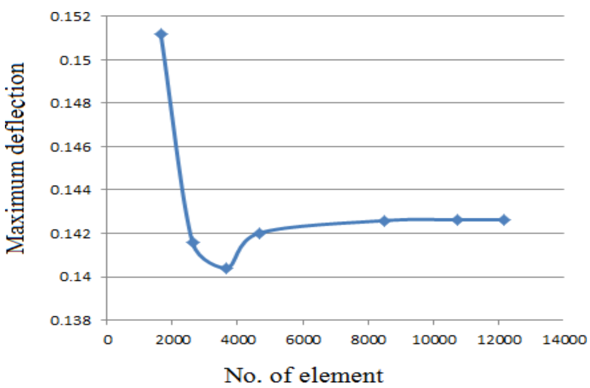

Fig.3. *Convergence test for Shore Pile.*

6.1.3 Meshing of ShorePile: As obtained from the convergence test, about 8500 number of element division showed satisfactory results, meshing was done such that the number of elements is around 8500. Meshing was done by setting global elements attributes to SOLID65 and using smart size to finer 5, and volume was sweep meshed as shown in Fig. 4.

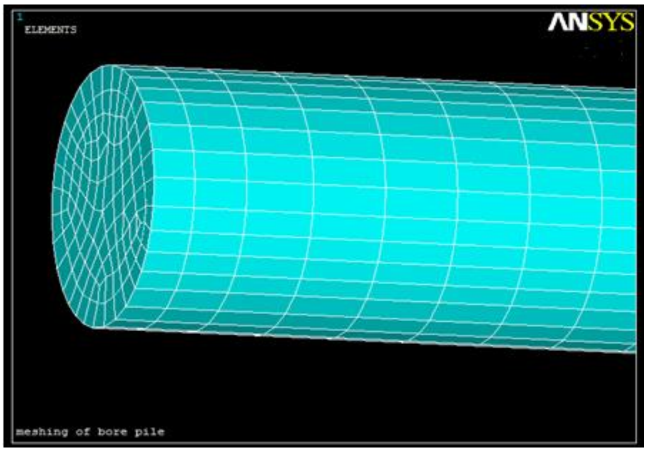

Fig. 4. *Meshed shore pile.*

*6.1.4 Reinforcing in ShorePile:*Eight sets of nodes maintaining 50mm clear cover were selected and then elements attribute was selected under creating element option to provide longitudinal bar section and material number. A view of the reinforcement is shown in Fig. 5.

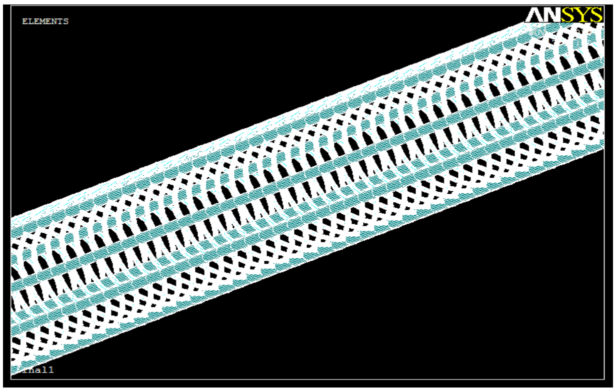

Fig. 5. *Reinforcement in Shore pile.*

6.1.5Loading Pattern of ShorePile: Loading was provided along Y-axis by applying pressure option of the magnitude of 0.05628MPa.

6.2 Analysing of ShorePile from FEM

6.2.1 Checking of Model: The analysis was done without controlling the solution and the number of sub-steps. Checking of the solution was done by comparing reaction readings. Total Reaction reading from ANSYS11was286290N and applied load on y direction was also 286290N. So the analysis was acceptable as total reaction satisfies checking criteria.

6.2.2Flexural Stresses Value at Different Nodes and elements of ShorePile: At the nodes near the support, compressive stress showed considerable variation and in the zone adjacent to support compressive stress was maximum as shown in Fig. 6 and 7.

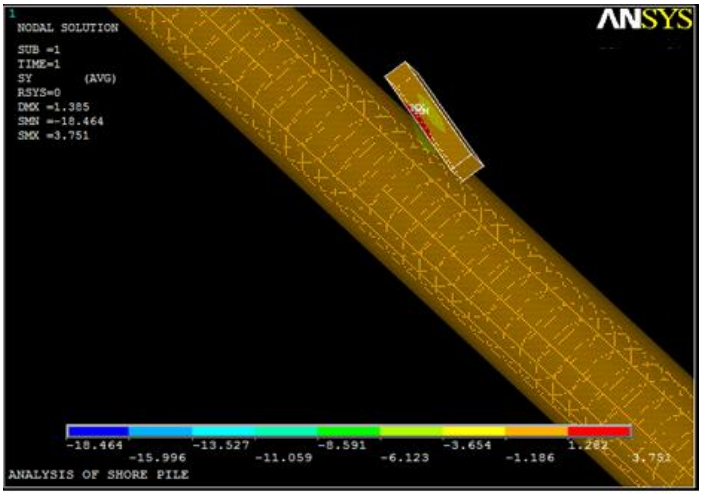

Fig. 6.*Flexural stress on the Shore pile.*

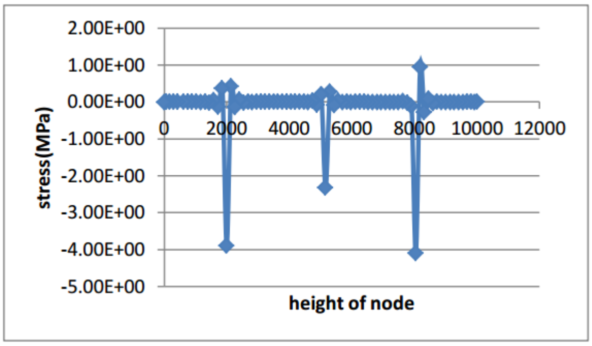

Fig.7. *Flexural stress variation on the Shore Pile.*

7. Results

Based on conventional soil mechanics apparent earth pressure wascalculated to obtain design requirements forthe design of the Shore Pile.To obtain a theory-based solution, the Moment Distribution Method was used. The analytical solution conducted usingFinite Element Analysis software (ANSYS11). An actual representation of reinforced concrete is not possible becauseof their complicatedbond behavior.Moreover concrete shows nonlinear stress—strain relation at lower stresses than that of steel. The stresses obtained from both methods were compared to determine the adequacy of the model as shown in Table 3.

Table 3 Comparison of Stresses

Stress (MPa)Method	ConventionalaAnalysis	FEManalysis	Variation
Maximum compressive	4.42	4.48	1.36 %
Maximum tensile	0.84	0.96	14.3 %

8. Discussion

The result showedgood agreement of FEM with the conventional theory of mechanics. However,the actual representation of RCCwasnot possible due to the non-uniformity characteristics of the constituent materials and bond behavior. Test data maybe incorporated for proper representation of nonlinear behavior of concrete and steel.

9. Conclusion

As the cost of construction materials is rising, for economical design engineers need analyzing stresses beyond linear elastic limits which are not possible by elementary structural mechanics. So in such cases, numerical analysis can play a vital role. So further research can be carried out for checking the design of such complex structures.

10. References

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