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BEHAVIOUR OF RETAINING WALL IN BLACK COTTON

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Abstract - *Maharashtra state is a faster growing state in India. The expansive soil in Maharashtra state is black cotton soil. Black cotton soil is a worldwide problem that poses several challenges for civil engineering. Black cotton soil shrinks and swells with wetting and drying. The shrink swell behavior of black cotton soil causes differential settlement of the structure like retaining wall, foundation of building etc. In this paper, Behavior of Cantilever retaining wall of height 4m in black cotton soil is observed. Behavior of cantilever retaining wall and result are obtained from using FEM based software Plaxis 2D (version 8.2) . Four Cases are consider and compare with each other on basis of Shear force, Bending moment, horizontal displacement and vertical displacement . Main objective of this paper is to find Shear force and bending moment on retaining wall when different cases are considered and to reduce the horizontal displacement and vertical displacement of cantilever retaining wall in black cotton soil. Last case model of retaining wall is made stable by point bearing piles and horizontal , vertical displacement of cantilever retaining wall is reduced by approximately 70 and 99 percentage respectively and shear force , bending moment on the retaining wall in last case is compared with shear force and bending moment on retaining wall in other cases.*

Key Words: *Black cotton soil, Cantilever Retaining wall with different cases, Shear force, bending moment, horizontal displacement, vertical displacement, point bearing piles.*

1. INTRODUCTION

Expansive soil is found in various part of the world such as USA, South Africa, Australia, Spain, Israel, Myanmar and India. In India these expansive soil are known as local name such as Black cotton soil (BC soil) in central India, Bentonite in Rajasthan and Kashmir, Mar or Kabar in UP. These soils occupy about 30 to 40% of the land of India. Urbanization and growth in the economy of cities of India have lead to the steep increased in the building construction activities and has necessitated the implementation of Infrastructure project such as highway, railway, air ships, water tanks, retaining wall, reclamation etc. But in Maharashtra, larger area is covered with highly plastic and expansive soil which is not suitable for such purpose. As per IS 1498-1970 black cotton soil cohesion of soil is 25-35kN/m2 and internal friction 12-24 degree. Black cotton soil of Aurangabad is considered as foundation soil [9]. The average depth of black cotton soil is 3.7m approximately [1]. Basalt is considered below black cotton soil and required value of basalt is taken from case history [9]. Backfill is cohesive soil of Chennai [6]. Retaining wall is a structure with primary purpose to prevent lateral movement, retain the earth or water and may function to vertical load. There are many type of retaining wall and commonly type of retaining wall are gravity retaining wall, cantilever wall, counter fort wall, crib wall, and reinforce concrete top support backfill soil by cantilever action. Base slab serves as permanent support and prevent overturning and sliding. The cantilever stem portion is rigid at bottom and free at top. A key can be an option to be installed at the bottom of slab. This type of concrete cantilever retaining wall is widely used because of the easiness in construction and cost effectiveness [5]. L shaped wall are simple to construction and thus often used as earth retaining solution in urban area. The numerical analysis shows that this type of wall and soil investigation, considerable displacement of the wall (rotation and translation) occurs during the backfill process. The rotation movement of the wall is not occurring around the land as it is usually assumed in design practices, but it follows that a total displacement path of the toe. It is recommended that a better estimation of rotation (s) of the wall is necessary to reach the state in which the active earth pressure can be fully mobilized [7]. If soil boring record establishes the presence of bed rock or rock like material at a site within reasonable depth, pile can be extended up to rock surface. In this case, the ultimate bearing capacity of pile entirely depend on the load bearing capacity of the underlying material this piles is called point bearing piles (NPTEL). Pile foundation is used to prevent uplift of structure, piles are provided where the depth of hard strata is 5m to 50m from ground surface, piles prevent settlement of foundation, and pile foundation is economical in black cotton soil, as the length and diameter of piles increases bearing capacity of piles [1]. For design of retaining wall reference of book is taken of Joseph E Bowels, foundation analysis and design 5th edition. Result are obtained by using FEM based software plaxis 2D. Plaxis is finite element program for geotechnical applications in which the soil models are used to simulate the soil behavior. The mesh element comprises of 15noded and 3 node elements. The various mesh type available are very coarse, coarse, medium, fine and very fine. Similarly interface elements are automatically generated to model the soil - structure interaction.. In this paper , Model is made by 2D and 15 nodded element, plain strain element for the finite element analysis. Friction between wall and soil is neglected and wall is modeled as plate bending member which gives both geotechnical and structure design parameters. Cantilever Retaining wall is placed on 3 – 4m black cotton soil and below black cotton soil basalt is consider and cohensionless soil is considered as backfill. Total 4 cases is considered. Case 1 – Cantilever retaining wall of 4m height as per bowels design, Case 2 – Cantilever retaining wall of 4m height with stem at 0.5 m from toe., Case 3 – Cantilever retaining wall of 4m height with stem at 0.5m from toe and having 1m fill in front of wall on toe., Case 4 – Cantilever retaining wall of 4m height with stem at 0.5m from toe and having 1m fill in front of wall on toe supported by end bearing piles. Result obtained from plaxis is compare with each other cases.

2. VALIDATION OF PLAXIS 2D

The validation of Plaxis is done using the profile reported by [4]. For the data reported in the above literature, the modeling and analysis was done using Plaxis 2D. The reported results are compared with result obtained from present analysis listed in table 1.

Table - 1: Comparisons of results

Result	Sivakumar et al (2013)	Present study
Factor of Safety	0.73	0.61

(∑m stage) which failure takes place. The factor of safety was found 0.73 and in validation factor of safety is found 0.61.

3. PROPERTIES OF INPUTS

Table - 2: Properties of foundation soil

Parameter	Name	Value
Material Model	Model	Mohr-Coulomb
Type of Material Behavior	Type	Drained
Dry Unit Weight	$^{\gamma}$unsat	18.35 kN/m3
Saturated Unit Weight	$^{\gamma}$sat	19.12 kN/m3
Youngs Modulus	E_{ref}	6525 kN/m2
Poissons Ratio	μ	0.25
Cohesion	C	30 kN/m2
Friction Angle	Φ	17

Table - 3: Properties of backfill soil

Parameter	Name	Value
Material Model	Model	Mohr-Coulomb
Type of Material Behavior	Type	Drained
Dry Unit Weight	$^{\gamma}$unsat	18 kN/m3
Satured Unit Weight	$^{\gamma}$sat	20 kN/m3
Youngs Modulus	E_{ref}	2E 4 kN/m2
Poissons Ratio	μ	0.3
Cohesion	C	1 kN/m2
Friction Angle	Φ	35

Table 4 -: Properties of Basalt

Parameter	Name	Value
Material Model	Model	Jointed Rock
Type of Material Behavior	Type	Non Porous
Dry Unit Weight	$^{\gamma}$unsat	27.86 kN/m3
Youngs Modulus	E_{ref}	23.34E 7 kN/m2
Poissons Ratio	μ	0.264
Cohesion	C	1061 kN/m2
Friction Angle	Φ	30
Dip Angle	α 1	40
Tensile strength		43 kN/m2.

Table - 5: Properties of Retaining wall and piles.

Parameter	Name	Value	Value
Material Model	Model	Linear elastic	Linear elastic
Axial stiffness	EA	0.88E7 kN/m2	1.1E7 kN/m2
Inertial stiffness	EI	0.01174E7 kN/m2	0.023E7 kN/m2
Poisson Ratio	μ	0.15	0.15

4. MODELLING WITH PLAXIS AND DEFORMATION MESH.

A Plane strain model of 15 nodded triangular elements was used for discretisation. The properties used in PLAXIS for the Foundation soil, Backfill soil , retaining wall and piles are taken from table 2, table 3, table4, and table5 respectively. The soil layers were modeled as Mohr-Coulomb material and retaining wall and pile as linear elastic material. The wall is modeled as plate bending member which gives both geotechnical and structural design parameters. Mesh type is chosen as very fine. After defining the geometry of the model and determining the boundary conditions and properties of the material, the software generates the initial stress condition, and after this, the finite element model is completed.

Fig - 1: Case 1: Retaining wall as per Bowles design.

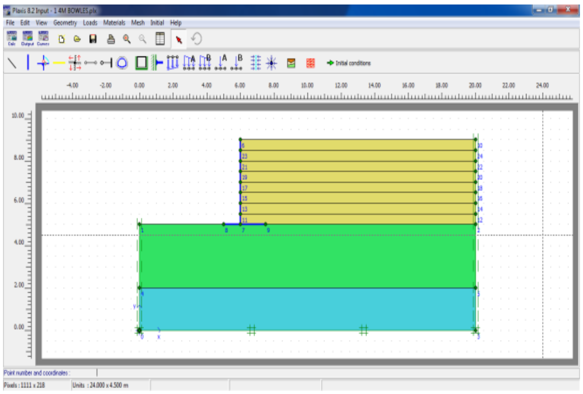


Fig - 2: Case 2: Retaining wall having stem at 0.5m from toe.

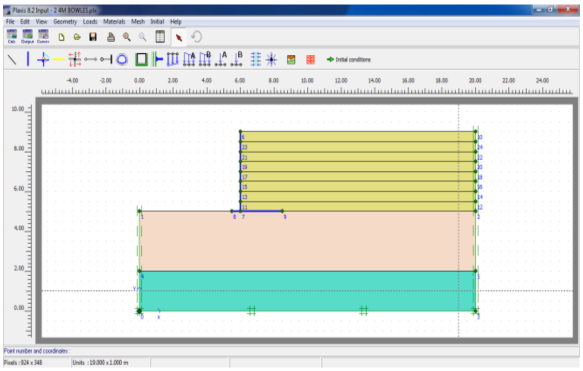


Fig – 3: Case 3: Retaining wall having stem at 0.5m from toe and having filled of 1m on toe.

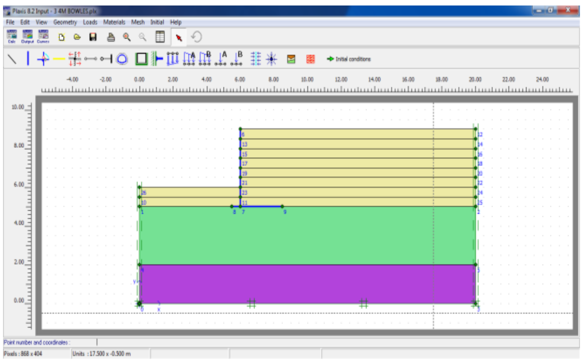


Fig - 4: Case 4: Retaining wall having stem at 0.5m from toe and having filled of 1m on toe and supported by piles.

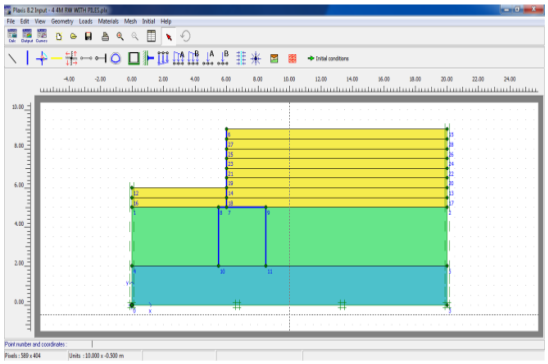


Fig - 5: Deformation mesh of Cash 1

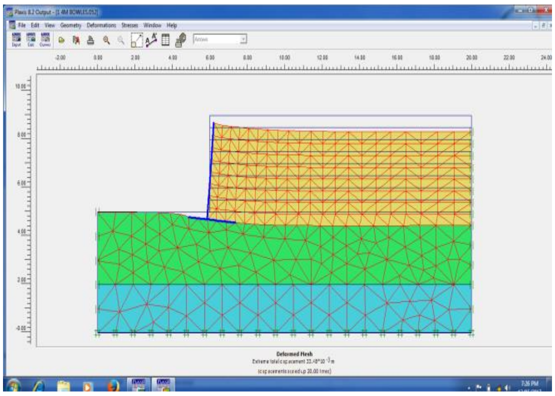


Fig – 6: Deformation mesh of Cash 2.

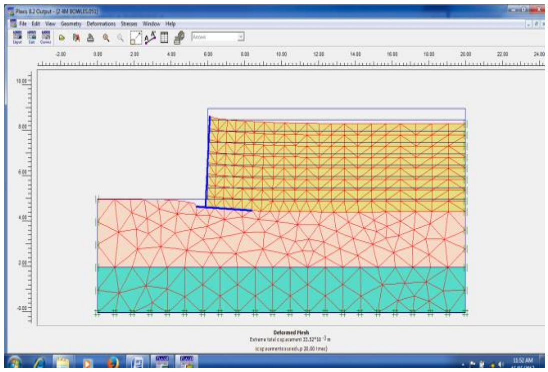


Fig - 7: Deformation mesh of Cash 3.

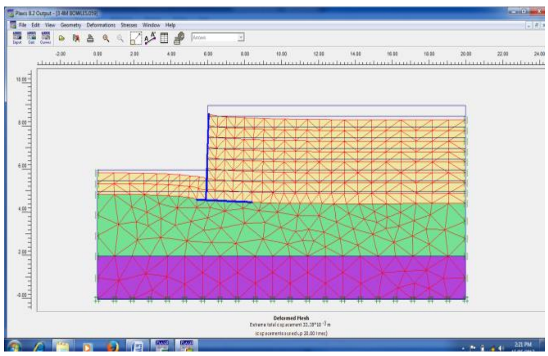
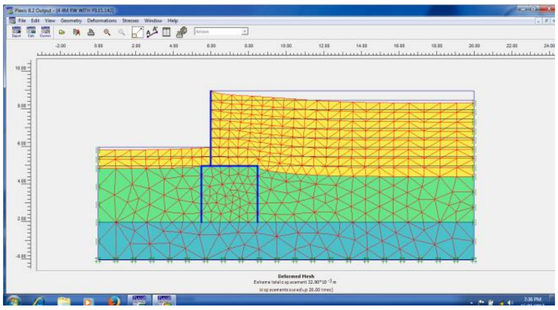


Fig - 8: Deformation mesh of Case 4.



4. Result and Discussions.

Table – 6:- Parameter of Cases.

Parameter	Case1	Case2	Case3	Case4
Shear force(kN/m)	39.55	35.53	20.42	28.67
Bending moment(kN-m/m)	-43.71	-38.55	-32.77	-35.64
Horizontal displacement(m)	0.01	0.0049	0.00243	-0.003
Vertical displacement(m)	-0.015	-0.018	-0.02	-0.00002

In Case1, Horizontal displacement of stem of retaining wall is 0.01m that indicates the retaining wall is in passive state. Vertical displacement of stem of retaining wall is -0.015m indicates that the retaining wall sink in the foundation soil i.e. in black cotton soil.

In Case 2, Extreme shear force on stem is reduced by 10.16 percentages on comparing with the extreme shear force on stem of Case 1 retaining wall. Bending moment on Case 2 retaining wall is reduced by 11.18 percentages on comparing with Case 1 retaining wall. Horizontal displacement of stem of retaining wall is 0.0049 m that indicates retaining wall is in passive state and horizontal displacement is reduced by 51 percentages on comparing with Case 1 retaining wall. Vertical displacement of stem of retaining wall is -0.018 m that indicate that retaining wall sinks in black cotton soil and vertical displacement is increases by 20 percent on comparing with Case 1 retaining wall.

In Case 3, Extremes shear force on stem is reduced by 48.56 and 42.52 percentage on comparing with the extremes shear force on stem of Case1 and Case 2 retaining wall respectively. Bending moment on stem is reduced by 25.02 and 14 percentages on comparing with case 1 and case 2 respectively. Horizontal displacement of stem of retaining wall is 0.00243 m that indicates retaining wall is in passive state and horizontal displacement of case 3 is reduced by 75.07 percentage and 50.40 percentage on comparing with case 1 and case2. Vertical displacement of stem of retaining wall is -0.02m that indicate that the retaining wall sinks in black cotton soil. Vertical displacement is increased by 25 percentages and 10 percentages on comparing with case 1 and case 3 respectively.

In case 4, Extremes shear force on stem is reduced by 27.5 percentages, 19.30 percentages and increased by 28.77 percentages on comparing with case 1, case2, and case3 respectively. Bending moment is reduced by 18.46 percentages, 7.54 percentages and increased by 8.05 percentages on comparing with case1, case2 and Case3 respectively. Horizontal displacement of stem of retaining wall is 0.003 m. Horizontal displacement of case 4 is reduced by 70 percentages, 38.77 percentage, increased by 19 percentages on comparing with case 1, case 2, and case 3 respectively. Vertical displacement of retaining wall is 0.00002 m. Vertical displacement of retaining wall is reduced by 99.86 percentages, 99.86 percentages, and 99.9 percentages on comparing with case 1, case 2 and case 3 respectively. Retaining wall is approximately stable.

6. Conclusions

The shear force, bending moment, horizontal displacement and vertical displacement of stem of retaining wall are compared. The observation made from this study is

1. In black cotton soil, Cantilever retaining wall is in passive state and sink in black cotton soil and if strong strata range from 3m-10m is available below black cotton soil then retaining wall can be supported on point bearing piles.
2. When stem of retaining wall is shifted at 0.5m from toe. Horizontal displacement is reduced but Vertical displacement is increased while Shear force and bending moment act less on the stem of the retaining wall on comparing with case1.
3. When front filling is provided on toe of retaining wall there is reduction in horizontal displacement and increases in vertical displacement of retaining wall while less shear force and bending moment acts on retaining wall on comparing with case1.
4. On comparing case 1 with case 4, shear force is reduced by 27.5 percentages. Shear force on stem of retaining wall acts less as when retaining wall is supported on point bearing piles.
5. On comparing case 1 with case 4, bending moment is reduced by 18.5 percentages. Bending moment on stem of retaining wall even acts less when retaining wall is supported on point bearing piles.
6. Horizontal displacement of stem of retaining wall is reduced up to approximately 70 percentages

when retaining wall is supported on point bearing piles.

7. Vertical displacement of stem of retaining wall is reduced up to approximately 99 percentages when retaining wall is supported on point bearing pile.

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