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Impact of Changes in Geotechnical Properties on the Serviceability of Cantilever Retaining Structure in Lateritic Soil

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Abstract - In this paper the comparative study of geotechnical properties of lateritic soil as input design parameters in pre and post construction condition of earth retaining structure is studied and its impact on serviceability is noted. Permanent RCC earth retaining structures (ERS) are constructed for total lifespan of 30-60 years but generally in most of cases, it cannot withstand for its total life. To find out the reasons of failure, parametric study is conducted to assess the serviceability of cantilever earth retaining wall at Dasgaon from Mahad Tehsil, Maharashtra. The input design parameters for Dasgaon retaining wall at the time of construction was analyzed and compared with current parameters, and it is found that there is a change in engineering properties of backfilled material. The results of the input design parameters are used to find out the factor of safety (FOS) considered for structural safety while designing cantilever retaining structure and the effect of changed input design parameters on factor of safety is compared from this authors concluded that factor of safety is going to decrease which reduces the serviceability of cantilever earth retaining structure.

Key Words: Lateritic soil, Input design parameters, cantilevers earth retaining structure (ERS), Serviceability, Structural safety.

1. INTRODUCTION

Landslides are natural hazard that affect at least 15% of the land area of our country, covering an area of more than 0.49 million sq. km. Landslides of different types occur frequently in geodynamical active areas in Konkan and Western Ghats. Landslides form a significant component of natural disaster in many hilly, lateritic areas of Konkan. The slopes along Konkan Railway and many other Ghat sections along roads have been affected by severe slope instabilities. To prevent landslide or such slope instability retaining walls are constructed. Retaining wall is structure that holds or retains soil behind it [(1)]. Design of retaining wall must satisfy geotechnical, structural and economic requirements [(2)]. The design philosophy deals with the magnitude and distribution of lateral pressure between soil mass and adjoining earth retaining structure. Earth pressure on retaining wall is designed from theories of soil mechanics but unfortunately the properties of soil not remain same in all weather conditions [(5)]. The properties of the soil such as plasticity, compressibility or strength of the soil always affect the design. Lack of understanding of the properties of the soil can lead to the construction errors or structural failure. The ERS design must satisfy two major requirements i.e. internal stability which is ensured by sufficient resistance against bending moment and shear force and external stability which means that except for small moments necessary to mobilize the earth pressure, the wall must be in equilibrium with respect to external forces [(7)].

There are many types of retaining walls according to use, according to material and according to life such as cantilever wall, counter fort wall, gravity walls etc and many types of material used to create retaining wall like R.C.C., concrete block, poured concrete, treated timber, rock and boulders. Some are easy to use and some have short life but all are used to retain soil. Among this RCC cantilever retaining wall is most commonly used. Retaining walls are designed for temporary and permanent structure. Temporary structures are designed for 3-5 years and permanent structures are designed for 30-60 years life span. But in majority of cases, the permanent structures are not withstood for its total life. Cantilever retaining walls are generally used in cut and fill operations also in hilly area. These types of wall are economical upto 6-8 meters height.

1.1 Details of study area and proposed ERS:

Study of a major landslide against relative mitigative measures for its serviceability at Dasgaon in South – Western Maharashtra has been presented in this paper. Dasgaon village is in Mahad tehsil and in Raigad district having Latitude- N18° 6' 46.08'' and Longitude- E 73° 21' 54'' E. Majorly lateritic soil occurs in Mahad tehsil. Mahad Tehsil is suffering from frequent landslides. In the year of 2005, major landslide was occurred in Dasgaon, Lower tudil, Jui, Sahilnagar and Kemburli villages and many people lost their lives as well as tremendous property loss was booked in this tragedy. To prevent such incidences, the retaining structure was constructed for this landslide is in dasgaon village, Raigad District. The fig. 1 shows the proposed retaining structure in dasgaon which was constructed in April 2017.

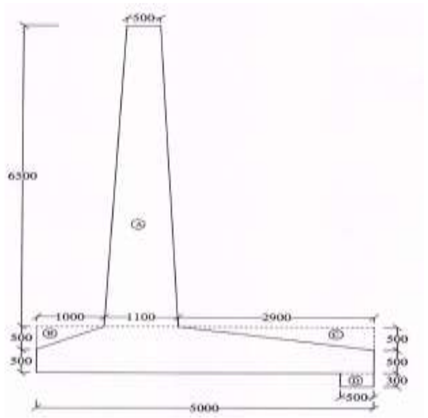

Fig. 1 Proposed ERS in Dasgaon village.

2 INPUT DESIGN PARAMETERS AND SAFETY CHECKS

2.1 Geotechnical Input Design Parameters Considered in Design of ERS:

From structural point of view shear Strength of Soil and soil bearing capacity and density of soil are important parameters. The various soil parameters and their relationship is described below.

2.1.1Density of soil: There are three types of densities are considered while designing that are dry density, saturated density and submerged density. Dry density of soil is the mass of soil itself. Saturated density is the mix density of soil and water. Submerged density is the difference between saturated density and unit density of water. The maximum value of density is at the saturated condition is considered to design ERS.

2.1.2 Shear Strength of Soil (cohesion and internal angle of friction): Shear strength is the most important geotechnical property of soils; help in stability of civil engineering structures on or below the earth. The shear strength of soil depends on the effective stress, drainage conditions, density of the particles, % of fines and natural moisture content.. Thus, the shearing strength is affected by the consistency of the materials, mineralogy, and grain size distribution, shape of the particles, initial void ratio and features such as layers, joints, fissures and cementation. Shear strength parameters are a result of the frictional forces of the particles, as they slide and interlock during shearing. Friction angle is high for a sandy soil than its cohesion and vice versa for clayey soil.

2.1.3 Bearing capacity of soil: Bearing capacity is the capacity of soil to support the loads applied to the ground. The bearing capacity of soil is the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the soil. Ultimate bearing capacity is the theoretical maximum pressure which can be supported without failure; allowable bearing capacity is the ultimate bearing capacity divided by a factor of safety. Sometimes, on soft soil sites, large settlements may occur under loaded foundations without actual shear failure occurring; in such cases, the allowable bearing capacity is based on the maximum allowable settlement. The soil bearing capacity can be affected by shear strength parameters, permeability, water content.

2.1.4 Specific Gravity: Increase in specific gravity can increase the shear strength parameters (cohesion and angle of shearing resistance). Also increase in specific gravity also increases the California bearing ratio.

2.1.5 Consistency Limit: Plastic limit and liquid limit are known as consistency limit. The plastic limit of soil is the condition at which the soil is behaves in plastic stage. Liquid limit of the soil is the maximum capacity of water to absorb and is the condition of soil in which soil converts from plastic condition to liquid condition. The consistency limit is used in soil classification and finding various correlations with other soil properties

2.1.6 Particle Size Analysis: The particle size analysis shows the classification of soil. The particle size distribution curve (gradation curve) represents the distribution of particles of different sizes in the soil mass. Information obtained from particle-size analysis can be used to predict soil-water movement. The permeability of soil shows the condition of backfill.

2.1.7 Permeability of Soil: The amount, distribution, and movement of water in soil have an important role on the properties and behavior of soil. Shear strength of soils also depends indirectly on its permeability, because dissipation of pore pressure is controlled by its permeability.

2.2. Safety checks to achieve serviceability:

To achieve fulfill serviceability of ERS the various factor of safeties are considered while design. These factors of safety are as follows

2.2.1 Check against overturning

The lateral pressure due to backfill tends to overturn the retaining wall about its toe. The stabilizing moment against overturning is given by the weight of wall and weight of earth on heel side of wall. The minimum value should be 1.5. This safety check mostly value can be increased by increasing mass of retaining structure.

Factor of safety against overturning = stabilizing moment / overturning moment
Where, Overturning moment = P_a X H/3
Stabilizing moment = ƐW X x
ƐW = sum of vertical forces acting at x from the toe and x = H/3, P_a = Horizontal active earth pressure.
H = height of structure.

2.2.2 Check for sliding

The sliding tendency is resisted by the frictional resistance between the base of retaining wall and the soil underneath. The factor of safety against sliding shall not be less than 1.4. If factor of safety is less than 1.55, a shear key is provided for additional resistant of failure.

Factor of safety against sliding = resisting force / horizontal force
Where, Resisting force to sliding = frictional resistance of soil X ƐW
Horizontal force causing sliding = P_a

2.3.3 Check for maximum and minimum pressure at toe

The maximum pressure at toe should not exceed than safe bearing capacity of soil and the minimum pressure should not be less than zero to ensure no tension at base. This is calculated by,

$$q_{\substack{min \\ max}} = \frac{\sum V}{B}\left(1 \mp \frac{6e}{B}\right)$$

Where q= pressure in toe, B = width of base slab
e = eccentricity developed in toe.

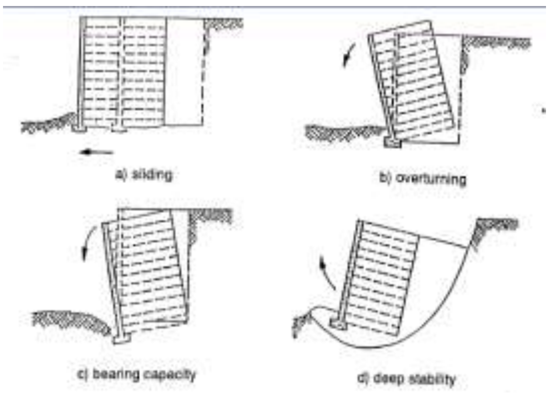

Fig. 2 Various modes of failure by reducing fos

3. EXPERIMENTAL SETUP TO FIND INPUT DESIGN PARAMETERS AND FACTOR OF SAFETY

To analyze the condition of backfill material at current state the following tests were conducted on backfill material. There are three samples are collected from the backfill of dasgaon retaining structure named as Sample A,B,C respectively

1. The determination of natural moisture content of soil by oven drying method.
2. The determination of specific gravity of soil.
3. Sieve analysis by mechanical method.
4. Determination of Atterbergs Limit.
5. Determination of Maximum dry density and Optimum Moisture Content of soil by Standard proctor test.
6. Determination of cohesion and internal angle of friction by direct shear method.

3.1 Input design parameter at the time of construction of ERS

The cohesion and Internal angle of friction was 0 Kg/cm^2 and 30^0 respectively at the time of construction. Dry density and Saturated Density of backfill material at both sites was 18 and 20 KN/m^3. Following enlisted Characteristics Properties of soil occurred while designing ERS at Dasgaon (Table No. 1).

Table 1. Input design parameters at the time of construction

Sr. No.	Parameters	Pre values
1	Specific gravity	2.9
2	dry density of soil (Kn/m^3)	18
3	Saturated density of soil (Kn/m^3)	20
4	cohesion of soil	0
5	Internal angle of friction (°)	30

3.2 Input design parameter at the current scenario of ERS

The following table shows the current backfill condition by assessing the geotechnical tests on collected backfill material. The three soil sample are collected namely case A, B, C respectively.

Table 2. Characteristics Properties of soil at current state for Dasgaon

Sr.No	Parameters	Case A	Case B	Case C
1	Natural moisture content (%)	16.95	11.39	17
2	Specific gravity	2.48	2.56	2.54
3	% of soil passing through 200 No. Sieve (%)	18.6	24.3	17.9
4	Liquid limit (%)	48.39	41.63	43.78
5	Plastic limit (%)	36.43	33.26	37.56
6	Plasticity index (%)	11.96	8.37	6.22
7	Optimum moisture content(gm/cc)	1.98	1.43	1.394

8	Maximum dry density(%)	25.05	28.47	34
9	Dry density of soil (Kn/M^2)	17.5	17.7	17.74
10	Cohesion of soil at N.M.C. (Kn/M^2)	27	21	25
11	Internal angle of friction at N.M.C.(°)	26.9	27	26.4
12	Saturated density	21.45	21.80	20.90
13	Cohesion at fully saturated condition	0	1	3
14	Internal angle of friction at fully saturated condition	22	22	24

3.3 Effect of natural moisture content on Ø value and cohesion value

The fig.1 and 2 shows the relationship between natural moisture content with respect to internal angle of friction Ø and cohesion value respectively.

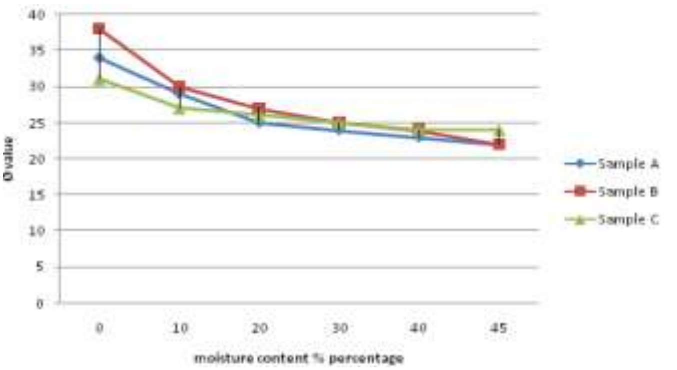

Fig. 2 Relationship of natural moisture content on internal angle of friction

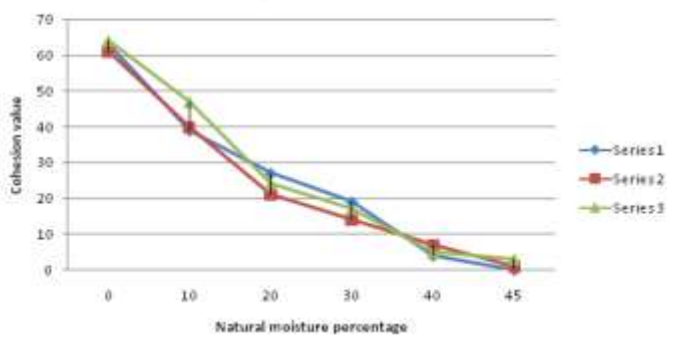

Fig. 3 Relationship of natural moisture content on Cohesion of soil

4. RESULT AND DISCUSSION

From the relationship between natural moisture content to the cohesion and internal angle of friction of soil, it is clear that increase in natural moisture content decreases the internal angle of friction and cohesion of soil. The water content increases also the saturated density is going to increase upto certain limit. The various safety checks in terms of factor of safety for overturning, stability, minimum and maximum pressure at toe for input design parameters before construction of cantilever earth retaining structure were compared against the current input design parameter observed by conducting geotechnical tests on soil sample borrowed from backfill of cantilever retaining structure considered in this study. The safety check results obtained with the study are tabulated in Table number 3.

Table 3. Factor of safeties with different design condition

Sr. No	Factor of safety	Design conditions		
		At the time of Pre design	At current Natural moisture condition	At fully saturated condition
1	Overturning	3.43	2.71	2.41
2	Sliding	2.54	1.96	1.40
3	Minimum pressure at base	74.24	53.30	34.06
4	Minimum pressure at base	143.48	174.95	209.28

CONCLUSION

Comparing the results of retaining wall design obtained by three sets of input design parameter shows the changes observed in current design parameters due to impact of rainfall intensity, overall climatic conditions and manmade activities like nearby construction. This change in input design parameters affects on the safety checks. The FOS against overturning is reduced by 70.26%, FOS against sliding is reduced by 55.12%, minimum pressure at base is decreased by 45.87% and maximum pressure is increased by 68.55%. This proves that due to change in the considered input design parameters at current condition the serviceability of cantilever earth retaining structure is about to decrease against pre decided lifespan of 60 years. This triggers the need to study the input design parameters periodically so as to one can able to manage these parameters in safe range to achieve and enjoy the service for design lifespan of 30-60 years.

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