



# Investigation on Geotechnical Properties Before and After the Construction of Earth Retaining Structures-West Konkan a Case Study

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**Abstract.** Characteristic geotechnical properties of soil vary from place to place. The classification of soil mass depends on rock family from which it originates its mineral composition and the environmental aspect of the area. Civil engineering structure is founded in or on the surface of the earth, and hence before designing any structures, it is necessary to closely observe the suitability of a soil for construction. Properties of soils observed before construction and after the construction of earth retaining structures (ERS) influences the stability of structures. Most of the geotechnical properties of surrounding soils in the vicinity of ERS changes after the construction of the ERS. In a developing country like India, the population density is very high due to which people are forced to reside in landslide-prone areas and this initiates the need to construct Earth Retaining Structures. The stability of these ERS is very crucial to protect the vulnerable slopes. If the ERS are displaced even slightly it can create havoc by bringing the lives and property in danger. In this paper, different geotechnical properties of soils such as specific gravity, density index, consistency limits, particle size analysis, compaction, consolidation, permeability, and shear strength have been studied for observing the changes in geotechnical properties of the soil before and after the construction of Earth Retaining Structures and conclusions are noted. This paper attempts to find out the correlation between the displacement of ERS against changes in soil characteristics using GNSS technology. It is observed from past research studies that GNSS technology can be used for tracing out the precise location of any object or structure. Keeping this in mind, the soil sample in the vicinity of ERS was regularly checked in the laboratory to correlate the soil characteristics and

location of the ERS. The practice of testing the soil characteristics in the laboratory was consistently followed. From the laboratory and field tests observation, it has been observed that soil characteristics of the soil in the vicinity of ERS change even with the minor displacement of the ERS from its initial position. Hence, GNSS technology can be used to give early warnings related to major displacements of ERS that could take place in the future. Thus GNSS technology can be used to produce a low-cost early warning system for the displacement of ERS so that a warning about a probable landslide can be received well in advance to evacuate the area and save life and property.

**Keywords:** Geotechnical properties · Earth retaining structures · Drainage · Shear strength-bearing capacity of soil · GNSS

## 1 Introduction

Landslide Hazard Mitigation as disaster management is a very tough job for a Civil, Structural, and Geotechnical Engineer. In hilly terrain, due to manmade and natural activities landslide occurs frequently. It affects the lifestyle of local people, ecosystem, and economy of that area. The soil stabilization techniques are introduced to reduce such landslide; the earth retaining structures provision is one of them.

Earth Retaining Structures (ERS) are relatively rigid walls used for supporting the soil mass laterally so that the soil can be retained at different levels on the two sides. They are used to bound soils between two different elevations often in areas of terrain possessing undesirable slopes or in areas where the landscape needs to be shaped severely and engineered for more specific purposes like hillside farming or roadway overpasses.

The geotechnical, structural and economic consideration is the most important to design the earth retaining structure. To design earth retaining structure it is important to know the characteristic geotechnical properties of soil in that area, which effects on the serviceability of that ERS. Properties of soils observed before construction and after the construction of earth retaining structures (ERS) influences the stability of structures. To study this changes various geotechnical tests are conducted on backfill material against precise positioning study of ERS using GNSS and its impact on design serviceable life in terms of factor of safety is calculated.

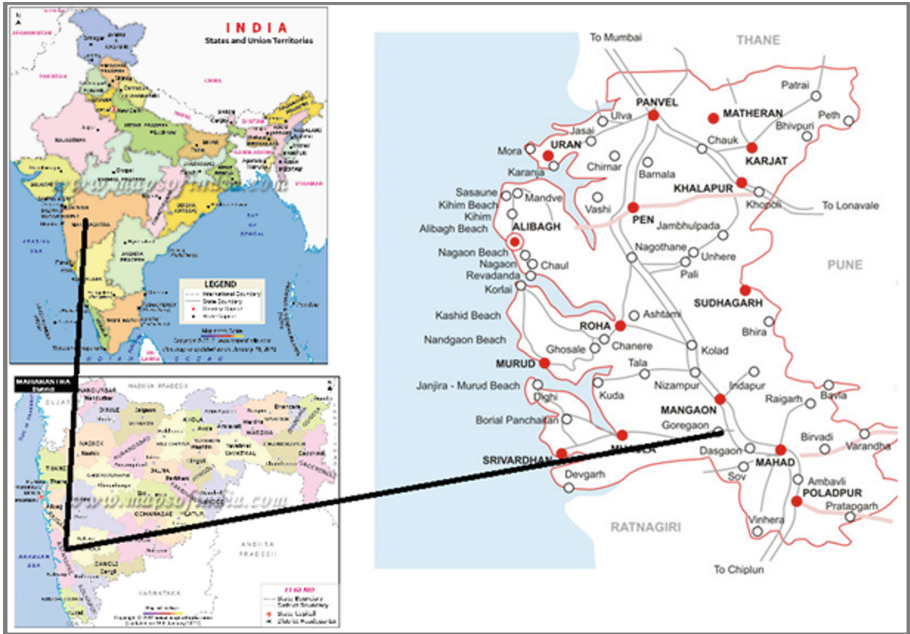
Majorly retaining structure was failed in the rainy season; therefore it triggers need to compute changes in input design parameters at current condition and at the full saturated condition of the soil. In the case of ERS, its structural design is mainly dependent on cohesion, internal angle of friction, soil bearing capacity, the density of soil, surcharge angle of backfill and height of retaining wall. Among these listed parameters cohesion, internal angle of friction, dry density and saturated density of soil are found to be dependent on % of fine aggregate and Natural moisture content in the composition of backfill material. As percentage fineness is increased it affects on the specific gravity, natural moisture content, cohesion, dry density and saturated density of soil.

This paper attempts to find out the correlation between the displacements of ERS using GNSS technology against changes in soil characteristics if any. It is observed from past research studies that GNSS technology can be used for tracing out the precise location of any object or structure. Keeping this in mind, the soil sample in the vicinity of ERS was regularly checked in the laboratory to correlate the soil characteristics and location of the ERS. The practice of testing the soil characteristics in the laboratory was consistently followed. From the laboratory and field tests observation, it has been observed that soil characteristics of the soil in the vicinity of ERS change even with the minor displacement of the ERS from its initial position. Hence, GNSS technology can be used to give early warnings related to major displacements of ERS that could take place in the future. Thus GNSS technology can be used to produce a low-cost early warning system for the displacement of ERS so that a warning about a probable landslide can be received well in advance to evacuate the area and save life and property.

## 2 Study Area and Geology

Detailed investigation of a major landslide against relative mitigative measures for its serviceability at Dasgaon in South – Western Maharashtra i.e. Kokan region has been presented in this paper. Location for this cantilever ERS is in Raigad District having Latitude- N18° 6' 46.08" and Longitude- E 73° 21' 54" East Dasgaon. The total height of Dasgaon cantilever ERS is 7.5 m. Geologically this region has Deccan Trap Basaltic rocks and lateritic rock, which are weathered near the surface due to highly oxidizing and humid climatic conditions, developing lithomarge clays and lateritic soil regolith. Loose cohesive soil matrix becomes soft and loses strength due to surface and sub-surface flow during heavy precipitation. Regolithic mass of overburden became heavy, lost support/interlocking and slumped along the hill slope. This region lies in zone IV as per map of seismic zones for our country. Therefore minute seismic event may act as a triggering factor leading to slope instability (Map 1).

The hilly terrain of Dasgaon area is south-western part of Sahyadri in the coastal strip. It is composed of the oldest rock formation of the world that is Archaean systems. This rock formation after weathering has converted to the relict hilly terrain with lateritic soil mass resting on the angle of repose of gneisses. This hilly terrain in coastal zone experiences very heavy rainfall during monsoon. It is seismically active and comes under zone IV as per seismic zonation map. Therefore Landslide is a frequently observed phenomenon in this area during monsoon.



Map 1. Study Area

### 3 Study of Characteristic Geotechnical Properties of Soil

#### 3.1 Input Design Parameters at the Time of Structural Design

The Table 1 shows the input design parameters at the time of structural design for Dasgaon cantilever ERS. The properties of concrete and steel are M 30 and Fe500. Height of retaining structure is 7.5 m for Dasgaon.

Table 1. Input design parameters at the time of structural design

Sr. No.	Parameters	Pre values
1	Specific gravity	2.9
2	The dry density of soil (KN/m <sup>3</sup> )	18
3	The saturated density of soil (KN/m <sup>3</sup> )	20
4	The cohesion of soil (KN/m <sup>2</sup> )	0
5	Internal angle of friction (°)	30

### 3.2 Input Design Parameters at the Current Scenario

To analyze the condition of backfill material at the current state the following tests were conducted on backfill material. Soil samples are collected from the backfill of the dasgaon retaining structure at two conditions from three different locations. The reasons to check these tests is that this design parameter effects on the Factor of safety considered while design.

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 Atterberg's 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 the direct shear method.

Tables 2 and 3 shows the input design parameters at the current condition by conducting the laboratory tests on a borrowed soil sample. This input design parameter effects on the serviceability in terms of calculation of factor of safety, therefore it is essential to find out the input design parameter.

**Table 2.** Characteristics Properties of soil at Dasgaon-Position 1 through GNSS - Latitude- N18° 6' 46.08" and Longitude- E 73° 21' 54"

Sr. No	Parameters	Sample A	Sample B	Sample 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	1.98	1.43	1.394
8	Maximum dry density	25.05	28.47	34
9	The dry density of soil	17.5	17.7	17.74
10	The saturated density of soil	20.48	20.42	20.17
11	Cohesion of soil	27	21	25
12	Internal angle of friction	26.9	27	26.4

**Table 3.** Characteristics Properties of soil at Dasgaon- Position 2 through GNSS - Latitude- N18° 6' 48" and Longitude- E 73° 21' 58"

Sr. No	Parameters	Sample A	Sample B	Sample C
1	Natural moisture content	21	24	23
2	Specific gravity	2.21	2.24	2.17
3	% of soil passing through 200 No. Sieve	36	34	33.8
4	Liquid limit	51.8	54.47	52.03
5	Plastic limit	41.78	43.23	43.67
6	Plasticity index	10.02	11.24	8.36
7	Optimum moisture content	1.58	1.51	1.46
8	Maximum dry density	27.3	24.1	20.76
9	The dry density of soil	18.390	18.301	18.792
10	The saturated density of soil	20.86	20.91	20
11	Cohesion of soil	30	26	29
12	Internal angle of friction	24	21	22

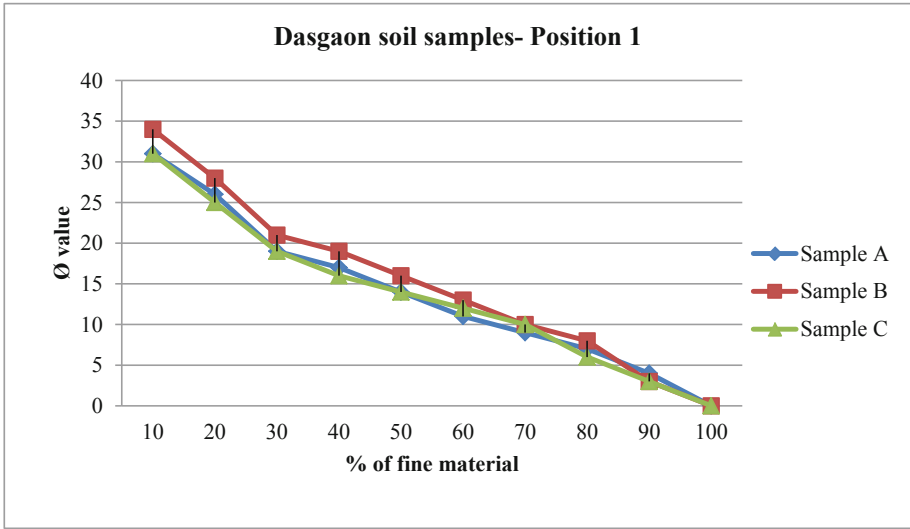
### 3.3 Use of GNSS to Study the Same Object for Position Change Observations

The survey has been carried out using GNSS receivers to study the changes if any for the predefined object in the vicinity of ERS, and it has been noted that the position of object was displaced against the initial one noted on a first field visit. The initial position was (Position-1) Latitude- N18° 6' 46.08" and Longitude- E 73° 21' 54"; later it is (Position-2) Latitude- N18° 6' 48" and Longitude- E 73° 21' 58". These minute changes were noted and the soil sample was collected for finding out input design parameters at real-time study. The changes in soil characteristics properties were observed and its impact on serviceability was studied in detail.

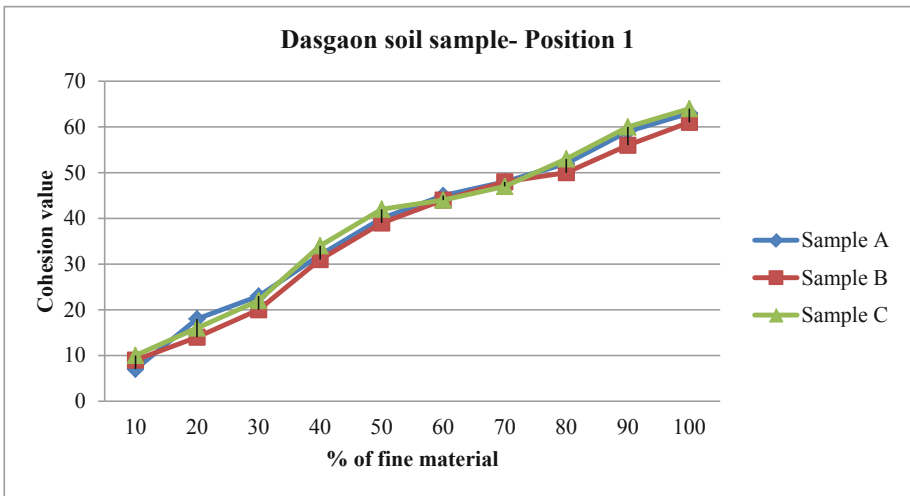
## 4 Different Geotechnical Properties of Soils and Their Impacts on Input Design Parameters of ERS

### 4.1 Effect of the Percentage of Finer Material on the Shear Strength Parameter of Soil

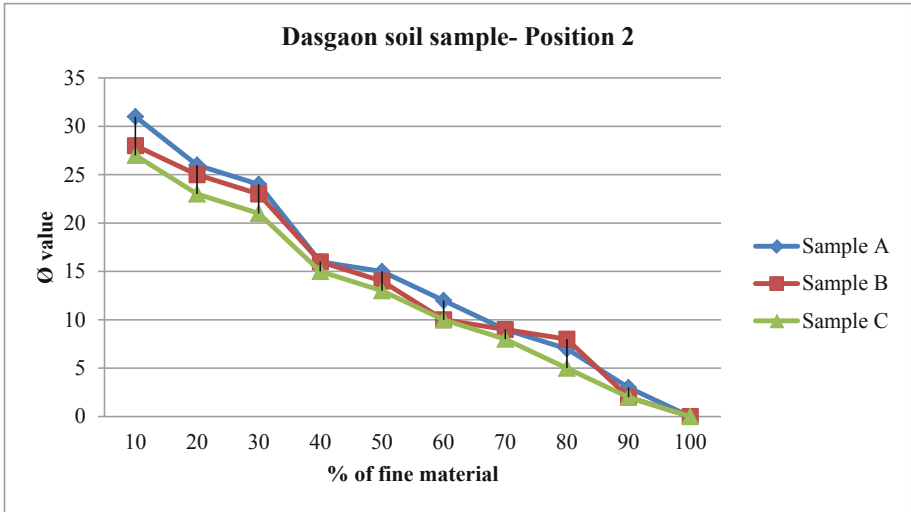
Due to weathering action, the percentage of finer material in the composition of the soil is going to increase. The percentage of finer material in the composition of soil may affect on shear strength parameter of soil which affects the calculation factor of safety while design. The Graphs [A](#), [B](#) and [C](#), [D](#) shows the effect of percentage of finer material on the internal angle of friction and cohesion of backfill material collected from Dasgaon for two different positions observed respectively. The direct shear test is used to find out this relationship.



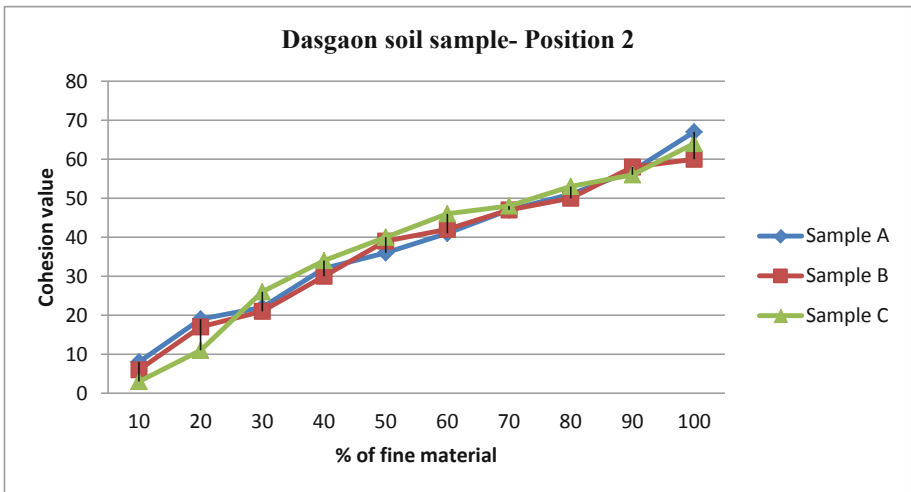
**Graph A.** Effect of percentage of finer material on the internal angle of friction



**Graph B.** Effect of percentage of finer material on cohesion



**Graph C.** Effect of percentage of finer material on the internal angle of friction



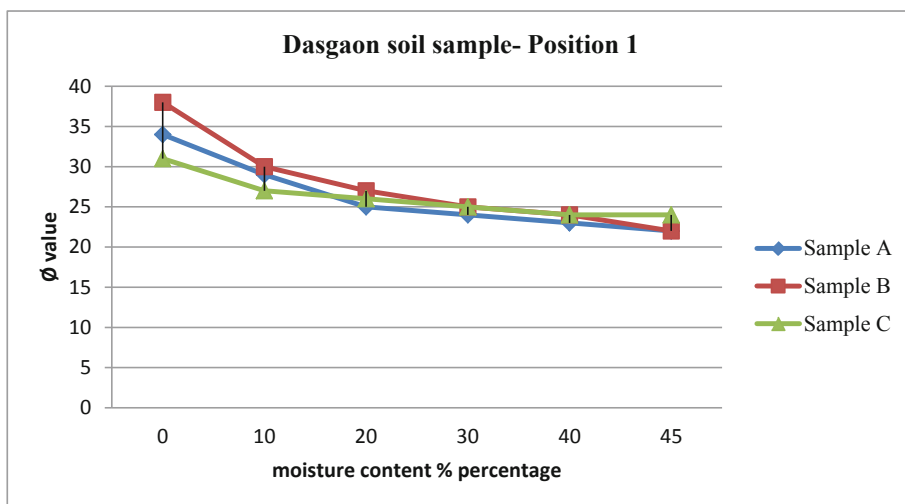
**Graph D.** Effect of percentage of finer material on cohesion

From this graph, it is concluded that as a percentage of finer material in soil composition goes on increasing the internal angle of friction is going to decrease and cohesion value is going to increase that means in terms of finer material composition, cohesion and internal angle of friction are inversely proportional.



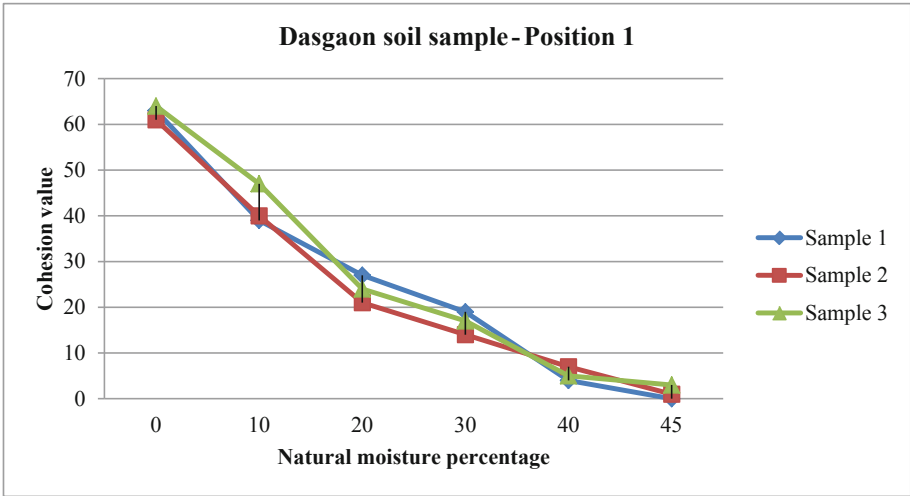
#### 4.2 Effect of the Percentage of Natural Moisture Content on the Shear Strength Parameter of Soil

Majorly retaining structure was failed in the rainy season; therefore it triggers to need to compute changes in shear strength parameters at the full saturated condition. The natural moisture content in soil effects on shear strength parameter and shear strength and which may affect the factor of safety. The Graphs E, F, and G, H shows the effect of Natural moisture content on the internal angle of friction and cohesion of backfill material collected from Dasgaon for two different positions respectively. The percentage of finer material is kept as it is described in Tables 2 and 3. The direct shear test is used to find out the changing effect of shear strength parameter.

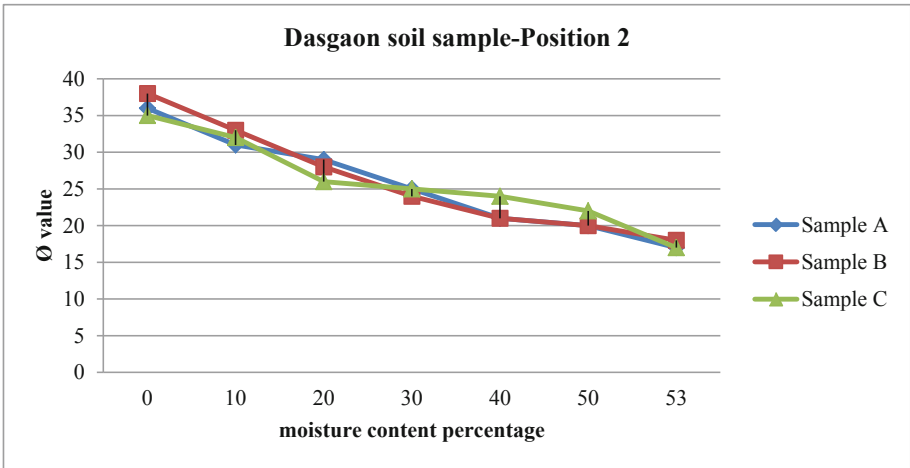


**Graph E.** Effect of natural moisture content on the internal angle of friction

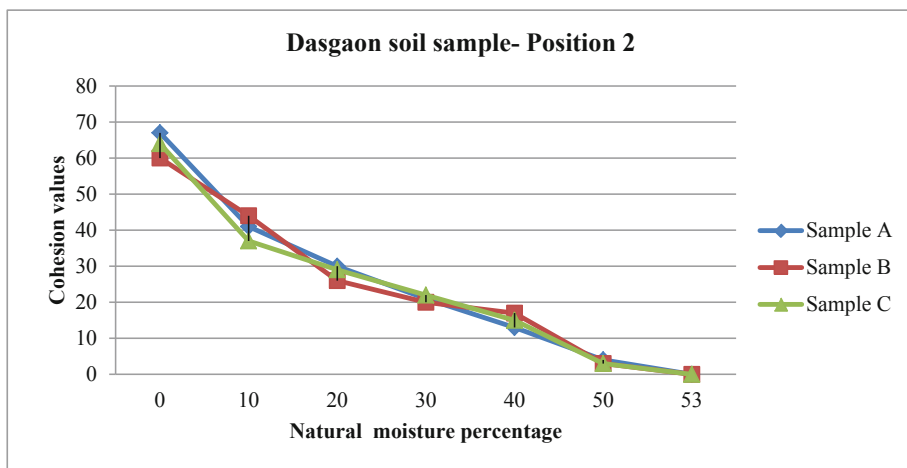
From this graph, it is concluded that a percentage of natural moisture content in soil composition goes on increasing then both cohesion and internal angle of friction of soil is going to decrease.



**Graph F.** Effect of percentage of natural moisture content on cohesion



**Graph G.** Effect of natural moisture content on the internal angle of friction



**Graph H.** Effect of percentage of natural moisture content on cohesion

### 4.3 Saturated Density at the Full Liquid Limit Condition of Soil

The saturated density is higher than that of dry density of soil and is the combination of soil mass and water. The saturated density is higher at the liquid limit of that soil and is occurred in the rainy season. Therefore the saturated density is calculated for every collected soil sample at their respective liquid limit. The Table 4 shows the maximum saturated density at their respective liquid limit for both positions.

**Table 4.** Values of liquid limit at their liquid limit

Sr. No.	Area of soil sample collected	Saturated density ( $\text{Kn}/\text{M}^2$ )		
		Sample 1	Sample 2	Sample 3
1	Dasgaon- Position 1	21.45	21.80	20.90
2	Dasgaon- Position 2	22.21	22.47	22.44

## 5 Study of Serviceability of ERS

### 5.1 Effect of Current Input Design Parameter on Design Serviceability in Terms of Factor of Safety

At fully saturated condition the cohesion is becoming negligible and minimum internal angle of friction becomes  $22^\circ$  and  $17^\circ$  for Dasgaon - Position 1 and Dasgaon – Position 2 backfill material respectively. The maximum saturated density also at the full liquid limit becomes 21.80, 22.47  $\text{KN}/\text{M}^3$  for Dasgaon - Position 1 and Dasgaon – Position 2 backfill material respectively. Height of retaining structure, Soil bearing capacity and properties of concrete and steel is kept as it is. Then the revised design of structure and changes in FOS are noted. The Table 5 shows the Factor of safety calculated at the fully saturated condition.

**Table 5.** Factor of safeties with different design condition

Sr. No.	Factor of safety	Dasgaon-Position 1			Dasgaon-Position 2		
		At the time of Pre-design	At current Natural moisture condition	At fully saturated condition	At the time of Pre-design	At current Natural moisture condition	At fully saturated condition
1	Overturning	3.43	2.71	2.41	3.84	2.71	2.18
2	Sliding	2.54	1.96	1.40	2.09	1.96	1.128
3	Minimum pressure at the base	74.24	53.30	34.06	56.57	53.30	-93.06
4	Maximum pressure at the base	143.48	174.95	209.28	128.49	174.95	248.76

## 6 Conclusion

The performance and reliability of Earth Retaining Structures (ERS) deteriorate with respect to time due to changes in characteristics geotechnical properties of soil due to severe environmental conditions such as heavy rainfall, humidity, maximum and minimum temperature, changes in physical and chemical properties of backfill material, changes in Land Use and Land Cover, resulting in effective influence in service life by displacing of ERS from its original position with potential loss of the economy.

Thus, it becomes necessary to consider the serviceability of ERS with these varying design parameters during the effective service period for proper planning and management. This can be achieved using a continuous monitoring system for precise positioning study, which will help in getting early warning related to displacement of ERS from its original position.

In this paper, the effect of changing input design parameters on serviceability of earth retaining structures was observed by studying cantilever retaining structures under different conditions with position change study using GNSS Technology.

The influence of several parameters such as natural moisture contents, the specific gravity of soil, Atterberg's limits, maximum dry density and optimum moisture content, cohesion and internal angle of friction are examined. A comparative study is carried out which shows the time-dependent changes in input design parameters which affect the design specifications, that impacts the serviceability of ERS.

Thus, the comparative study shows the need to monitor and control the input design parameters considered in the design of ERS with some early warning system, continuously to enjoy design service life of ERS effectively using Modern tool of GNSS Technology.

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