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Prediction of Class-A and Class-C of a trial Embankment over soft organic peaty ground

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Abstract

The Southwest Road Network Development Project (SRNDP) in Gopalganj, Faridpur, Bagerhat, had completed in 2006 in Bangladesh. The road alignment in the Bagerhat region passes through mostly waterlogged and marshy areas. The subsoil beneath the road embankment consists of organic peat soil with a depth of upto 5m. Two trial embankments with a height of 3m were constructed to observe the design performance of the consolidation settlement of the soft subsoil. In this study, the Class-A (1D consolidation test and empirical correlation) and Class-C prediction of the time-dependent settlement behavior have been performed by PLAXIS 2D software. The soft organic peat layer has employed the Soft Soil Creep (SSC) constitutive model. The Mohr-Coulomb (MC) model for the embankment fill, and the underlain sand layers have been used. Finally, the study reveals that the Class-A prediction based on the laboratory 1D consolidation tests predicts well with the field settlement. The time settlement curve fits well with the field measurement by changing the stiffness parameters (λ^*, κ^*, μ^*) in Class-C prediction.

Keywords: *Soft organic peat; consolidation; trial embankment; PLAXIS; finite element modelling.*

1 Introduction

As a result of urbanization and population growth, soft soil grounds are increasingly being used for construction projects, including expressways, housing plans, and industrial projects. Soft soil often consists of clays, clayey silts, and organic peat that have not been properly cemented. However, due to poor engineering features, including inadequate bearing capacity, large void ratio, and high moisture content, stability issues, and excessive settlement are usually present when building over soft soil deposits rather than especially organic peat (Nasvi & Krishnya, 2019). Due to the predominance of creep behavior, organic peat deposits might still settle for a considerable time. (Nasvi & Krishnya, 2019) studied the stability of expressway embankment over the soft organic peat in Colombo Sri Lanka. Moisture contents between 200 and 800 percent, an initial void ratio between 2 and 8, an organic content between 20 and 50 percent, and a specific gravity between 1.5 and 2.2 are typical of Sri Lanka's organic peat deposits. The organic peat deposits accumulate in low-lying places where the groundwater table rises and falls frequently due to heavy rainfall. There are now about 2500 acres of the marshy area beneath with peat that surrounds Colombo city due to the long-term accumulation process that has occurred there. In this study, three materials models as Mohr-Coulomb (MC), Soft Soil (SS), and Soft Soil Creep (SSC), have been employed to simulate the field consolidation behavior. After that, the best combination of these materials models has been chosen for the stability analysis. Their study revealed that the MC, SS, and SSC had been shown better agreement with the field measurement. Lambe, 1973 reported that the event took place before the construction with preliminary subsoil investigation data was called Class-A prediction. Similarly, the event took place after the construction with available field measurement was called Class-C prediction.

In Ethiopia, Muhammed et al., 2020 performed numerically Class-A and Class-C predictions based on the consolidation behavior of the PVD-improved soft soil due to an 8m high railway embankment. The SSC and Hardening Soil (HS) have been used for the soft soil layers. SSC model showed better agreement with field measurement in Class-A prediction than HS model. The discrepancies that occurred between the field and numerical analysis were 25%. Duncan, 2000 reported that the discrepancies limit of 25% to 30% can be allowed.

The SRND project for the Mollahat to Noapara was completed about two decades ago (Hoque et al., 2004). During the construction period of this highway project, a trial embankment was constructed to observe the design performance as the settlement limit. In this study, the Class-A prediction (before the embankment construction) based on the laboratory 1D consolidation test, the well-established empirical correlation, the back analysis, and the Class-C (after the embankment construction) prediction have been aimed to perform numerically.

1.1 Project Description

The scope of the current investigation is limited to the Southwest Route Network Development Project (SRNDP) section in the Bagerhat district, where the route from Mollahat to Noapara is currently being built. At chainage Ch.6+000 to Ch.18+000, there is an extended very soft' to soft soil layer to a maximum depth of 12 m (SPT-N value 0 to 1). Chainage Km 10+000 to Km 18+000 was chosen as the study region since it is more problematic than other areas. Most of the project area is a low-lying corridor through a marshy landscape composed of organic substance or peat (likely, given the proximity to Sundarban) at the upper 0.5 m to 3 m depth (N-value =0; 1) or more. The details layer-wise subsoil parameters are given in Table 1.

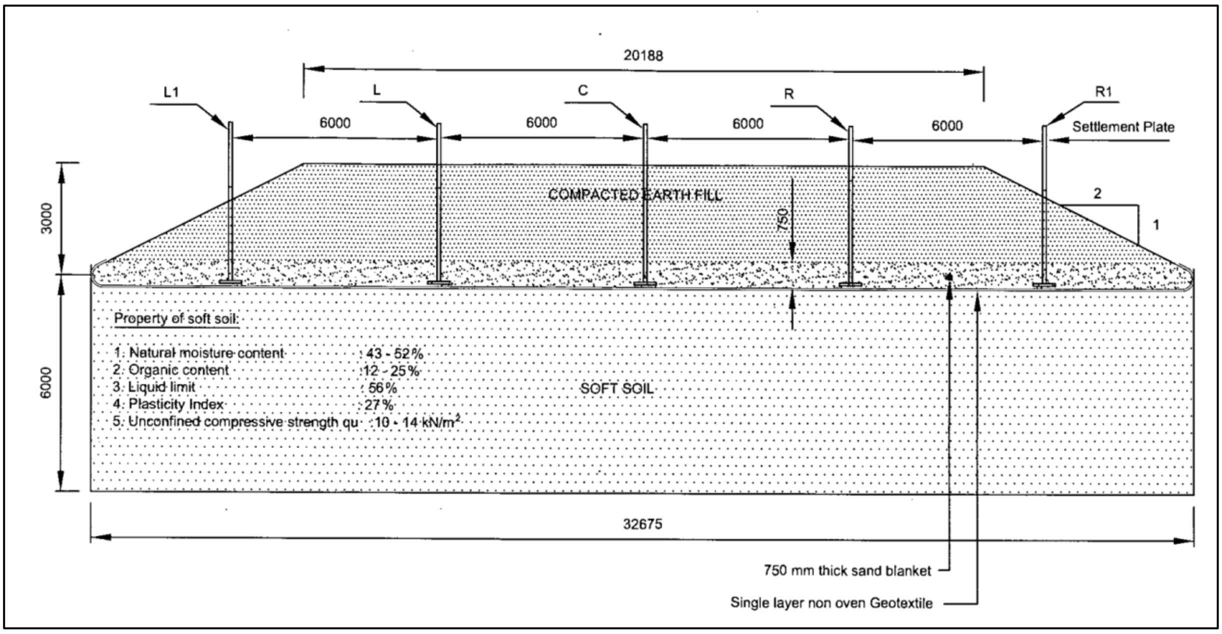

Figure 1: Typical cross section of the Saga trial embankment (Hoque et al., 2004)

Table 1:Insitu properties of the sub-soil (After Hoque et al., 2004)

Parameters	Magnitude		
Layer of subsoil	EGL to 12m	12m-20m	20m to 35m
SPT-N value	1-5	20-25	30-50
Natural moisture content, w_n (%)	30-165	27-55	30-50
Organic content (%)	5-30%	0-5	0-2.5
Liquid limit, (%)	35-68	30-42	Non plastic
Plasticity index, PI (%)	17-35	7-22%	-
Sand (%)	0-10	0-20	40-90
Silt (%)	55-85	45-80	10-30%
Clay (%)	20-35	0-20	0-5
Unconfined compressive strength, q_u (kPa)	10-150	-	-
Compression index, C_c	0.160-0.630	-	-
Coefficient of consolidation, c_v (m^2/year)	4.9-27	-	
Initial void ratio, e_0	0.95-2.07	-	
Group symbol (Unified Soil Classification System)	OL, OH	OL	SM, SW

To assess the soft organic clay behavior, two trial embankments were constructed similar to the road (Figure 1). Total 5Nos settlement plates have been installed in the different locations of the embankment body. The embankment layers consisted of 150mm thickness, and it took 30 days to reach the full height. After reaching the full height, a 150-day consolidation period as the observation time was kept. Silty clay was used for the embankment fill materials. The physical properties of the fill materials have been depicted in the Table 2.

Table 2: Embankment fill properties

Parameters	Magnitude
Specific gravity Gs	2.68
Liquid limit, (%)	38
Plasticity index, PI (%)	18
Υ_d max(kN/m^3)	16.22
w_{opt} (%)	16.9

2 Numerical Modelling

To conduct this analysis to capture the consolidation behavior of the trial embankment, PLAXIS v21 software has been used. A simple linear elastoplastic Mohr-Coulomb (MC) model has modeled the sand and the embankment fill materials. The soft Soil Creep (SSC) model has modeled the organic layer. The following correlations (Ameratunga et al., 2016) have been used for Class-A prediction:

(i) $C_c=0.0015\times w_n$ (1)

(ii) $C_r=C_c/5$ (2)

(iii) $C_\alpha=0.06\times C_c$ (3)

The details input parameters for these constitutive models have been depicted in Table 3.

The plane strain setup and 15-node triangular element have been chosen to set up the model. The lateral boundary has been extended three times the vertical boundaries of the subsoil (Chai et al., 2013). The top and bottom vertical boundaries have been drained to allow the water flow. The standard fixities condition has been applied as the displacement boundaries as shown in Figure 2. A very fine mesh option has been employed due to the computer's efficiency (Fulambarkar et al., 2021).

According to the real construction sequences in the field, a total of four construction phases have been defined as follows:

(i) laying of geotextile (stiffness 15kN/m)
(ii) construction of 1m height in 10 days
(iii) construction of 2m height in 10 days
(iv) construction of 3m height in 10 days
(v) consolidation period of 180 days for the observation of the surface settlement

For the prediction of Class-C as back analysis, λ*, κ*, μ*, and c_K have been modified as reported by (Sadiq et al., 2022).

Table 3: Input parameters for the subsoil and embankment fill materials

Parameters	Organic peat Class-A (1D consolidation)	Organic peat Class-A (Empirical correlation)	Organic peat Class-C	Fill	Sand
Modified compression index, λ*	0.06324	0.1523	0.04091		
Modified recompression index, κ*	0.02530	0.06097	0.01636		
Modified creep index, μ*	3.794E-3	9.145E-3	1.842E-3		
Ratio creep to compression, μ*/ λ*	0.06	0.06	0.045		
Initial void ratio e_0	1.2	4.42	1.2		
Effective cohesion, c′ (kPa)	5	5	10	5	1
Effective Friction Angle, φ′	18	18	23	32	35
Permeability change index, c_K	0.3200	1.898	0.207		
Vertical permeability, k_y (m/day)	0.04260	0.1730	0.04260	1	1
Bulk unit weight (kN/m^3)			14.65	16.22	18

Parameters	Organic peat Class-A (1D consolidation)	Organic peat Class-A (Empirical correlation)	Organic peat Class-C	Fill	Sand
Young's modulus E (kPa)				20.00E3	27.50E3
Poission ratio ν				0.3	0.3

$\lambda^*=C_c/2.303(1+e_o)$, $\kappa^*= 2C_r/2.303(1+e_o)$, $\mu^*=C\alpha/2.303(1+e_0)$;

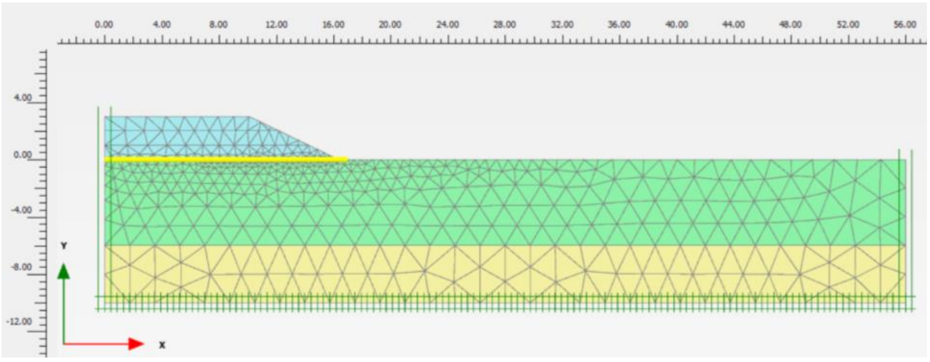

Figure 2: Finite element mesh discretization of the trial embankment

3 Results and Discussion

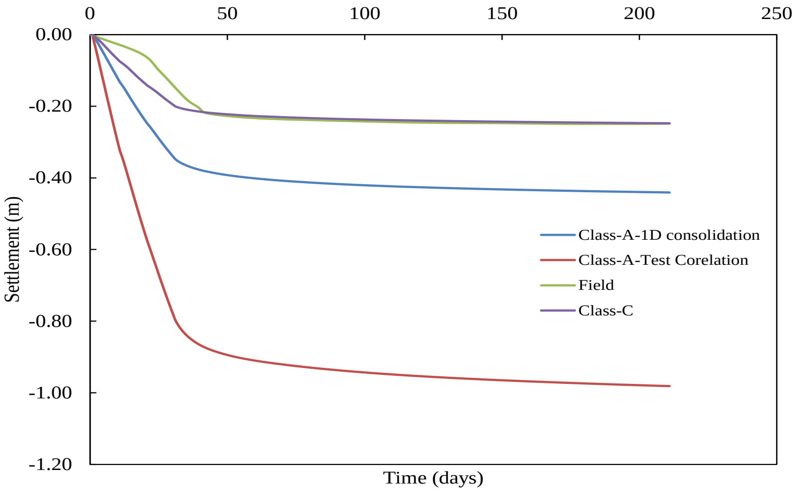

Figure 3: Comparison of time settlement curve

As shown from the Figure 3, the Class-A prediction based on the laboratory 1D consolidation (441mm) test shows better agreement with the field data (250mm). However, 57% of discrepancies have occurred, which is unacceptable (Duncan, 2000). On the other hand, the Class-A prediction based on the empirical test correlation exhibits a large settlement magnitude than the field. This outcome confirms that the correlation is not valid for this subsoil. There could be the following reasons for discrepancies:

1) input parameters for the lab data
2) inadequate subsoil stratigraphy
3) vandal effect of the monitoring instrument

Similar findings have been reported by Kelly et al., 2018, Muhammed et al., 2020, and Wu et al., 2019

By modifying the λ^*, κ^*, μ^*, and c_K the time settlement curve fits well with the field measurements.

4 Conclusion

The following findings were reached by the authors after taking into account the outcomes of the framework's analysis and working towards the stated aims:

1) The SSC model could capture the consolidation behavior of the organic peat.
2) The lab 1D consolidation test results agree well with the field measurement.
3) The empirical correlation could not represent the field behavior.
4) The Class-C prediction can be performed successfully by modifying λ^*, κ^*, μ^* and c_K parameters.

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