FOUNDATION OF STILLING BASIN ON SOIL STRATA

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ABSTRACT

Stilling basins are external energy dissipaters placed at the outlet of a spillway. These basins are designed to trigger a hydraulic jump in combination with a required tail water condition. A fixed elevation is required to maintain for the efficiency of hydraulic jump. The foundation for such basin slab requires measures for its differential settlement due to the load of slab and water above the soil foundation along with hydrodynamic pressure. This paper deals with a case where stilling basin slab is to be constructed at a level above the existing excavated bed level, hence requires filling above the excavated bed level to accommodate the stilling basin. The settlement of the existing excavated bed material & filled material under the loads and the measures to reduce the same are being studied.

Keyword *: Settlement, Stilling Basin Foundation, Differential settlement, Stone column*

1. INTRODUCTION

It has been well recognized that the constructions of stilling basin over the natural bed material are often beset by settlement problems at various degrees. The construction of a stilling basin slab will require proper design for all the possible loads coming to the slab of stilling basin i.e, Hydrostatic load, Uplift, Hydrodynamic load etc. The dimension of stilling basin slab based on the stresses is fixed and should be checked for settlement.

2. ANALYSIS PROCEDURE

A basic case of stilling basin slab is to be constructed at a particular elevation with respect to tail water level is considered and the excavated bed level (present level of river bed) is below the required elevation thereby filling is required upto the desired elevation.

2.1 Geometry

To simulate this case, a model consist of 3 number layers is being modeled in PLAXIS 3D for the settlement analysis. To reduce calculation time, only one-quarter of the stilling basin slab and required filling is modeled using symmetry boundary condition along the lines of symmetery. To avoid any influence of the outer boundry, the model is extended in both directions to twice the dimension. A general arrangement is adopted for the modelling in which 3 layers of soil namely: Fill Material (35m thick), Bed material (15m thick) below fill material & rock (50m thick) at the bottom are considered.

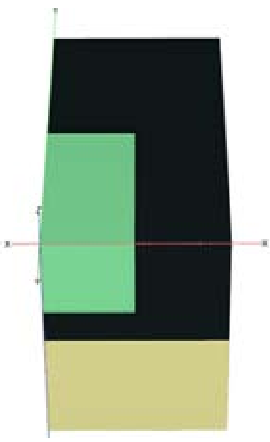


Figure 1 : Soil layers

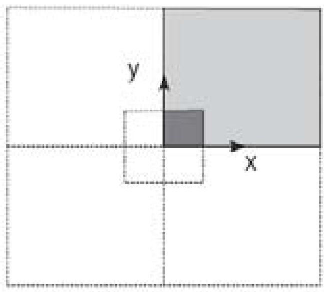


Figure 2 : Geometry of Model

2.2 Material properties

Based on the properties (range of values) considered by CSMRS in the report for Soil material, the following properties are taken for the modelling:

Table 1 : Properties of material

S. No	Properties	Fill Material	Bed Material	Rock	Stone Column
1	Unit Weight (kN/m^2)	21	20	26	21
2	Void Ratio	.5	.4	.05	.5
3	Young's Modulus of Soil (MPa)	50-200*	50	4500	200
4	Poisons ratio	.25	.3	.17	.2
5	Cohesion (kN/m^2)	0	15	800	0
6	Phi (^{o})	45	30	40	45

•The value of young's modulus of soil for fill material will be changed from 50Mpa to 200MPa for different cases for comparison.

2.3 Analysis:

The model is analyzed in PLAXIS 3D software in which Mohr Coulomb model is considered for soil. In this, soil behaves non-linearly when subjected to change of stress and strain. Mohr-Coulomb model can also be stated as Linear elastic perfectly plastic model as the linear elastic part is based on Hooke's law of isotropic elasticity and perfectly plastic is based on its failure criteria (formulated in non-associated plasticity framework).

The following 3 cases will be considered for the analysis:

Case 1: Considering Uniform Value of E_0 (Initial Tangent modulus) for soil material.

Case 2: Considering constant Value of E_0 (Initial Tangent modulus) for soil material along with E_{incl}- value to incorporate the increased stiffness of material.

Case 3: Considering Uniform Value of E_0 (Initial Tangent modulus) for soil material along with soil improvement with Stone column.

The model is been analyzed in 3 stages for the settlement analysis. Stages are:

Stage - 1 :

This is the initial phase in which initial stresses in the soil mass is been generated by considering gravity analysis. Gravity loading is a type of Plastic calculation, in which initial stresses are generated based on the volumetric weight of the soil. In this stage the model consist of 2 layers of soil (Bed material and Rock Level) for the initial stresses computation.

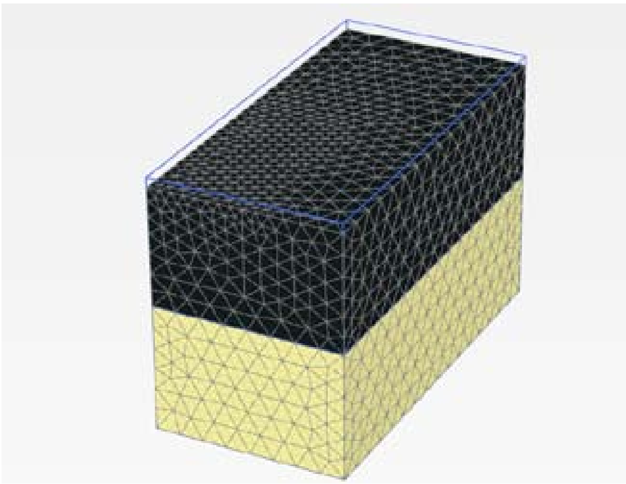


Figure 3 : Meshed model for Bed material (Black) & Rock

Stage - 2 :

This stage is modeled on the assumption that the bed material is been replaced with the fill material (from bed excavation level) to reach the elevation required for stilling basin slab construction. The Slab is assumed to be founded on material with 3 soil layers i.e., Fill Material (35m), Bed Material (15m) & supported with rock at bottom. The stress generated in the fill material because of plastic loading in which undrained elastoplastic analysis is performed without considering consolidation. The Settlement generated in this stage is re set to zero for next phase calculation as this filling will takes places in stages thereby settlement in soil layer corresponding to the stage will be taken care of.

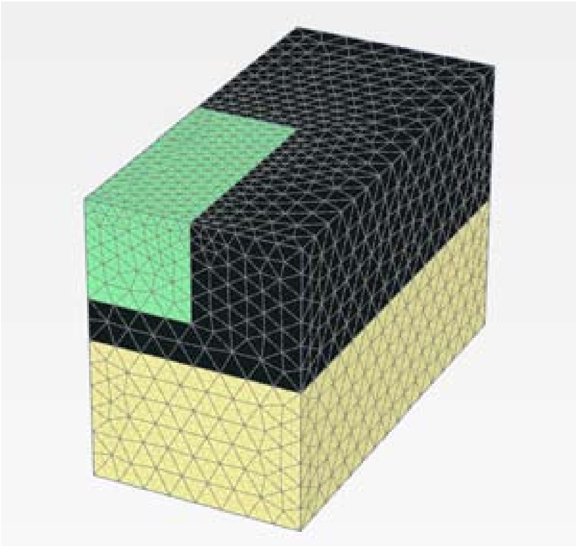


Figure 4 : Meshed model for fill material (Green) with Bed Material and Rock

Stage - 3 :

The most vulnerable scenario will be for settlement analysis is when the water is standing (ignoring dynamic condition) on the slab.

For the analysis, Taking a 7m thick designed concrete slab on which 30m standing water load is been applied, the load under which settlement will takes place is as follows:

- Weight of Concrete = Unit weight of concrete X Thickness of concrete slab
  = 25 X 7
  = 175 kN/m^2
- Weight of water = Unit weight of water X Standing Height of water above slab
  = 10 X 30
  =300 kN/m^2

In this stage under uniform loading of 475kN/m^2, the settlement is been computed based on the plastic calculation. Also consolidation is neglected.

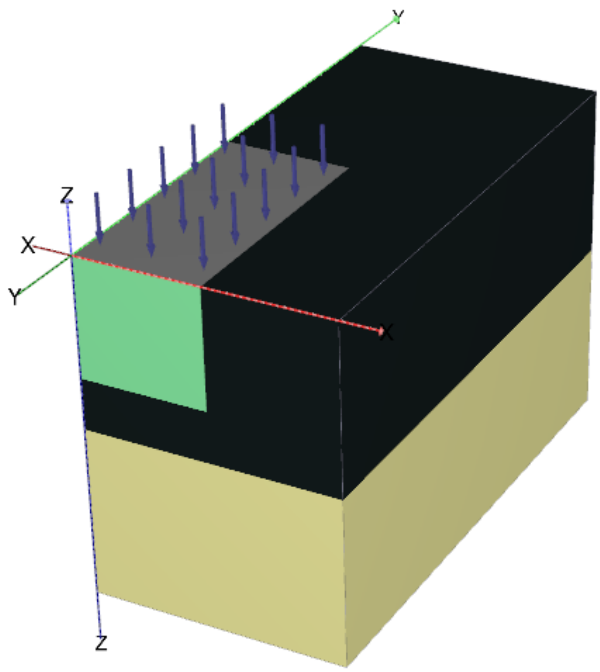


Figure 5 : Model for load condition

2.3.1 *Case-1*

A comparative study is performed for the sensitivity of the settlement under the load condition with uniform young's modulus of elasticity (of the fill material) which is the basic stiffness modulus for elastic model of soil for all the stages.

2.3.2 *Case- 2*

Also based on Moayed(4) , in soils, the stiffness depends on the stress level thereby its value increases with the depth. Hence in order to account for the same, increased value of young's modulus per unit depth is considered and settlement for the condition is analyzed and studied.

E_{incl}–value (which is increase young's modulus per unit depth) available in PLAXIS 3D is considered to incorporate the increase in stiffness along the depth. The value of E_{incl} is taken as 500 kN/m^2 per unit depth of soil. Hence at a particular level the value of stiffness is given as

$$E_{ref} = E_o + E_{incl} * Y_{ref}$$

Where;

Y_{ref} = depth below reference

E_o = initial young's modulus

Hence accounting the E_{incl} value, increased value of young's modulus per unit depth is considered and settlement for this condition is analyzed and studied.

2.3.3 Case-3

Another case is been analyzed in which the existing bed material properties will be improved by soil improvement technique using stones columns in the existing bed surface. This type of soil improvement technique is required where there is a restriction of Excavation of the existing bed level and foundation is to be constructed on that bed level only.

For this, a model comprising a stone column of size 1m X 1m is been modeled below the fill surface (into the bed material) and settlement is been computed. The properties of stone column are referred in Table 1. The spacing of stone column arrangement is kept 5m center to center.

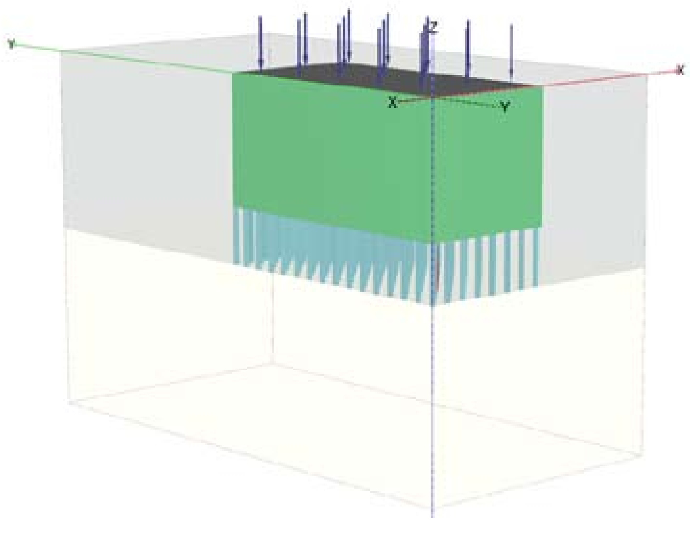


Figure 6 : Model for Stone column

3. RESULTS

All the models are analyzed and their settlement corresponding to the young's modulus for Fill material is as follows:

Stage - 1

Table 2 : Settlement and stresses in 2 cases

Properties	Case1	Case 2
E-Value (MPa)	50	50 +(E_{incl}=.5 MPa/m)
Stresses(Cartesian total stress, s_{xx}) (Mpa)	0.796 (figure 14)	0.796
Settlement (mm)	188.9	147.2

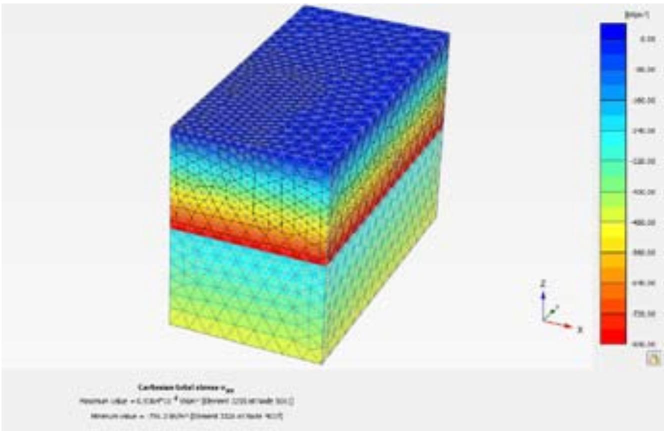


Figure 7 : Cartesian total Stress,sxx

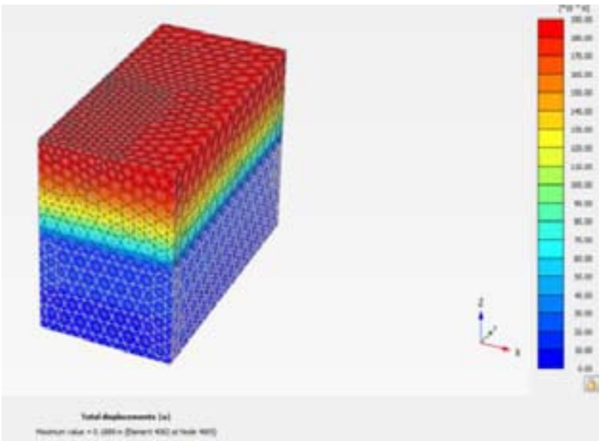


Figure 8 : Settlement with Uniform E=200Mpa

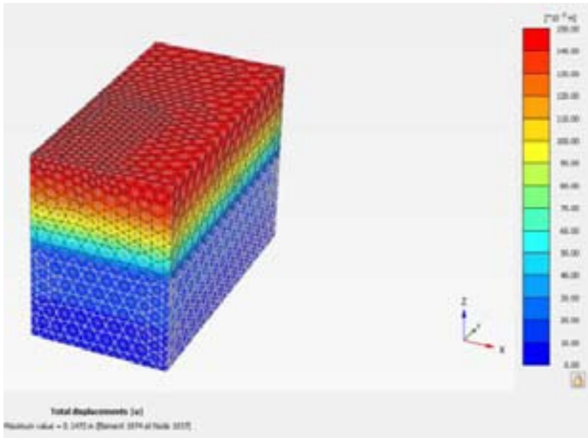


Figure 9 : Settlement with E=200Mpa + E_{incl}=.5Mpa/m

Stage - 2 :

Table 3 : Settlement vs. Young's Modulus value for various cases (without loading)

S.No.	Young's Modulus (fill material) (MPa)	Maximum Settlement (mm)	
		Case-1	Case-2
1	50	16.93	13.06
2	75	13.77	10.82
3	100	12.15	09.58
4	125	11.16	08.78
5	150	10.47	08.22
6	175	09.97	07.79
7	200	09.582	07.47

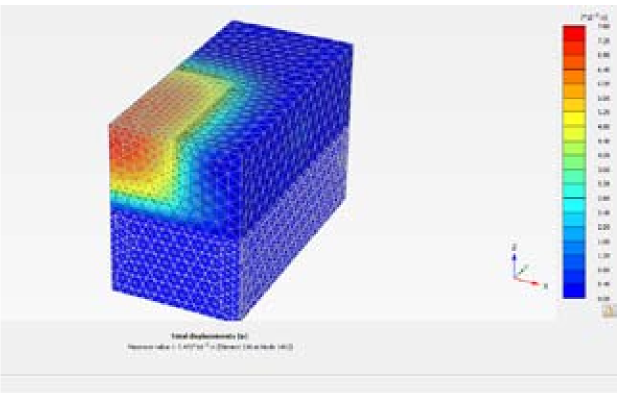


Figure 10 : Settlement corresponding to uniform E=200Mpa For Case 1

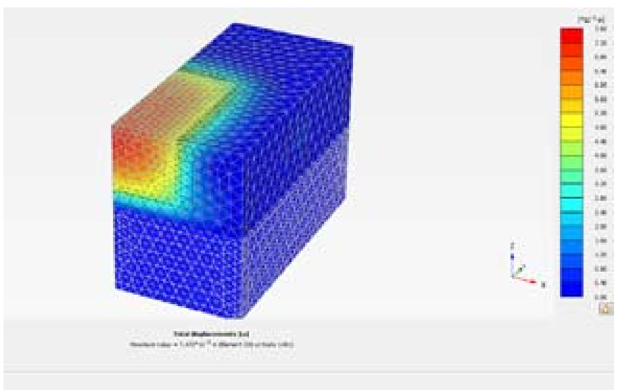


Figure 11 : Settlement value corresponding to E=200MPa+ E_{incl}=.5MPa/m for Case 2

Stage 3

Table 4 : Settlement vs. Young's Modulus value for various cases (with loading)

S.No.	Young's Modulus (fill material) (MPa)	Maximum Settlement (mm)		
		Case-1	Case-2	Case-3
1	50	368.6	293.7	362.9
2	75	282.8	227.4	277.0
3	100	240.0	191.5	233.4
4	125	215.9	168.8	206.7
5	150	199.9	153.0	178.3
6	175	188.5	141.4	165.2
7	200	179.9	132.5	155.2

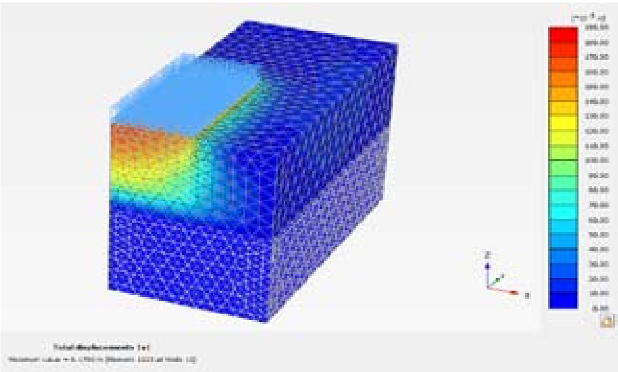


Figure 12 : Settlement corresponding to E=200Mpa for Case 1

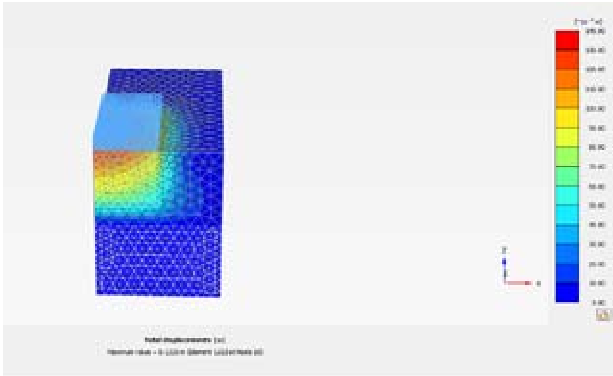


Figure 13 : Settlement value corresponding to E=200Mpa + E_{incl}=.5Mpa/m for Case 2

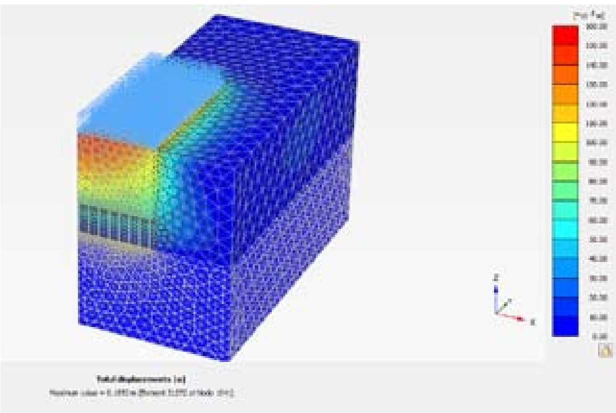
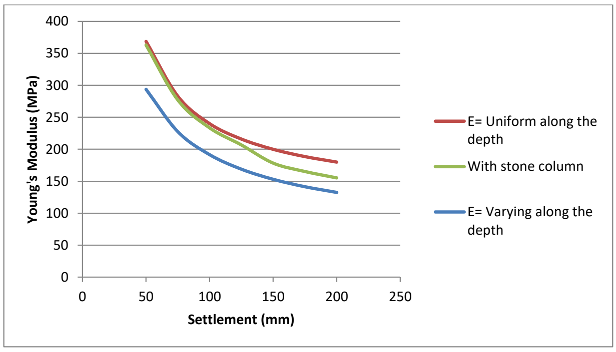


Figure 14 : Settlement value corresponding to E=200Mpa with Stone Column for Case 3



Graph 1 Settlement vs. Young's modulus for 3 cases

4. CONCLUSION

1. From Graph 1 it can be conclude that as the stiffness (Young's Modulus) increase the settlement will reduce to a great extent. Hence a well compacted foundation is required to subjacent the effect of differential settlement of slab.
2. From Table 3, as the values of stresses in both the cases remain same but the settlement changes this emerge to consider the effect of E_{incl}-value. The E_{incl}-value will incorporate the confinement pressure which increases along the depth thereby there is a reduction of settlement is noticed.
3. The foundation for the stilling basin slab can be improved for differential settlement by installing stone columns. And installation of stone columns can be done without further excavation of whole bed material.

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