Analysis for Pore Pressure Buildup Using UBC-Sand Model

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***Abstract*—The pressures generated during large earthquake shaking can cause the liquefied soil and excess water to force its way to the ground surface. Soil particles can no longer support all the weight of overlying civil infrastructures. Bridges and large buildings constructed on pile foundations may lose support from the adjacent soil and come to rest at a tilt after shaking.**

To represent the non-linear and complex nature of pore pressure buildup with in the soil mass, efficient constitutive models are developed. One of such model is UBC SAND and it has well validated with experimental data in the previous research publications.

Hence the present paper has focused to analyses the pore pressure buildup of foundation soil for bridge abutment by using UBC-SAND constitutive soil model into the finite element GT software. The results are displayed in the form of graphical output. UBC sand model addresses the pore pressure ratios at different levels of soil profile.

***Index Terms*—Eigen value, FE software, liquefaction, Seismic Analysis, UBC SAND model**

I. INTRODUCTION

Soil liquefaction describes a phenomenon whereby a saturated or partially saturated soil substantially loses its strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid. During an earthquake the pore water pressure generation in a saturated sand layer leads to the reduction of strength and even liquefaction of the soil.

Today, a large number of advanced constitutive models are available to simulate the liquefaction behavior under static and cyclic triaxial conditions. The models like elasto-plastic, kinematic or anisotropic hardening models have performed well in modeling liquefaction and other cyclic loading phenomena. One of such UBCSAND model is more advanced over the elasto-plastic models and it has also been proved that this model performed well in modeling the undrained behavior of soils.

This will focus on how to set up the material model UBC Sand as well as how to set up special dynamic boundary, load conditions, and time steps for liquefaction analysis. It will conclude on how to use GTS NX advance features to inspect the pore water pressure generation as well as identifying the liquefied regions over the scope of the earthquake.

II. METHODOLOGY

A. General

The seismic analysis of bridge foundation in liquefiable soil deposit using time history analysis is performed using the finite element software MIDAS GTS NX.

Plane strain elements are used to model both the ground conditions and Abutment. Pile elements are modeled as beam elements and embedded in Embankment, UBC Sand, and Soft Rock layers. Modeled the load in surrounding ground generated by earthquake and evaluated dynamic behavior and vibration effect of ground and abutment. Checked the eigen value of ground through Eigen value analysis, Analyze ground dynamic behavior affected by earthquake.

B. Geometry and ground conditions

The cross section of the bridge, the embankment, the pile group and soil profile are created using software as shown in Figure1Using the features of geometry and boundary conditions in the software like part, line and assembly, etc. the bridge foundation was modeled.

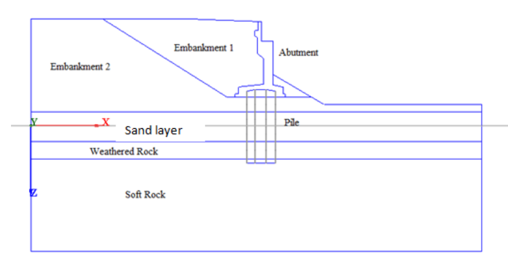

Figure. 1 Cross section of bridge foundation

C. Material parameters

The embankment, clay, weathered rock and soft rock are modeled as plane strain element using simple Mohr - Coulomb model. The abutment is modeled by using Elastic model and the Piles are modeled as beam with Elastic model. The values of soil parameters used for modeling are presented in Table I.

Table I
Soil parameters used

ID	1	2	3	4	5
Name	Embankment	Clay	Weathered Rock	Soft Rock	Abutment
Model Type	Mohr Coulomb	Modified Ubc sand	Mohr Coulomb	Mohr Coulomb	Elastic
Modulus of elasticity (ton/ m^2)	4000	850	15000	30000	232,000
Poisson's ratio (ν)	0.35	0.3	0.35	0.27	0.19
Unit weight γ, (ton/ m^3)	1.8	1.7	2	2.4	2.5
Unit weight (Saturated ton/ m^3)	1.9	1.8	2.1	2.5	2.5
cohesion(c) (ton/ m^2)	1.5	5	20	45	-
Internal Friction Angle,ϕ	25	20	32.5	35	-
Damping Ratio	0.05	0.05	0.05	0.05	0.05
K_0	1	1	1	1	1

The pore water pressure in stress analysis can be divided into normal state pore water pressure and abnormal state pore water pressure - the excess pore water pressure generated between soil particles due to external loading under undrained conditions. An excess pore water pressure of nearly 0 is called the drainage condition.

The most general case is where the input stiffness parameters and strength parameters are the parameters of the ground skeleton. Like drained analysis, GTS NX uses the input stiffness/strength parameters for undrained analysis. The disadvantage is that the effective strength parameters in the undrained state are hard to obtain through experimentation.

Undrained Poisson's ratio and Skempton (B) coefficient are parameters used to calculate the bulk modulus of elasticity for water. The undrained Poisson's ratio has a standard value of 0.495with a compressibility of nearly '0 (zero)' and the Skempton coefficient expresses the saturation, with 1 meaning full saturation

D. Loading

The earthquake wave data of the 2012 Assam earthquake with magnitude of 5.4 was provided as load. The earthquake incident happened on 12th May 2012. The details regarding the earthquake are as follows.

Table II
Assam earthquake Data

Origin Time	18:41:28
Latitude.	26.6 N
Longitude	93.0 E
Depth (km)	20.0
Magnitude	5.4
Region	Assam

Table III
Recorded Station details

Station Code	GOL
Station Latitude	26.516 N
Station Longitude	93.972 E
Station Height (m)	93.0
Record Time	11.05.2012 12:41:51.184
Sampling Rate	200. Hz
Record Duration	66.690 Sec.
Direction	E-W (E positive)

III. RESULTS AND DISCUSSION

To understand the post-liquefaction behaviour of liquefied ground, it is important to get a better understanding and a more suitable characterization of the variation of excess pore pressure after liquefaction. The maximum excess pore pressure is obtained as 57.74 kN/m^2 as shown in Figure. 2. The variation of excess pore pressure is plotted in Figure. 3 which show the increment of pore water pressure and it stabilizes at the end.

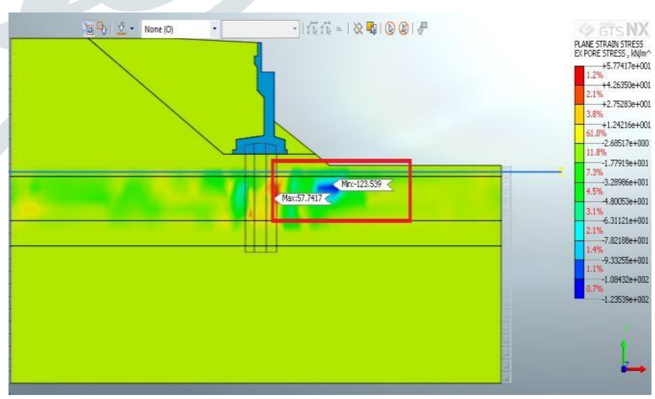

Figure. 2 Excess pore pressure

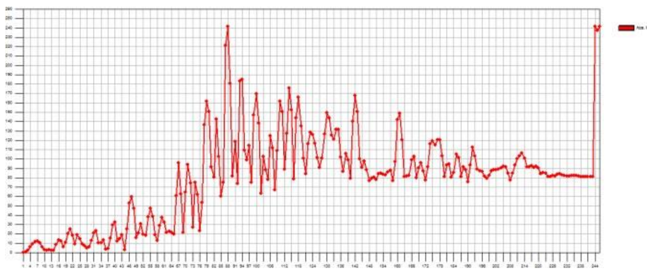

Figure. 3 Excess pore pressure curve

During an earthquake the pore water pressure generation in a saturated sand layer leads to the reduction of strength and even liquefaction of the soil. When based on pore pressure-related criteria, soil liquefaction has often been defined as the state at which the excess pore water pressure ratio (r_u) equals 1.0. This occurs when the pore water pressure increase (Δu) becomes equal to the initial vertical effective overburden stress ($r_u = \Delta u / \sigma'v,o = 1.0$) in simple shear tests and in field studies, or when Δu equals the initial effective minor principal stress ($ru = \Delta u/\sigma'3c = 1.0$) in triaxial compression tests. Sometimes, the terms "initial liquefaction" and "partial liquefaction" are used to describe the occurrence of ru =1.0.

In this case, Figure. 4 shows the liquefied soil profile in which the red region and some of the yellow region as the area identified as the region where liquefaction has occurred. Pore pressure ratio is obtained as 1.245.

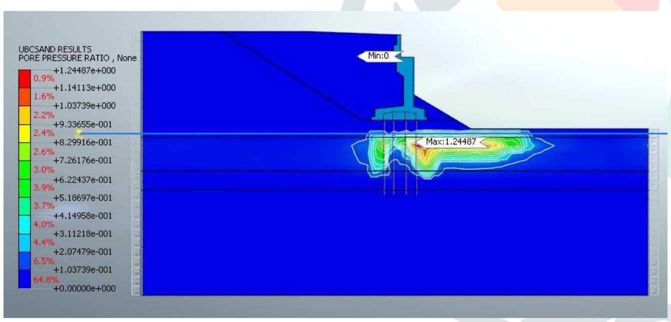

Figure. 4 Pore pressure ratio

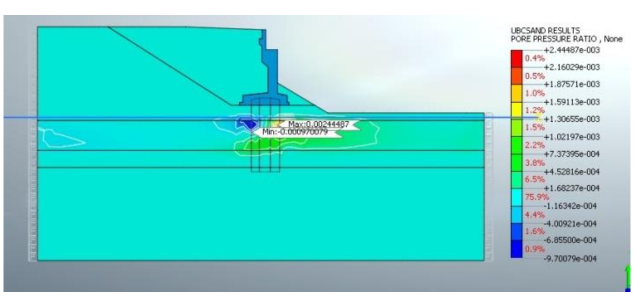

Figure. 5 Different stages of liquefaction

We can identify at what stage in the seismic function, this happened. Here it can be seen a jump from 0.002 to 1.245. About 2.48seconds is where it is starting to see the liquefaction effect occur.

IV. CONCLUSION.

The seismic analysis of bridge foundation in liquefiable soil deposit using time history analysis is performed using the finite element software MIDAS GTS NX. Geometry and ground conditions were modeled and the mesh was formed. Material parameters were selected arbitrarily. Properties were assigned and Eigen value analysis was carried out.

The bottom most soil profile is subjected to 2012 Assam earthquake time history. Occurrence of liquefaction in saturated sand deposits underlying the pile foundation of structure can cause a wide range of structural damages starting from minor settlement, and leading to general failure due to loss of bearing capacity. It is identified the different stages of liquefaction in the seismic function. A jump from 0.002 to 1.245 is observed in pore pressure ratio which is a measure of liquefaction. About 2.48seconds in is where it is starting to see the liquefaction effect occur.

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