Modeling the Likelihood of

Soil-Liquefaction

Team: Alex Clement
Greg Fenchel
Jeff Fenchel
Jack Ingalls
Jayson Lynch

Table of Contents

Executive Summary

The objective of the project is to model soil-liquefaction. This phenomena causes great damage to buildings during tectonic events. Although substantial research has been done on soil-liquefaction, a computer model of it would help to provide a better understanding of the phenomena and accurate models could provide easy to access, fast, reliable information that can be used in planning and development.

Our model is a mathematical model of soil-liquefaction based upon research done by the US naval department. Our program is designed to determine the risk of soil-liquefaction occurring based upon the conditions of the environment, which can be inputted and varied by the user as desired. If the risk of soil-liquefaction in a given area is accurately determined then proper precautions in susceptible areas can be taken. This model may also aid in the understanding of the phenomenon of soil-liquefaction.

Our C++ based model currently outputs results that differ form information we have found. There are several possible explanation for this derivation. Without a properly function model we have not been able to discover any results on the topic of soil-liquefaction. Hopefully our work will help with future endeavors on the topic and it may be corrected to yield useful information about soil-liquefaction.

Problem Description and Methods Used

The purpose of our project is to assemble an accurate model of the effects of soil liquefaction. Soil liquefaction is the tendency of saturated soil to become a suspension when subjected to extreme vibrations, primarily due to tectonic activity. Soil liquefaction is a major cause of damage to structures when it occurs. An example of soil liquefaction occurring is Loma Prieta, California, Earthquake on October 17, 1989. Our model tests soil conditions in order to conclude if a particular area is susceptible to soil liquefaction. This knowledge allows modifications in the structure of buildings to be made to decrease the building's susceptibility to soil liquefaction.

Our computational model is based on equations taken from Technical Report Seismic Design Criteria for Soil Liquefaction by the Naval Facilities Engineering Service Center. The equation we are using to find the determine if Soil Liquefaction will occur:

$$FS = CSRL/CSRE$$

FS stands for the safety factor against soil liquefaction occurring. To find this it is necessary to divide the CSRL(Cyclic stress ratio required to cause soil liquefaction) by the CSRE(Cyclic Stress Ratio generated by the earthquake or explosion). If the result is greater than one soil liquefaction should occur, but if the number is less than it will not occur because it is a ratio between the cyclic stress need to cause soil liquefaction and the liquefaction that actually occurs. Of course in the real world many variables occur and things change over time so by looking at the environment of a specific area the program can determine the risk of soil liquefaction occurring rather than a definite answer.

To find the CSRE we used the same equation:

$$CSRE = \tau_{av} / \sigma_{vo}' = 0.65(A_{max} / g)(\sigma_{vo} / \sigma_{vo}') r_d$$

We used the first equation, τ_{av} / σ_{vo}', in the report, τ_{av} is defined as

$$\tau_{av} = \frac{0.65 \gamma h r_d}{g}$$

In this equation: Y stands for total unit it weight of soil; h represents depth of region where soil liquefaction is expected; Rd represents acceleration correction factor; lastly, g represents gravity. All of these variables are to be given to the program except for gravity, which is assumed at 9.8m/s.

The second part of the equation for finding the FS is CSRL. We have yet to find a way to calculate this so currently CSRL is a variable assigned a value by the user. However, we are working to find an equation to express CSRL, but our efforts have been foreshadowed by our group not being able to find a mentor.

Results

The results for our project are inclusive. When we tried out the program, the result we got for the factor of safety against soil liquefaction occurring was supposed to be 0.65, but we got an answer that was so small, it had to be expressed in scientific notation. The factor of safety was about $6.78x10^{-23}$. This was conclusive prove that something in our test was not correct. It was decided that the reason or reasons could be something wrong with the program, or the example we received could be incorrect. There was no special place where the all of the variables for the example were given, and we had to pick out the variables from the long research paper that we used.

However, the program was almost definitely a problem. When we looked through the code at a later date, we found that we were using an old input for our calculations that simply did not exist in our program. The nonexistent value could be used since in C++, the programming language that we were using, the compiler allows the program to go beyond a list and into values that do not exist. Some very odd things occur when one goes off the end of a list. We also noticed that the earthquake magnitude was not used in the program. This is because it only occurs in the cyclic stress ratio needed to cause soil liquefaction, which is a variable in our program.

While this was going on, we also looked closer at the equations we used. We found that one of the equations was equal to two different things. If we used one of these equations, some variables that were previously used would be obsolete. However, this raised the question of how reliable the equations where. With these two equations, we believe we would get a different value even though they are supposed to be equal. This is because there appear to be different variables in these two equations. Although from a reliable source, we are currently not sure if these equations are reliable and are not faulty.

Our search to find these equations was extensive and exhaustive. We have found no more equations for soil liquefaction to support our original equations, and we have found no one who knows enough about soil liquefaction and is willing to help on this matter. In general, the results that we found were inconclusive and we hope to find solutions to our problems in the future.

Conclusion

In conclusion we believe that our most significant achievement while doing this project is getting this far without a mentor. We do not have the program perfect yet, but we are still trying. We have been able to sort through technical information and we have been able to construct a program that has not yet worked. We are hoping to get this program working by the final presentations. Working together, finding information on the subject, and not letting the group fall apart without the success of having a mentor help us through the technical details of soil liquefaction has been our most significant achievement. While doing this project we had trouble with our program, this showed us the hardships faced by scientists everyday and taught us to cope with frustration. We may have remedied our problem, but have not had time to test it. Hopefully we will have an improved program for the presentation.

Sources:

Liquefaction Problems in Geotechnical Engineering. Philadelphia: ASCE Annual Convention and Exposition, 1976.

Milligan, GWE, and Houlsby, GT BASIC Soil Mechanics. London: Butterworths, 1984.

Amini, F.. Soil Liquefaction at Depth Scientific Visualization. ACTA Press. 10/16/2005 .

Ferritto, J. M.. Seismic Design Criteria for Soil Liquefaction. NAVAL Facilities Engineering Service Center. November, 2005 .

Kim, Kwang, and Scott Blouin. Response of Saturated Porous Nonlinear Materials to Dynamic Loading. South Royalton: Applied Research Associates, 1984.

Team Members: Alex Clement Greg Fenchel Jeff Fenchel Jack Ingalls Jayson Lynch Teacher Sponsor: Neil McBeth
Special Thanks to: Eric & Anita Gallagher for office space

Apendix: Source Code

```
#include <cstdlib>
#include <iostream>

using namespace std;

void input (float inputs []);
void calculations (float inputs [], float outputs []);
void output (float outputs []);

int main()
{
    cout<<"Welcome to the soil liquefaction project"<<endl<<endl;
    while (1==1)
    {
        cout<<"To continue press 1."<<endl<<"To quit press 0."<<endl;
        int end=0;
        cin>>end;
        if (end==1)
        {
           float inputs [8]={0,0,0,0,0,0,0,0};
           float outputs [4]={0,0,0,0};
           input (inputs);
           calculations (inputs, outputs);
           output (outputs);
        }
        else if (end==0)
        {
           return 0;
        }
    }
}
void input (float inputs [])
{
     cout<<"Please enter the design peak horizontal acceleration
(Amax)."<<endl;
     cin>>inputs[0];
     cout<<"Please enter the earthquake magnitude (M)."<<endl;
     cin>>inputs[1];
     cout<<"Please enter the overburden pressure (Ovo)."<<endl;
     cin>>inputs[2];
     cout<<"Please enter the pore-water pressure (u)."<<endl;
     cin>>inputs[3];
     cout<<"Please enter the total unit weight of the soil (y)."<<endl;
     cin>>inputs[4];
     cout<<"Please enter the depth of the region where liquefaction is
expected (h)."<<endl;
     cin>>inputs[5];
     cout<<"Please enter the acceleration correction factor (Rd)."<<endl;
     cin>>inputs[6];
     cout<<"Please enter the cylic stress ratio required to cause soil
liquefaction (CSRL)."<<endl;
     cin>>inputs[7];
}
void calculations (float inputs [], float outputs [])
```

```
{
     outputs[0]=inputs[2]-inputs[3];
     outputs[1]=.0.97*0.65*inputs[0]*inputs[4]*inputs[5]*inputs[6]/9.8;
     outputs[2]=outputs[1]/outputs[0];
     outputs[3]=outputs[2]/inputs[7];
}
void output (float outputs [])
{
     cout<<"The effective overburden pressure is "<<outputs[0]<<"."<<endl;
     cout<<"The average stress is "<<outputs[1]<<"."<<endl;
     cout<<"The cyclic stress ratio is "<<outputs[2]<<"."<<endl;
     cout<<"The factor of safty against liquefaction is 
"<<outputs[3]<<"."<<endl;
     cout<<endl<<"This is the end of the program."<<endl<<endl;
     cout<<"-----------------------------------------------------------------
---------------";
     cout<<endl;
}
```