2018 ASEE Annual Conference & Exposition
June 24–27, 2018, Salt Palace Convention Center, Salt Lake City, UT

Paper ID #22057

Integration of a Highway Fill Embankment Case Study in Engineering Design Courses for Instructional Improvement

Prof. Jiliang Li P.E., Purdue University Northwest

Dr. Jiliang Li, D.Eng, Ph.D., P.E., M.ASCE, M.ASEE, is an Assistant Professor of Civil Engineering at Purdue University Northwest. Before coming back to teach at University, he had industrial experience in several States with projects consulting experience ranging from small residential, commercial and subdivision projects to larger scale State DOT and federal projects after additional courses and research study of geotechnical engineering at UAkron. Dr. Li has teaching and research interests ranging from engineering mechanics encompassing statics, dynamics, mechanics of materials and geotechnics (including geomechanics, rock mechanics, soil mechanics and engineering geology/hydrology), probability and statistics applications in civil engineering, and reliability based LRFD of geotechnical engineering, design of earth structures, soil and rock exploration, geotechnical and foundation engineering in particular.

Prof. Nuri Zeytinoglu P.E., Purdue University Northwest

Dr. Nuri Zeytinoglu has been a faculty member at Purdue University Northwest since 1987. He teaches thermodynamics, mechanics of materials and computer aided design in the department of mechanical and civil engineering. Currently he is the program coordinator at Westville campus

Prof. Masoud Mojtahed, Purdue University Northwest

Dr. Mojtahed is a professor of mechanical engineering at Purdue University Northwest. His areas of expertise are theoretical and experimental mechanics, fracture and failure analysis, finite element methods, and dynamic systems. Dr. Mojtahed served as the ABET evaluator for six years. He also served as a Summer Faculty Visitor and as a consultant at Argonne National Laboratory for five years. Dr. Mojtahed is the recipient of the Air Force Summer Research Award. He also served as the Coordinator of Technical Assistance Program and the coordinator of Mechanical Engineering Program at Purdue University Northwest (formerly Purdue University Calumet). Dr. Mojtahed has served as a reviewer for several technical journals and conferences, National Science Foundation (NSF), and the Air Force and Army/Navy Research Awards Panels.

Mr. Matthew William Wooden, Purdue University Northwest

Matthew Wooden is an undergraduate student at Purdue University Northwest pursuing his Bachelor's degree in Civil Engineering with a minor in applied mathematics. He has strong interests in geotechnical engineering, more specifically, soil mechanics and foundation engineering, as well as hydrology and hydraulics.

Mr. Ikechukwu I Nnachi, Purdue University Northwest

University: Purdue Northwest University Graduate: 2019

Integration of a Highway Fill Embankment Case Study in Engineering Design Courses for Instructional Improvement

ABSTRACT:

This paper focuses on the application of a case study of fundamentals of geotechnics to a highway embankment slope failure movement investigation for civil engineering curriculum development and education. The proposed case study is introduced into the first year elementary engineering design course. The proposed highway fill embankment slope case study project is planned to be further introduced for expanded discussions in the later semesters. Early student exposure of case studies in the curriculum will benefit upper level engineering geology and soil mechanics courses. This project will also be helpful by connecting hydrologic engineering and transportation highway pavement engineering research work in the later semesters, especially with senior design projects.

Keywords: Geotechnics, Geotechnical Engineering, Engineering Education, Civil Engineering Curriculum, Soil Mechanics, Rock Mechanics, Engineering Geology

INTRODUCTION

Case studies have been used in many different subjects' fields, such as physical and medical sciences, business, law as well as different engineering fields. "A case study typically is a record or a narrative account of a technical and a business issue (problem) that actually has been faced by an individual and/or a group, together with relevant facts, opinions, and prejudices upon which decisions have to depend" [1]. Different case formats may appear in different fields' literature. Most cases are intended to engage students in a learning process through: analysis, open discussion, and an ending with evaluations and recommendations. A case history describes how a problem is approached and solved, and often examines the consequences of the decisions made. A case problem remains open ended - leaving the analysis and choice of a solution up to the students. It often includes an "ideal" or "benchmark" solution provided by practicing engineers; also, identifies or illustrates best practice" [1]. According to Richards et al. (1995), the main purpose of a case study is to help illustrate a principle and/or the value of a specific approach or method while a case method refers to a particular strategy for using cases in the classroom to structure an active learning process of self-discovery [26].

As both a practitioner and professor, Akili (2006) used case studies in his geotechnical foundation engineering course, which greatly engaged students, brought the real world geotechnical practice into the classroom [1]. The findings of Akili (2006) and students' feedback indicates that students really appreciate professors who bring real world projects into classrooms. The authors strongly support Akili's practice of call out to local geotechnical industry for real world geotechnical soil projects for classroom case studies. Due to students' limited time and different subjects' courses teaching assignment, the author assigned students in his soil mechanics I and II and soil engineering as well as intermediate soil mechanics classes to research and find an interesting soil report to critique and review for independent study [21-23]. This has methodically built up students' independent research and networking skills by personally contacting and looking for geotechnical opportunities to study, and at the same time, preparing themselves for geotechnical employment prior to their graduation.

Delatte et al. introduced the state of the art forensic case studies in civil engineering education [5]. They reported their implementation of forensics and failures in civil engineering curriculum [5], subsequently they reported their findings of assessment of the impact of case studies on the civil engineering and engineering mechanics curriculum. Borrego (2007) paper [33] describes conceptual difficulties that may be experienced by engineering faculty as they become engineering education researchers. The paper provides guidance to any engineering educators seeking for educational research and warns that student survey alone is not sufficient in any rigorous educational research.

Literature research and the authors' own personal experience show that students are interested in innovative way of instructions, transferring all their knowledge learned among different courses, synthesize them and apply them in different courses, and ultimately implementing in a senior design project through a reported case study. The senior design students have many choices to choose a subject based on the proposed topics provided by different engineering educators' proposal. Their voluntary selection and decision to work on a real world highway embankment project indicates their strong interests and desire to be well prepared and trained for similar projects in the real world. The paper is not meant to seek students' surveys at this stage which may be carried out later with further more introduction of the proposed case study in different courses instructions.

A real-world highway embankment landslide project that the primary author once studied and visited before was partly documented for personal study. At that time, a field trip was organized and pertinent pictures and brief videos were recorded for the self-learning purpose only. A fascinating topic that interests this study is a highway embankment slope movement due to static liquefaction, highway construction and/or high pore water pressure owing to its unique engineering geology and surface water hydrology conditions. The case study has been introduced in elementary engineering design and is being utilized in several different courses' instructions. And how to introduce the same case study and fitting the pertinent course instructions materials and content has been of great interests.
Another objective of this paper is to help and promote usage and the critical importance of case studies in different and yet immediate related geotechnical courses offered or to be offered in an ABET civil engineering program. A briefly quick scanning observation of the aforementioned project site indicates the project is not only directly related and focused on to geotechnical engineering, but also hydrologic and hydraulics engineering as well as transportation and construction engineering and management all come closely into play and influence each other in the study.

IMPLEMENTATION OF THE CASE STUDY

ENGR190 elementary engineering design course is a gateway course developed at Purdue University Northwest, formerly known as Purdue University Calumet. This course is taken by all freshman engineering students including mechanical, electrical, civil, and computer engineering students. It is a required course with lecture and lab components integration. Lab portion includes a project from each engineering discipline.

The of the course includes two parts with the first eight (8) weeks focused on mechanical and civil engineering (MCE) fields and the second half semester covers electrical and computer engineering (ECE) disciplines. For the MCE part, the following objectives are expected [9]. 1) analyze forces in trusses; 2) design a bass wood bridge, using statics analysis and material properties; 3) show that the design process is iterative in nature; 4) write a technical laboratory report; 5) determine simple types of equations that can represent a set of data, using x-y, Semi log and log-log plots; 6) use EXCEL software for analyzing data and prepare semi log and log-log plots.

In addition to meeting all the above course objectives, the authors also will devise the geotechnical design concept to the curriculum as the purpose of this ENGR190 elementary engineering design is to expand its scope and motivate students learning of engineering designs. As all engineering projects are built on, in or below the Earth's soil and rocks such as a bridge having solid foundation built below the ground and its structure above the ground. Naturally, the engineering students and in particular the civil engineering students will be exposed to geotechnical design options and applications. For example, after showing the highway fill embankment design project and performing a soil sieve analysis lab, students have a better understanding that engineering design is not just focused on and limited to mechanical and electrical design, but they will learn that civil engineering design has an important role in the human lives. Large and small civil/geotechnical designs are also critically important in the engineering profession in which students can choose a major to practice their engineering knowledge and design skills.

Introducing a real world project to the engineering students foreshadows courses they are expected to take and learn to become best prepared for such a noble profession. It is observed that most people including many engineering students do not have a complete picture and idea of what is engineering and in particular geotechnical engineering.

GEOTECHNICS MAJOR RELATED COURSES

Engineering geology is so important that the father of soil mechanics Karl Terzaghi, when he taught at University of Illinois at Urbana Champaign, it is said that he only taught the engineering geology course [16]. His teaching and emphasis on engineering geology instead of instruction of soil mechanics, that was created and developed by himself, shows the importance of engineering geology in the father of soil mechanics' mind. The introduced fundamental case study and explanation of the failure mechanism of the highway embankment slope movement is illustrated with the geotechnics in conjunction of both soil mechanics and engineering geology processes. Most civil engineering programs offer at least one geotechnical engineering course such as soil mechanics or soil engineering and sometimes rock mechanics, but not necessarily, all include engineering geology at the same time. Some engineering geology course may be delegated to the earth science programs which unfortunately may not be the best and most effective learning method for engineering students. This inadequacy might create a problem for the large and small civil/geotechnical project investigation, design, and constructions. Coduto et al (2011) properly emphasizes [4] the great importance of geotechnics in civil engineering program that should be adopted, endorsed or encouraged by all ABET accredited civil engineering programs.

All the civil engineering students, and in particular, those who aspire to become competent geotechnical engineers and who will practice in the real world after their graduation should take at least one engineering geology course. For instance, the father of soil mechanics, Professor Terzaghi, when he was teaching at Harvard University, MIT, and University of Illinois, legend said that he taught one and only one course that was not soil mechanics engineering, but it was actually the engineering geology course[16]. This effectively shows why all civil engineering programs should offer an engineering geology course or a required prerequisite geology course.

During the ice age, nature sometimes geologically engineered a phenomenon similar to “quick sand” condition by creating a large kettle lake that works like a “quick sand” barrel, at the right time and right place with proper geological conditions, and under the right external loading conditions. Both West and Shakoor (2018) [30] and Holtz et al. (2011) [10] graphically illustrate the great importance of landforms formation and the process due to continental glaciation. The lake/pond shown in Figure1 and other surrounding lakes/ponds around the project site as shown in Figure 2 are kettle lakes formed by glaciers. The roads and surrounding buildings are overlying the kettle lakes where the bottom layers of the soils are suspected or essentially connected via some high permeability sand layers. Therefore, the kettle lakes essentially function like the laboratory “quick sand” geology conditions with the right low permeability clay layers surrounding the deep connected sand layers. This ingress of water to the kettle lake, if any, could come from the precipitation and underground water level rising, and especially with the excess pore water pressure having no outlet to dissipate quickly under external static loading fill. To recreate such a real world project scenario, an undergraduate research project [11] as well as a senior design project [34], were designed and carried out by the civil engineering students.

Figure 1 illustrates how glacial kettle lakes are formed. It shows that while the glaciers are receding, big chunks of ice were left on the outwash plains [27]. Later additional outwash deposited and surrounded the leftover old glacier ice. With the eventual melting of the old ice, kettle lakes were formed. The term "kettle lake" describes the way the lake basin was developed. Kettle lake basins were formed as the glaciers receded [7, 11, 14, 15]. While this was happening, a block of ice broke off the glacier, and just sat there. As the glacier continued to melt, the debris from the glacier (silt, clay, sand, gravel, stones and rocks, etc.) filled in around the block of ice. Subsequently, when the block of ice finally melted, all the debris surrounding it fell into the hole, creating the kettle type basin. The depression was filled with water and became a kettle lake as we know it today.

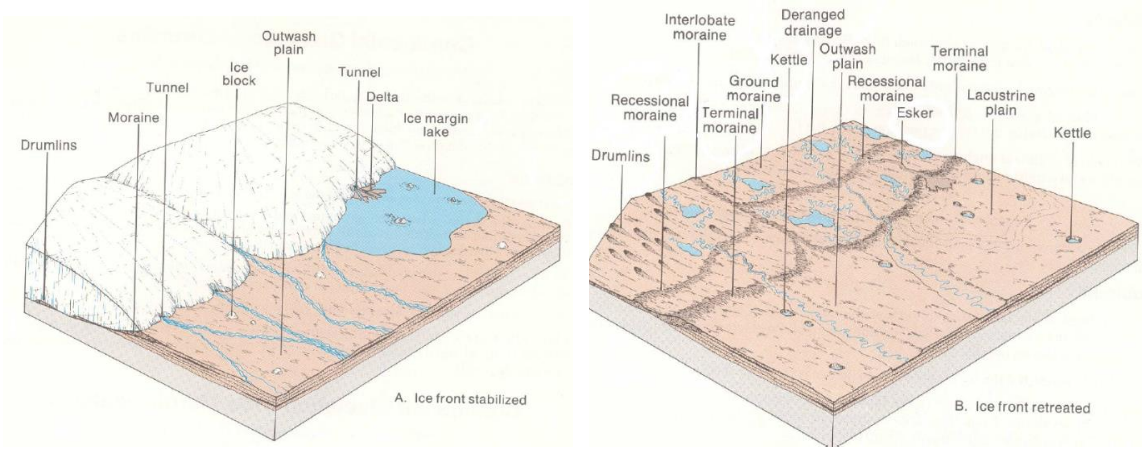

Fig. 1. Glaciation landforms stages illustration (after Strahler, 2013).

Google Earth view of kettle lake formation can be found in many other different places around the world. By offering an engineering geology course to the engineering students, and in particular those civil and geotechnical engineering majors, students will experience a whole view of an engineering project life cycle, and thus more comprehensive design can be accomplished [25].

Local Ohio geology maps in Figure 2 shows that the studied project site has exactly or similar glacial valley geology of a kettle lake formation [13, 14, 15]. The embankment slope movement location in the buried glacial valley is oriented N-S, Figure 2, where a fully saturated strata is formed. The valley constricts at the project site is resulting in a "charged" strata under external load. The local kettle lake strata results in rapid change in strata. The deposition of peat and organic soil, and the alternating sand and clay layer is causing the "confined" conditions. Therefore, an ideal large-scale "quick sand" condition is formed, at the right place and at the time, when heavy rainfall precipitation occurred in October 2008, after an additional lane was added. Like a laboratory, a "quick sand" experiment herein was created by mother nature on the earth. The pore water pressure increase required three conditions [2-3, 10]: 1) availability of water drainage with sufficient head through the area to completely saturate and "charge" the soil; 2) the prevention of free drainage; and 3) an increase of the strain on the soil through dynamic or static loading.

Fig.2. The case study project site condition, geology map (Weber and Bredkhin [29], 2009).

For the studied project site, the first condition is met by the geology (buried valley and constriction) as seen in Figure 2. The second criterion was met due to the presence of confining clay layers (vertical) and the clay kettle bottom and sides (vertical and horizontal) that severely restricted drainage of the sands in the site of investigation. The final criterion [29] was satisfied once the fill was placed and traffic load applied (Weber and Bredikhin 2010). The slope movement was further exacerbated by the heavy rainstorm occurred on Friday October 24, 2008.

This paper is prepared with an objective to show undergraduate civil engineering students, and in particular, those who desire to design and build anything on earth need to be familiar with geotechnology as a result, the engineering geology must be required as a core civil engineering course subject. Lack of knowledge in geotechnical engineering leads insufficient knowledge and understanding of large or small scale civil engineering projects' needs. Thus, the civil engineering students might lack the minimum requirement for an ABET accredited civil engineering program. Hopefully, the article serves the purpose to inform pertinent college and university administrators to become aware of the need and importance of geotechnics in their course planning and curriculum development and improvement.

Virtually all construction projects on earth have to be built or on the ground. For those that are not built under or above ground, they either fly, float or fall over [8, 20]. Therefore, the site investigation of a project site engineering geology and its past history are very important. In this paper, we focus and limit our discussions and investigation on the important fundamentals of geotechnics, soil mechanics, engineering geology, and design of earth structures course curriculum via a highway embankment fill slope failure study.

Google Earth has a function of displaying the past history of a project site. This function can reveal and display a myriad of important information related to the project site over the years [23]. It could provide engineering decision makers with very useful and important information in planning and implementation of many engineering practices or measures. In the following sections, we use a highway embankment geotechnical engineering as an illustration example to emphasize the importance of geotechnics and Google Earth in the mankind's engineering work and planning efforts.

The following 1994 Fig 3.a shows the kettle lake/pond size and conditions near a highway embankment in northeast Ohio. Seven (7) years later, 2001 Figure 3.b, shows the kettle lake/pond size and conditions remains almost the same with no immediate construction activities in its vicinity. By December 31, 2002, Google Earth shows some kettle lake/pond size conditions change, and the addition of a new building built across the E Steel Corners road is seen in the picture. Six (6) years later, in October 2008, there was a dramatic embankment slope movement at the site. The slope movement may have been caused by many factors including embankment fill load, external transportation or construction load, wet-soft toe with a kettle lake/pond nearby, and especially exasperated with the increase of pore water pressure during a heavy rainfall precipitation as shown in Fig.5 of the historical precipitation data (wunderground.com) [32]. The worst case causing failure is the saturation of the slope or increase of the pore water pressure combined with external fill load and thus leading to reduction of effective stress, and hence slope strength greatly was reduced, especially, under external load and undrained condition, that lowered the factor of safety of the slope below 1.0.

Figure 3.a Figure 3.b

Fig.3. Google Earth Time History Map of the Project Site Development

Figure 3.a shows the pond size/shape before embankment slope movement in 1994; Fig. 3b. May 14, 2017 imagery shows pond size/shape changed due to surrounding mitigation and construction work.

Comparison of Figures 3a and 3.b, both viewed at 996 ft altitude, shows the effects of the embankment slope movement before and after the slide rehabilitation with a time span of 23 years. The lake/pond size has become smaller due to the bulging of embankment toe movement as shown in Figures 3.b and 2.a. Immediately after the slope movement, the titling plants observed in Figure 2.a shows the movement characteristic trend of the failure slope.

Google Earth beside its history function, it also has other powerful capabilities of showing soil borings profiles, distance and project areas, as well as, climate/weather conditions at the site of interest [23]. US Geology Survey soil/rock profile can also be displayed by incorporating ohgeol.kml to visually locate and display project site location and approximate subsurface strata conditions. This can be of great benefits for preliminary site investigation and planning for accessing the pathways to project sites, and for detailed site investigation as well.

Figures 4.a and 4.b are obtained and modified from the website of https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx that shows the surface soil and its pertinent geology conditions. Both Google Earth and WebSoilSurvey are almost routinely utilized by practicing engineers [24, 31] while many civil engineering students learning geotechnical engineering may not be aware of their existence.

“Summit County, Ohio
Cg—Carlisle muck
Map Unit Setting
- National map unit symbol: wpsx
- Elevation: 600 to 3,700 feet
- Mean annual precipitation: 28 to 40 inches

Map Unit Composition
- Carlisle and similar soils: 90 percent

Description of Carlisle Setting
- Landform: Bogs, kettles
- Down-slope shape: Concave
- Across-slope shape: Concave
- Parent material: Organic material

Typical profile
- O - 0 to 55 inches: muck

Properties and qualities
- Slope: 0 to 2 percent
- Depth to restrictive feature: More than 80 inches
- Natural drainage class: Very poorly drained
- Capacity of the most limiting layer to transmit water (Ksat): High (2.00 to 6.00 in/hr)
- Depth to water table: About 0 inches
- Frequency of flooding/ponding: Frequent
- Available water storage: Very high (about 12.1 in)

Interpretive groups
- Land capability classification (irrigated): None specified
- Land capability classification (nonirrigated): 3w
- Hydrologic Soil Group: A/D
- Hydric soil rating: Yes

Minor Components
Areas with an overwash of mineral material
- Percent of map unit: 5 percent
- Landform: Bogs, kettles
- Hydric soil rating: Yes

Areas with a thinner layer of organic material
- Percent of map unit: 5 percent
- Landform: Bogs, kettles
- Hydric soil rating: Yes”


a)


b)

Fig. 4 https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

Above project site conditions are useful and needs to be completed within the phase I desktop study because at this stage, experienced geotechnical engineer can judge whether or not rock drilling rigs are needed or soil boring rigs are sufficient enough to complete the drilling project. For example, if the rock layer depths are very shallow and close to ground surface, sending a subsurface investigation drilling team with only soil boring rig is not proper as it may take a long time or even impossible to complete the task. The engineering impression still needs to be verified and seconded by the geotechnical engineer on site visit of the phase II of the project. Phase III involves field drilling, logging, and sampling while phase IV involves detailed soil laboratory tests and soil boring logs creations. Moist or water content testing is a simple and yet one of the most important and most frequently assigned laboratory tests that can be performed for all different types of soils, be it coarse grained cohesion less sandy/gravel soil or fine grained cohesive silty and/or clay soils. In addition, soil strength properties can be correlated with soil water/moist content. Last but not the least is the final phase V of geotechnical engineering analysis and soil report writing for delivery to the clients.

April | 24 | 2008 | View

Thursday, April 24, 2008

« Previous Day   Next Day »

Daily | Weekly | Monthly | Custom

	Actual	Average	Record
Temperature			
Mean Temperature	58 °F	52 °F	
Max Temperature	72 °F	63 °F	88 °F (1925)
Min Temperature	44 °F	42 °F	27 °F (1930)
Degree Days			
Heating Degree Days	7	13	
Month to date heating degree days	310	408	
Since 1 July heating degree days	5637	5803	
Cooling Degree Days	0	0	
Month to date cooling degree days	0	0	
Year to date cooling degree days	0	0	
Growing Degree Days	8 (Base 50)		
Moisture			
Dew Point	30 °F		
Average Humidity	35		
Maximum Humidity	46		
Minimum Humidity	24		
Precipitation			
Precipitation	0.00 in	0.12 in	0.86 in (1970)
Month to date precipitation	1.34	2.87	
Year to date precipitation	14.90	10.77	
Snow			
Snow	0.00 in	0.00 in	- ()
Month to date snowfall	0.0	2.6	
Since 1 July snowfall	68.1	47.3	
Snow Depth	0.00 in		

October | 25 | 2008 | View

Saturday, October 25, 2008

« Previous Day   Next Day »

Daily | Weekly | Monthly | Custom

	Actual	Average	Record
Temperature			
Mean Temperature	46 °F	49 °F	
Max Temperature	55 °F	58 °F	79 °F (1963)
Min Temperature	37 °F	40 °F	26 °F (1896)
Degree Days			
Heating Degree Days	19	16	
Month to date heating degree days	301	313	
Since 1 July heating degree days	364	452	
Cooling Degree Days	0	0	
Month to date cooling degree days	2	3	
Year to date cooling degree days	624	649	
Moisture			
Dew Point	41 °F		
Average Humidity	72		
Maximum Humidity	93		
Minimum Humidity	50		
Precipitation			
Precipitation	0.12 in	0.08 in	0.82 in (2002)
Month to date precipitation	1.67	2.26	
Year to date precipitation	34.92	32.91	
Snow			
Snow	0.00 in	0.00 in	- ()
Month to date snowfall	0.0	0.2	
Since 1 July snowfall	0.0	0.2	
Since 1 September snowfall	0.0	0.2	
Snow Depth	0.00 in		

Fig. 5. Historical data from April 24, 2008 to the 24th day of October 2008 with precipitation amounts to 32.91-10.77 = 22.14 inches and total snowfall depth 47.3 inches.

It appears that over 22 inches of rain fell over the period of construction of the highway fill embankment while adding an additional lane at the project site from April 24 through October 24, 2018. The project lasted almost 6 months from spring till October 24, 2008 when the embankment slope movement failure occurred. This does not include the addition of 47.3 inches snowfall precipitation melting. Though the data of vapor evaporation is not readily available, conclusions can be drawn that the surface water hydrologic conditions and the site specific geology conditions did somehow contribute greatly to the highway embankment failure. Whether expediting the construction process might have helped to prevent failure or might have even accelerated the failure process is still a question of great interests to debate. These project site related hydrologic precipitation information are important as they may help to investigate the failure mode the in the slope stability analysis.

Based on the desktop study of the project site reconnaissance, fielding drilling logs, laboratory soil test, and classification, and the subsurface investigation soil report, the engineering analysis profile could be generalized and produced. The Kettle lake model was supported by the following physical evidence [28-29]: saturated sand cuttings flowed onto the ground; very low SPT blow counts in sand with “No Blow” or WOR in the peat to -50.0 feet; Blowing sands into auger where augers got stuck; Volume of cuttings is far larger than expected in sands; and Water “squeezed” into ditch.

Documented site visit pictures and videos, as well as, published literature show the characteristics of glacial outwash deposits in the project site with alternating clay-rich and sand-rich layered soil strata. This soil sequence is prone to develop artesian and/or perched water tables. Figures 1 through 6 show landscape surface are literally pocket-marked with isolated, circular and near-circular lakes. These topographies are indicative of “deranged drainage”, wherein kettle lakes are formed by retreating glaciers, which usually lack an inflowing or outflowing stream (or both) [19]. The observed phenomena are due to the formation of the kettle, which is either a clay-lined depression isolated from the groundwater and recharged by surface inflow; or a depression that intercepts the groundwater table and is recharged by that underground source. The site investigation results also confirmed the aforementioned reasoning [28-29].

Slope stability analysis indicate why the highway embankment have induced large slope movement while after the rehabilitated highway embankment with an engineered drained condition by adoption of wick drain and granular material layers added in the construction. The factor of safety from the slope before failure and after failure improved from a low factor safety of 0.791 to a relatively high margin of safety factor of 1.772 after embankment rehabilitation [29].

Locally in Valparaiso Indiana areas, we also have Kettle lakes as shown in the right Fig. 6. Therefore, learning and offering students the engineering geology curriculum courses is necessary and meaningful and the students may learn and apply both geotechnical engineering and pertinent engineering geology knowledge to their future professional practice.

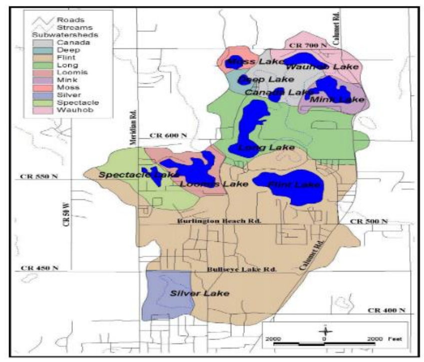

Fig. 6. Indiana Valparaiso Kettle Lakes [18]

CONCLUDING REMARKS

An innovative adoption of a geotechnical case study of a highway fill embankment in different engineering courses and subjects is introduced in this paper. Emphasis is placed on the different pertinent knowledge threads connected in different subjects’ lectures instructions. Though the first author’s major field primarily lies in geotechnical engineering, the different engineering disciplines can greatly benefit from this investigation. Subject courses assigned have a wide range from geomatics engineering course of surveying and GIS to mechanical and materials science courses, structures and properties of materials and civil engineering materials to water resources engineering course of surface water hydrology, engineering geology and different geotechnical subjects courses. It appears that the introduced case study can somehow always find some important applications and fundamental connections in all the different subjects courses. However, no matter how weak the links may exist between them, it surely will take considerate amount of time and efforts of research to highlight their inseparable connections. Research progress may be dispersed in different subjects, be it slow and less likely and if any new innovative progress and discovery among them actually being made, the award of taking such a detoured teaching and educational research may still be worthy.

Google Earth has been playing a significant role in geotechnical/foundation engineers’ routine daily work schedules. Therefore, Google Earth could and should be employed for the best engineering planning, investigation and optimization for current and future investigation of engineering projects. Access to Google Earth allows for the public, scientists, practicing engineers, and students to view and monitor the shoreline and geotechnical/foundation projects in a historical context. The public, geotechnical engineers, and especially the entering undergraduate students who study geotechnical/coastal engineering should be aware of this useful and effective tool in their unbiased approach to their engineering projects research, planning, optimization and implementation. Geotechnics encompassing engineering geology and geotechnical engineering of soil and rock mechanics are emphasized in this study for the best understanding and practice of geological/geotechnical engineering. The critical importance of a simple "quick sand" laboratory demonstration is introduced for its extended application to a practical case study of the failure of a real world highway fill embankment lying over a buried kettle lake due to external fill loading and excessive precipitation.

Another conclusion is that to educate and train competent civil and geotechnical engineers, in particular, to emphasize that additional courses beyond of soil mechanics and engineering are definitely needed for a thorough engineering analysis. Factual conclusions can be drawn that for a successful senior design project such as highway fill embankment, additional geotechnical courses work in engineering geology, intermediate soil mechanics, design of earth structures, foundation engineering, soil improvement, advanced soil mechanics, soil dynamics and earthquake geotechnical engineering will all help make a better and more meaningful and sustainable geotechnical designs.

ACKNOWLEDGEMENTAND DISCLAIMER

The authors thank the reviewers' constructive suggestions/comments for improvement of the paper and appreciate all the research accommodation and support from all the organizations involved in this project. The article is written with the purpose of emphasizing the critical importance of teaching engineering geology in addition to soil mechanics and rock mechanics as all of them play an integral part and role in the instruction of modern civil engineering principles and practices. Interdisciplinary courses instructions and learning are closely tied to each other. Constructive feedback from engineering educators in different expertise areas are gratefully appreciated and sincerely thanked by the authors. The voice, opinions and remarks conveyed in the paper does not reflect any organization's endorsement but purely the authors' own observations and comments.

REFERENCES

1. Akili W. (2006) CASE STUDIES IN GEOTECHNICAL/FOUNDATION ENGINEERING: ENGAGING STUDENTS AND BRINGING THE PRACTICE INTO THE CLASSROOM, 2006-784
2. Castro, G. (1975), "Liquefaction and Cyclic Mobility of Saturated Sands". Journal of the Geotechnical Engineering Division, ASCE, Vol 101, No. GT6, pp 551-569.
3. Castro, G. and Poulos, S. J. (1977). "Factors Affecting Liquefaction and Cyclic Mobility". Journal of the Geotechnical Engineering Division, ASCE, Vol 103, No. GT6, pp 501-516.
4. Coduto, D. P., Yeung, M. R., Kitch William A., (2011), Geotechnical Engineering, Principles and Practices, 2nd Edition, Pearson Higher Education, Inc.
5. Delatte N. (2009) "Beyond Failure: Forensic Case Studies For Civil Engineers," ASCE Press, Reston, VA.

6. Drummond Jr., Frederic, (2013) A. U.S. Army Corps of Engineers, “Illinois Beach State Park, Lake County, Illinois Section 204 Beneficial Use of Dredged Materials”, November 2013, Chicago District.
7. GabrinowitzJ., http://www.geo.sunysb.edu/esp/Science_Walks/carmans/index.htm,Science Drive of Carmans River Headwaters, last assessed, September 11, 2017.
8. Handy, Richard L. (1980), “Realism in Site Exploration: Past, Present, Future and then Some - All Inclusive”, Site Exploration on Soft Ground Using In-Situ Techniques, P.239-248, Report No. FHWA-TS-80-202, Federal Highway Administration, Washington, DC.
9. Harvey Abramowitz, (2007), AC 2008-1952: BASSWOOD BRIDGES, American Society for Engineering Education.
10. Holtz, Robert D., Kovacs William D. and Sheahan Thomas C, (2011), Introduction to Geotechnical Engineering, 2nd Edition, Prentice Hall.
11. Laviolette, E., Briones, D. S. and Heredia F. (2017) “Effective Stress and Seepage: Quick Sand Laboratory and Field Demonstrations”, Proposal submitted for Summer Undergraduate Research Grant, not funded and not published.
12. http://web.gccaz.edu/~lnewman/gph111/topic_units/glacial/glacial2.html, last assessed, September 11, 2017.
13. https://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
14. https://www.youtube.com/watch?v=CcwbmxosFh8, last assessed, September 11, 2017.
15. https://www.youtube.com/watch?v=JXdbsbAgdo8, last assessed, September 11, 2017.
16. https://www.youtube.com/watch?v=zm7PHNrp1DQ, "The Settlements of Embankments on Soft Clays" by Roy E. Olson, last assessed, September 11, 2017.
17. https://www.youtube.com/watch?v=QMBj896bzXs&list=PLXHjEGSzGOPNLB-M3oFeO0eMt20UZguOr, Geo-Institute of ASCE, Spencer J. Buchanan Lecture Series
18. http://www.vlacd.org/lakes/lakeenhancement/JFNew/Watershed%20Management%20Plan.pdf, last assessed, September 11, 2017.
19. http://www.geo.mtu.edu/KeweenawGeoheritage/Glaciers/Kettles.html,last assessed December 11, 2017.
20. Soil and rock properties, https://www.fhwa.dot.gov/engineering/geotech/pubs/010549.pdf
21. Li, J. (2018), “Teaching/Learning Fundamentals of Geotechnics and Its Application to a Highway Fill Embankment Slope Movement Case Study”, Paper manuscript prepared and submitted for review and constructive feedback.
22. Li, J., & Zhai, Jinyuan (2017, June), “Teaching/Learning Soil Mechanics with Mnemonics, Intuition, Insight and Inspiration” Paper presented at 2017 ASEE Annual Conference & Exposition, Columbus, Ohio.
23. Li, Jiliang (2016, June), “Using Google Earth in the Study of Shoreline Erosion Process” Paper presented at 2016 ASEE Annual Conference & Exposition, New Orleans, Louisiana. 10.18260/p.27148
24. Li, J. (2010), Geotechnical Study of Proposed Residence at Indian Forest Circle, Sun Creek Estate Rosharon Texas, Geotechnical Report, Geotechnical Engineering and Testing, Internal Client Report, not published.
25. Rahn, Perry H. (1996), Engineering Geology, An Environmental Approach, 2nd Edition, Prentice Hall PTR.
26. Richards, L.G., M.Gorman, W.T. Scherer, and R.D. Landel, “Promoting Active Learning with Cases and Instructional Modules,” ASEE Journal of Engineering Education, vo.84, no.4, Oct.1995, pp.375-381.

27. Strahler, Alan H. (2013), Introduction to Physical Geography, 6th Edition, Wiley.
28. Weber, M. W. and Bredikhin, A. J. (2009) “SUM9.9.10 Steel Corners Roads Embankment Fill Statics Liquefaction Failure Repair”, Ohio Transportation Engineering Conference (OTEC), Columbus, Ohio.
29. Weber, M. W. and Bredikhin, A. J. (2010) "Static Load Induced Liquefaction, Steels Corners Road Embankment Failure", Fifth International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics.
30. West, Terry R and Shakoor Abdul (2018), Geology Applied to Engineering, 2nd Edition, Waveland Press, Inc., Long Grove, Illinois. U.S.A.
31. Witherspoon, W. Tom (2008), Residential Foundation Performance - A Study of Repaired Foundations, Published by ADSC: The International Association of Foundation Drilling, Dallas Texas.
32. Wunderground,http://www.wunderground.com/history/airport/KCAK/2008/10/24/DailyHistory.html, last accessed July 18, 2017.
33. Borrego, Maura (2007) "Conceptual Difficulties Experienced by Trained Engineers Learning Educational Research Methods." Journal of Engineering Education 96 (2):91-102.
34. Wooden, M., Li, Jiliang, and Laviolette, E. and Liu, Y. (2018) “Effective Stress and Upward Seepage Laboratory Demonstration”, accepted to ASEE annual conference, to appear.