Sustainable Development Goals
Research Paper

DIT.ADS International Multidisciplinary Research Journal
Volume 1; Issue 4; November 2025; pp: 443-454; No.: 11-2025-104
Website: https://ditadsresearchcenter.com
E-ISSN: 3082-5148; P-ISSN: 3082-513X

Geotechnical Assessment of the University of Southeastern Philippines (USeP) Obrero Campus Buildings

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Received 30th July 2025; Accepted 11st September 2025; Published Online 4th November 2025
DOI: 10.63941/DIT.ADSimrj.2025.1.4.104

ABSTRACT

The study was conducted to evaluate the potential liquefaction and foundation settlement in the supporting soils of the University of Southeastern Philippines Obrero Campus buildings. The Philippines is prone to ground shaking or earthquakes caused by fault movement or volcanic activity, and it has recently experienced destructive earthquakes with magnitudes ranging from 6.1 to 7.3. Making an evaluation of the effects of seismic events is a useful tool for developing risk-reduction strategies and will expand current knowledge of how high-magnitude earthquakes will affect the supporting soils of the buildings. In this study, data were collected from the USeP Physical Development Division (PDD) and utilized a descriptive quantitative non-experimental design to evaluate the supporting soils of the buildings. The techniques offered by Youd and Idriss (2001) and Liu (1995) were used to evaluate the potential liquefaction and foundation settlement in the buildings. The study showed that the Administrative, Graduate School, and TBI buildings are prone to liquefaction and eventual foundation settlement for earthquake magnitudes 7, 8, and 9, whereas the Engineering Laboratory and Arts and Sciences have some liquefaction-safe depths.

Keywords: *Geotechnical, Liquefaction, Seismic Risk Evaluation, Soil Stability*

INTRODUCTION

The Philippines is prone to ground shaking or earthquakes generated by fault movement or volcanic activity. It has had around 100 destructive earthquakes in the past 400 years (DOST-PHIVOLCS, 2021). Since time immemorial, earthquakes have been some of the most destructive events in the Philippines, affecting people and both natural and built structures. In fact, the Philippines' earthquake hazard level is classified as high, which means that the country has more than a 20% chance of experiencing destructive earthquakes in the next 50 years (Global Facility for Disaster Reduction and Recovery, n.d.).

Table 1.1
Destructive Earthquakes in the Philippines

No.	Description	Date	Magnitude
1	Moro Gulf Earthquake	August 17, 1976	M 7.9
2	Panay Earthquake	June 14, 1990	M 7.1
3	Palimbang Earthquake	March 6, 2002	M 6.8
4	Cotabato Earthquakes	October 2019	M6.3, M6.6, M6.1, M6.5
5	Davao del Sur Earthquake	December 15, 2019	M6.9

Note: Adapted from "Destructive Earthquakes in the Philippines," by DOST-PHIVOLCS, 2022, https://www.phivolcs.dost.gov.ph/index.php/earthquake/destructive-earthquake-of-the-philippines

Table 1.1 lists some of the more destructive earthquakes that the country has experienced, including the recent Cotabato and Davao del Sur earthquakes with magnitudes ranging from 6.1 to 6.9. This event alerts the USeP Disaster Risk Reduction and Management (DRRM), which immediately conducts a Post-Earthquake Assessment Report and discovers some of the damage in the buildings, as shown in Appendix A.

Numerous reports of case histories of earthquake ground motions causing slope instability, liquefaction, settlement, and fault rupture have been published. Liquefaction occurs when excessive build-up of pore water pressure during earthquakes leads to the loss of the stiffness and strength of soils (Elnashai & Di Sarno, 2015). The formation of pore pressure occurs because cohesionless soils tend to compact during earthquake shaking, causing pore water pressures in the soil to rise until the pore water has time to drain from the soil skeleton (Federal Highway Administration, 2011).

Figure 1. 1
Two Adjacent Buildings Tilted Away From Each Other Due to Liquefaction in Foundation Soils

Note: From "Liquefaction-Induced Building Performance and Near-Fault Ground Motions" by Connor Patrick Hayden, 2014, p. 26 https://escholarship.org

Figure 1. 2
2011 Tohoku Earthquake Caused Severe Soil Collapse

Note: From "Japan Quake Caused Surprisingly Severe Soil Collapse" by Live Science, 2011, https://www.livescience.com/13765-japan-earthquake-soil-liquefaction.html

Liquefaction is the most dangerous sort of foundation failure according to earthquake experience and can result in several catastrophic structural failures (Armouti, 2008). Ground settling refers to the post-earthquake dissipation of excess pore water pressure caused by earthquake-induced liquefaction (Federal Highway Administration, 2011). Figure 1.1 depicts a spectacular instance of liquefactionrelated structural destruction, in which two nearby structures tilted apart from one another (Hayden, 2014). In addition, the severe soil collapse depicted in Figure 1.2 occurred during the 2011 Tohoku Earthquake, the fourth most powerful quake ever recorded with a magnitude of 9.0 (Live Science, 2011).

Earthquakes are extremely dangerous, as are their impacts, such as liquefaction and eventual foundation settlement in the supporting soil of the buildings. Making an evaluation of the effects of seismic events is an effective tool for creating risk-reduction strategies. Evaluating the soil properties of the University of Southeastern Philippines' Obrero campus will expand current understanding of how high-magnitude earthquakes affect the stability of the supporting soils of the campus buildings and ultimately of the campus structures themselves.

The University of Southeastern Philippines, as of the second semester of school year 2019-2020, has a total of 8,486 students enrolled in various tertiary education programs in all four campuses (David, 2020). Seventy percent (70%) of them (i.e., 5,946 students) were assigned to the Obrero campus. The fact that thousands of people congregate on one campus at any given time is enough reason to strive to ensure their safety. This means ascertaining that the buildings on campus are safe and stable from liquefaction and foundation settlement. The safety of people in the Obrero campus, as well as of the university's physical properties and structures, is the starting point of this investigation. Furthermore, the results of the geotechnical assessment can illuminate the university's efforts to develop and improve its infrastructure.

MATERIALS AND METHODS

The researcher utilized a descriptive quantitative non-experimental design to evaluate the supporting soil of the buildings in the University of Southeastern Philippines Obrero Campus to check for the presence of potential liquefaction and foundation settlement in the supporting soils. Descriptive Non-experimental research is defined as research that does not involve the manipulation of an independent variable, the random assignment of participants to conditions or orders of conditions, or both - all of which are characteristics of experimental designs (O'Dwyer & Bernauer, 2013). In a nutshell, this investigation applied well-established and recommended geotechnical engineering equations and formulas to the collected measurement data in order to arrive at the answers to the research questions.

RESULTS AND DISCUSSION

Potential Liquefaction in the Supporting Soil of the Buildings in the University of Southeastern Philippines Obrero Campus

Tables 1 to 5 presents the data on the potential liquefaction in the supporting soil of the buildings in the University of Southeastern Philippines Obrero Campus with magnitude scaling factor for M7, M8, and M9 of 1.1927, 0.8474, and 0.6268, respectively, using Eq. (12). Liquefaction is predicted to occur when FS ≤ 1 and not when FS > 1.

Table 1
Potential Liquefaction in the Supporting Soil for the Administrative Building

Depth (m)	USCS Symbol	Factor of Safety Against Liquefaction					
		M7		M8		M9	
1.5	ML	0.59	Liquefied	0.42	Liquefied	0.31	Liquefied
3	ML	0.45	Liquefied	0.32	Liquefied	0.24	Liquefied
4.5	ML	0.40	Liquefied	0.28	Liquefied	0.21	Liquefied
6	ML	0.37	Liquefied	0.26	Liquefied	0.19	Liquefied
7.5	ML	0.32	Liquefied	0.23	Liquefied	0.17	Liquefied

9	ML	0.33	Liquefied	0.23	Liquefied	0.17	Liquefied
10.5	ML	0.31	Liquefied	0.22	Liquefied	0.16	Liquefied
12	ML	0.31	Liquefied	0.22	Liquefied	0.16	Liquefied
13.5	ML	0.30	Liquefied	0.21	Liquefied	0.16	Liquefied
15	ML	0.31	Liquefied	0.22	Liquefied	0.16	Liquefied
16.5	ML	0.32	Liquefied	0.23	Liquefied	0.17	Liquefied
18	ML	0.41	Liquefied	0.29	Liquefied	0.22	Liquefied
19.5	ML	0.33	Liquefied	0.24	Liquefied	0.17	Liquefied
21	ML	0.36	Liquefied	0.25	Liquefied	0.19	Liquefied
22.5	ML	0.28	Liquefied	0.20	Liquefied	0.15	Liquefied
24	ML	0.33	Liquefied	0.24	Liquefied	0.17	Liquefied
25.5	ML	0.35	Liquefied	0.25	Liquefied	0.19	Liquefied

Table 2
Potential Liquefaction in the Supporting Soil for the Arts and Science Building

Depth (m)	USCS Symbol	Factor of Safety Against Liquefaction					
		M7		M8		M9	
1.5	MH	0.66	Liquefied	0.47	Liquefied	0.35	Liquefied
3	GM	0.94	Liquefied	0.67	Liquefied	0.49	Liquefied
4.5	GM	3.28	Non-Liquified	2.33	Non-Liquified	1.72	Non-Liquified
6	GM	1.50	Non-Liquified	1.06	Non-Liquified	0.79	Liquefied
7.5	GM	0.95	Liquefied	0.67	Liquefied	0.50	Liquefied
9	GM	3.14	Non-Liquified	2.23	Non-Liquified	1.65	Non-Liquified
10.5	GM	3.24	Non-Liquified	2.30	Non-Liquified	1.70	Non-Liquified
12	GM	0.28	Liquefied	0.20	Liquefied	0.15	Liquefied
13.5	GM	0.53	Liquefied	0.38	Liquefied	0.28	Liquefied
15	GM	1.09	Non-Liquified	0.77	Liquefied	0.57	Liquefied
16.5	GM	0.98	Liquefied	0.70	Liquefied	0.52	Liquefied
18	GM	0.94	Liquefied	0.67	Liquefied	0.49	Liquefied
19.5	GM	0.93	Liquefied	0.66	Liquefied	0.49	Liquefied
21	GM	0.91	Liquefied	0.65	Liquefied	0.48	Liquefied
22.5	GM	0.89	Liquefied	0.63	Liquefied	0.47	Liquefied
24	GM	0.95	Liquefied	0.68	Liquefied	0.50	Liquefied
25.5	GM	0.91	Liquefied	0.65	Liquefied	0.48	Liquefied

Table 3
Potential Liquefaction in the Supporting Soil for the Engineering Laboratory Building

Depth (m)	USCS Symbol	Factor of Safety Against Liquefaction					
		M7		M8		M9	
1.5	GM	0.78	Liquefied	0.55	Liquefied	0.41	Liquefied
3	SM	0.99	Liquefied	0.70	Liquefied	0.52	Liquefied
4.5	SM	1.06	Non-Liquified	0.75	Liquefied	0.55	Liquefied
6	GM	3.05	Non-Liquified	2.17	Non-Liquified	1.60	Non-Liquified
7.5	GM	1.13	Non-Liquified	0.80	Liquefied	0.59	Liquefied
9	GM	0.76	Liquefied	0.54	Liquefied	0.40	Liquefied
10.5	GM	0.69	Liquefied	0.49	Liquefied	0.36	Liquefied
12	GM	0.38	Liquefied	0.27	Liquefied	0.20	Liquefied
13.5	GM	0.53	Liquefied	0.38	Liquefied	0.28	Liquefied
15	GM	0.57	Liquefied	0.41	Liquefied	0.30	Liquefied
16.5	GM	0.56	Liquefied	0.40	Liquefied	0.29	Liquefied
18	GM	0.65	Liquefied	0.46	Liquefied	0.34	Liquefied
19.5	GM	0.63	Liquefied	0.45	Liquefied	0.33	Liquefied
21	SM	0.59	Liquefied	0.42	Liquefied	0.31	Liquefied
22.5	SM	0.58	Liquefied	0.42	Liquefied	0.31	Liquefied
24	GM	0.60	Liquefied	0.43	Liquefied	0.32	Liquefied
25.5	GM	0.57	Liquefied	0.40	Liquefied	0.30	Liquefied

27	GM	0.71	Liquefied	0.51	Liquefied	0.37	Liquefied
28.5	GM	0.75	Liquefied	0.54	Liquefied	0.40	Liquefied
30	GM	0.76	Liquefied	0.54	Liquefied	0.40	Liquefied

Table 4
Potential Liquefaction in the Supporting Soil for the Graduate School Building

Depth (m)	USCS Symbol	Factor of Safety Against Liquefaction					
		M7		M8		M9	
1.5	ML	0.84	Liquefied	0.60	Liquefied	0.44	Liquefied
3	ML	0.70	Liquefied	0.50	Liquefied	0.37	Liquefied
4.5	ML	0.44	Liquefied	0.31	Liquefied	0.23	Liquefied
6	ML	0.42	Liquefied	0.30	Liquefied	0.22	Liquefied
7.5	ML	0.35	Liquefied	0.25	Liquefied	0.18	Liquefied
9	ML	0.34	Liquefied	0.24	Liquefied	0.18	Liquefied
10.5	ML	0.29	Liquefied	0.20	Liquefied	0.15	Liquefied
12	ML	0.27	Liquefied	0.20	Liquefied	0.14	Liquefied
13.5	CH	0.29	Liquefied	0.20	Liquefied	0.15	Liquefied
15	CH	0.30	Liquefied	0.21	Liquefied	0.16	Liquefied
16.5	CH	0.33	Liquefied	0.24	Liquefied	0.17	Liquefied
18	CH	0.35	Liquefied	0.25	Liquefied	0.18	Liquefied
19.5	CH	0.34	Liquefied	0.24	Liquefied	0.18	Liquefied
21	CH	0.36	Liquefied	0.25	Liquefied	0.19	Liquefied
22.5	CH	0.37	Liquefied	0.27	Liquefied	0.20	Liquefied
24	CH	0.36	Liquefied	0.26	Liquefied	0.19	Liquefied
25.5	CH	0.36	Liquefied	0.26	Liquefied	0.19	Liquefied

Table 5
Potential Liquefaction in the Supporting Soil for the TBI Building

Depth (m)	USCS Symbol	Factor of Safety Against Liquefaction					
		M7		M8		M9	
1	ML	0.69	Liquefied	0.49	Liquefied	0.36	Liquefied
2	ML	0.49	Liquefied	0.35	Liquefied	0.26	Liquefied
3	ML	0.38	Liquefied	0.27	Liquefied	0.20	Liquefied
4	ML	0.34	Liquefied	0.24	Liquefied	0.18	Liquefied
5	ML	0.30	Liquefied	0.21	Liquefied	0.16	Liquefied
6	ML	0.27	Liquefied	0.19	Liquefied	0.14	Liquefied
7.5	ML	0.26	Liquefied	0.19	Liquefied	0.14	Liquefied
9	ML	0.26	Liquefied	0.18	Liquefied	0.13	Liquefied
10.5	ML	0.24	Liquefied	0.17	Liquefied	0.12	Liquefied
12	ML	0.23	Liquefied	0.17	Liquefied	0.12	Liquefied
13.5	ML	0.23	Liquefied	0.17	Liquefied	0.12	Liquefied
15	ML	0.24	Liquefied	0.17	Liquefied	0.13	Liquefied
16.5	ML	0.26	Liquefied	0.18	Liquefied	0.13	Liquefied
18	ML	0.27	Liquefied	0.19	Liquefied	0.14	Liquefied
19.5	ML	0.26	Liquefied	0.19	Liquefied	0.14	Liquefied
21	ML	0.28	Liquefied	0.20	Liquefied	0.15	Liquefied

Potential Foundation Settlement Due to Liquefaction of the Buildings in the University of Southeastern Philippines Obrero Campus

Tables 6 to 10 present the data on the potential foundation settlement of the buildings in the University of Southeastern Philippines Obrero Campus. This is based on the result of the potential liquefaction as presented in Tables 4.1 to 4.5. The full data in the computation is shown in Appendices O to S.

Table 6
Potential Foundation Settlement Due to Liquefaction of the Administrative Building

Depth (m)	Settlement (m)		
	Intensity 7	Intensity 8	Intensity 9
1.5	0.01	0.02	0.05
3	0.02	0.05	0.11
4.5	0.03	0.09	0.17
6	0.04	0.12	0.25
7.5	0.06	0.18	0.36
9	0.07	0.21	0.42
10.5	0.09	0.27	0.54
12	0.10	0.31	0.63
13.5	0.13	0.39	0.77
15	0.14	0.43	0.86
16.5	0.16	0.49	0.97
18	0.15	0.46	0.92
19.5	0.21	0.62	1.24
21	0.22	0.66	1.32
22.5	0.29	0.87	1.74
24	0.28	0.84	1.68
25.5	0.29	0.88	1.75

Table 7
Potential Foundation Settlement Due to Liquefaction of the Arts and Science Building

Depth (m)	Settlement (m)		
	Intensity 7	Intensity 8	Intensity 9
1.5	0.01	0.03	0.07
3	0.01	0.03	0.06
4.5	NA	NA	NA
6	NA	NA	0.08
7.5	0.02	0.07	0.14
9	NA	NA	NA
10.5	NA	NA	NA
12	0.15	0.45	0.89
13.5	0.09	0.28	0.55
15	NA	0.14	0.28
16.5	0.06	0.19	0.37
18	0.08	0.23	0.47
19.5	0.09	0.28	0.56
21	0.11	0.33	0.66
22.5	0.13	0.38	0.77
24	0.13	0.39	0.79
25.5	0.15	0.46	0.92

Table 8
Potential Foundation Settlement Due to Liquefaction of the Engineering Laboratory Building

Depth (m)	Settlement (m)		
	Intensity 7	Intensity 8	Intensity 9
1.5	0.01	0.03	0.05
3	0.01	0.03	0.06
4.5	NA	0.04	0.07
6	NA	NA	NA
7.5	NA	0.06	0.11
9	0.03	0.10	0.20
10.5	0.04	0.13	0.26
12	0.11	0.32	0.64

13.5	0.09	0.26	0.52
15	0.09	0.28	0.56
16.5	0.11	0.34	0.68
18	0.11	0.33	0.67
19.5	0.13	0.40	0.80
21	0.16	0.49	0.98
22.5	0.18	0.55	1.11
24	0.20	0.60	1.20
25.5	0.23	0.70	1.39
27	0.20	0.59	1.18
28.5	0.20	0.60	1.21
30	0.22	0.65	1.29

Table 9
Potential Foundation Settlement Due to Liquefaction of the Graduate School Building

Depth (m)	Settlement (m)		
	Intensity 7	Intensity 8	Intensity 9
1.5	0.01	0.02	0.04
3	0.01	0.04	0.07
4.5	0.03	0.09	0.17
6	0.04	0.11	0.22
7.5	0.06	0.17	0.33
9	0.07	0.21	0.41
10.5	0.09	0.28	0.56
12	0.11	0.34	0.68
13.5	0.13	0.38	0.76
15	0.14	0.43	0.87
16.5	0.15	0.46	0.91
18	0.17	0.50	1.00
19.5	0.19	0.58	1.16
21	0.21	0.62	1.24
22.5	0.22	0.66	1.33
24	0.25	0.75	1.49
25.5	0.27	0.81	1.62

Table 10
Potential Foundation Settlement Due to Liquefaction of the TBI Building

Depth (m)	Settlement (m)		
	Intensity 7	Intensity 8	Intensity 9
1	0.01	0.02	0.04
2	0.02	0.05	0.10
3	0.03	0.08	0.17
4	0.04	0.11	0.22
5	0.05	0.15	0.29
6	0.06	0.18	0.37
7.5	0.08	0.23	0.47
9	0.09	0.28	0.56
10.5	0.12	0.35	0.70
12	0.14	0.41	0.82
13.5	0.16	0.48	0.96
15	0.18	0.54	1.07
16.5	0.20	0.59	1.19
18	0.22	0.65	1.30
19.5	0.25	0.75	1.49
21	0.27	0.80	1.59

Figure 1
Variations of Potential Liquefaction with Depth and Earthquake Magnitude in the Supporting Soil of the Buildings

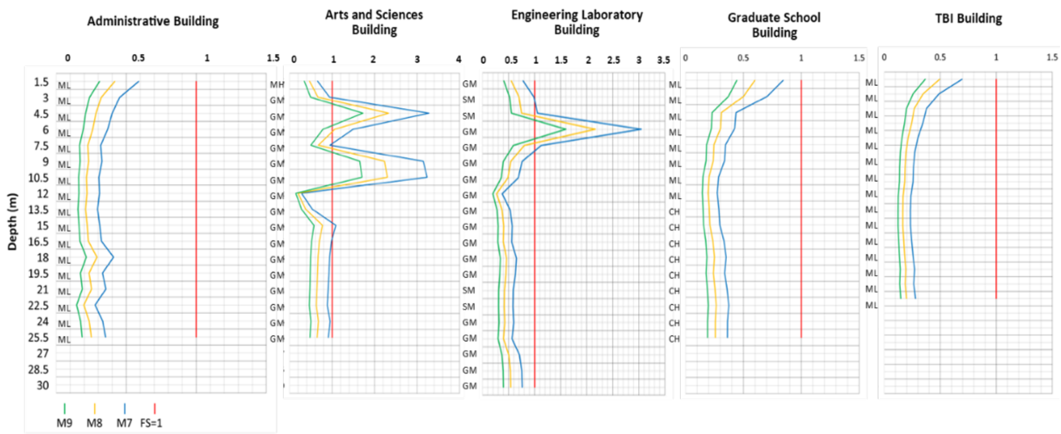
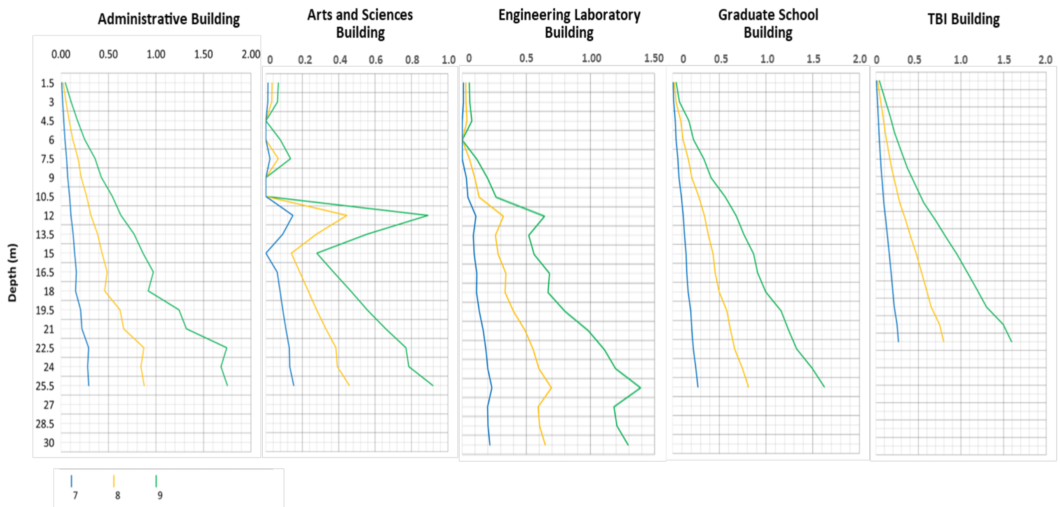


Figure 2
Variations of Potential Foundation Settlement Due to Liquefaction with Depth and Earthquake Intensities in the Supporting Soil of the Buildings



Discussions

Figure 4.1 depicts the potential liquefaction variations, including the USCS symbol at various depths in the supporting soil. The colors blue, yellow, and green were used to represent the factor of safety (FS) against liquefaction for earthquake magnitudes M7, M8, and M9, respectively, while the color red line represented the liquefaction boundary. It demonstrates that non-liquefied depths are associated with coarse-grained soils, whereas liquefied depths are typically associated with fine-grained soils. In addition, Figure 4.2 shows the variations of potential foundation settlement in the supporting soil, using the colors blue, yellow, and green to represent the potential foundation settlement for earthquake intensities 7, 8, and 9, respectively.

Administrative Building

The Factor of Safety (FS) for earthquake magnitudes M7, M8, and M9 in all depths is less than one, as shown in Table 4.1. This implies that the building is potential to liquefaction considering the peak ground acceleration (amax) of 0.4g. It is observed in the computation that the higher the amax value, the more the building is potentially susceptible to liquefaction, as defined as a function of the earthquake magnitude, distance from the fault to the site, and the general site condition parameter. The building's potential settlement is also possible because it is directly proportional to the result in liquefaction. The highest potential settlement, as shown in earthquake intensities 7, 8, and 9, as shown in Table 4.6, is recorded at a depth of 25.5 meters, which is 0.29, 0.88, and 1.75 meters, respectively. Figures 4.1 and 4.2 show the variation of the Factor of Safety (FS) against potential liquefaction and settlement for the Administrative Building.

Arts and Sciences Building

The Factor of Safety (FS) for earthquake magnitudes M7 and M8 in depths 4.5, 6.0, 9.0, and 10.5 meters, including the 15-meter depth on M7, is greater than one (1), as shown in Table 4.2. This implies a very dense layer at the said depths, which is supported by the geotechnical report, which classifies the majority of the layer as well-graded gravels, gravel-sand mixtures, little or no fines, and rock cores. The potential settlement of the supporting soil is almost zero (0) in earthquakes of intensity 7 until the depth of 10.5 meters and up to 0.15 meters in depths ranging from 16.5 to 25.5 meters. The highest potential settlement in earthquake intensities 7, 8, and 9, as shown in Table 4.7, is recorded at a depth of 25.5 meters, which is 0.15, 0.46, and 0.92 meters, respectively. Figures 4.1 and 4.2 show the variation in the Factor of Safety (FS) with respect to potential liquefaction and settlement for the Arts and Sciences Building.

Engineering Laboratory Building

The Factor of Safety (FS) for earthquake magnitudes M7, M8, and M9 is less than one (1) in almost all depths except 6 meters and 7.5-meter depth on M7, as shown in table 4.3. This implies that the building is potential to liquefaction considering the peak ground acceleration of 0.4g. It is observed in the computation that the higher the amax value the more the building is potential to liquefaction, as defined that it is as a function of the earthquake magnitude, distance from the fault to the site, and the general site condition parameter. The building's potential settlement is also possible because it is directly proportional to the result in liquefaction. The highest potential settlement in earthquake intensities 7, 8, and 9 as shown in Table 4.8 is recorded at depth 25.5 meters, which is 0.23, 0.70, and 1.39 meters, respectively. Figures 4.1 and 4.1 show the variation of the Factor of Safety (FS) against potential liquefaction and settlement for the Engineering Laboratory Building.

Graduate School Building

The findings for potential liquefaction and settlement in the Graduate School Building are similar to those in the Administrative Building. The Factor of Safety (FS) for earthquake magnitudes M7, M8, and M9 in all depths is less than one, as shown in Table 4.4. This implies that the building is potentially susceptible to liquefaction, considering the peak ground acceleration (amax) of 0.4g. It is observed in the computation that the higher the amax value, the more the building is potentially susceptible to liquefaction, as defined as a function of the earthquake magnitude, distance from the fault to the site, and the general site condition parameter. The building's potential settlement is also possible because it is directly proportional to the result of liquefaction. The highest potential settlement in earthquake intensities 7, 8, and 9, as shown in Table 4.9, is recorded at a depth of 25.5 meters, which is 0.27, 0.81, and 1.62 meters, respectively. Figures 4.1 and 4.2 show the variation of the Factor of Safety (FS) against potential liquefaction and settlement for the Administrative Building.

TBI Building

The findings for potential liquefaction and settlement in the TBI Building are similar to those in the Administrative and Graduate School Building. The Factor of Safety (FS) for earthquake magnitudes M7, M8, and M9 in all depths is less than one, as shown in Table 4.5. This implies that the building is potentially susceptible to liquefaction, considering the peak ground acceleration (amax) of 0.4g. It is observed in the computation that the higher the amax value, the more the building is potentially susceptible to liquefaction, as defined as a function of the earthquake magnitude, distance from the fault to the site, and the general site condition parameter. The building's potential settlement is also possible because it is directly proportional to the result of liquefaction. The highest potential settlement in earthquake intensities 7, 8, and 9, as shown in Table 4.10, is recorded at a depth of 21 meters, which is 0.27, 0.80, and 1.59 meters, respectively. Figures 4.1 and 4.2 show the variation of the Factor of Safety (FS) against potential liquefaction and settlement for the Administrative Building.

CONCLUSION

The following conclusions were reached based on the study's findings:

1. The Administrative, Graduate School, and TBI buildings are susceptible to liquefaction in earthquake magnitudes M7, M8, and M9 and settlement in intensities 7, 8, and 9.
2. The Arts and Sciences building has a liquefaction-resistant layer for earthquake magnitudes M7 and M8 at depths of 4.5, 6.0, 9.0, and 10.5 meters, including a 15-meter depth on M7. The non-liquefiable depths on M9 are 4.5, 9.0, and 10.5 meters. It has very little settlement for intensities 7, 8, and 9 up to the 10.5-meter depth since it is non-liquefiable.
3. The Engineering Laboratory building is potentially vulnerable to liquefaction in earthquake magnitudes M7, M8, and M9 and settlement in intensities 7, 8, and 9 except at a depth of 6 meters and depth 7.5 meters on M7.

Recommendations

Based on the findings, the following are recommended.

1. A copy of the study will be forwarded to the USeP Physical Development Division (PDD) to serve as a reference.
2. The findings could be investigated further, particularly in terms of the peak ground acceleration value (amax) to be used. The National Structural Code of the Philippines (NSCP, 2015) recommended that a site-specific study be conducted to determine the value of peak ground acceleration.
3. Retrieval of geotechnical reports from other buildings in the USeP Obrero Campus in order to assess them for potential liquefaction and settlement.
4. Retrieval of the study titled "Soil Profiling of USeP-Obrero Campus" by (Cabadonga, 2008) so that it can be used to assess existing buildings for potential liquefaction and settlement and as reference for potential soil bearing capacity reduction.
5. Liquefaction mitigation methods for existing buildings are suggested based on the study of Hausler and Sitar (2001), as cited by Schepers et al., (2015). They examined over 90 case studies of liquefaction mitigation methods used during 14 seismic events ranging in magnitude from 6.3 to 8.1. Table 5.1 summarizes the findings. In general, techniques that work with existing structures demand that no actions be taken by the structures directly. Therefore, any approach that involves drilling, piling, or other comparable processes is not appropriate. Only the latter two categories of technologies, which both exhibit promising performance, are thus appropriate for existing

buildings.

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