2021 SDC - Geotechnical/Seismicity Deliverable

Background and Problem Statement

Hospital space in the greater Seattle area is currently at a premium due to the COVID-19 pandemic. New hospitals are currently under construction, but time is of the essence. An existing hospital structure (near site coordinates 47.6163, -122.3534) that was already slated to have a structural addition has had its timeline moved forward in order to increase its patient capacity to help with the rising infections.

However, the current hospital structure is old -- so old that the original geotechnical reports have been lost. Fortunately an adjacent lot is under construction (not related to the hospital) and the engineers of that site are willing to share some of the geotechnical documents, including a boring log and a P-S suspension log. Although they did not share the full geotechnical report, any additional information that is needed can be found by conducting some research and using readily available online tools.

The principal engineers who are acting as project managers (PM) for the geotechnical and seismic design of the hospital addition have decided that the group of recently-hired interns should get some practice working with these geotechnical documents and online tools. The PMs are not always available and recognize that the interns are not familiar with a lot of the information that they are being asked to find and/or analyze. The following document has been created to guide the interns, stating the specific deliverables that the intern group should present to the PMs. In addition to this document, the intern group needs access to *ASCE Standard Document 7-16: Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. The interns are expected to be able to obtain access to this document from other associates (i.e., from their professors or graduate students). If the intern group is unable to gain access to this document, they may contact the PMs via email (sdc@eeri.org) so that an alternative may be provided. Any additional questions/clarifications regarding the following document should also be sent to the PMs via the SDC rules clarification online portal (see Official General Rules).

The final deliverable created by the intern group should be a single pdf document with all explanations and justifications clearly expressed. All requested items (e.g., written responses, figures, tables) should be presented in sequential order and categorized under the subheadings of this document. A title page and a references section should be included in the deliverable and formatted according to the provided rubric.

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Part 1: Memo of Regional and Local Site Conditions

DELIVERABLE - Please present a brief (1000 words or less) memo describing the regional and local site conditions. Any outside references used should be properly cited within the text, with references included at the end of the deliverable (You can use any major/widely acceptable citation style). Please include the following:

- Regional geology and nearby geologic units.
- Local faults and general seismicity of the area.
- General subsurface description of significant soil layers based on the provided boring log. Comment on the groundwater at the site.

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Part 2: Subsurface Challenges and Determination of Site Class per ASCE 7-16

DELIVERABLE - Please provide short answers for the following questions. Any outside references used should be properly cited.

1. What general subsurface conditions (e.g., soil types and consistencies, groundwater conditions) may typically indicate the existence of liquefiable soils? Based on only qualitative observations of the provided boring log, are there any potentially liquefiable soils at this site? If so, what are the depth(s) and thickness(es) of the liquefiable soils?

2. Provide a brief description of three different ground improvement techniques that may be considered to mitigate the effects of liquefaction at this site.

3. Based only on the preliminary information provided in the boring log, to what approximate depth below the ground surface do you expect the pile foundations for the existing structure might extend? Why?

4. Assuming *no ground improvement* is conducted at this site, what is the Site Class per Chapter 20 of ASCE 7-16? Explain what information was used to determine this.

5. Now assume that *liquefaction mitigation will be performed* at this site. Liquefaction is no longer a concern. Conservatively assume the in-situ shear wave velocity (V_S) is unaffected by the mitigation technique used. Use the P-S suspension log readings to determine V_S in the top 30 m (i.e. 100 ft) of the site ($V_{S,30}$) per Chapter 20 of ASCE 7-16. What is the estimated $V_{S,30}$? What is the new Site Class based on this information?

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Part 3: Prepare a Design Response Spectrum per Chapter 11 of ASCE 7-16

DELIVERABLE - Provide short answers and required plots for the following questions.

NOTE: Future geophysical tests following liquefaction mitigation indicate that the $V_{S,30}$ has changed. For all subsequent calculations, assume a Site Class of D. For the purpose of this deliverable, it will also be assumed that the structure is exempt from the need to perform Site-Specific Ground Motion Procedures (i.e., site response and ground motion hazard analysis) per Chapter 21 of ASCE 7-16.

1. What is the Risk Category of this structure per Chapter 1 of ASCE 7-16?

2. Using this Risk Category, develop the design response spectrum per Chapter 11.4 of ASCE 7-16. Assume Site Class D and that the requirements for site-specific ground motions do not apply. *Hint: We recommend using the online ATC Hazard Tool to obtain parameters S_S and S_1. This online tool will not provide all necessary parameters, since typically a site-specific analysis would be necessary. Missing parameters can instead be obtained from ASCE 7-16.*
    a. Create and present a plot of the design response spectrum up to a period of 10 seconds.
    b. Create and present a table that includes the values used for S_S, S_1, F_a, F_v, S_{MS}, S_{M1}, S_{DS}, S_{D1}, T_0, T_s, and T_L.

3. The approximate fundamental period (T) of the existing structure is estimated as 1.0 seconds, and T of the structure with the proposed addition is estimated as 2.0 seconds. Based on the design response spectrum, what are the approximate spectral accelerations (Sa) for the existing structure and the existing structure with the proposed addition?

4. What is the Seismic Design Category of this structure per Chapter 11.6 of ASCE 7-16? Based on this category, please succinctly list all hazards and analyses that should typically be considered for the site as part of the Geotechnical Investigation Report requirements.

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Part 4: Interpret the Seismic Hazard Deaggregation

DELIVERABLE - Include the contributors tables, screenshots of the plots, and short answers to the following questions.

NOTE: Seismic hazard deaggregation is used to compile probabilistic ground motion hazard data for a site based on previous earthquakes (background sources), nearby faults, and other earthquake scenarios. The deaggregation provides a breakdown of the magnitude (m), site-to-source distance (r), and hazard contribution (%) for each of the contributing sources.

1. Go to the USGS website and enter the following information under the 'Input' section. Fill in the rest of the inputs with the information already provided.
    a. Edition: Dynamic: Conterminous U.S. 2014 (v4.1.4)
    b. Time Horizon (return period): 2475 years

NOTE: The design spectrum parameters used by ASCE 7-16 (as obtained in Part 3) are based on a target risk of structural collapse equal to 1% in 50 years, as obtained from a structural fragility analysis. While this is not identical to a ground motion time horizon (return period) of 2475 years, the results from the seismic hazard deaggregation are expected to be similar.

2. Provide screenshots of the resulting deaggregation plots for periods of T = 1.0 sec and T = 2.0 sec. Fill out the following table and use the entered values to answer the following questions. Use the plots and the deaggregation report to estimate the appropriate information.

    Hint: The report typically divides the contribution from major sources into segments. Weighted averages based on percent contribution can be used to combine the data for each major contributing source. Grid, slab, and other sources without a defined m and r should be grouped in the "Other" category.

Table 1: Approximate deaggregation contributors to earthquake hazard for the project site at the fundamental periods of the existing (old) and new (with addition) structures.

Contributing Sources	T = 1.0 sec			T = 2.0 sec		
	m	r (km)	%	m	r (km)	%
Nearby Faults (< 15 km)						
Cascadia Subduction Zone (CSZ) Interface						
Other	---	---		---	---	

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3. At what magnitude and distance is the source with the largest percent contribution to hazard for both T = 1.0 sec and T = 2.0 sec?

4. Report the mean values for m (magnitude) and r (rupture distance) for T = 2.0 sec. Do these values represent individual seismic sources? For developing ground motion models, should the mean values or the individual source (fault, interface, etc.) values be used?

5. ***BONUS QUESTION*** How does the Cascadia Subduction Zone (CSZ) Interface contribution percentage change between T = 1.0 sec and T = 2.0 sec? Why might this difference occur?

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<u>Part 5: Select and Scale Time Histories for Future Analyses</u>

DELIVERABLE - Provide all requested plots, tables and short answers to the following questions.

NOTE: Future analyses will require realistic earthquake ground motions for assessing the seismic design of the hospital structure with proposed additions. You have so far obtained a design acceleration response spectrum from Part 3, which may act as a target for the selection and scaling of more realistic ground motions. You will use this design response spectrum, the hazard deaggregation from Part 4, and ground motion data from past earthquakes to <u>select and scale a total of five ground motions.</u>

1. Deaggregation is an important step in selecting how many different *types* of ground motions should be considered for scaling (e.g., if two different sources each contribute to 50% of the total hazard, then half of the selected motions should represent one source, and the other half of selected motions should represent the other source). Refer to the completed Table 1 from *Part 4*. Assume now that the hazards for the site are only composed of the nearby faults and CSZ Interface sources (i.e., assume only these two sources make up 100% of the total hazard). What are the new overall contributing percentages of these two sources for T = 2.0 sec?

2. Using the values reported from the previous question, how many ground motions (out of five) should be selected to represent the nearby faults and how many ground motions (out of five) should be selected to represent the CSZ Interface?

Now that it has been decided *how many* ground motions from each source should be selected, the ground motions *themselves* need to be selected. The ground motions selected will eventually be scaled; the ground motions that will be scaled are referred to as *seed motions*. In practice, it is recommended that the acceleration response spectra of the seed motions have the same general shape as the design response spectra. However, there are other preliminary analyses that should be considered in the selection of seed motions prior to plotting them.

When selecting seed motions (especially when considering the CSZ), there are no past recorded magnitude 8.0 or greater motions that originate in the Pacific Northwest. Recent earthquakes with such large magnitudes have typically occurred within subduction zones, so candidate ground motions from similar tectonic environments should be chosen. Typically, seed motions are selected from a variety of sources; this introduces variability due to the different conditions in which the earthquakes occurred. Seed motions are chosen based on criteria such as magnitude, rupture distance, rupture mechanism (e.g. tectonic region, fault type), and $V_{s,30}$, among others.

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3. From the candidate ground motions provided, which 5 motions do you recommend should be considered as seed motions for the site? Provide a short justification for each choice. The number of seed motions proposed from the different sources should match the number determined from the previous question.

In the previous step, the candidate ground motions were provided; however, ground motions can be selected from various databases online. The following step will explain how to find a seed motion representing a *nearby fault* with a pulse. Since the current site may be considered a "near-fault site" per section 11.4.1 of ASCE 7-16, it is beneficial to consider at least one ground motion with a pulse that may be caused by near-fault effects.

4. Go to the online ground motion database by the Pacific Earthquake Engineering Research Center (PEER). Enter the NGA-West2 database using the link located on the right side of the page.
    a. Sign up to create an account. For 'primary field of work' and 'primary use of database' choose the option *other*. The email account entered needs to be confirmed before access is granted to the database.
    b. For 'target spectrum model' enter *no scaling* and hit submit.
    c. Under 'search parameters' enter the following (leaving all else blank):
        i. Fault type: select 'all types'.
        ii. Magnitude: enter a minimum and a maximum magnitude for T = 2.0 sec. These values should bound the values obtained from the deaggregation results obtained in *Part 4*.
        iii. R_JB: enter a minimum and maximum distance (km) for T = 2.0 sec. These values should bound the values obtained from the deaggregation results obtained in *Part 4*.
        iv. R_rup: enter the same values as R_JB.
        v. Pulse: select 'ONLY pulse-like records'.
        vi. Leave all other search criteria blank and click 'search records' located at the bottom of the page.
        vii. On the right-hand side under 'suite', leave the spectral ordinate as SRSS, the damping ratio as 5%, and the suite average as arithmetic. This should not matter, since we will ultimately be using the unscaled and unrotated data.
    d. Download the ".csv" search results (metadata + spectra).
    e. Select one motion from the downloaded file that may best represent a near fault motion at this site. Try to select a motion with parameters consistent with the site and with a "T_P - Pulse Period" below 4.0 sec. Provide the record sequence number, earthquake name, and station name of the selected motion. Briefly describe why you selected this motion.

f. Finally, look at the spectral data for the H1 and H2 horizontal direction components of your selected motion, and pick the component that carries the greatest peak in spectral acceleration near T_p. The spectral data from this component will be used for scaling, as discussed next.

Open the provided spreadsheet that contains the seed motions selected by the PMs (download the file in the excel format; do not convert to sheets). Four (4) motions have been pre-selected for you based on the complete deaggregation results for this site. The pseudo-spectral acceleration (pSa) response spectra for each of the pre-selected motions has been plotted in log-log space. Linked formulas for plotting an overall geomean response spectrum and your design spectrum are also provided. Two graphs will auto-populate: one with the original acceleration time history, and one with the scaled acceleration time history. *Hint: There are notes used within the provided spreadsheet; the cell with the note attached to it has a red flag - hover over the cell to see the note.*

5. On the provided spreadsheet, plot the design spectrum that was created in *Part 3*. Enter the associated values under the pre-labelled column headings; the graph should auto-populate with the design spectrum and +/- 15% bounds.

6. Obtain the spectral data for the selected H1 or H2 motion (from question 4). Enter the values for the period and pSa selected from this motion. *Make sure the values chosen are from the unscaled spectra portion of the data!*

7. Scale the pSa response spectra of each seed motion so they each approximately match the design response spectrum between the periods of interest for your structure (T = 1.0 sec and T = 2.0 sec). Try to stay within the +/- 15% error bounds as much as possible for this period range. The purpose of scaling is to prepare the selected ground motions, so that they better represent the design scenario for future analyses. The scale factor should typically be between ⅓ to 3. *Provide the graph of the final selected and scaled seed motions with respect to the design spectrum created in Part 3. Also complete and include the table that lists the seed motion ID and the scale factor used. Please use the provided templates of the plot and table.*

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The completion of this memo covers the preliminary geotechnical and seismic analyses for the hospital site. The PMs may consider additional analyses to better refine the ground motion data for future analyses by the structural engineers. These refinements may include spectral matching of the ground motions, the selection of additional ground motions, and compliance with the *Site-Specific Ground Motion Procedures* (i.e., site response and ground motion hazard analysis) per Chapter 21 of ASCE 7-16. However, these analyses require additional background information that the PMs cannot teach you at this time.

The complete pdf deliverable that you present to the PMs will be used to decide how to proceed with future analyses. Make sure that your deliverable is clear and concise so that there is little to no confusion for the PMs and other coworkers using your work.