LIQUEFACTION RISK

According to
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"CPT and SPT based liquefaction triggering procedures"
Report No. UCD/CGM-14/01
Center of geotechnical modeling

Structure:
Project:
Location:

INPUTS

Specific weight of water $\gamma_{water} := 9.8 \frac{kN}{m^3}$

CPTu tip area net ratio $a_n := 0.81$ Value from calibration. Examplary value from NCHRP page 14-15

CPTu sleeve are net ratio $b_n := 0.00$ Value from calibration. Examplary value from NCHRP page 14-15

SOIL LAYER INPUTS

DEPTH FROM z_{from} [m]	DEPTH TO z_{to} [m]	THICK-NESS z_i [m]	UNIT WEIGHT γ_{tot} [kN/m³]	WATER TABLE 0=above WT 1=below WT [0/1]	NUMBER OF DIVISIONS n_{split} [-]	EFF. VERT. STRESS σ'_{v_bottom} [kPa]	VERTICAL STRESS σ_{v_bottom} [kPa]
0,0	1,5	1,5	18,0	0	30	27,0	27,0
1,5	21,5	20,0	18,0	1	300	191,0	387,0
21,5	21,5					191,0	387,0
21,5	21,5					191,0	387,0
21,5	21,5					191,0	387,0
21,5	21,5					191,0	387,0

▶ Soil stress calculations

INPUTS FROM CPTu SOIL INVESTIGATION TEST

NOTE: Depth correction to measured tip and sleeve resisance must be made manually, before inserting the values to the table below.

DEPTH FROM z_{from} [m]	DEPTH TO z_{to} [m]	THICK-NESS $z_{split\ i}$ [m]	UNCORRECTED TIP RESISTANCE q_c [kPa]	UNCORRECTED SLEEVE RESISTANCE f_s [kPa]	PORE WATER PRESURE u [kPa]
0,000	0,00	0,000	0	0	0
0,000	0,01	0,010	0	0	0
0,010	0,02	0,010	0	0	0
0,020	0,03	0,010	0	0	0
0,030	0,04	0,010	0	0	0
0,040	0,05	0,010	0	0	0
0,050	0,06	0,010	0	0	0
0,060	0,07	0,010	0	0	0
0,070	0,08	0,010	0	0	0
0,080	0,09	0,010	0	0	0
0,090	0,10	0,010	0	0	0
0,100	0,11	0,010	0	0	0
0,110	0,12	0,010	0	0	0
0,120	0,13	0,010	0	0	0
0,130	0,14	0,010	0	0	0
0,140	0,15	0,010	0	0	0
0,150	0,16	0,010	0	0	0
0,160	0,17	0,010	0	0	0
0,170	0,18	0,010	0	0	0
0,180	0,19	0,010	0	0	0
0,190	0,20	0,010	0	0	0
0,200	0,21	0,010	0	0	0
0,210	0,22	0,010	0	0	0
0,220	0,23	0,010	0	0	0
0,230	0,24	0,010	0	0	0
0,240	0,25	0,010	0	0	0
0,250	0,26	0,010	0	0	0
0,260	0,27	0,010	0	0	0
0,270	0,28	0,010	0	0	0
0,280	0,29	0,010	0	0	0
0,290	0,30	0,010	0	0	0
0,300	0,31	0,010	0	0	0
0,310	0,32	0,010	0	0	0
0,320	0,33	0,010	0	0	0
0,330	0,34	0,010	0	0	0
0,340	0,35	0,010	0	0	0
0,350	0,36	0,010	0	0	0
0,360	0,37	0,010	0	0	0
0,370	0,38	0,010	0	0	0
0,380	0,39	0,010	0	0	0
0,390	0,40	0,010	0	0	0
0,400	0,41	0,010	0	0	0

Depth from

$$z_{from\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{i\_cptux}) - 1 \\ \quad z_{from\_cptu_i} \leftarrow z_{from\_cptux_i} \text{ if } z_{to\_cptux_i} \neq 0 \\ z_{from\_cptu} \cdot m \end{array} \right.$$

Depth to

$$z_{to\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{i\_cptux}) - 1 \\ \quad z_{to\_cptu_i} \leftarrow z_{to\_cptux_i} \text{ if } z_{to\_cptux_i} \neq 0 \\ z_{to\_cptu} \cdot m \end{array} \right.$$

Thickness of each layer

$$z_{i\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{i\_cptux}) - 1 \\ \quad z_{i\_cptu_i} \leftarrow z_{i\_cptux_i} \text{ if } z_{to\_cptux_i} \neq 0 \\ z_{i\_cptu} \cdot m \end{array} \right.$$

Uncorrected tip resistance

$$q_{c\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{c\_cptu_i} \leftarrow q_{c\_cptux_i} \\ q_{c\_cptu} \cdot kPa \end{array} \right.$$

Uncorrected sleeve resistance

$$f_{s\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad f_{s\_cptu_i} \leftarrow f_{c\_cptux_i} \\ f_{s\_cptu} \cdot kPa \end{array} \right.$$

Measured pore water pressure

$$u_{cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad u_{cptu_i} \leftarrow u_{cptux_i} \\ u_{cptu} \cdot kPa \end{array} \right.$$

Effective vertical stress at depth of each cpt measurement

$$\sigma'_{v\_bottom\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad \sigma'_{v\_bottom\_cptu_i} \leftarrow \text{linterp}\left(z_{to\_split}, \sigma'_{v\_bottom\_split}, z_{to\_cptu_i}\right) \\ \sigma'_{v\_bottom\_cptu} \end{array} \right.$$

Total vertical stress at depth of each cpt measurement

$$\sigma_{v\_bottom\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad \sigma_{v\_bottom\_cptu_i} \leftarrow \text{linterp}\left(z_{to\_split}, \sigma_{v\_bottom\_split}, z_{to\_cptu_i}\right) \\ \sigma_{v\_bottom\_cptu} \end{array} \right.$$

Water pressure in soil at depth of each cpt measurement

$$u_{0\_bottom\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad u_{0\_bottom\_cptu_i} \leftarrow \text{linterp}\left(z_{to\_split}, u_{0\_bottom\_split}, z_{to\_cptu_i}\right) \\ u_{0\_bottom\_cptu} \end{array} \right.$$

Corrected tip resistance

$$q_{T\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{T\_cptu_i} \leftarrow q_{c\_cptu_i} + u_{cptu_i} \cdot \left(1 - a_n\right) \\ q_{T\_cptu} \end{array} \right.$$

Corrected sleeve resistance

$$f_{T\_cptu} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad f_{T\_cptu_i} \leftarrow f_{s\_cptu_i} - u_{cptu_i} \cdot b_n \\ f_{T\_cptu} \end{array} \right.$$

Normalized cone resistance

$$Q_t := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad Q_{t_i} \leftarrow \dfrac{q_{T\_cptu_i} - \sigma_{v\_bottom\_cptu_i}}{\sigma'_{v\_bottom\_cptu_i}} \\ Q_t \end{array} \right.$$

Normalized friction ratio

$$F_r := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad F_{r_i} \leftarrow \dfrac{f_{T\_cptu_i}}{q_{T\_cptu_i} - \sigma_{v\_bottom\_cptu_i}} \cdot 100 \\ F_r \end{array} \right.$$

$$p_{atm} := 100\text{kPa}$$

This works for sands ony

$$Q_n := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad Q_{n_i} \leftarrow \dfrac{q_{T\_cptu_i} - \sigma_{v\_bottom\_cptu_i}}{p_{atm}} \cdot \left(\dfrac{p_{atm}}{\sigma'_{v\_bottom\_cptu_i}} \right)^{0.5} \\ Q_n \end{array} \right.$$

Soil type index

$$I_c := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad I_{c_i} \leftarrow \left| \begin{array}{ll} \left[\left(3.47 - \log\left(Q_{n_i}\right)\right)^2 + \left(1.22 + \log\left(F_{r_i}\right)\right)^2 \right]^{0.5} & \text{if } Q_{n_i} > 0 \wedge F_{r_i} > 0 \\ 0 & \text{otherwise} \end{array} \right. \\ I_c \end{array} \right.$$

$$C_{FC} := 0$$

$$\text{Fine\_content} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}\left(z_{to\_cptu}\right) - 1 \\ \quad \text{Fine\_content}_i \leftarrow \left| \begin{array}{ll} 0 & \text{if } 80 \cdot \left(I_{c_i} + C_{FC}\right) - 137 \le 0 \\ 80 \cdot \left(I_{c_i} + C_{FC}\right) - 137 & \text{if } 0 < 80 \cdot \left(I_{c_i} + C_{FC}\right) - 137 < 100 \\ 100 & \text{if } 80 \cdot \left(I_{c_i} + C_{FC}\right) - 137 \ge 100 \end{array} \right. \\ \text{Fine\_content} \end{array} \right.$$

Cone resistance

$$q_{cN} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{cN_i} \leftarrow \dfrac{q_{c\_cptu_i}}{p_{atm}} \\ q_{cN} \end{array} \right.$$

Vertical stress

$$\sigma'_{v\_bottom\_cptu\_N} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{cN_i} \leftarrow \dfrac{\sigma'_{v\_bottom\_cptu_i}}{p_{atm}} \\ q_{cN} \end{array} \right.$$

$$C_{FC} := 0$$

Fine content

$$FC := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad FC_i \leftarrow \left| \begin{array}{l} 0 \text{ if } 80\cdot\left(I_{c_i} + C_{FC}\right) - 137 \le 0 \\ 80\cdot\left(I_{c_i} + C_{FC}\right) - 137 \text{ if } 0 < 80\cdot\left(I_{c_i} + C_{FC}\right) - 137 < 100 \\ 100 \text{ if } 80\cdot\left(I_{c_i} + C_{FC}\right) - 137 \ge 100 \end{array} \right. \\ FC \end{array} \right.$$

k - term

$$k_{term} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad k_{term_i} \leftarrow e^{\left[1.63 - \frac{9.7}{FC+2} - \left(\frac{15.7}{FC+2}\right)^2\right]} \\ k_{term} \end{array} \right.$$

m - parameter

$$m_{parameter}(q_{c1Ncs}) := 1.338 - 0.249\cdot(q_{c1Ncs})^{0.264}$$

Definition of CN

$$C_N(q_{c1Ncs}) := \left| \begin{array}{l} \left(\dfrac{100kPa}{\sigma'_{v\_bottom\_cptu}}\right)^{m_{parameter}(q_{c1Ncs})} \text{ if } \left(\dfrac{100kPa}{\sigma'_{v\_bottom\_cptu}}\right)^{m_{parameter}(q_{c1Ncs})} \le 1.7 \\ 1.7 \text{ if } \left(\dfrac{100kPa}{\sigma'_{v\_bottom\_cptu}}\right)^{m_{parameter}(q_{c1Ncs})} > 1.7 \end{array} \right.$$

Definition of qc1N

$$q_{c1N}(q_{c1Ncs}) := C_N(q_{c1Ncs})\cdot q_{cN}$$

Initial guesses:

$$q_{c1Ncs} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{c1Ncs_i} \leftarrow 200 \\ q_{c1Ncs} \end{array} \right.$$

$$\Delta q_{c1N} := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad \Delta q_{c1N_i} \leftarrow 0.5 \\ \Delta q_{c1N} \end{array} \right.$$

Given

$$q_{c1Ncs} = q_{c1N}(q_{c1Ncs}) + \Delta q_{c1N}$$

$$\Delta q_{c1N} = \left(11.9 + \frac{q_{c1N}(q_{c1Ncs})}{14.6}\right) \cdot k_{term}$$

$$\begin{pmatrix} q_{c1Ncs} \\ \Delta q_{c1N} \end{pmatrix} := \text{Find}(q_{c1Ncs}, \Delta q_{c1N})$$

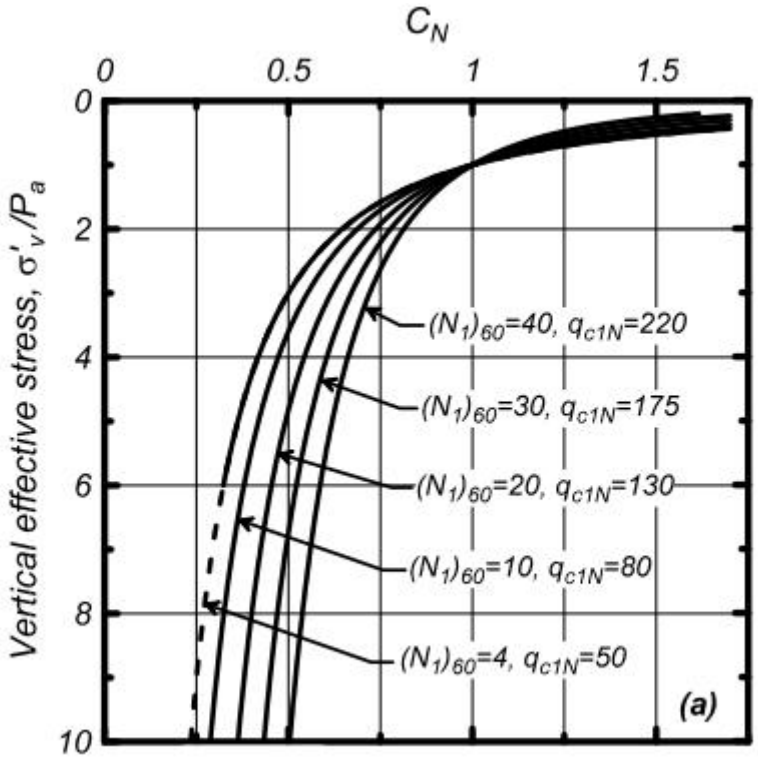
$$\begin{pmatrix} q_{c1Ncs} \\ \Delta q_{c1N} \end{pmatrix} = \blacksquare$$

$$q_{c1Ncs}(q_{c1Ncs}, \Delta q_{c1N}) := \left| \begin{array}{l} \text{for } i \in 0..\text{rows}(z_{to\_cptu}) - 1 \\ \quad q_{c1Ncs_i} \leftarrow \text{Find}(q_{c1Ncs}, \Delta q_{c1N}) \\ q_{c1Ncs} \end{array} \right.$$

The sheet should compute q_{c1Ncs} C_N and q_{c1N} for all rows of qcN

$$C_N(q_{c1Ncs}) = \blacksquare$$

$$q_{c1N}(q_{c1Ncs}) = \blacksquare$$


C_N
0
0.5
1
1.5
0
2
4
6
8
10
Vertical effective stress, σ'_v/P_a
$(N_1)_{60}$=40, q_{c1N}=220
$(N_1)_{60}$=30, q_{c1N}=175
$(N_1)_{60}$=20, q_{c1N}=130
$(N_1)_{60}$=10, q_{c1N}=80
$(N_1)_{60}$=4, q_{c1N}=50
(a)