Addendum for Report NPR 9998 for liquefaction and foundations

To
NEN
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tbv TG2

Date	**Our reference**		**Number of pages**
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Subject
NPR 9998, liquefaction in webtool V6, starting points

1 Introduction

Liquefaction was included in the NPR 9998:2018 (nl) and in the webtool https://seismischekrachten.nen.nl/. The general calculation procedure for LPI_{ish} is described in NPR 9998:2018 (nl) and details of the application of the model for the hazard version V5 are given in the Deltares report “NPR-9998 for liquefaction and foundations - background document for NPR2018”, 1208782-007-GEO-0004, 20 August 2018.

The webtool has now been updated to hazard version V6. This addendum describes the additional starting points and assumptions for the calculation of LPI_{ish} for the webtool release of August 2020 (hazard version V6) as some of the parameters of the calculation need to be simplified for a field wide approach and some parameters are not defined in detail in NPR9998:2018.

2 Approaches used

Basis for the calculation of LPI_{ish} are the methods described in NOR9998:2018. Not all aspects are described in full detail in NPR9998:2018. The assumptions used in the calculation of LPI_{ish} are listed in this section. Changes in assumptions between 2018 and 2020 are indicated.

2.1 Unit weight of the soil

The unit weight of the soil is assessed from the I_c value. The following values are used in the 2020 calculations:

- $I_c < 2.6$: assumed to be sand with a unit dry weight of $\gamma_{dry} = 17$ kN/m^3 and unit saturated weight of $\gamma_{sat} = 20$ kN/m^3
- $2.6 \leq I_c < 3.6$: assumed to be clay with $\gamma = 16$ kN/m^3
- $I_c \geq 3.6$: assumed to be peat with $\gamma = 11$ kN/m^3

2.2 Missing data near surface (CPT’s with pre-drill)

For a significant number of CPT’s in the database predrilling was used, see Figure 1. This was done to avoid hitting cables or pipelines during performing the CPT. In such cases part of the near surface data are missing. For the determination of the vertical stresses the following is assumed:

- unit weight $\gamma = 15$ kN/m^3

It is assumed that the predrilled layer can not liquefy. This assumption implies that the predrilled layers are considered to be part of the non-liquefied crust and therefore do not contribute to the

value of LPI_{ish}. For low values of pre-drilling (e.g. < 0.5 m) this is considered a valid assumption, because the predrilling is generally above the groundwater table. For larger values of pre-drilling this assumption is not always correct. This may result in an underestimation of LPI_{ish} for the considered location.

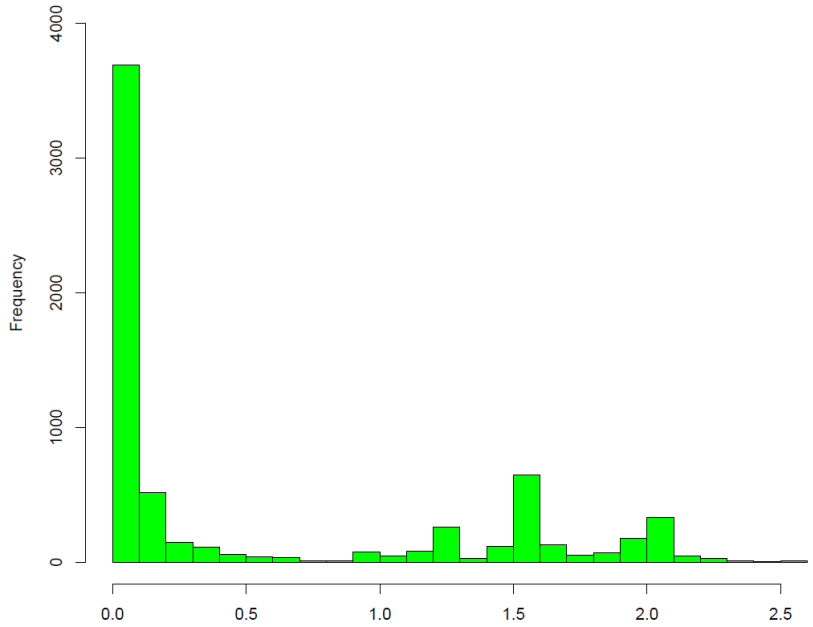

Figure 2.1 Distribution of depths of pre-drilling for the current database (2020)

2.3 Fines Content correction

The Fines Content (*FC*) is estimated from the I_c value as follows:

- $I_c < 2.05$: $FC = 0\%$
- $2.05 \leq I_c < 2.6$: $FC = 20\%$
- $I_c \geq 2.6$: no liquefaction, value of FC irrelevant

In the 2018 version of the webtool, the empirical relation from Boulanger and Idriss (2014) was used:
$FC = \max(0;\ 80 \cdot I_c - 137)$

The 2020 approach is consistent with recommended approach described in NPR9998:2018 in case no local FC measurements are available.

2.4 Groundwater table

The groundwater table is taken from the MIPWA model (https://publicwiki.deltares.nl/display/MIPWA/MIPWA).

The average of the GLG (gemiddeld laagste grondwaterstand = average lowest groundwater table) and GHG (gemiddeld hoogste grondwaterstand = average highest groundwater table) were used.

2.5 Normalized cone resistance

The normalized cone resistance with stress level is given by equation D.20 in NPR9998:2018, with a power m that depends on the normalized cone resistance for clean sand. In the LPI_{ish} calculation,

the power m in this expression is simplified and assumed to have a constant value of m = 0.5. For low values of the normalized cone resistance $q_{c1N,cs}$ ($q_{c1N.cs}$ < 110) the effect is negligible (Figure 2.2). For high normalized cone resistances this value is considered a reasonable estimate of the real m value.

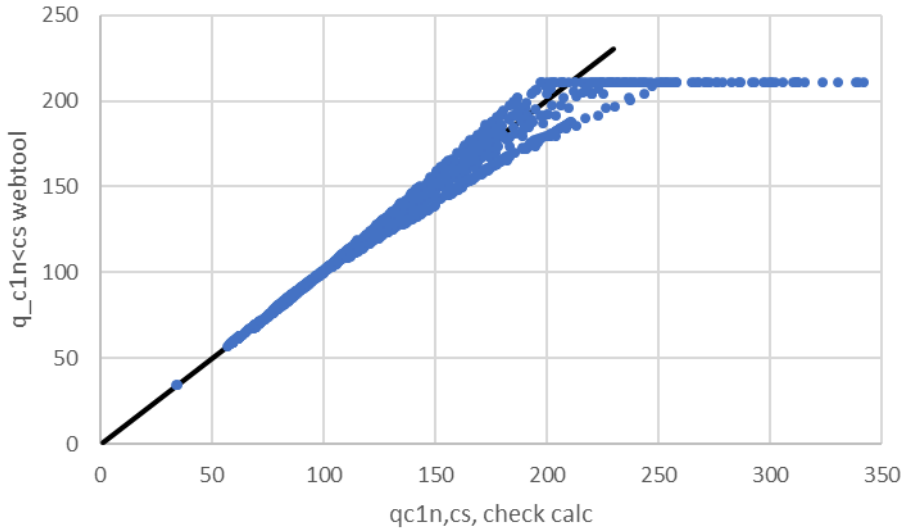

Figure 2.2 Comparison normalized cone resistance with m = 0.5 and with m according to equation D.20 of NPR9998:2018.

2.6 Top of Pleistocene

The top of the Pleistocene is assumed to be the base of the Naaldwijk formation. The depth of the base of this formation is taken from GeoTOP, version 01r3, May 2019. (https://www.dinoloket.nl/ondergrondmodellen).

2.7 Thin layer correction

No thin layer correction has been applied.

2.8 Transition zone

No correction for the cone resistance at the transition zone between sand and cohesive (clay, peat) layers has been used.

2.9 Thickness H1 of non-liquefied crust

The thickness of the non-liquefied crust is taken as the depth of the first point with γ_L < 1. Cohesive layers (I_c > 2.6) and sand above the groundwater table are assumed to be not liquefiable. This corresponds to a factor of safety against liquefaction (γ_L) above 1 for these layers.

3 References

Boulanger, R.W. & I.M. Idriss (2014). CPT and SPT based liquefaction triggering procedures. Report No. UCD/CGM-14/01, Center for Geotechnical Modeling, Department of Civil and Environmental Engineering, University of California at Davis, 134 pp.

Deltares (2018) “NPR-9998 for liquefaction and foundations - background document for NPR2018”, Deltares report 1208782-007-GEO-0004, 20 August 2018

GeoTOP:
https://www.dinoloket.nl/ondergrondmodellen

MIPWA model: https://publicwiki.deltares.nl/display/MIPWA/MIPWA

NEN (2018). NPR 9998:2018+C1:2020 nl Beoordeling van de constructieve veiligheid van een gebouw bij nieuwbouw, verbouw en afkeuren - Geïnduceerde aardbevingen - Grondslagen, belastingen en weerstanden

Webtool NPR 9998: https://seismischekrachten.nen.nl/

Doc. version	Author	Reviewer	Approver	Publish
1.0	Piet Meijers	Pauline Kruiver	Leo Voogt b/a H. Aantjes	July 2020