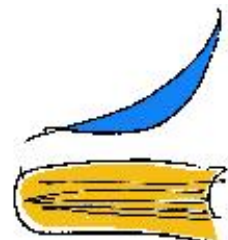


Liquefaction Assessment Report

PEYSANJ 3.0 **geotechnical engineering software**

Developer: Alireza Afkhami (MSc, MCP, ICDL)
www.afkhami.com



ABCD Consulting Engineers

Project : Storage building
Client : North vancouver, BC
Location : BDT08 - 1
Code : 108-2254



PGA max : 0.455
M=7
Method : NCEER
Workshop (1996)

Water Level (m) : 6

Required FS : 1

Soil layers

Layer (m)

0 to 35

Properties

D50=0.1 cm

g=1.85 gr/cm³

SPT data

Depth (m)

0.3048

SPT N value

32

0.6096

35

0.9144

28

1.2192

19

1.524

9

1.8288

8

2.1336

7

2.4384

3

2.7432

7

3.048

15

3.3528

61

3.6576

61

3.9624

61

4.2672

74

4.572

45

4.8768

43

5.1816

48

5.4864

48

5.7912

43

6.096

45

6.4008

37

6.7056

41

7.0104

39

7.3152

19

7.62

28

7.9248

26

8.2296

32

8.5344

35

8.8392

35

9.144

35

9.4488

35

9.7536

37

10.0584

35

10.3632

32

10.668

30

10.9728

28

11.2776

32

11.5824

35

11.8872

35

12.192

30

12.4968

32



ABCD Consulting Engineers

Project : Storage building
Client : North vancouver, BC
Location : BDT08 - 1
Code : 108-2254



12.8016	32
13.1064	41
13.4112	43
13.716	43
14.0208	30
14.3256	32
14.6304	24
14.9352	24
15.24	22
15.5448	22
15.8496	22
16.1544	15
16.4592	17
16.764	24
17.0688	9
17.3736	7
17.6784	9
17.9832	24
18.288	32
18.5928	35
18.8976	37
19.2024	30
19.5072	28
19.812	26
20.1168	19
20.4216	28
20.7264	28
21.0312	26
21.336	26
21.6408	24
21.9456	26
22.2504	32
22.5552	26
22.86	28
23.1648	28
23.4696	22
23.7744	22
24.0792	22
24.384	22
24.6888	32
24.9936	28
25.2984	32
25.6032	37
25.908	39
26.2128	43
26.5176	28
26.8224	19
27.1272	13
27.432	9



ABCD Consulting Engineers

Project : Storage building
Client : North vancouver, BC
Location : BDT08 - 1
Code : 108-2254



27.7368	9
28.0416	17
28.3464	15
28.6512	15
28.956	24
29.2608	32
29.5656	32
29.8704	28
30.1752	26



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



Z=0.3 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 2$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 48$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 48$:

Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$

SPT (N) = 32

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.998$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.06 / 0.06 * 0.998 = 0.295$

Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.295 * 1.08 * 1 = 2.563$

Z=0.6 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 2$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 52.5$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 52.5$:

Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$

SPT (N) = 35

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.995$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.11 / 0.11 * 0.995 = 0.294$

Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.294 * 1.08 * 1 = 2.569$

Z=0.9 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 2$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 42$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 42$:

Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$

SPT (N) = 28

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.993$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.17 / 0.17 * 0.993 = 0.294$

Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.294 * 1.08 * 1 = 2.575$

Z=1.2 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 2$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 28.5$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 28.5$:

Cyclic Resistance Ratio $CRR = 0.37$

SPT (N) = 19

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.991$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.23 / 0.23 * 0.991 = 0.293$

Safety Factor = $CRR / CSR * MSF * K = 0.37 / 0.293 * 1.08 * 1 = 1.363$

Z=1.5 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 1.883$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 12.7$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 12.7$:

Cyclic Resistance Ratio $CRR = 0.138$

SPT (N) = 9

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.988$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.28 / 0.28 * 0.988 = 0.292$

Safety Factor = $CRR / CSR * MSF * K = 0.138 / 0.292 * 1.08 * 1 = 0.511$

Z=1.8 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 1.719$$

$$C_r = 0.75, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 10.3$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 10.3$:

Cyclic Resistance Ratio $CRR = 0.113$

SPT (N) = 8

Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.986$

Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 0.34 / 0.34 * 0.986 = 0.292$

Safety Factor = $CRR / CSR * MSF * K = 0.113 / 0.292 * 1.08 * 1 = 0.418$

Z=2.1 m :



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.592$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 8.4$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 8.4$:
Cyclic Resistance Ratio $CRR = 0.092$
SPT (N) = 7
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.984$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.39 / 0.39 * 0.984 = 0.291$
Safety Factor = $CRR / CSR * MSF * K = 0.092 / 0.291 * 1.08 * 1 = 0.341$

Z = 2.4 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.489$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 3.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 3.3$:
Cyclic Resistance Ratio $CRR = 0.061$
SPT (N) = 3
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.981$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.45 / 0.45 * 0.981 = 0.29$
Safety Factor = $CRR / CSR * MSF * K = 0.061 / 0.29 * 1.08 * 1 = 0.227$

Z = 2.7 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.404$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 7.4$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 7.4$:
Cyclic Resistance Ratio $CRR = 0.082$
SPT (N) = 7
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.979$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.51 / 0.51 * 0.979 = 0.29$
Safety Factor = $CRR / CSR * MSF * K = 0.082 / 0.29 * 1.08 * 1 = 0.307$

Z = 3 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.332$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 15$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 15$:
Cyclic Resistance Ratio $CRR = 0.16$
SPT (N) = 15
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.977$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.56 / 0.56 * 0.977 = 0.289$
Safety Factor = $CRR / CSR * MSF * K = 0.16 / 0.289 * 1.08 * 1 = 0.6$

Z = 3.4 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.27$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 58.1$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 58.1$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$
SPT (N) = 61
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.974$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.62 / 0.62 * 0.974 = 0.288$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.288 * 1.08 * 1 = 2.624$

Z = 3.7 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.216$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 55.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 55.6$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$
SPT (N) = 61
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.972$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.68 / 0.68 * 0.972 = 0.287$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.287 * 1.08 * 1 = 2.63$

Z = 4 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.168$
 $C_r = 0.75$, $C_b = 1$, $C_s = 1$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



$N_{cor} = C_n * C_r * C_s * C_b * N = 53.4$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=53.4$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=61
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.97$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.73 / 0.73 * 0.97 = 0.287$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.287 * 1.08 * 1 = 2.637$

Z=4.3 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.125$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 70.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=70.8$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=74
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.967$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.79 / 0.79 * 0.967 = 0.286$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.286 * 1.08 * 1 = 2.643$

Z=4.6 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.087$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 41.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=41.6$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=45
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.965$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.85 / 0.85 * 0.965 = 0.285$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.285 * 1.08 * 1 = 2.649$

Z=4.9 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.053$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 38.5$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=38.5$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=43
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.963$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.9 / 0.9 * 0.963 = 0.285$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.285 * 1.08 * 1 = 2.656$

Z=5.2 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 1.021$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 41.7$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=41.7$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=48
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.96$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 0.96 / 0.96 * 0.96 = 0.284$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.284 * 1.08 * 1 = 2.662$

Z=5.5 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.993$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 40.5$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=40.5$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=48
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1 - 0.00765 * Z = 0.958$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 1.01 / 1.01 * 0.958 = 0.283$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.283 * 1.08 * 0.998 = 2.663$

Z=5.8 m :

$C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.966$
 $C_r = 0.85$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 35.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :





:: 'NCEER Workshop (1996)' for $N_{cor}=35.3$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=43
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.956$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.07/1.07*0.956=0.283$
Safety Factor = $CRR/CSR*MSF*K = 0.7/0.283*1.08*0.989 = 2.645$

Z=6.1 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.945$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 40.4$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=40.4$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=45
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.953$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.13/1.12*0.953=0.284$
Safety Factor = $CRR/CSR*MSF*K = 0.7/0.284*1.08*0.981 = 2.613$

Z=6.4 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.931$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 32.7$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=32.7$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=37
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.951$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.18/1.15*0.951=0.289$
Safety Factor = $CRR/CSR*MSF*K = 0.7/0.289*1.08*0.976 = 2.555$

Z=6.7 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.918$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 35.7$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=35.7$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=41
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.949$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.24/1.19*0.949=0.293$
Safety Factor = $CRR/CSR*MSF*K = 0.7/0.293*1.08*0.97 = 2.502$

Z=7 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.905$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 33.5$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=33.5$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR=0.7$
SPT (N)=39
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.946$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.3/1.22*0.946=0.297$
Safety Factor = $CRR/CSR*MSF*K = 0.7/0.297*1.08*0.965 = 2.454$

Z=7.3 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.893$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 16.1$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=16.1$:
Cyclic Resistance Ratio $CRR=0.172$
SPT (N)=19
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.944$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.35/1.25*0.944=0.301$
Safety Factor = $CRR/CSR*MSF*K = 0.172/0.301*1.08*0.96 = 0.591$

Z=7.6 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.882$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 23.4$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=23.4$:
Cyclic Resistance Ratio $CRR=0.267$

ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



SPT (N)=28
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.942$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.41/1.29*0.942=0.305$
Safety Factor = $CRR/CSR*MSF*K = 0.267/0.305*1.08*0.955 = 0.902$

Z=7.9 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.87$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 21.5$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=21.5$:
Cyclic Resistance Ratio $CRR=0.241$
SPT (N)=26
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.939$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.47/1.32*0.939=0.309$
Safety Factor = $CRR/CSR*MSF*K = 0.241/0.309*1.08*0.951 = 0.802$

Z=8.2 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.86$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 26.1$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=26.1$:
Cyclic Resistance Ratio $CRR=0.297$
SPT (N)=32
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.937$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.52/1.35*0.937=0.312$
Safety Factor = $CRR/CSR*MSF*K = 0.297/0.312*1.08*0.946 = 0.973$

Z=8.5 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.849$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 28.2$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=28.2$:
Cyclic Resistance Ratio $CRR=0.355$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.935$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.58/1.39*0.935=0.315$
Safety Factor = $CRR/CSR*MSF*K = 0.355/0.315*1.08*0.941 = 1.147$

Z=8.8 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.839$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 27.9$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=27.9$:
Cyclic Resistance Ratio $CRR=0.34$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.932$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.64/1.42*0.932=0.318$
Safety Factor = $CRR/CSR*MSF*K = 0.34/0.318*1.08*0.937 = 1.083$

Z=9.1 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.83$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 27.6$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=27.6$:
Cyclic Resistance Ratio $CRR=0.328$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.93$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*1.69/1.45*0.93=0.32$
Safety Factor = $CRR/CSR*MSF*K = 0.328/0.32*1.08*0.932 = 1.032$

Z=9.4 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.82$
 $C_r=0.95$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 27.3$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=27.3$:
Cyclic Resistance Ratio $CRR=0.319$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1-0.00765*Z=0.922$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*1.75/1.49*0.922=0.321$
Safety Factor = $CRR/CSR*MSF*K = 0.319/0.321*1.08*0.928 = 0.997$

Z=9.8 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.811$
 $Cr=0.95$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 28.5$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=28.5$:
Cyclic Resistance Ratio $CRR=0.37$
SPT (N)=37
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.914$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*1.8/1.52*0.914=0.321$
Safety Factor = $CRR/CSR*MSF*K = 0.37/0.321*1.08*0.923 = 1.152$

Z=10.1 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.802$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 28.1$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=28.1$:
Cyclic Resistance Ratio $CRR=0.348$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.905$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*1.86/1.55*0.905=0.321$
Safety Factor = $CRR/CSR*MSF*K = 0.348/0.321*1.08*0.919 = 1.076$

Z=10.4 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.794$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 25.4$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=25.4$:
Cyclic Resistance Ratio $CRR=0.288$
SPT (N)=32
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.897$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*1.92/1.59*0.897=0.321$
Safety Factor = $CRR/CSR*MSF*K = 0.288/0.321*1.08*0.915 = 0.887$

Z=10.7 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.786$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 23.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=23.6$:
Cyclic Resistance Ratio $CRR=0.268$
SPT (N)=30
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.889$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*1.97/1.62*0.889=0.32$
Safety Factor = $CRR/CSR*MSF*K = 0.268/0.32*1.08*0.911 = 0.823$

Z=11 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.778$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 21.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=21.8$:
Cyclic Resistance Ratio $CRR=0.245$
SPT (N)=28
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.881$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*2.03/1.65*0.881=0.32$
Safety Factor = $CRR/CSR*MSF*K = 0.245/0.32*1.08*0.907 = 0.749$

Z=11.3 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.77$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 24.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=24.6$:
Cyclic Resistance Ratio $CRR=0.28$
SPT (N)=32
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.873$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*2.09/1.69*0.873=0.319$
Safety Factor = $CRR/CSR*MSF*K = 0.28/0.319*1.08*0.903 = 0.854$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



Z=11.6 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.763$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 26.7$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 26.7$:

$$\text{Cyclic Resistance Ratio CRR} = 0.306$$

$$\text{SPT (N)} = 35$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.865$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.14 / 1.72 * 0.865 = 0.319$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.306 / 0.319 * 1.08 * 0.899 = 0.932$$

Z=11.9 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.755$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 26.4$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 26.4$:

$$\text{Cyclic Resistance Ratio CRR} = 0.301$$

$$\text{SPT (N)} = 35$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.857$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.2 / 1.75 * 0.857 = 0.318$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.301 / 0.318 * 1.08 * 0.895 = 0.917$$

Z=12.2 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.748$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 22.4$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 22.4$:

$$\text{Cyclic Resistance Ratio CRR} = 0.254$$

$$\text{SPT (N)} = 30$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.848$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.26 / 1.79 * 0.848 = 0.317$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.254 / 0.317 * 1.08 * 0.891 = 0.771$$

Z=12.5 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.741$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 23.7$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 23.7$:

$$\text{Cyclic Resistance Ratio CRR} = 0.27$$

$$\text{SPT (N)} = 32$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.84$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.31 / 1.82 * 0.84 = 0.316$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.27 / 0.316 * 1.08 * 0.887 = 0.819$$

Z=12.8 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.735$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 23.5$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 23.5$:

$$\text{Cyclic Resistance Ratio CRR} = 0.267$$

$$\text{SPT (N)} = 32$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.832$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.37 / 1.85 * 0.832 = 0.315$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.267 / 0.315 * 1.08 * 0.884 = 0.811$$

Z=13.1 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.728$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 29.9$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 29.9$:

$$\text{Cyclic Resistance Ratio CRR} = 0.499$$

$$\text{SPT (N)} = 41$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.824$$

$$\text{Cyclic Stress Ratio CSR} = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 2.42 / 1.89 * 0.824 = 0.313$$

$$\text{Safety Factor} = \text{CRR} / \text{CSR} * \text{MSF} * K = 0.499 / 0.313 * 1.08 * 0.88 = 1.514$$

Z=13.4 m :



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



$C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.722$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 31$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 31$:
Cyclic Resistance Ratio $CRR > 0.7$, Consider $CRR = 0.7$
SPT (N) = 43
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.816$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.48 / 1.92 * 0.816 = 0.312$
Safety Factor = $CRR / CSR * MSF * K = 0.7 / 0.312 * 1.08 * 0.876 = 2.124$

Z = 13.7 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.716$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 30.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 30.8$:
Cyclic Resistance Ratio $CRR = 0.668$
SPT (N) = 43
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.808$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.54 / 1.95 * 0.808 = 0.31$
Safety Factor = $CRR / CSR * MSF * K = 0.668 / 0.31 * 1.08 * 0.873 = 2.028$

Z = 14 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.71$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 21.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 21.3$:
Cyclic Resistance Ratio $CRR = 0.238$
SPT (N) = 30
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.8$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.59 / 1.99 * 0.8 = 0.309$
Safety Factor = $CRR / CSR * MSF * K = 0.238 / 0.309 * 1.08 * 0.869 = 0.723$

Z = 14.3 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.704$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 22.5$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 22.5$:
Cyclic Resistance Ratio $CRR = 0.255$
SPT (N) = 32
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.792$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.65 / 2.02 * 0.792 = 0.307$
Safety Factor = $CRR / CSR * MSF * K = 0.255 / 0.307 * 1.08 * 0.866 = 0.776$

Z = 14.6 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.698$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 16.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 16.8$:
Cyclic Resistance Ratio $CRR = 0.179$
SPT (N) = 24
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.783$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.71 / 2.05 * 0.783 = 0.306$
Safety Factor = $CRR / CSR * MSF * K = 0.179 / 0.306 * 1.08 * 0.862 = 0.544$

Z = 14.9 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.692$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 16.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 16.6$:
Cyclic Resistance Ratio $CRR = 0.177$
SPT (N) = 24
Stress reduction factor after 'Liao & Whitman (1986)' $R_d = 1.174 - 0.0267 * Z = 0.775$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'v * R_d = 0.65 * 0.46 * 2.76 / 2.09 * 0.775 = 0.304$
Safety Factor = $CRR / CSR * MSF * K = 0.177 / 0.304 * 1.08 * 0.859 = 0.541$

Z = 15.2 m :
 $C_n = (1/S'v)^{0.5} < 2$, $C_n = 0.687$
 $C_r = 1$, $C_b = 1$, $C_s = 1$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



$N_{cor} = C_n * C_r * C_s * C_b * N = 15.1$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=15.1$:
Cyclic Resistance Ratio $CRR=0.162$
SPT (N)=22
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.767$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*2.82/2.12*0.767=0.302$
Safety Factor = $CRR/CSR*MSF*K = 0.162/0.302*1.08*0.856 = 0.495$

Z=15.5 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.682$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 15$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=15$:
Cyclic Resistance Ratio $CRR=0.161$
SPT (N)=22
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.759$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*2.88/2.15*0.759=0.3$
Safety Factor = $CRR/CSR*MSF*K = 0.161/0.3*1.08*0.853 = 0.493$

Z=15.8 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.676$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 14.9$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=14.9$:
Cyclic Resistance Ratio $CRR=0.159$
SPT (N)=22
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.751$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*2.93/2.19*0.751=0.298$
Safety Factor = $CRR/CSR*MSF*K = 0.159/0.298*1.08*0.849 = 0.491$

Z=16.2 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.671$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 10.1$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=10.1$:
Cyclic Resistance Ratio $CRR=0.11$
SPT (N)=15
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.743$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*2.99/2.22*0.743=0.296$
Safety Factor = $CRR/CSR*MSF*K = 0.11/0.296*1.08*0.846 = 0.34$

Z=16.5 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.666$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 11.3$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=11.3$:
Cyclic Resistance Ratio $CRR=0.124$
SPT (N)=17
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.735$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.04/2.25*0.735=0.294$
Safety Factor = $CRR/CSR*MSF*K = 0.124/0.294*1.08*0.843 = 0.384$

Z=16.8 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.662$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 15.9$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=15.9$:
Cyclic Resistance Ratio $CRR=0.169$
SPT (N)=24
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.726$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.1/2.29*0.726=0.292$
Safety Factor = $CRR/CSR*MSF*K = 0.169/0.292*1.08*0.84 = 0.527$

Z=17.1 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.657$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 5.9$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



:: 'NCEER Workshop (1996)' for $N_{cor}=5.9$:
Cyclic Resistance Ratio $CRR=0.071$
SPT (N)=9
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.718$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.16/2.32*0.718=0.289$
Safety Factor = $CRR/CSR*MSF*K = 0.071/0.289*1.08*0.837 = 0.222$

Z=17.4 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.652$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 4.6$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=4.6$:
Cyclic Resistance Ratio $CRR=0.064$
SPT (N)=7
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.71$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.21/2.35*0.71=0.287$
Safety Factor = $CRR/CSR*MSF*K = 0.064/0.287*1.08*0.834 = 0.202$

Z=17.7 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.648$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 5.8$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=5.8$:
Cyclic Resistance Ratio $CRR=0.071$
SPT (N)=9
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.702$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.27/2.39*0.702=0.285$
Safety Factor = $CRR/CSR*MSF*K = 0.071/0.285*1.08*0.831 = 0.223$

Z=18 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.643$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 15.4$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=15.4$:
Cyclic Resistance Ratio $CRR=0.165$
SPT (N)=24
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.694$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.33/2.42*0.694=0.282$
Safety Factor = $CRR/CSR*MSF*K = 0.165/0.282*1.08*0.828 = 0.523$

Z=18.3 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.639$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 20.4$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=20.4$:
Cyclic Resistance Ratio $CRR=0.226$
SPT (N)=32
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.686$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.38/2.45*0.686=0.28$
Safety Factor = $CRR/CSR*MSF*K = 0.226/0.28*1.08*0.826 = 0.719$

Z=18.6 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.634$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 22.2$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=22.2$:
Cyclic Resistance Ratio $CRR=0.251$
SPT (N)=35
Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.678$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.44/2.48*0.678=0.277$
Safety Factor = $CRR/CSR*MSF*K = 0.251/0.277*1.08*0.823 = 0.803$

Z=18.9 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.63$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 23.3$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=23.3$:
Cyclic Resistance Ratio $CRR=0.265$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



SPT (N)=37

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.669$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.5/2.52*0.669=0.275$

Safety Factor = $CRR/CSR*MSF*K = 0.265/0.275*1.08*0.82 = 0.854$

Z=19.2 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.626$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 18.8$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=18.8$:

Cyclic Resistance Ratio $CRR=0.203$

SPT (N)=30

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.661$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.55/2.55*0.661=0.272$

Safety Factor = $CRR/CSR*MSF*K = 0.203/0.272*1.08*0.817 = 0.658$

Z=19.5 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.622$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 17.4$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=17.4$:

Cyclic Resistance Ratio $CRR=0.186$

SPT (N)=28

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.653$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.61/2.58*0.653=0.27$

Safety Factor = $CRR/CSR*MSF*K = 0.186/0.27*1.08*0.815 = 0.607$

Z=19.8 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.618$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 16.1$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=16.1$:

Cyclic Resistance Ratio $CRR=0.171$

SPT (N)=26

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.645$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.67/2.62*0.645=0.267$

Safety Factor = $CRR/CSR*MSF*K = 0.171/0.267*1.08*0.812 = 0.563$

Z=20.1 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.614$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 11.7$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=11.7$:

Cyclic Resistance Ratio $CRR=0.127$

SPT (N)=19

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.637$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.72/2.65*0.637=0.264$

Safety Factor = $CRR/CSR*MSF*K = 0.127/0.264*1.08*0.809 = 0.421$

Z=20.4 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.61$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 17.1$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=17.1$:

Cyclic Resistance Ratio $CRR=0.182$

SPT (N)=28

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.629$

Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*3.78/2.68*0.629=0.262$

Safety Factor = $CRR/CSR*MSF*K = 0.182/0.262*1.08*0.807 = 0.607$

Z=20.7 m :

$C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.607$

$C_r=1$, $C_b=1$, $C_s=1$

$N_{cor} = C_n*C_r*C_s*C_b*N = 17$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor}=17$:

Cyclic Resistance Ratio $CRR=0.181$

SPT (N)=28

Stress reduction factor after 'Liao & Whitman (1986)' $R_d=1.174-0.0267*Z=0.621$



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*3.83/2.72*0.621=0.259$
Safety Factor = $CRR/CSR*MSF*K = 0.181/0.259*1.08*0.804 = 0.608$

Z=21 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.603$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 15.7$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=15.7$:
Cyclic Resistance Ratio $CRR=0.167$
SPT (N)=26
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.612$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*3.89/2.75*0.612=0.256$
Safety Factor = $CRR/CSR*MSF*K = 0.167/0.256*1.08*0.802 = 0.566$

Z=21.3 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.599$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 15.6$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=15.6$:
Cyclic Resistance Ratio $CRR=0.166$
SPT (N)=26
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.604$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*3.95/2.78*0.604=0.253$
Safety Factor = $CRR/CSR*MSF*K = 0.166/0.253*1.08*0.799 = 0.567$

Z=21.6 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.596$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 14.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=14.3$:
Cyclic Resistance Ratio $CRR=0.154$
SPT (N)=24
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.596$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*4/2.82*0.596=0.251$
Safety Factor = $CRR/CSR*MSF*K = 0.154/0.251*1.08*0.797 = 0.528$

Z=21.9 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.592$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 15.4$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=15.4$:
Cyclic Resistance Ratio $CRR=0.165$
SPT (N)=26
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.588$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*4.06/2.85*0.588=0.248$
Safety Factor = $CRR/CSR*MSF*K = 0.165/0.248*1.08*0.795 = 0.57$

Z=22.3 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.589$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 18.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=18.8$:
Cyclic Resistance Ratio $CRR=0.204$
SPT (N)=32
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.58$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*4.12/2.88*0.58=0.245$
Safety Factor = $CRR/CSR*MSF*K = 0.204/0.245*1.08*0.792 = 0.712$

Z=22.6 m :

$Cn=(1/S'v)^{0.5} < 2$, $Cn=0.585$
 $Cr=1$, $Cb=1$, $Cs=1$
 $Ncor = Cn*Cr*Cs*Cb*N = 15.2$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $Ncor=15.2$:
Cyclic Resistance Ratio $CRR=0.163$
SPT (N)=26
Stress reduction factor after 'Liao & Whitman (1986)' $Rd=1.174-0.0267*Z=0.572$
Cyclic Stress Ratio $CSR=0.65*a_{max}*Sv/S'v*Rd=0.65*0.46*4.17/2.92*0.572=0.242$
Safety Factor = $CRR/CSR*MSF*K = 0.163/0.242*1.08*0.79 = 0.574$





Z=22.9 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.582$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 16.3$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 16.3$:

$$\text{Cyclic Resistance Ratio } CRR = 0.174$$

$$\text{SPT (N)} = 28$$

$$\text{Stress reduction factor after 'Liao & Whitman (1986)'} \quad R_d = 1.174 - 0.0267 * Z = 0.564$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.23 / 2.95 * 0.564 = 0.239$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.174 / 0.239 * 1.08 * 0.788 = 0.618$$

Z=23.2 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.579$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 16.2$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 16.2$:

$$\text{Cyclic Resistance Ratio } CRR = 0.173$$

$$\text{SPT (N)} = 28$$

$$\text{Stress reduction factor after 'Robertson & Wride (1996)'} \quad R_d = 0.744 - 0.008 * Z = 0.559$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.29 / 2.98 * 0.559 = 0.237$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.173 / 0.237 * 1.08 * 0.785 = 0.617$$

Z=23.5 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.576$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 12.7$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 12.7$:

$$\text{Cyclic Resistance Ratio } CRR = 0.138$$

$$\text{SPT (N)} = 22$$

$$\text{Stress reduction factor after 'Robertson & Wride (1996)'} \quad R_d = 0.744 - 0.008 * Z = 0.556$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.34 / 3.02 * 0.556 = 0.237$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.138 / 0.237 * 1.08 * 0.783 = 0.492$$

Z=23.8 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.573$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 12.6$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 12.6$:

$$\text{Cyclic Resistance Ratio } CRR = 0.137$$

$$\text{SPT (N)} = 22$$

$$\text{Stress reduction factor after 'Robertson & Wride (1996)'} \quad R_d = 0.744 - 0.008 * Z = 0.554$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.4 / 3.05 * 0.554 = 0.236$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.137 / 0.236 * 1.08 * 0.781 = 0.489$$

Z=24.1 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.569$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 12.5$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 12.5$:

$$\text{Cyclic Resistance Ratio } CRR = 0.136$$

$$\text{SPT (N)} = 22$$

$$\text{Stress reduction factor after 'Robertson & Wride (1996)'} \quad R_d = 0.744 - 0.008 * Z = 0.551$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.45 / 3.08 * 0.551 = 0.236$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.136 / 0.236 * 1.08 * 0.779 = 0.487$$

Z=24.4 m :

$$C_n = (1/S'_v)^{0.5} < 2, \quad C_n = 0.566$$

$$C_r = 1, \quad C_b = 1, \quad C_s = 1$$

$$N_{cor} = C_n * C_r * C_s * C_b * N = 12.5$$

Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :

:: 'NCEER Workshop (1996)' for $N_{cor} = 12.5$:

$$\text{Cyclic Resistance Ratio } CRR = 0.136$$

$$\text{SPT (N)} = 22$$

$$\text{Stress reduction factor after 'Robertson & Wride (1996)'} \quad R_d = 0.744 - 0.008 * Z = 0.549$$

$$\text{Cyclic Stress Ratio } CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.51 / 3.12 * 0.549 = 0.235$$

$$\text{Safety Factor} = CRR / CSR * MSF * K = 0.136 / 0.235 * 1.08 * 0.776 = 0.484$$

Z=24.7 m :





$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.563$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 18$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 18$:
Cyclic Resistance Ratio $CRR = 0.193$
SPT (N) = 32
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.546$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.57 / 3.15 * 0.546 = 0.234$
Safety Factor = $CRR / CSR * MSF * K = 0.193 / 0.234 * 1.08 * 0.774 = 0.69$

Z = 25 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.56$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 15.7$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 15.7$:
Cyclic Resistance Ratio $CRR = 0.167$
SPT (N) = 28
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.544$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.62 / 3.18 * 0.544 = 0.234$
Safety Factor = $CRR / CSR * MSF * K = 0.167 / 0.234 * 1.08 * 0.772 = 0.598$

Z = 25.3 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.558$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 17.8$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 17.8$:
Cyclic Resistance Ratio $CRR = 0.191$
SPT (N) = 32
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.542$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.68 / 3.22 * 0.542 = 0.233$
Safety Factor = $CRR / CSR * MSF * K = 0.191 / 0.233 * 1.08 * 0.77 = 0.682$

Z = 25.6 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.555$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 20.5$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 20.5$:
Cyclic Resistance Ratio $CRR = 0.227$
SPT (N) = 37
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.539$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.74 / 3.25 * 0.539 = 0.232$
Safety Factor = $CRR / CSR * MSF * K = 0.227 / 0.232 * 1.08 * 0.768 = 0.81$

Z = 25.9 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.552$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 21.5$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 21.5$:
Cyclic Resistance Ratio $CRR = 0.241$
SPT (N) = 39
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.537$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.79 / 3.28 * 0.537 = 0.232$
Safety Factor = $CRR / CSR * MSF * K = 0.241 / 0.232 * 1.08 * 0.766 = 0.861$

Z = 26.2 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.549$
 $C_r = 1$, $C_b = 1$, $C_s = 1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 23.6$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor} = 23.6$:
Cyclic Resistance Ratio $CRR = 0.268$
SPT (N) = 43
Stress reduction factor after 'Robertson & Wride (1996)' $R_d = 0.744 - 0.008 * Z = 0.534$
Cyclic Stress Ratio $CSR = 0.65 * a_{max} * S_v / S'_v * R_d = 0.65 * 0.46 * 4.85 / 3.32 * 0.534 = 0.231$
Safety Factor = $CRR / CSR * MSF * K = 0.268 / 0.231 * 1.08 * 0.764 = 0.959$

Z = 26.5 m :

$C_n = (1/S'_v)^{0.5} < 2$, $C_n = 0.546$
 $C_r = 1$, $C_b = 1$, $C_s = 1$

ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



$N_{cor} = C_n * C_r * C_s * C_b * N = 15.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=15.3$:
Cyclic Resistance Ratio $CRR=0.164$
SPT (N)=28
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.532$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*4.91/3.35*0.532=0.23$
Safety Factor = $CRR/CSR*MSF*K = 0.164/0.23*1.08*0.762 = 0.584$

Z=26.8 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.544$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 10.3$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=10.3$:
Cyclic Resistance Ratio $CRR=0.113$
SPT (N)=19
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.529$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*4.96/3.38*0.529=0.23$
Safety Factor = $CRR/CSR*MSF*K = 0.113/0.23*1.08*0.76 = 0.404$

Z=27.1 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.541$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 7$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=7$:
Cyclic Resistance Ratio $CRR=0.079$
SPT (N)=13
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.527$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*5.02/3.42*0.527=0.229$
Safety Factor = $CRR/CSR*MSF*K = 0.079/0.229*1.08*0.758 = 0.284$

Z=27.4 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.538$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 4.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=4.8$:
Cyclic Resistance Ratio $CRR=0.065$
SPT (N)=9
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.525$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*5.07/3.45*0.525=0.228$
Safety Factor = $CRR/CSR*MSF*K = 0.065/0.228*1.08*0.756 = 0.234$

Z=27.7 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.536$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 4.8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=4.8$:
Cyclic Resistance Ratio $CRR=0.065$
SPT (N)=9
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.522$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*5.13/3.48*0.522=0.227$
Safety Factor = $CRR/CSR*MSF*K = 0.065/0.227*1.08*0.754 = 0.234$

Z=28 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.533$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 9.1$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=9.1$:
Cyclic Resistance Ratio $CRR=0.099$
SPT (N)=17
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.52$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'v*R_d=0.65*0.46*5.19/3.52*0.52=0.227$
Safety Factor = $CRR/CSR*MSF*K = 0.099/0.227*1.08*0.752 = 0.356$

Z=28.3 m :
 $C_n=(1/S'v)^{0.5} < 2$, $C_n=0.531$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n * C_r * C_s * C_b * N = 8$
Correction factor K for $S'v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :



ABCD Consulting Engineers

Project : Storage building
Client : North Vancouver, BC
Location : BDT08 - 1
Code : 108-2254



:: 'NCEER Workshop (1996)' for $N_{cor}=8$:
Cyclic Resistance Ratio $CRR=0.088$
SPT (N)=15
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.517$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.24/3.55*0.517=0.226$
Safety Factor = $CRR/CSR*MSF*K = 0.088/0.226*1.08*0.75 = 0.315$

Z=28.7 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.528$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 7.9$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=7.9$:
Cyclic Resistance Ratio $CRR=0.088$
SPT (N)=15
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.515$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.3/3.58*0.515=0.225$
Safety Factor = $CRR/CSR*MSF*K = 0.088/0.225*1.08*0.748 = 0.314$

Z=29 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.526$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 12.6$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=12.6$:
Cyclic Resistance Ratio $CRR=0.137$
SPT (N)=24
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.512$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.36/3.62*0.512=0.224$
Safety Factor = $CRR/CSR*MSF*K = 0.137/0.224*1.08*0.746 = 0.493$

Z=29.3 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.523$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 16.8$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=16.8$:
Cyclic Resistance Ratio $CRR=0.178$
SPT (N)=32
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.51$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.41/3.65*0.51=0.224$
Safety Factor = $CRR/CSR*MSF*K = 0.178/0.224*1.08*0.745 = 0.642$

Z=29.6 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.521$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 16.7$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=16.7$:
Cyclic Resistance Ratio $CRR=0.178$
SPT (N)=32
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.507$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.47/3.68*0.507=0.223$
Safety Factor = $CRR/CSR*MSF*K = 0.178/0.223*1.08*0.743 = 0.639$

Z=29.9 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.519$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 14.5$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=14.5$:
Cyclic Resistance Ratio $CRR=0.156$
SPT (N)=28
Stress reduction factor after 'Robertson & Wride (1996)' $R_d=0.744-0.008*Z=0.505$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.53/3.72*0.505=0.222$
Safety Factor = $CRR/CSR*MSF*K = 0.156/0.222*1.08*0.741 = 0.562$

Z=30.2 m :
 $C_n=(1/S'_v)^{0.5} < 2$, $C_n=0.516$
 $C_r=1$, $C_b=1$, $C_s=1$
 $N_{cor} = C_n*C_r*C_s*C_b*N = 13.4$
Correction factor K for $S'_v > 1$ kg/cm² after 'Harder & Boulanger (NCEER 1996)' :
:: 'NCEER Workshop (1996)' for $N_{cor}=13.4$:
Cyclic Resistance Ratio $CRR=0.145$



ABCD Consulting Engineers

Project : Storage building
Client : North vancouver, BC
Location : BDT08 - 1
Code : 108-2254

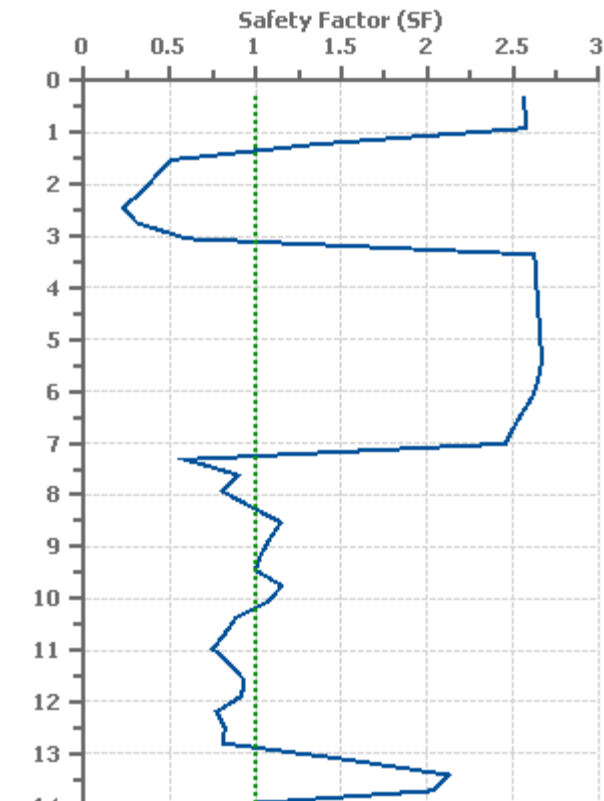
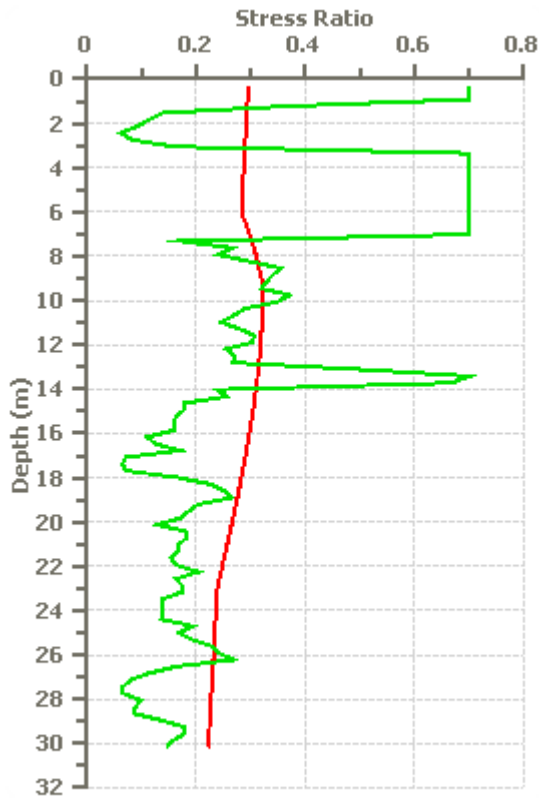


SPT (N)=26
Stress reduction factor after 'W.F. Marcuson (1996)' $R_d=0.5$
Cyclic Stress Ratio $CSR=0.65*a_{max}*S_v/S'_v*R_d=0.65*0.46*5.58/3.75*0.5=0.22$
Safety Factor = $CRR/CSR*MSF*K = 0.145/0.22*1.08*0.739 = 0.527$

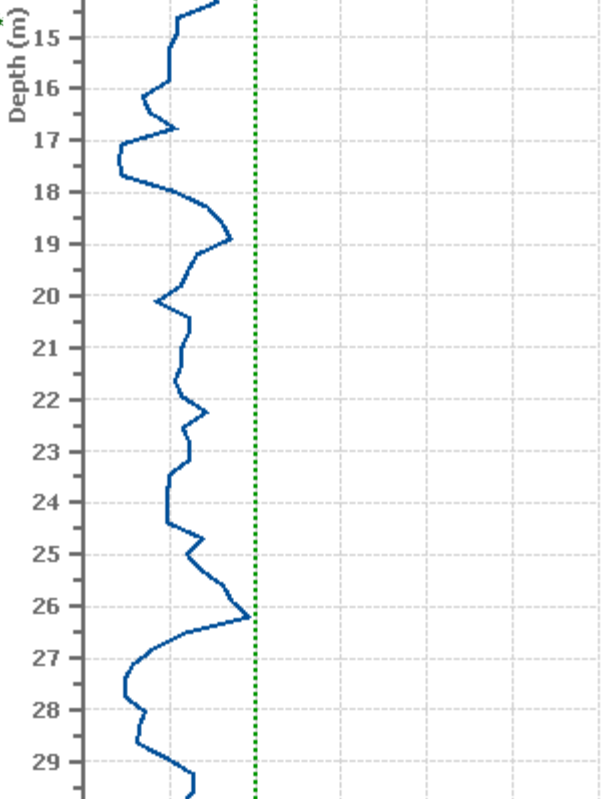
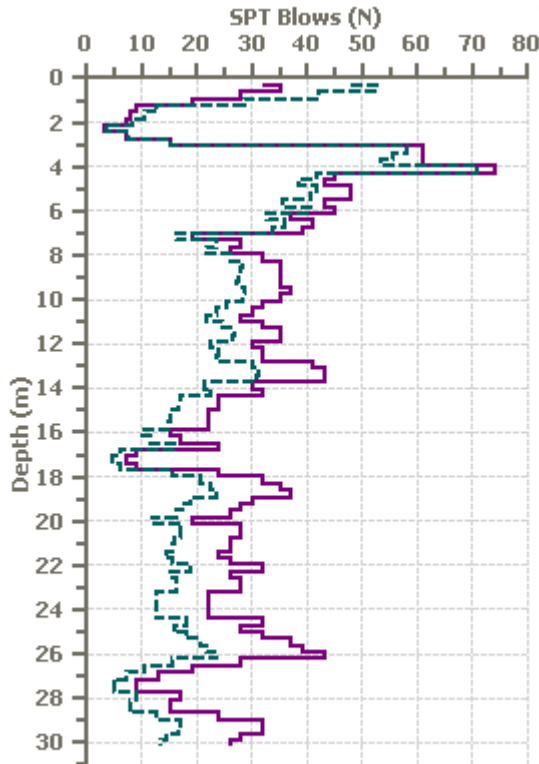


ABCD Consulting Engineers

Project : Storage building
 Client : North Vancouver, BC
 Location : BDT08 - 1
 Code : 108-2254



— Cyclic Stress Ratio — Cyclic Resistance Ratio



Post Liquefaction Lat. Disp. \sim 4.19 m

Post Liquefaction Vertical Settlement = 43.91 cm

— SPT - - - SPT (corrected)

— Calculated Safety Factor ····· Criteria



ABCD Consulting Engineers

Project : Storage building
Client : North vancouver, BC
Location : BDT08 - 1
Code : 108-2254

