BRIDGwall v2 – CHBDC and AASHTO Abutment and Retaining Wall Design

User's Manual

Simplified Bridge Solutions Ltd.
admin@bridge-structural.com (705-446-9694)
www.bridge-structural.com

CONTENTS

1.0 INSTALLATION

1.1 Hardware Requirements

To successfully install BRIDGwall, your computer must be equipped with the minimum:

- Windows 10 or later operating system
- P2 processor
- 64 MB of Ram
- 2 MB of free disk space
- 800 x 600 video
- Microsoft Excel 2010 (Excel 2007 not recommended)

1.2 Installation and Uninstall Program

BRIDGwall is equipped with an automatic installation program.

- The program is run and installed directly from our website. The package includes the Excel workbooks required as the starting point of your first new design. Later designs may utilize these workbooks or other saved workbooks generated from the original Excel file.

- The application as received will require registration to enable full design functionality. The program will operate in demo until registered.

- The Excel files contain macros. The User will need to accept the macros in order to enable the program functionality.

- An Uninstall routine will be installed in the same directory as the program directory. The program may be uninstalled and then reinstalled during an active license without issue.

- Your system requires Microsoft .NET Framework (included in Windows 7 and later) to operate the BRIDGwall program. During the BRIDGwall installation, your system may automatically be directed to the Windows download website to retrieve the necessary file.

- After installation, the program will automatically check for the latest program version when the application is re-opened.

2.0 DEFINITIONS

For definitions, see the applicable section of the Canadian Highway Bridge Design Code (CHBDC) CAN/CSA-S6-19 or the American Association of State Highway and Transportation Officials (AASHTO).

3.0 NOTATION

For notations, see the applicable section of CHBDC or AASHTIO and as follows:

DC – dead load of structural component and non-structural attachments
EH – horizontal earth pressure
EQ – earthquake
ES – earth surcharge load
EV – vertical pressure from dead load of earth fill
F_h – horizontal force
F_v – vertical force
Fh_x – horizontal force along X axis
Fh_y – horizontal force along Y axis
Hx – horizontal force in X direction
Hy – horizontal force in Y direction
Ka, Kah, Ko, Koh – earth pressure coefficients
LH – horizontal force from live surcharge
LL – vehicular live load
LV – vertical load from live surcharge
Pa – soil force
Pah – horizontal soil force
Pa_y – soil force along Y axis
P_{Hx} – horizontal forces along the X axis
P_{Hy} – horizontal forces along the Y axis
Ph_y – horizontal component of Pa_y
P_oh, P_oh_y – horizontal force from resisting soil
Pv_y – vertical component of Pa_y
M_{hx} – moment about the Y axis or in the X axis direction
N/A – not applicable
p – horizontal distance from the front face of abutment at bearing seat level
WA – water load
X axis – direction parallel to wall face
Y axis – direction perpendicular to wall face

4.0 INTRODUCTION

4.1 General

BRIDGwall by Simplified Bridge Solutions Ltd. is a program that provides abutment and retaining wall (including gravity walls) conforming to CHBDC and AASHTO, herein after referred to as 'the bridge codes' or 'the codes'. The intent of this program is to provide a user-friendly tool for many of the earth retaining structures being designed today.

As most of the User information is contained in the bridge codes, the User should refer primarily to the codes more so than the BRIDGwall manual when using the program. Therefore, references to clauses, sections, tables and figures shall be that of the codes unless noted otherwise.

4.2 Description

BRIDGwall is a program that uses Microsoft Excel (output) and Visual Basic (input) for designing abutments, retaining walls, and gravity walls.

BRIDGretainingwall and BRIDGabutment complete the available Excel files to the BRIDGwall program.

BRIDGretainingwall is very similar to BRIDGabutment with the exception that a footing key may be modeled, a water table may be entered on the retained backfill side, and rotation of gravity walls is available.

BRIDGabutment allows forces to be entered at the bearing seat location and includes input for a ballast wall.

5.0 INPUT

5.1 General

For BRIDGabutment, a bridge structure may first be modeled using our BRIDGframe program to obtain the forces at the bearings

To begin using the BRIDGwall program, the User is required to LOAD (see the LOAD buttons found on file tab of the program) the BRIDGabutment or BRIDGretainingwall model into BRIDGwall. See Appendix 3.

Input data is posted to the various Excel worksheets to be utilized by the program, by the selection of the 'Synchronize' button.

The program uses fixed units of measurement in the international or metric system.

5.1.1 Sign Convention

The program will only allow positive or negative values as dictated by the program. If an incorrect value (positive or negative) is enter, an error message pops up saying the value is INVALID.

Generally, positive vertical forces act downwards, positive horizontal forces contribute to overturning, and positive transverse moments increase the soil bearing pressure. See Appendix 4.

5.2 Properties

The Properties tab provides for the property and parameter input of the resisting and retained backfill, and the founding material.

Angle of Wall Friction (BRIDGabutment and BRIDGretainingwall) and Wall Rotation (BRIDGretainingwall) is applicable to Gravity Walls only and must me left bank when designing a cantilever style wall. Angle of Wall Friction is a mandatory input requirement for gravity type walls.

For abutment design, Road Top to Abutment Top is included as an input value. The program **does not** use this information to calculate the backfill surcharge load at the top of the abutment; but uses this information to determine the amount of compaction surcharge (CHBDC only) at the top of abutment wall only. This input is typical for semi-integral abutment bridges.

The Height of Water Table is measured vertically from the end of the footing toe. The height of water table is applied to the Retained Backfill side only. Hydrostatic uplift is assumed to act linearly from the end of heel (maximum uplift pressure) to the end of toe (minimum uplift pressure = 0).

The starting point for the sloped retained backfill is at the top corner of the wall on the retained soil side.

To eliminate sliding as part of the 'Optimization' (Geometry tab) of the footing, the 'Effective Friction Angle' and 'Effective Friction Angle at u/s of Footing' may to set to 45 $^{\circ}$ on the Properties tab or cohesion can be added even if not a condition. This may be applicable when footings are keyed into bedrock or dowels are provided between the footing and bedrock.

5.3 Loads

5.3.1 Loads 1

The Loads 1 tab is used to input the General Loads of, surcharges, lateral seismic uniform pressure on the retained soil side (provided by Geotechnical Engineer), along with identifying the use of approach slabs and the density of the structure. General Loads are applicable to both BRIDGretainingwall and BRIDGabutment. As per the code, earthquake or seismic loads are not applied with live loads. As such, BRIDGwall will only allow one of these loads to be entered at any one time.

Amplification of soil pressure due to earthquake load is applied as an additional uniform soil pressure.

'Permanent UDL Surcharge' requires completion regardless of if 'Road Top to Abutment Top' was completed on the Properties tab.

Loads 1 also provides for Additional Horizontal/Overturning Loads for BRIDGretainingwall.

5.3.2 Loads 2

Loads on the Bearing Seat is available to BRIDGabutment and provides for the input of forces on the bearing seat. These loads are assumed to act through the centroid of the abutment in the X direction and at a distance "p" from the front face of the abutment wall.

As per cl.3.5.2.2 (CHBDC), minimum Dead & SIDL's should use a load factor of 1.0 when establishing Fv and Mhx using Fv.

5.3.3 Loads 3

The Loads 3 tab is used to input the Load Factors, typically at ULS (CHBDC) or Strength (AASHTO).

The resisting soil pressure calculated by the program is that of At-rest Earth Pressure rather than that of Passive Earth Pressure. An input load factor box for SLS (CHBDC) or Service (AASHTO) horizontal earth pressure has been provided so the User may increase the horizontal resisting soil pressure from At-rest up to that of Passive. Likewise, the User can modify the ULS or Strength maximum and minimum horizontal load factors to obtain Passive resistance instead of At-rest resistance.

Default values are automatically loaded for the applicable code when the code is selected on the File tab. To change the load factor values back to the original defaults, if changes were made, a Get Defaults button is provided.

As per cl.3.5.2.2 (CHBDC), the vertical loads are defaulted to 1.0.

5.4 Geometry

The Geometry tab is used to establish the dimensional properties of the wall structure.

Input varies somewhat depending on whether a BRIDGabutment or BRIDGretainingwalll file was loaded.

If a Gravity Wall is being modeled (see 5.2 Properties), the Heel Width will not be available for input.

For Gravity Walls with no footings, use a very small footing depth such as 0.0001 m to remove the warning message on the Geometry tab.

A dynamic cross section of the wall structure is provided at scale to assist in verifying the input values.

An Optimize button is provided to allow the User to determine the smallest possible overall footing size, or the smallest heel size using a designation toe width, or the smallest toe size using a designated heel width.

A value greater than zero shall be entered for the Heel Width of Cantilevered Walls when using the Optimize option.

The length of the footing should be set equal to the length of the abutment or just slightly larger at most. Additional fill on the abutment footing that extends beyond the abutment wall length is not considered in design. The length of footing is only used for calculating bearing resistance as per cl.6.10.2 (CHBDC).

5.5 Design

A Rebar Design tool and a Pile Foundation design tool have been provided to assist the User in completing the design of the wall structure.

For pile foundation design, the plan geometry of the piles is input, and the remaining design focuses on a single pile as chosen by the User.

Input of the forces obtained from the worksheets, is done through the program on the Design tab. Additional input is done directly in the Excel workbooks. See Example 3 in Appendix 6.

6.0 OUTPUT

6.1 General

References to CHBDC or AASHTO are provided on each output sheet to assist the User in verifying the application.

Serviceability and Strength conditions are addressed.

6.2 Results

The output consists of typical combinations using varying maximum and minimum load combinations. It is unlikely some combinations will ever govern design; however, they are shown for information purposes only. It is assumed the User may only wish to print the governing worksheet, so service conditions which may be the same on all worksheets, is provided on all worksheets.

A summary of the results for soil bearing, sliding, overturning, and resultant location, is provided at the bottom of the Input worksheet.

If a water table was input, the program does not automatically check if the worst condition is without a water table.

6.2.1 Geotechnical Analysis

The Info contained on the Geo 1 to Geo 4 worksheet contains the analysis of the various load combinations for the allowable bearing pressure on the founding material.

The Geo 5 worksheet contains the analysis of eccentricity limits, overturning and sliding resistance.

6.2.2 Structural Analysis

The Info contained on the Str 1 to Str 4 worksheet contains the analysis of the various load combinations for the structural forces in the wall, toe and heel components which make up the structure.

6.2.3 Design 1

The Design 1 worksheet shows the structural design of the chosen component. Design includes service stresses and strength design for rebar reinforced concrete, for moment and shear design.

6.2.4 Design 2

The Design 2 worksheet shows the properties of the pile group configuration, and the design results of a single User selected pile.

Structural design includes the axial force in the selected pile and a structural axial capacity work area. For a structure requiring passive resistance against the pile to satisfy horizontal displacement of the structure, a more rigorous design may be required to account for bending moments and shear.

This Page is intentionally left blank

7.0 Printing

Printing of Excel sheets is done by selection of each worksheet as found on the program 'Print' sheet. Printing may also be done manually by selecting the data of interest and designating it for printing using the Print Area command.

To print the program input sheets (tab dialogue pages), the User may press 'Ctrl,' 'Alt' and 'Prt Sc' simultaneously when on the sheet of preference to print; then in Microsoft Word place the cursor where the top left corner of the saved print screen will be dropped and press 'Ctrl' and 'V' simultaneously.

8.0 Troubleshooting

If the User does not Load a compatible Excel file, an Error or Error message will appear. Probable Resolution: Load a compatible Excel BRIDGabutment or BRIDGretainingwall spreadsheet that was received with the program.

The program fails during registration confirmation. Probable Resolution: The firewall may be blocking communication with our website. Configure the firewall to allow communication with www.bridge-structural.com. Confirm there is an internet connection. Further configuration of the firewall may be required to allow BRIDGwall.exe and BRIDGwallUpdater.exe to access the internet.

If the appearance of the program is not as per the screen prints shown in the Appendix 4 Input Examples, the issue may be with the monitor settings. Right click on the Desk Top, select Properties/ Settings/ Advanced/ General Tab/ the DPI setting should be that of Normal Setting.

The program fails and gives an error message when trying to analyze. Probable Resolution: Macros have not been allowed to run. Excel 2007 and later require special attention to have Trust settings configured to allow macros within BRIDG wall to run.

Computer Regional Settings must be set for English. See also www.support.microsoft.com/kb/320369

Error Number 5 Access to the path 'C:\ProgramFiles(x86)\Simplified Bridge Solutions\BRIDGframe\SBS.ini' is denied. Probable Resolution: writing permission is required to C:\ProgramFiles\Simplified Bridge Solutions\BRIDGframe, or location program is saved in.

If the diagram section of the wall is not visible on the Geometry tab it may be because i) preceeding tabs are not synchronized, ii) move cursor over tab to regenerate.

9.0 Limitations

Cross sectional dimensions are constant over length of wall being analyzed.

Forces at bearing seat for abutment design are assumed to act along the centre line of the transverse length of the structure.

Earth fill beyond the length of abutment wall is not included in the abutment analysis.

For pile foundation design, a tool has been provided for axial structural design only. A later version will allow for moment and shear design also.

Longitudinal force at the abutment bearing seat acting against the restrained soil is not available.

Vertical forces causing uplift in the abutment is not available.

APPENDIX 1 - PROGRAM FEATURES

BRIDGwall
Abutment, retainingwall, and gravity wall design software

- conformance with CHBDC and AASHTO
- simple and minimal tabular input
- automatic importing of data from earlier BRIDGwall Excel files
- SLS / Service and ULS / Strength analysis and design
- load combinations pre-set to cover any governing condition
- 'Optimize' options provided to quickly establish minimum footing component widths to satisfy all conditions
- reinforcing steel and pile foundation tool included
- print tab makes printing worksheets simple
- print results are as per they appear on the worksheets
- output is very clearly defined
- output is in Microsoft Excel
- metric or imperial input and results

APPENDIX 2 - SOFTWARE LICENSING AGREEMENT AND INSTALLATION

BRIDGwall
Software Licensing Agreement

By installing the BRIDGwall Software (which consists of software, documentation and other items; hereafter: "Software") created by Simplified Bridge Solutions Ltd., you agree to be bound by the terms and conditions of this License Agreement. As used in this License Agreement, "You" shall mean the individual using or installing the Software together with any individual or entity, including but not limited to your employer, on whose behalf you are acting in using or installing the Software. You shall be the "licensee" under this License Agreement.

This License Agreement constitutes the complete agreement between you and Simplified Bridge Solutions Ltd. No amendment or modification may be made to this Agreement except in form of writing signed by you and Simplified Bridge Solutions Ltd.

If you do not agree to any of the terms and conditions of the Agreement, you must discontinue use of the Software immediately.

1. License Grant

In consideration for the license fee paid, and other good and valuable consideration, Simplified Bridge Solutions Ltd. grants to you only, the Licensee, the non-exclusive, non-transferable right to use the Software in accordance with the license you purchase. If you are using this product for your employer, this Agreement also includes your employer. You may only use the Analysis functionality of the Software on the computer for which the Software is licensed. The software may be distributed freely to facilitate the printing of analysis output.

2. Copyright

The Software as developed by Simplified Bridge Solutions Ltd. and the accompanying materials are copyrighted and contain proprietary information. Unauthorized modification of the Software is expressly forbidden. Unauthorized copying of accompanying materials even if merged, or included with other software, is expressly forbidden. You may be held legally responsible for any infringement of intellectual property rights that is caused or encouraged by your failure to abide by the terms of this Agreement. Simplified Bridge Solutions Ltd. reserves all rights not specifically granted to Licensee.

Simplified Bridge Solutions Ltd. warrants that Simplified Bridge Solutions Ltd. is the sole owner of all copyrights or other applicable intellectual property rights in and to the Software unless otherwise indicated in the documentation for the Software. Simplified Bridge Solutions Ltd. shall defend and hold Licensee harmless from any third party claims for intellectual property infringement for properly licensed Software provided by Simplified Bridge Solutions Ltd.

You do not own the Software. The Software and documentation are licensed, not sold to you. You may not disassemble, decompose or otherwise reverse engineer the Software. You must not alter the Software. You may freely distribute the software to others. Others to print analysis output may use distributed copies; the analysis functionality will be disabled until a license is purchased.

3. Warranty and Risks

Although extensive efforts have been made to assure that the Software is date compliant, correct, reliable and technically accurate, the Software is licensed to you as is and without warranties. You, your organization, and all users of the Software, assume all risks when using it. In any case, the entire liability under any provision of this Agreement shall be limited to the greater of the amount actually paid by You for the Software or the equivalent of the amount paid by You for the Software.

4. Support, Upgrades and Service Releases

Simplified Bridge Solutions Ltd. shall offer free technical support that does not fall under the scope of providing engineering services, and product upgrades for the licensed term after purchasing the product. The product license expires at the term end; therefore, you must pay the annual maintenance fee in order to receive a renewal license and ongoing support and product upgrades.

5. Termination

This Agreement is effective until terminated. This Agreement will terminate automatically without notice from Simplified Bridge Solutions Ltd. if you fail to comply with any provision contained herein or if the funds paid for the license are refunded or are not received. Upon termination, you must destroy the Software, and all copies of the Software, in part and in whole, including modified copies if any.

6. Non-Waiver

The failure by either party at any time to enforce any of the provisions of this License Agreement or any right or remedy available hereunder or at law or in equity, or to exercise any option herein provided, shall not constitute a waiver of such provision, right, remedy, or option or in any way affect the validity of this License Agreement. The waiver of any default by either party shall not be deemed a continuing waiver, but shall apply solely to the instance to which such waiver is directed.

BRIDGwall
Installation

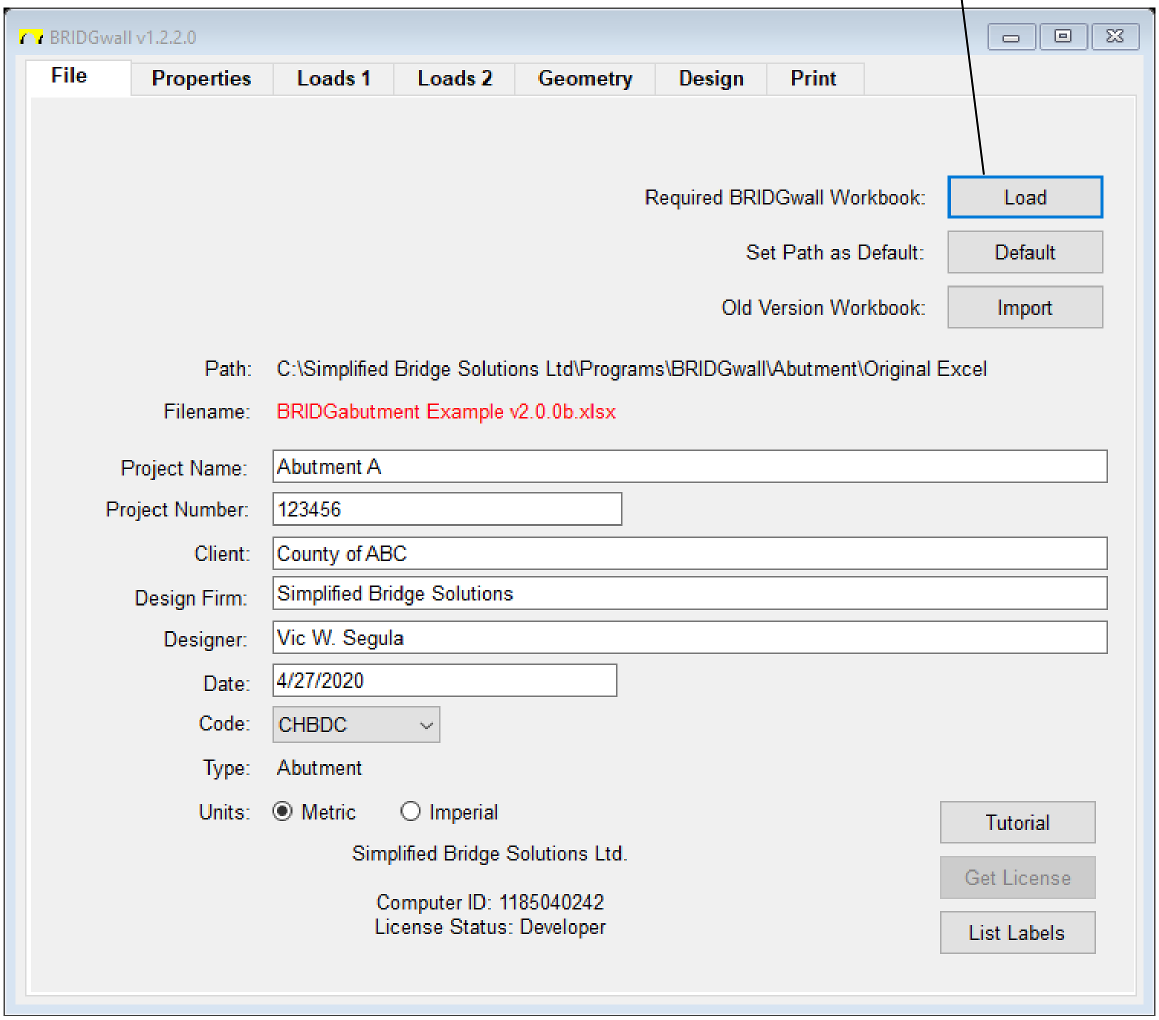
Design parameters and calculation results for retaining soil walls are stored in Excel workbooks, one workbook per design. BRIDGwall is a dialog that provides the User Interface to these Excel workbooks. An example workbook is required as the starting point for your first new analysis. Later analysis may utilize this workbook or other saved workbooks generated from the original Excel file. All files are available for download directly from our website.

Certain advanced features are disabled until the application is registered.

BRIDGwall will run in Demo mode until it is registered.

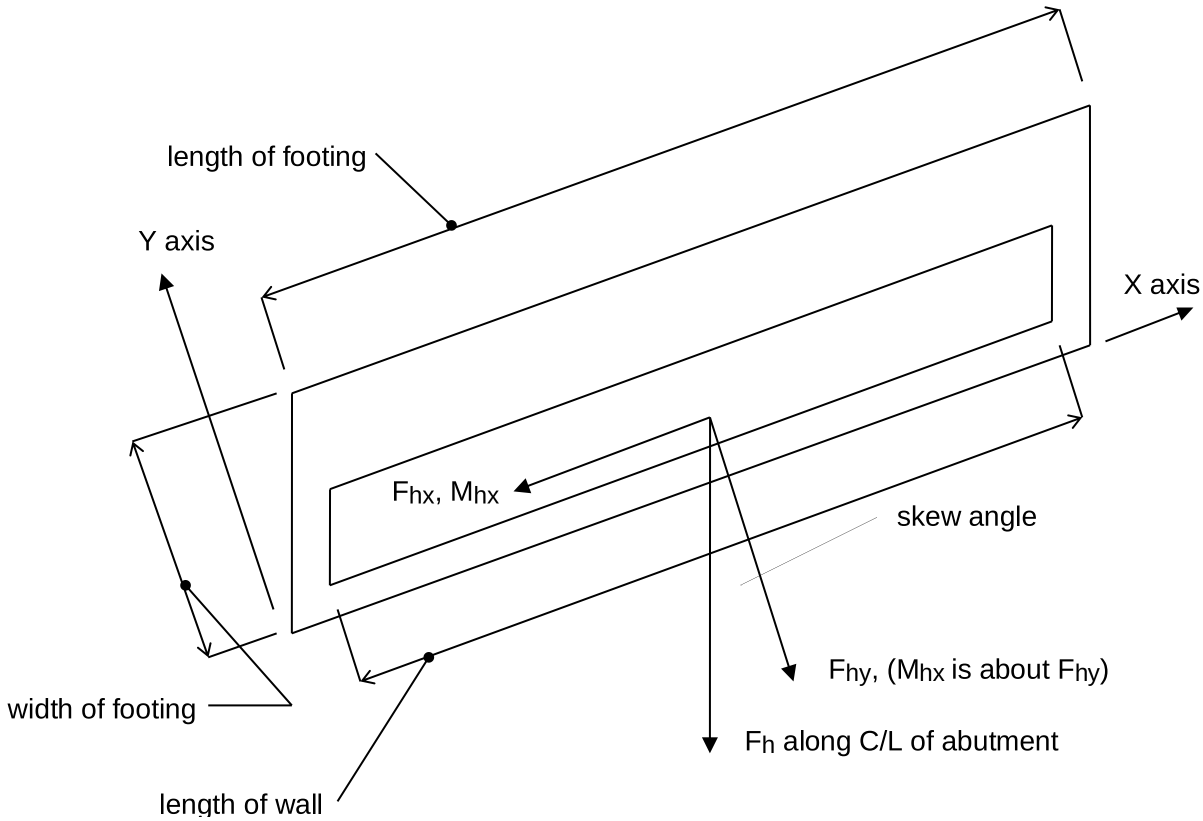
APPENDIX 3 – FILE TAB

BRIDGretainingwall or BRIDGabutment Load button



- Load: load the BRIDGwall Excel file to be used in design
- Default: resets to the path of the loaded excel file, where the program will automatically open to upon reopening
- Import: imports data from one Excel file into the loaded Excel file.
- Input project particulars
- Tutorial: this button provides a link to the web site
- Get License: this button provides a link to the web site

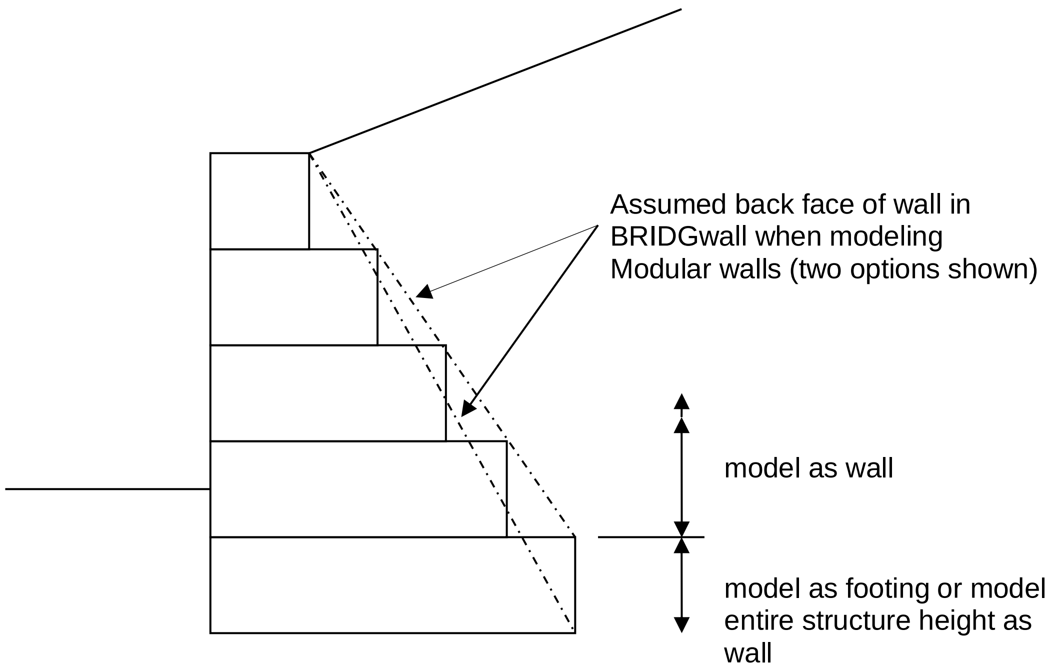
APPENDIX 4 – PLAN GEOMETRY AND APPLICATION OF FORCES



Plan – Abutment

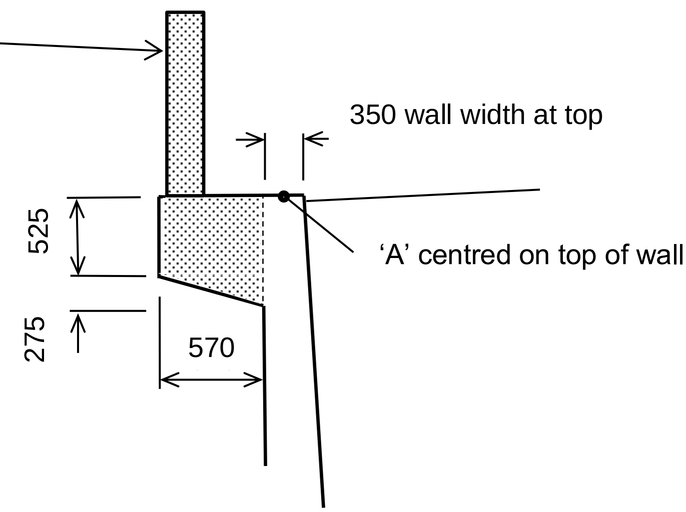
- 'Additional Loads' for abutments as found on the Loads 1 tab provides for load input from the superstructure. Horizontal loads from BRIDGframe due to temperature contraction, shrinkage, etc., may be entered as F_h. BRIDGwall will convert the load to F_{hx} and F_{hy} components.
- Input the total Fh forces. These forces are assumed to act along the centre line of abutment.
- M_{hx} moments are acting about the F_{hy} axis or in the F_{hx} direction
- Although the ends of the footing may be skewed, for simplicity, non-skewed ends are assumed.

APPENDIX 5 – MODULAR WALLS



- When modeling modular walls in BRIDGwall, the gravity wall will form that of a trapezoid
- Refer to Figure 3.11.5.9-2 of AASHTO

APPENDIX 6 – RETAINING WALL



Parapet wall: 0.25 x 0.85 x 24 kN/m^3 = 5.1 kN @ 0.57 m from A

Corbel: rect: 0.525 x 0.57 x 24 kN/m^3 = 7.2 kN @ 0.46 m from A
tri: 0.275 x 0.57/2 x 24 kN/m^3 = 1.9 kN @ 0.365 m from A

For minimum vertical load, parapet wall weight will be excluded.

Fv = 14.2 kN max unfactored
Fv = 9.1 kN min unfactored

x = (5.1 x 0.57 + 7.2 x 0.46 + 1.9 x 0.365) / 14.2 = 0.487 m max
x = (7.2 x 0.46 + 1.9 x 0.365) / 9.1 = 0.440 m min

SLS Fv max = 14.2 kN
SLS Mv max = 14.2 x 0.487 = 6.92 kN.m (positive for rotation away from retained fill)

SLS Fv min = 9.1 kN
SLS Mv min = 9.1 x 0.440 = 4.00 kN.m

ULS Fv max = 14.2 x 1.2 = 17.1kN
ULS Mv max = 6.92 x 1.2 = 8.31 kN.m

ULS Fv min = 9.1 x 0.9 = 8.2 kN
ULS Mv min = 4.00 x 0.9 = 3.60 kN.m

Input above values into Loads 1, Additional Loads, Vertical:

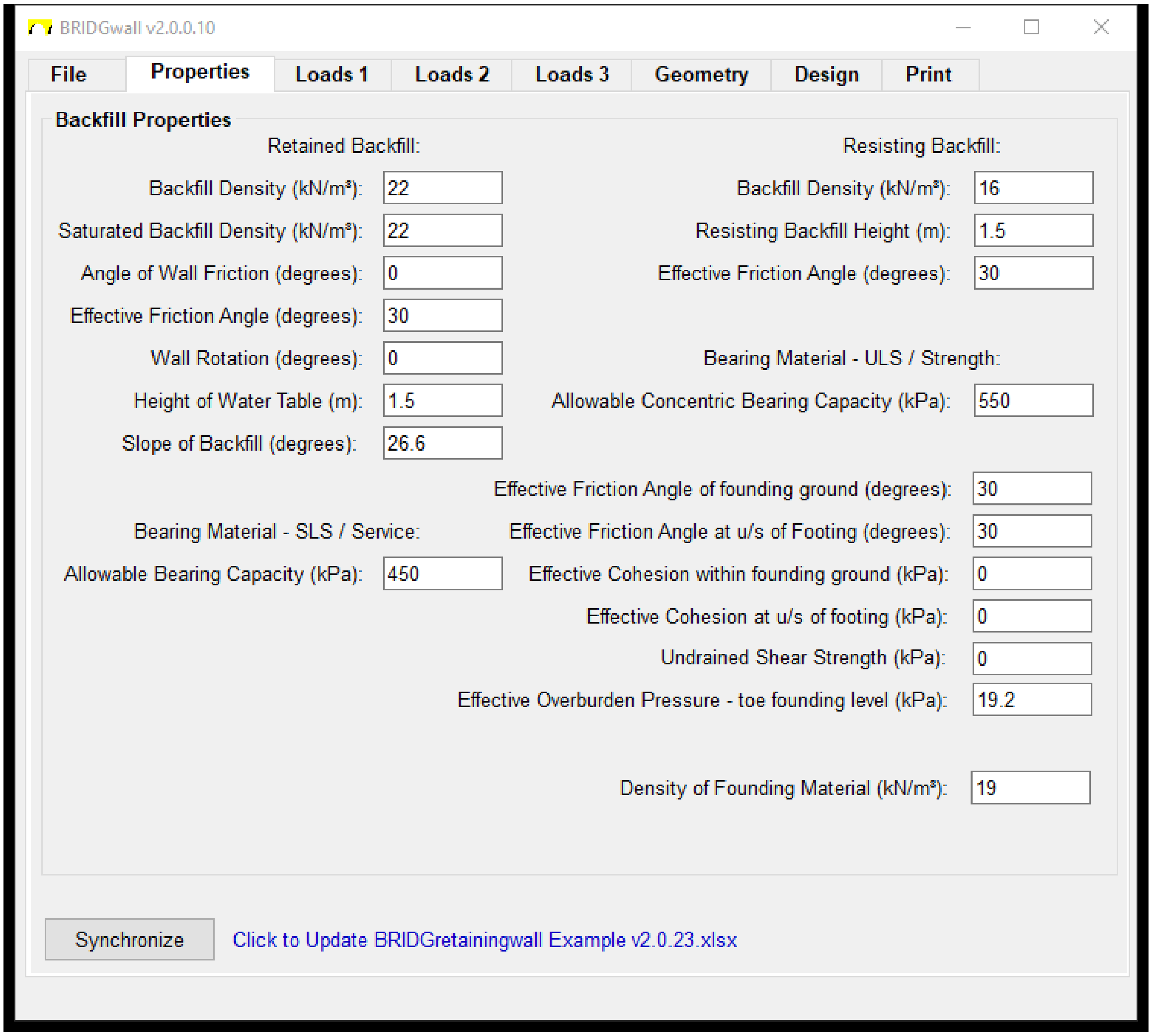
APPENDIX 7 – RETAINING WALL

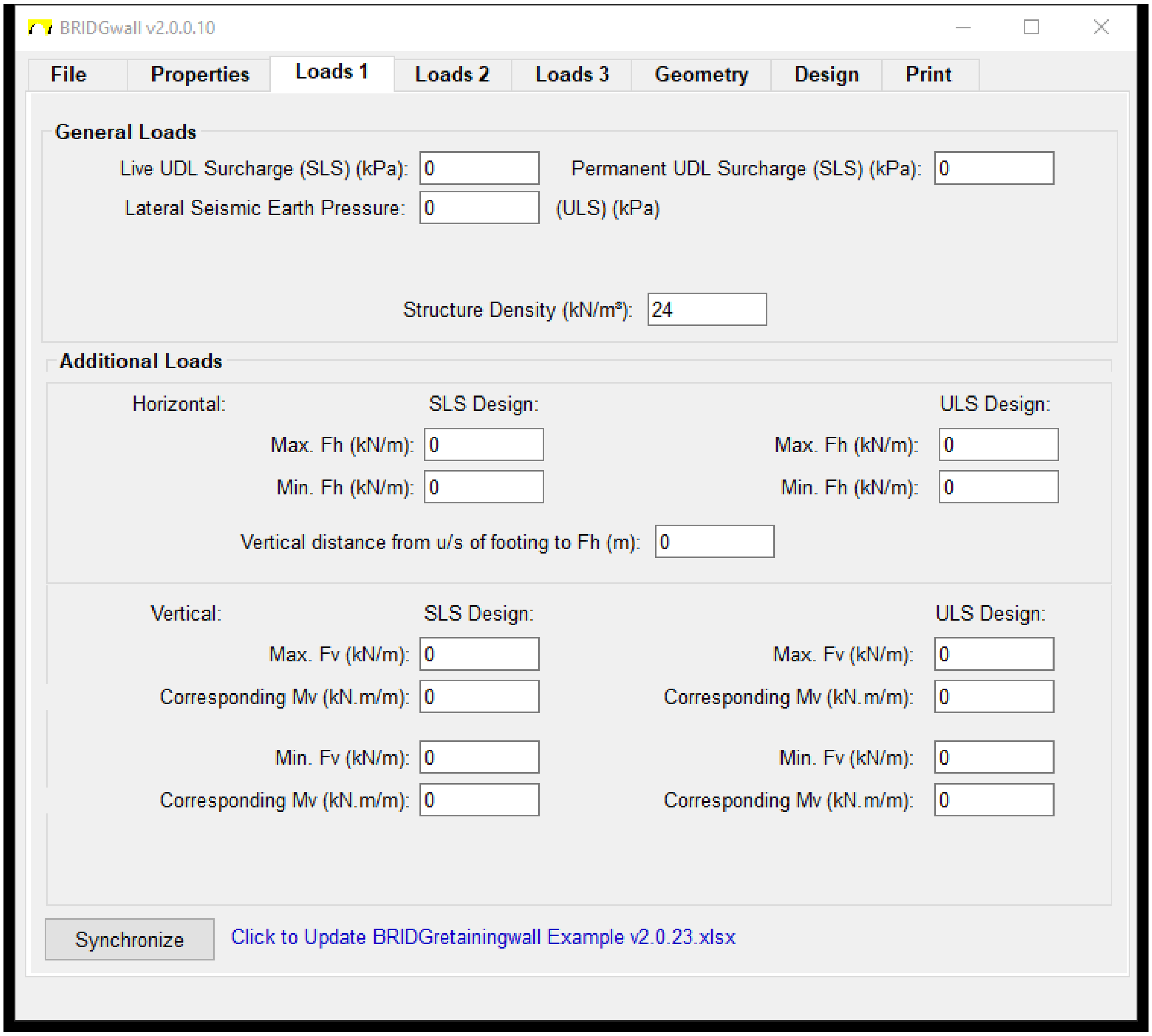
Backfill slope: 26.6 ° (2 horizontal to 1 vertical)

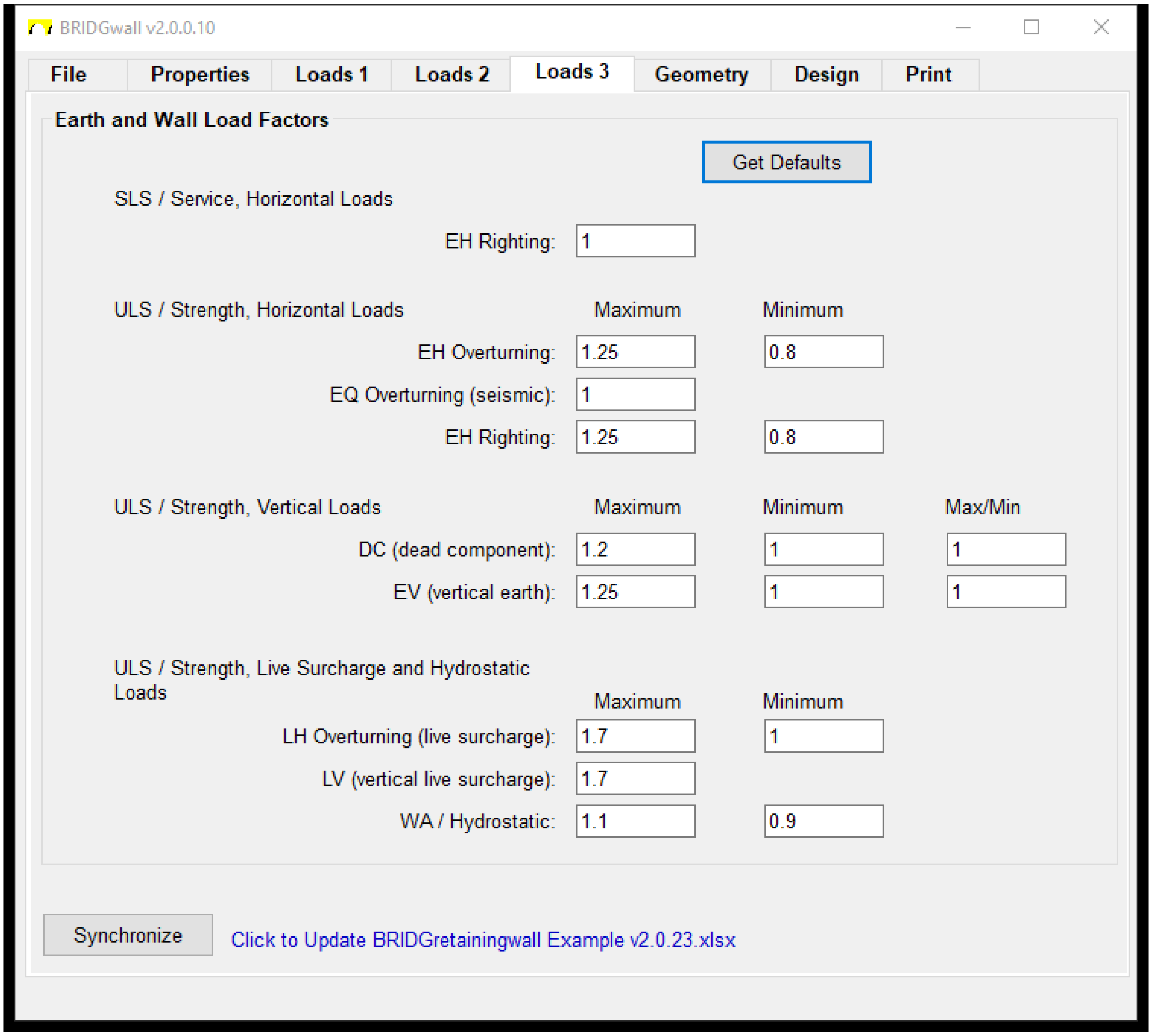
Effective overburden pressure at toe = resisting backfill density x depth of fill = 1.2 x 16 = 19.2 kPa.

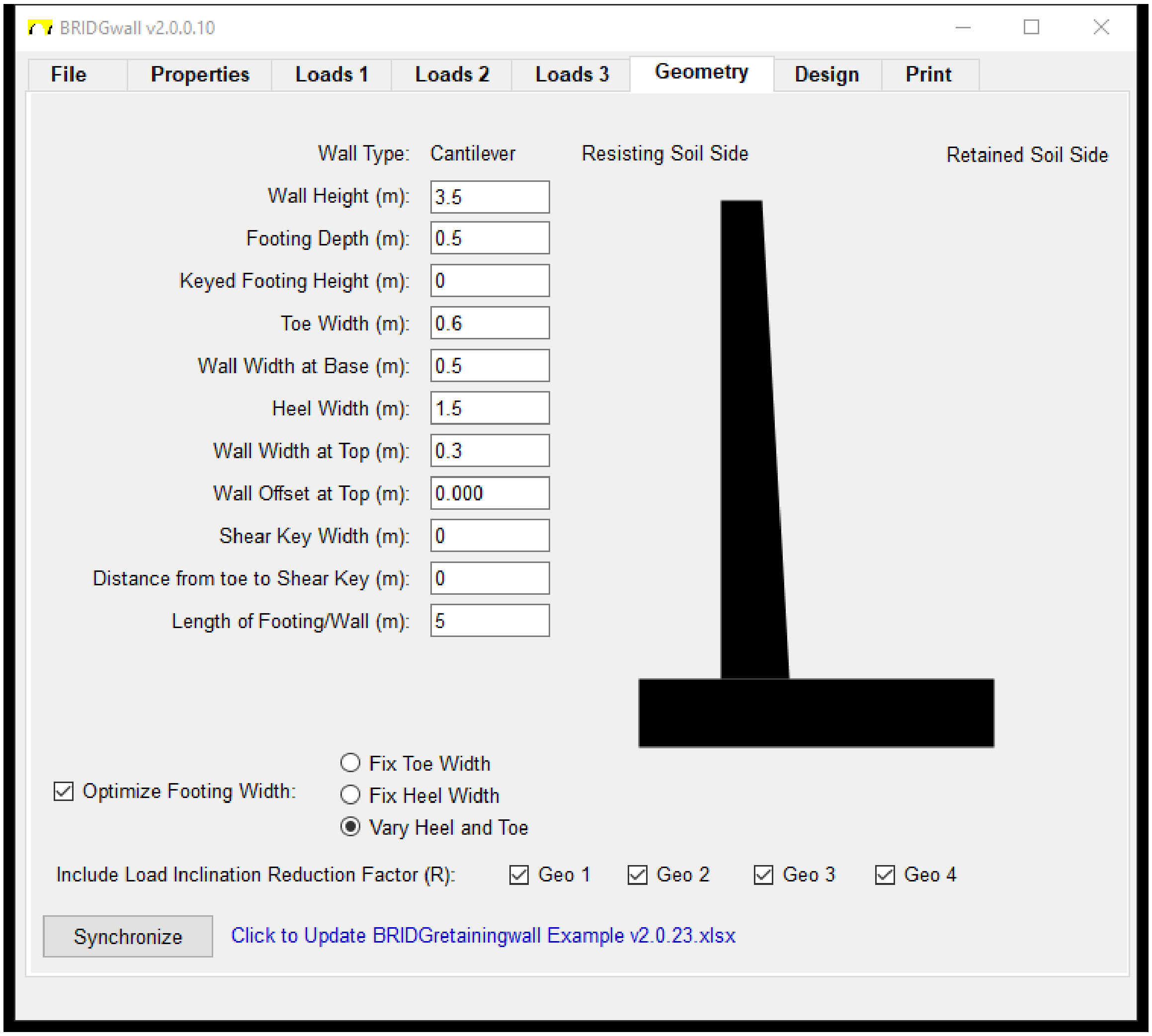
Load factors for EH Righting may be entered as 0 (zero) to eliminate any horizontal resisting earth pressure. Or these same factors may be increased to change horizontal resisting earth pressure from at-rest to passive conditions.

Note: A value greater than zero shall be entered for the Heel Width of Cantilevered Walls when using the Optimize option.


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Backfill Properties
Retained Backfill:
Backfill Density (kN/m³): 22
Saturated Backfill Density (kN/m³): 22
Angle of Wall Friction (degrees): 0
Effective Friction Angle (degrees): 30
Wall Rotation (degrees): 0
Height of Water Table (m): 1.5
Slope of Backfill (degrees): 26.6
Bearing Material - SLS / Service:
Allowable Bearing Capacity (kPa): 450
Resisting Backfill:
Backfill Density (kN/m³): 16
Resisting Backfill Height (m): 1.5
Effective Friction Angle (degrees): 30
Bearing Material - ULS / Strength:
Allowable Concentric Bearing Capacity (kPa): 550
Effective Friction Angle of founding ground (degrees): 30
Effective Friction Angle at u/s of Footing (degrees): 30
Effective Cohesion within founding ground (kPa): 0
Effective Cohesion at u/s of footing (kPa): 0
Undrained Shear Strength (kPa): 0
Effective Overburden Pressure - toe founding level (kPa): 19.2
Density of Founding Material (kN/m³): 19
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
General Loads
Live UDL Surcharge (SLS) (kPa): 0
Permanent UDL Surcharge (SLS) (kPa): 0
Lateral Seismic Earth Pressure: 0 (ULS) (kPa)
Structure Density (kN/m³): 24
Additional Loads
Horizontal:
SLS Design:
ULS Design:
Max. Fh (kN/m): 0
Min. Fh (kN/m): 0
Max. Fh (kN/m): 0
Min. Fh (kN/m): 0
Vertical distance from u/s of footing to Fh (m): 0
Vertical:
SLS Design:
ULS Design:
Max. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Min. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Max. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Min. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Earth and Wall Load Factors
Get Defaults
SLS / Service, Horizontal Loads
EH Righting: 1
ULS / Strength, Horizontal Loads
Maximum
Minimum
EH Overturning: 1.25 0.8
EQ Overturning (seismic): 1
EH Righting: 1.25 0.8
ULS / Strength, Vertical Loads
Maximum
Minimum
Max/Min
DC (dead component): 1.2 1 1
EV (vertical earth): 1.25 1 1
ULS / Strength, Live Surcharge and Hydrostatic Loads
Maximum
Minimum
LH Overturning (live surcharge): 1.7 1
LV (vertical live surcharge): 1.7
WA / Hydrostatic: 1.1 0.9
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Wall Type: Cantilever
Resisting Soil Side
Retained Soil Side
Wall Height (m): 3.5
Footing Depth (m): 0.5
Keyed Footing Height (m): 0
Toe Width (m): 0.6
Wall Width at Base (m): 0.5
Heel Width (m): 1.5
Wall Width at Top (m): 0.3
Wall Offset at Top (m): 0.000
Shear Key Width (m): 0
Distance from toe to Shear Key (m): 0
Length of Footing/Wall (m): 5
Optimize Footing Width:
Fix Toe Width
Fix Heel Width
Vary Heel and Toe
Include Load Inclination Reduction Factor (R):
Geo 1
Geo 2
Geo 3
Geo 4
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx

APPENDIX 8 – GRAVITY WALL

Angle of Wall Friction: 20 ° (Note: Entering a value for angle of wall friction determines a gravity wall type. Absence of this value determines a cantilever wall type)

The 'Optimize' button on the Geometry tab will find the smallest toe width. For gravity walls with no toe, do not use the Optimize button.

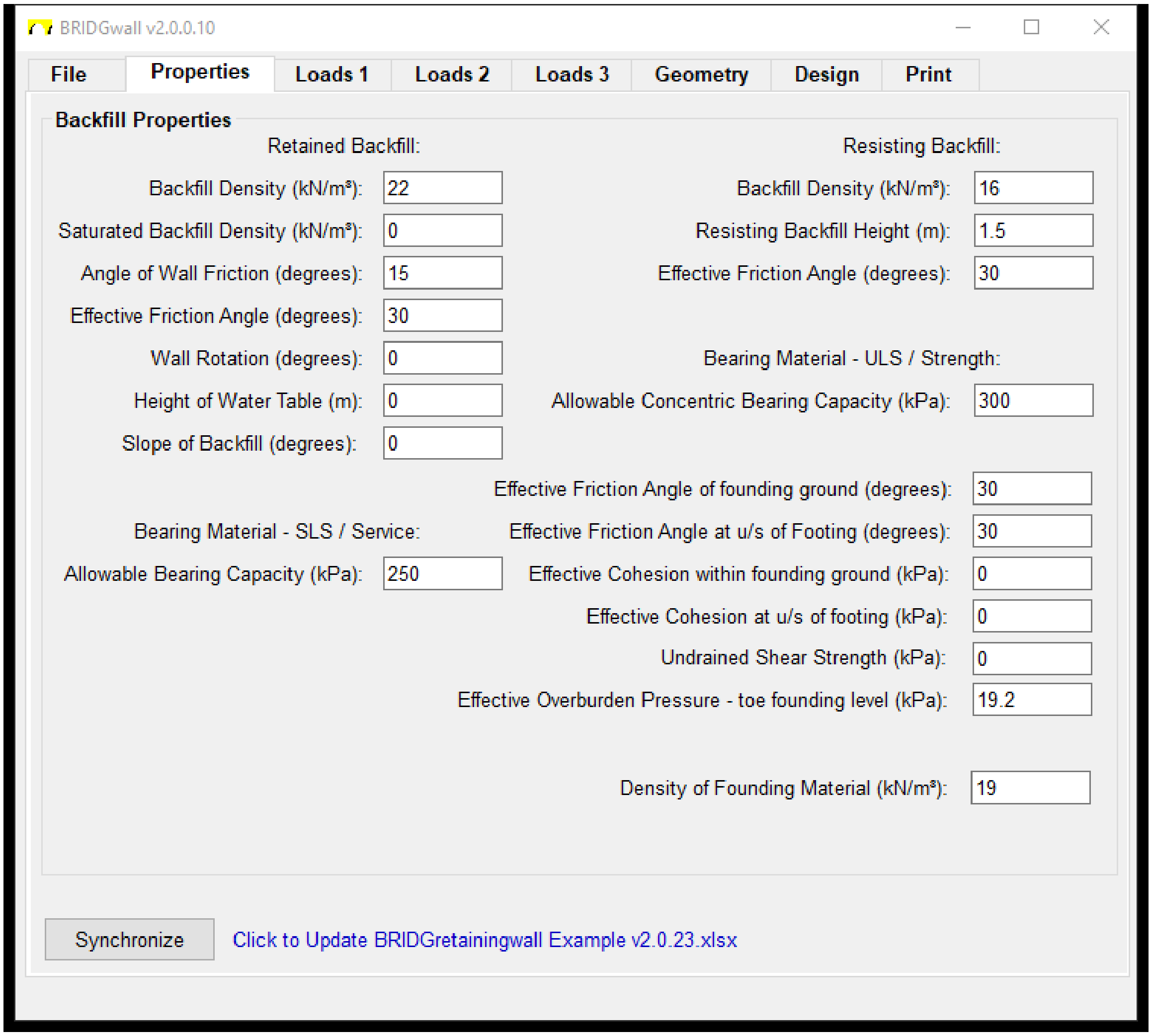
Effective overburden pressure at toe = resisting backfill density x depth of fill = 1.2 x 16 = 19.2 kPa.

Load factors for EH Righting may be entered as 0 (zero) to eliminate any horizontal resisting earth pressure. Or these same factors may be increased to change horizontal resisting earth pressure from at-rest to passive conditions.

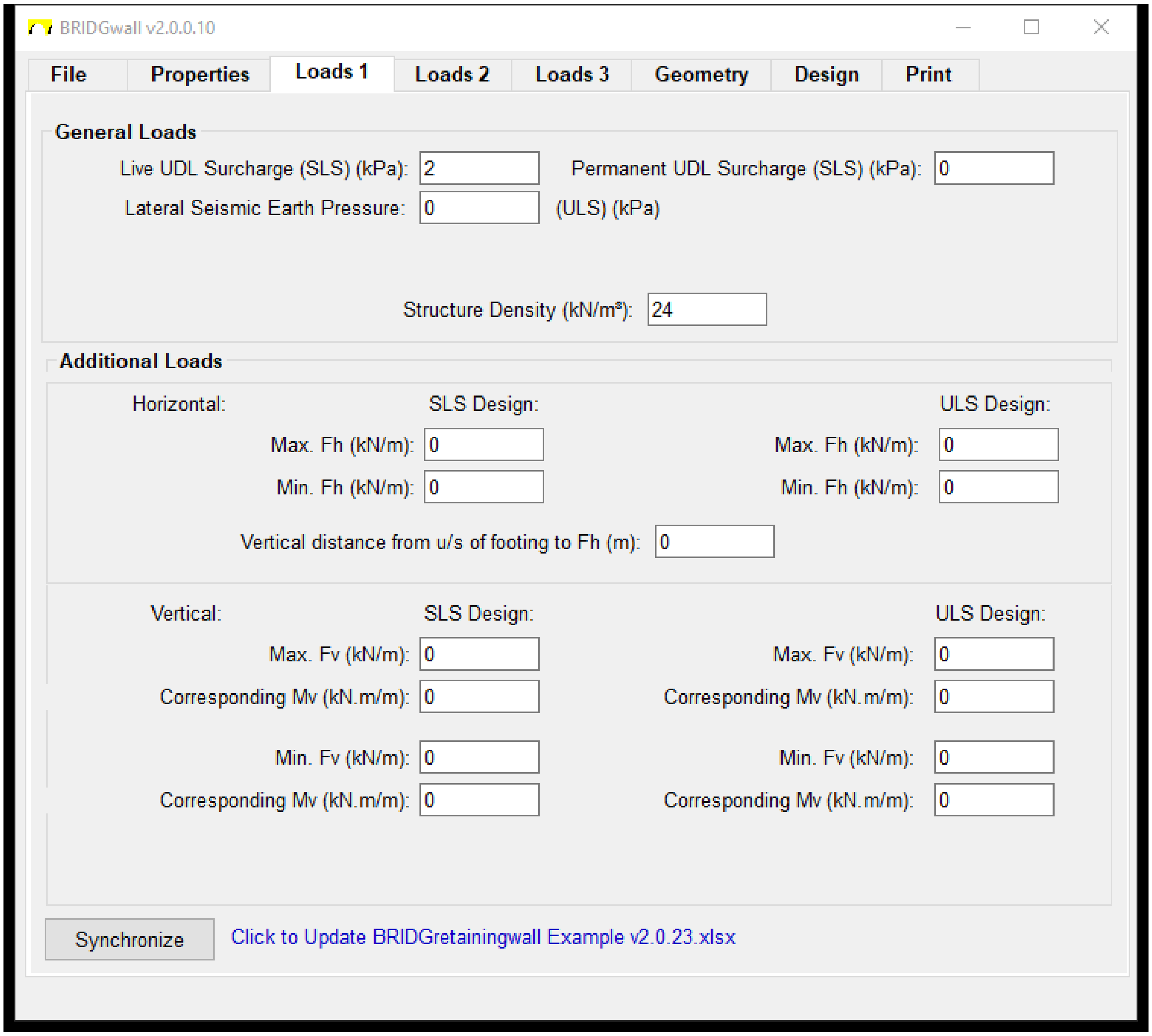
Live UDL Surcharge = 2 kPa for snow load

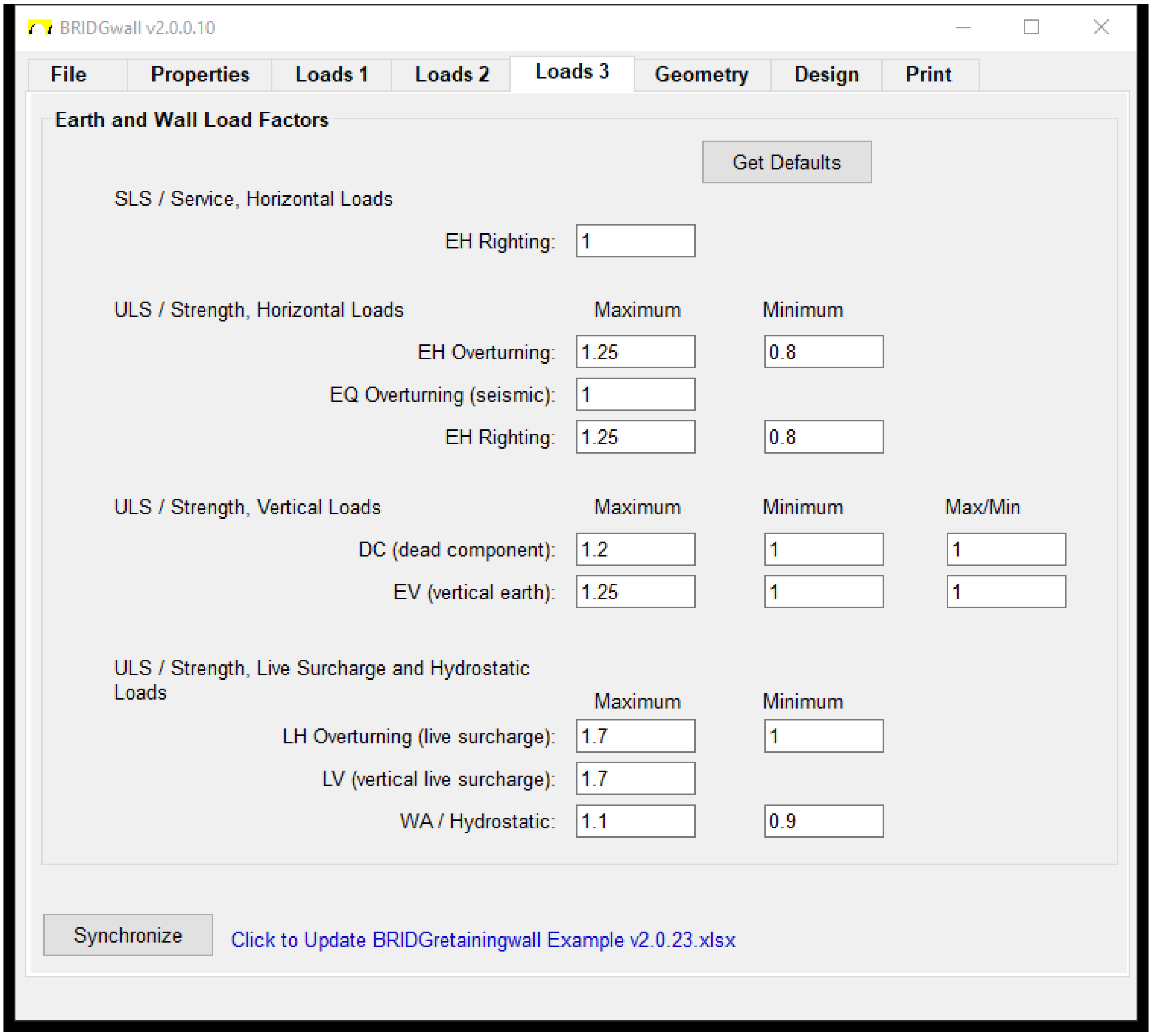
Structure is concrete. For modular walls constructed of gabions or other, use appropriate structure density (Loads 1).

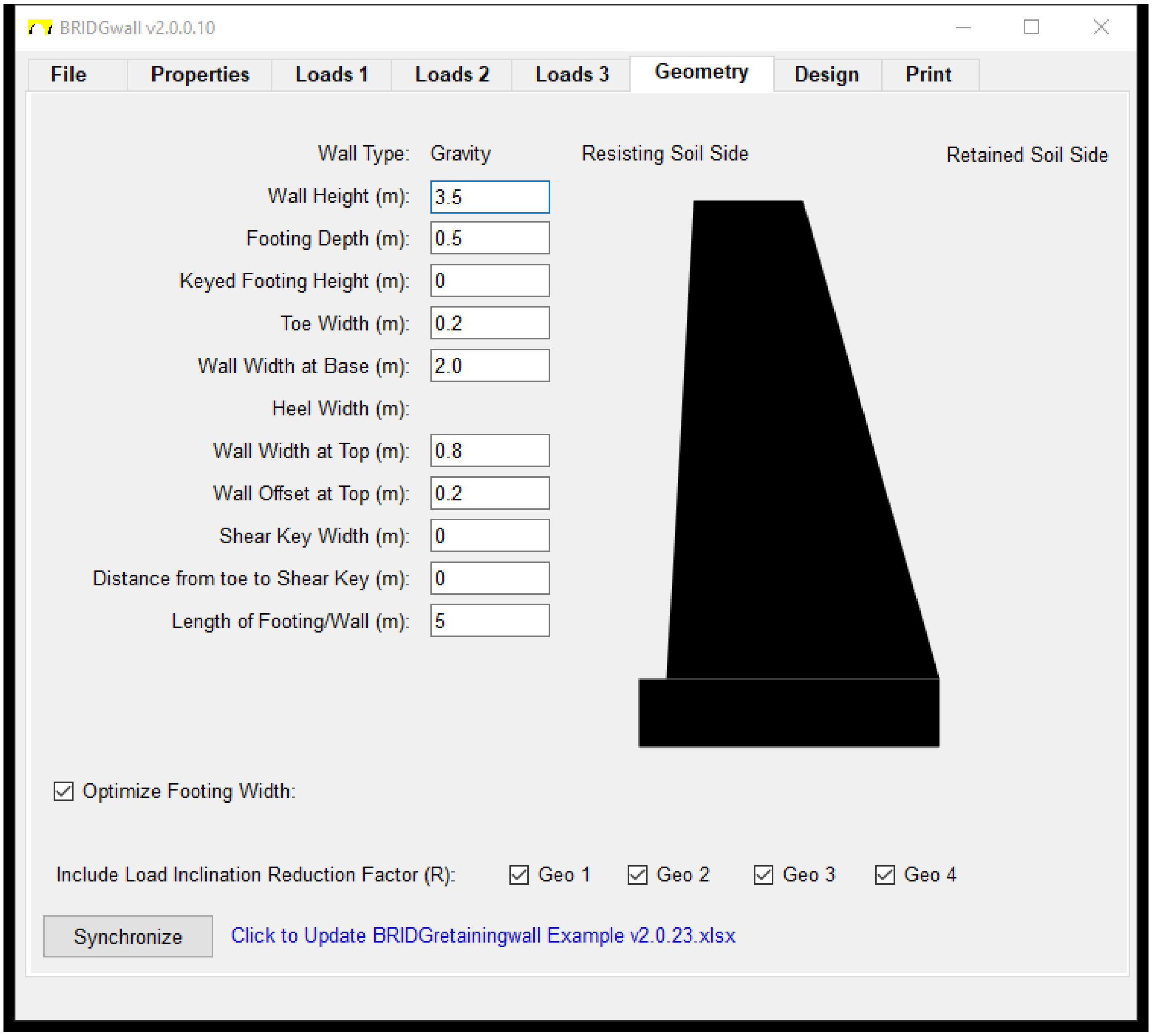
Note: For Gravity Walls with no footings, use a very small footing depth such as 0.0001 m to remove the warning note on the Geometry tab.



- Angle of Wall Friction is typically 1/2 to 2/3 of Effective Friction Angle


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
General Loads
Live UDL Surcharge (SLS) (kPa): 2
Permanent UDL Surcharge (SLS) (kPa): 0
Lateral Seismic Earth Pressure: 0 (ULS) (kPa)
Structure Density (kN/m³): 24
Additional Loads
Horizontal:
SLS Design:
ULS Design:
Max. Fh (kN/m): 0
Min. Fh (kN/m): 0
Max. Fh (kN/m): 0
Min. Fh (kN/m): 0
Vertical distance from u/s of footing to Fh (m): 0
Vertical:
SLS Design:
ULS Design:
Max. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Min. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Max. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Min. Fv (kN/m): 0
Corresponding Mv (kN.m/m): 0
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Earth and Wall Load Factors
Get Defaults
SLS / Service, Horizontal Loads
EH Righting: 1
ULS / Strength, Horizontal Loads
Maximum
Minimum
EH Overturning: 1.25 0.8
EQ Overturning (seismic): 1
EH Righting: 1.25 0.8
ULS / Strength, Vertical Loads
Maximum
Minimum
Max/Min
DC (dead component): 1.2 1 1
EV (vertical earth): 1.25 1 1
ULS / Strength, Live Surcharge and Hydrostatic Loads
Maximum
Minimum
LH Overturning (live surcharge): 1.7 1
LV (vertical live surcharge): 1.7
WA / Hydrostatic: 1.1 0.9
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Wall Type: Gravity
Resisting Soil Side
Retained Soil Side
Wall Height (m): 3.5
Footing Depth (m): 0.5
Keyed Footing Height (m): 0
Toe Width (m): 0.2
Wall Width at Base (m): 2.0
Heel Width (m):
Wall Width at Top (m): 0.8
Wall Offset at Top (m): 0.2
Shear Key Width (m): 0
Distance from toe to Shear Key (m): 0
Length of Footing/Wall (m): 5
Optimize Footing Width:
Include Load Inclination Reduction Factor (R):
Geo 1
Geo 2
Geo 3
Geo 4
Synchronize
Click to Update BRIDGretainingwall Example v2.0.23.xlsx

APPENDIX 9 – DEEP PILE FOUNDATION TO CHBDC

Abutment Geometry

Bridge structure data: 13 girders / span semi-continuous with semi-integral abutments

Abutment data: (Distance between top of road and top of abutment ≅ 650 mm)

Skew:	30 °
Wall length:	29.951 m perpendicular to road, therefore skewed length = 34.585 m
Footing length:	say same as skewed wall length = 34.585 m
Wall dimensions:	see input sheet screen prints
Piles:	HS 324 dia. ULS geotechnical compressive resistance = 620 kN tension resistance = 600 kN SLS geotechnical compressive resistance = 415 kN tension resistance = 400 kN Initially assuming SLS and ULS horizontal resistance of piles is not required

Step 1) Produce a model assuming no piles. (From results the applicable forces will be used for pile design)

Total loading at bearing seat (from BRIDGframe) at SLS and showing ULS 3:

Note: The following example is for ULS 3; other ULS are also applicable including during construction conditions. Using vertical loads from wingwalls only; ignoring moments.

SLS Vertical:

Transitory loads: 1697 kN
Remaining loads: 4120 kN (incl. weight of wingwallsl / barriers on wingwalls)

ULS 3 Vertical:

Max. transitory loads: 2713 kN
Min. transitory loads: -679 kN
Max. remaining loads: 4497 kN (incl. weight of wingwalls / barriers on wingwalls)
Min. remaining loads: 3181 kN (incl. weight of wingwalls / barriers on wingwalls)

SLS Horizontal: (ignoring eccentricity of wingwalls / barriers on wingwalls)

Temperature Contraction: load factor = 0.8

13 bearings with horizontal shear stiffness of 4.0 kN / mm / brg
Contraction movement = 16.7

Max. corresponding load: 13 x 4.0 x 16.7 x 0.8 = 695 kN

ULS 3 Horizontal (Longitudinal): (ignoring eccentricity of wingwalls / barriers on wingwalls)

Temperature Contraction: load factor = 1.0

Max. corresponding load: 13 x 4.0 x 16.7 x 1.0 = 868 kN
Min. corresponding load: say = 0 kN (would be negative for expansion)

SLS Horizontal (Transverse): Transitory

Transverse Wind Load on Superstructure: N/A
Transverse Wind Load on Live Load: N/A

Transverse Temperature Contraction:
(transverse loading from temperature will be automatically calculated by program)

ULS 3 Horizontal (Transverse): Transitory

Transverse Wind Load on Superstructure: acting 1.38 m above the bearing seat

Fhx = 24 x 0.45 = 11 kN
Mhx = 11 x (1.38 + abut wall ht + ftg dpth)
= 11 x (1.38 + 1.7 + 0.7) = 42 kN.m

Transverse Wind Load on Live Load: acting 3.74 m above the bearing seat

Fhx = 24 x 0.45 = 11 kN
Mhx = 11 x (3.74 + 1.7 + 0.7) = 68 kN.m

Transverse Temperature Contraction:
(transverse loading from temperature will be automatically calculated by program)

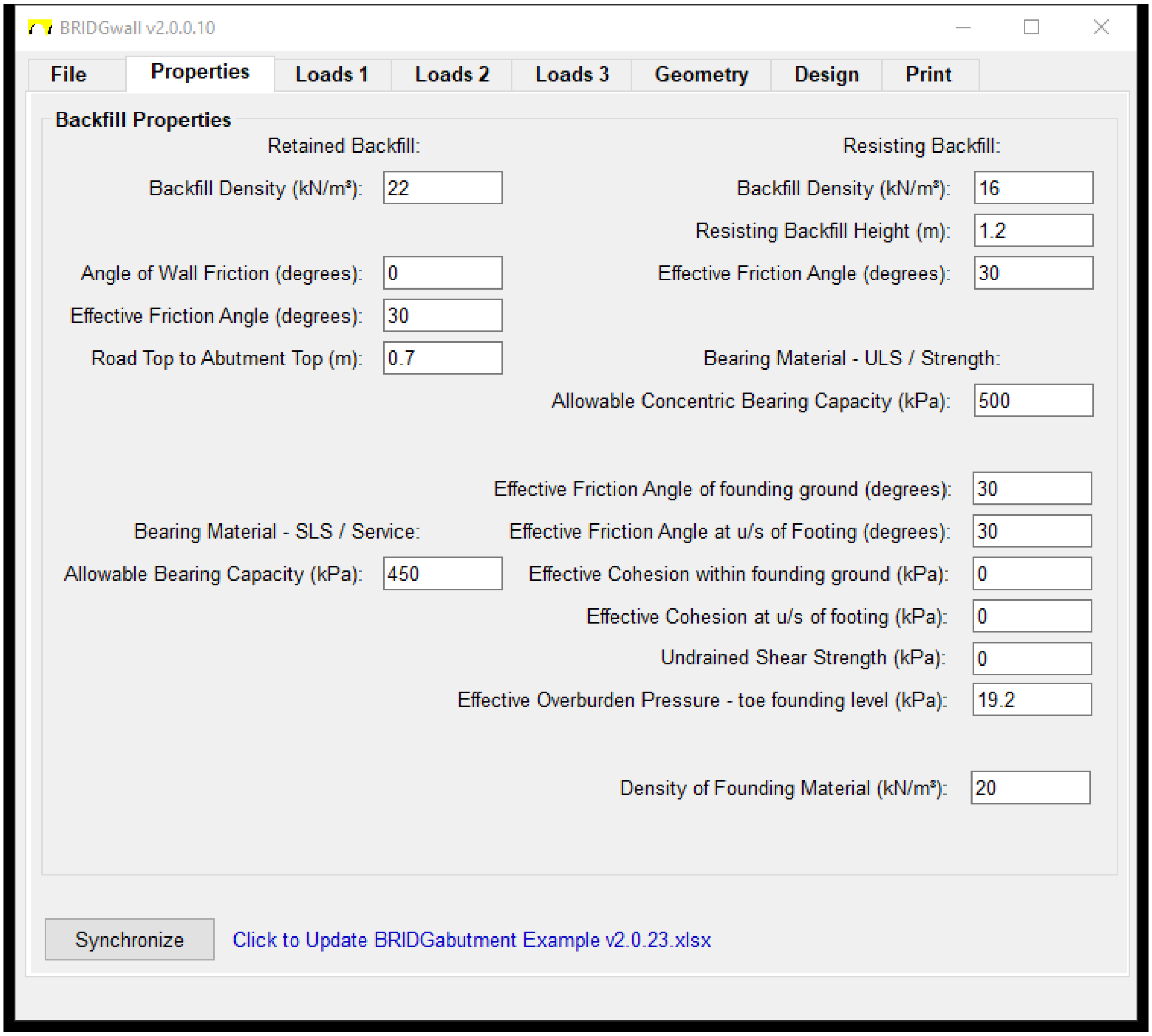
Surcharge Loads:

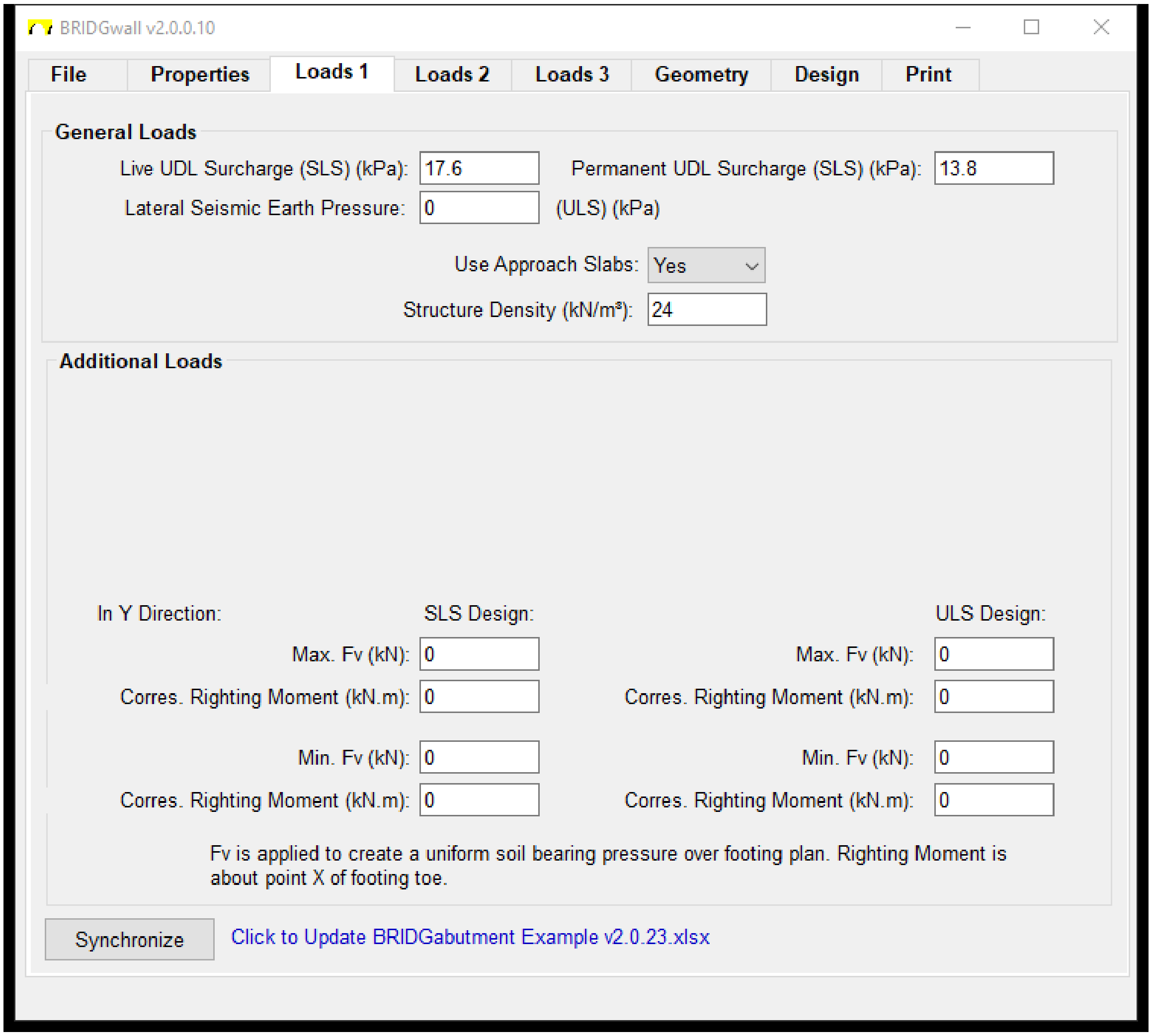
Backfill: 0.65 x 21.2 = 13.78 kPa (top of abutment is 0.65 m below grade)
Live: 0.8 x 21.2 = 16.96 kPa

Effective overburden pressure at toe = resisting backfill density x depth of fill = 1.2 x 16 = 19.2 kPa.

Assume SLS and ULS allowable bearing capacities as a starting point only for approximating footing size; they are not applicable to the pile foundation design.

Load factors for EH Righting may be entered as 0 (zero) to eliminate any horizontal resisting earth pressure. Or these same factors may be increased to change horizontal resisting earth pressure from at-rest to passive conditions.

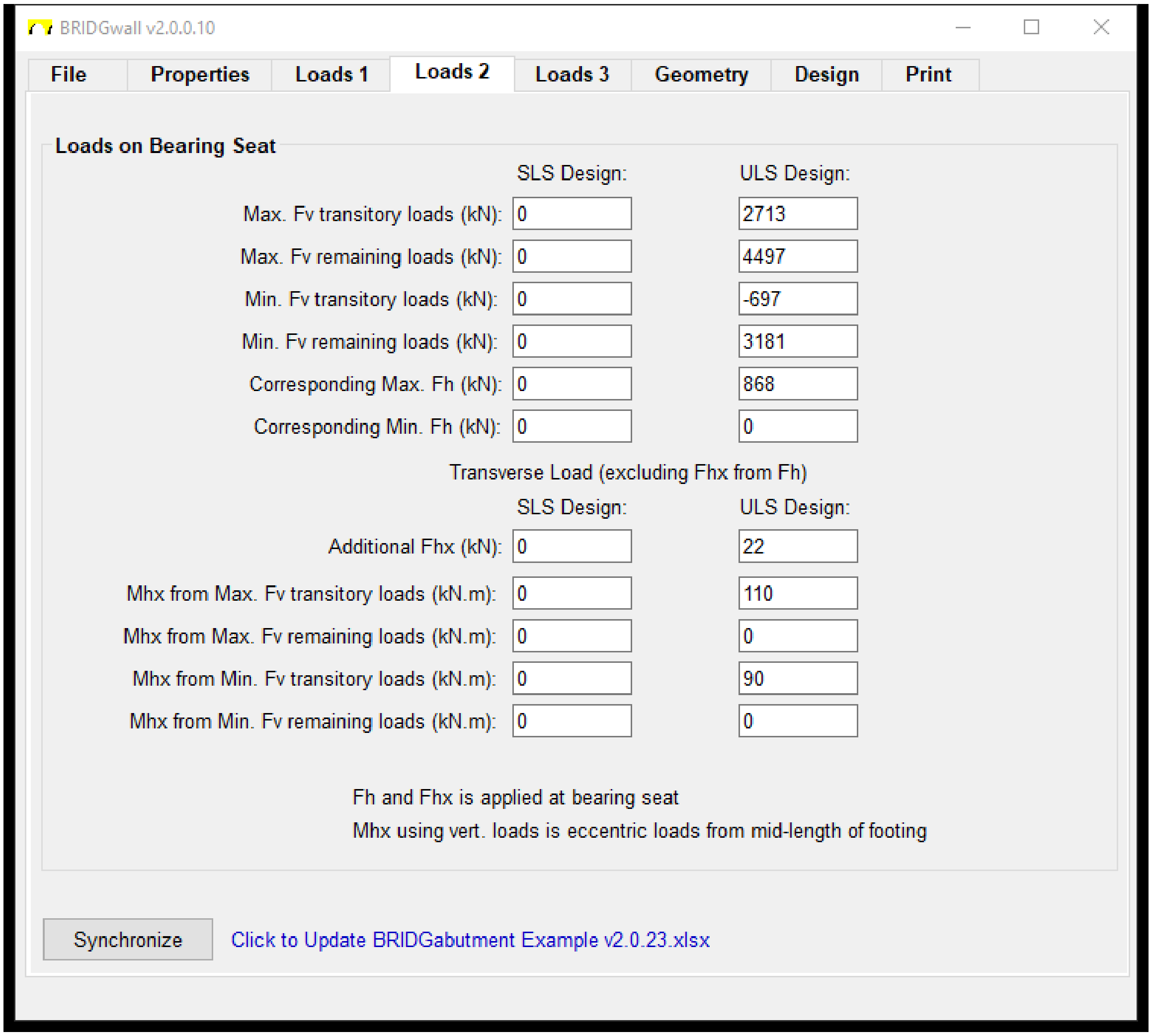

BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Backfill Properties
Retained Backfill:
Backfill Density (kN/m³): 22
Angle of Wall Friction (degrees): 0
Effective Friction Angle (degrees): 30
Road Top to Abutment Top (m): 0.7
Resisting Backfill:
Backfill Density (kN/m³): 16
Resisting Backfill Height (m): 1.2
Effective Friction Angle (degrees): 30
Bearing Material - ULS / Strength:
Allowable Concentric Bearing Capacity (kPa): 500
Effective Friction Angle of founding ground (degrees): 30
Bearing Material - SLS / Service:
Effective Friction Angle at u/s of Footing (degrees): 30
Allowable Bearing Capacity (kPa): 450
Effective Cohesion within founding ground (kPa): 0
Effective Cohesion at u/s of footing (kPa): 0
Undrained Shear Strength (kPa): 0
Effective Overburden Pressure - toe founding level (kPa): 19.2
Density of Founding Material (kN/m³): 20
Synchronize
Click to Update BRIDGabutment Example v2.0.23.xlsx



- Live and Permanent UDL Surchanrge should be applied over the length between the inside faces of wingwalls only. Therefore, if the Live UDL surcharge is calculated as 0.8m of earth fill x 22 kN/m^3 = 17.6 kPa, and the total abutment wall length is 12.0m with 0.4m wingwalls, multiply 17.6 x 11.2 / 12.0 = 16.427 kPa to use as the Live UDL Surcharge.

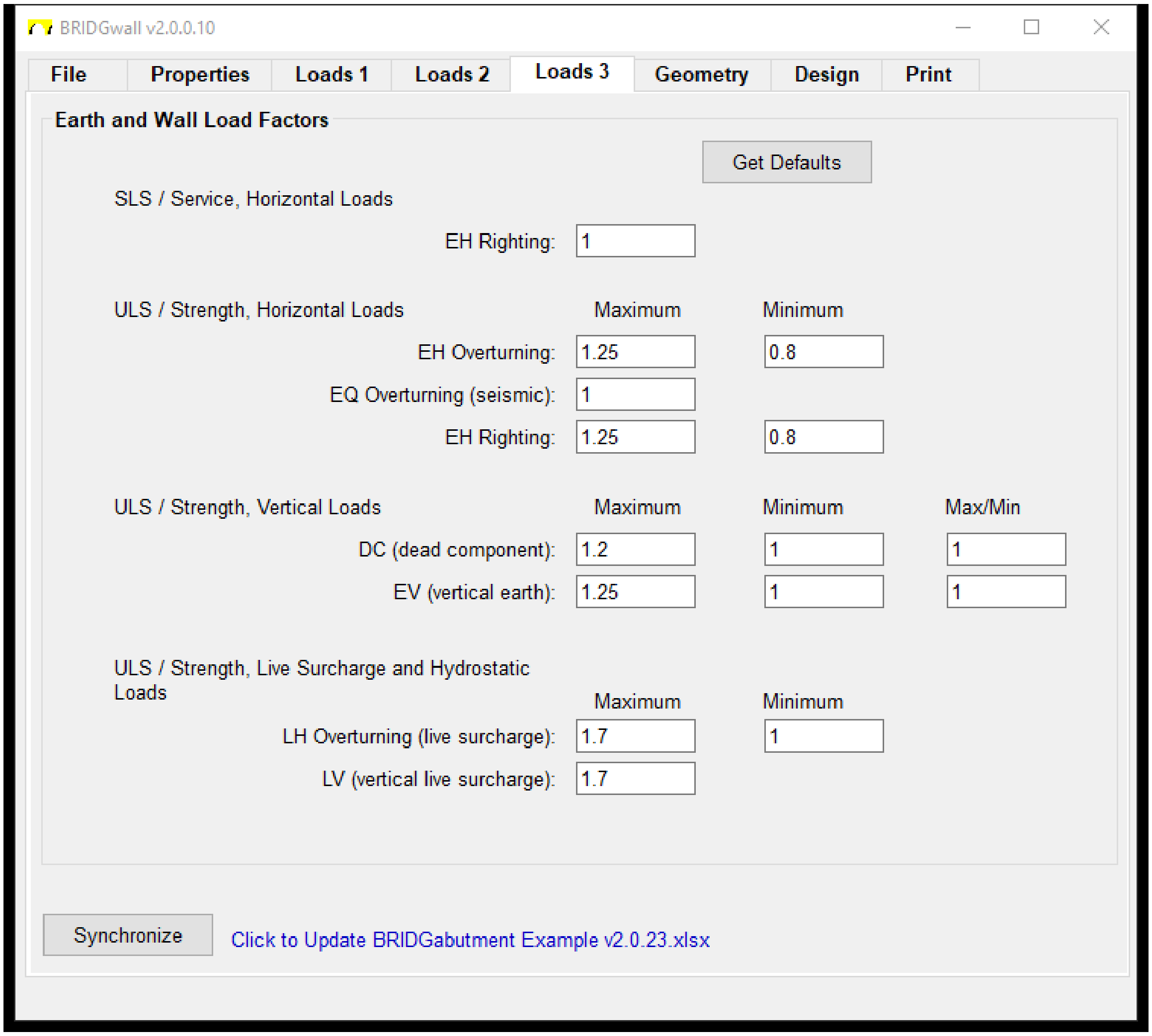
- Vertical Additional Loads may be used to model the portion of wingalls that extend beyond the heel of the footing. The portion of the wingwall that is directly over the heel of the footing will be modeled as backfill by the program, and since concrete and backfill are approximately the same weight, the portion of wingwall over the heel is being accounted for.

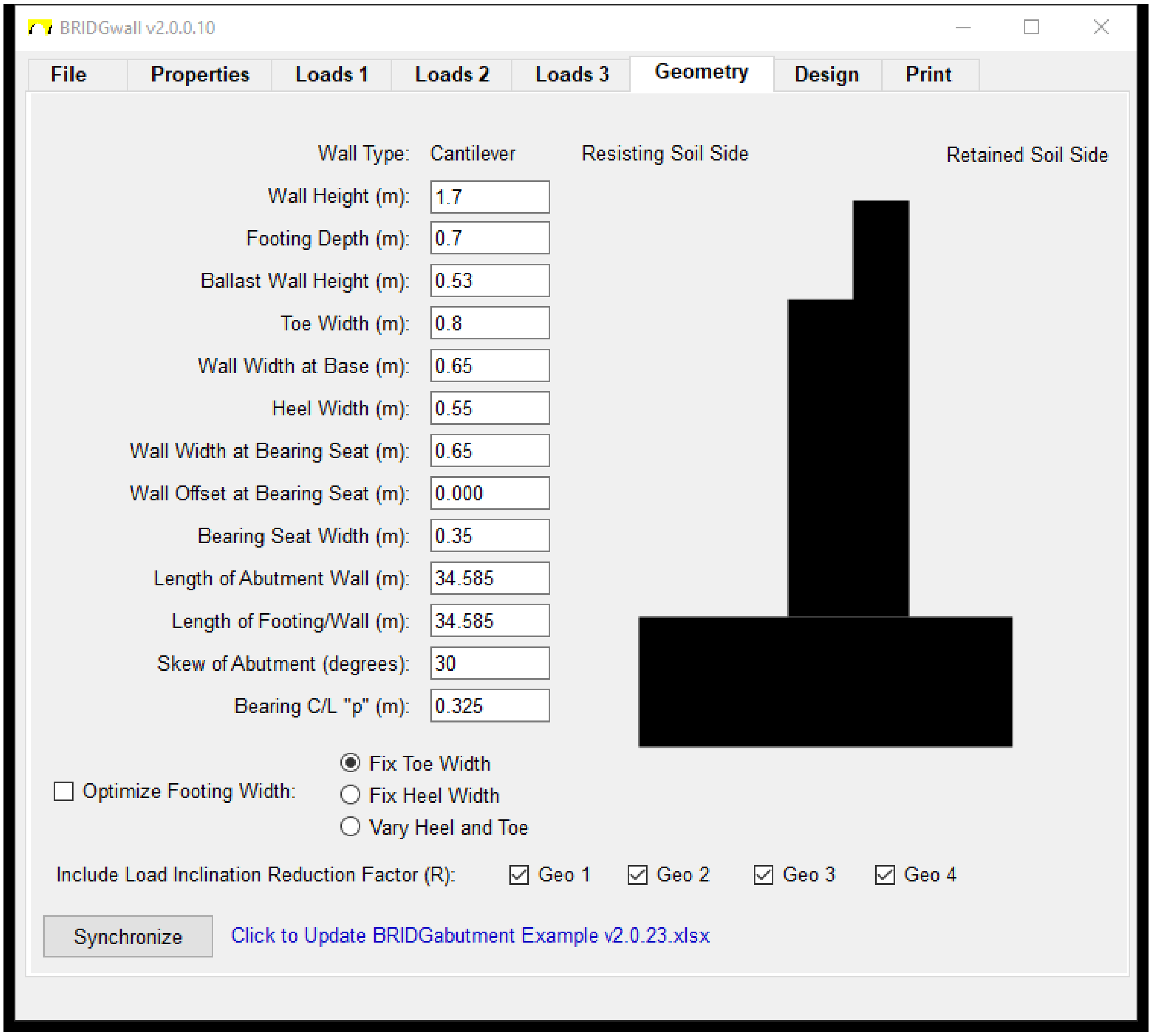
- If the Heel Width is calculated by the program, the actual forces from the wingwall may need to be recalculated for consistancy.



Example:

- Corresponding Max Fh might be if Max Fv transitory included live load, then Max Fh could include braking. If Fv did not include truck load then Fy would not include braking.
- Corresponding Fh may be for temperature only where no value for temperature might be in Fv.
- Corresponding Min Fh will likely always be 0


BRIDGwall v2.0.0.10
File
Properties
Loads 1
Loads 2
Loads 3
Geometry
Design
Print
Earth and Wall Load Factors
Get Defaults
SLS / Service, Horizontal Loads
EH Righting:
1
ULS / Strength, Horizontal Loads
Maximum
Minimum
EH Overturning:
1.25
0.8
EQ Overturning (seismic):
1
EH Righting:
1.25
0.8
ULS / Strength, Vertical Loads
Maximum
Minimum
Max/Min
DC (dead component):
1.2
1
1
EV (vertical earth):
1.25
1
1
ULS / Strength, Live Surcharge and Hydrostatic Loads
Maximum
Minimum
LH Overturning (live surcharge):
1.7
1
LV (vertical live surcharge):
1.7
Synchronize
Click to Update BRIDGabutment Example v2.0.23.xlsx



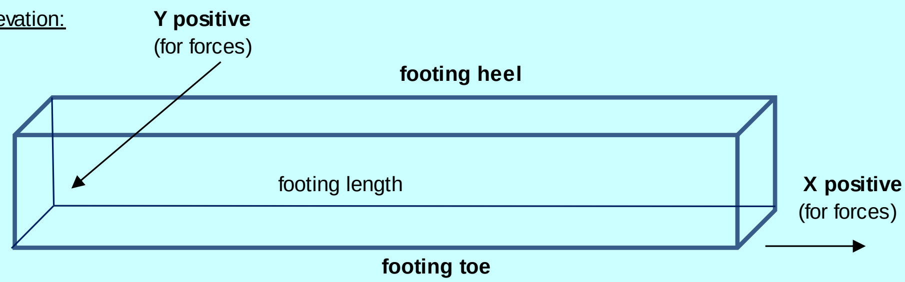
- For simplicity, enter length of abutment and length of footing as the same value. Additional soil fill on the footing that extends past the abutment wall length is not included in design. The length of the footing is only used for calculating bearing resistance as per cl.6.10.2 (CHBDC)

Project Name:	Bridge ABC
Project Number:	123456
Client:	County of ABC
Design Firm:	Simplified Bridge Solutions Ltd.
Designer:	Vic W. Segula
Date:	14-Jan-24
Version:	2.0.23
Type:	Abutment
Code:	CHBDC

ABUTMENT WALL DESIGN TO THE CANADIAN HIGHWAY BRIDGE DESIGN CODE
*****

Notes: 1) assumes free draining granular backfill and drains, therefore no water or negligable water table — cl.C6.9.1(h)

Footing Elevation:

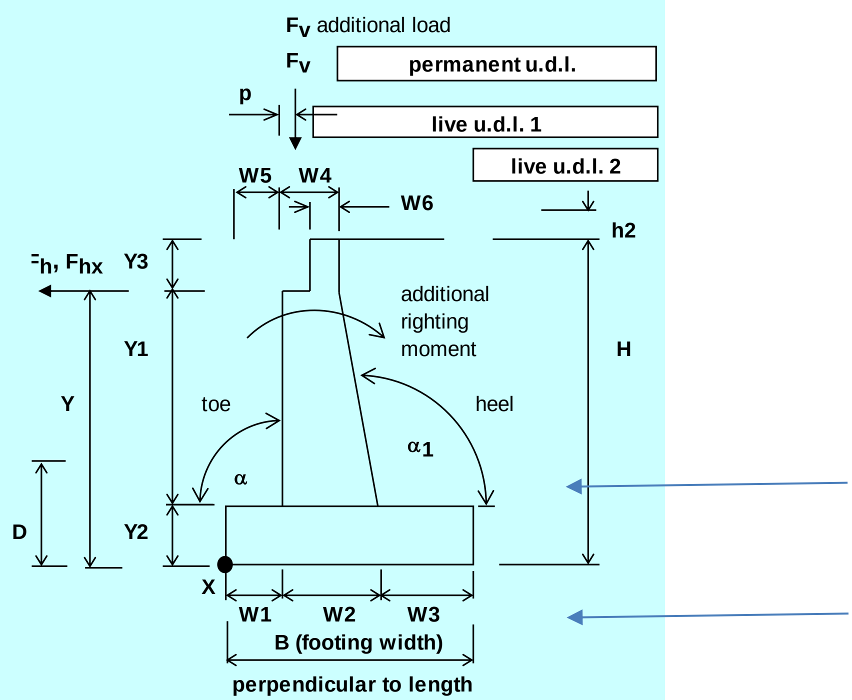


Properties:

Y1 =	1.700	m
Y2 =	0.700	m
Y3 =	0.530	m
W1 =	0.800	m
W2 =	0.650	m
W3 =	0.550	m
W4 =	0.650	m
W5 =	0.800	m
W6 =	0.300	m
p =	0.325	m

Design for: Cantilever Wall

Y =	2.400	m
B =	2.000	m
H =	2.930	m



Inclined wall angle from horiz. "α" = 90.0 °
Inclined wall angle from horiz. "α_1" = 90.0 °

Length of abutment wall "L1" = 34.585 m
Length of footing "L2" = 34.585 m
Skew of abutment = 30.0 °

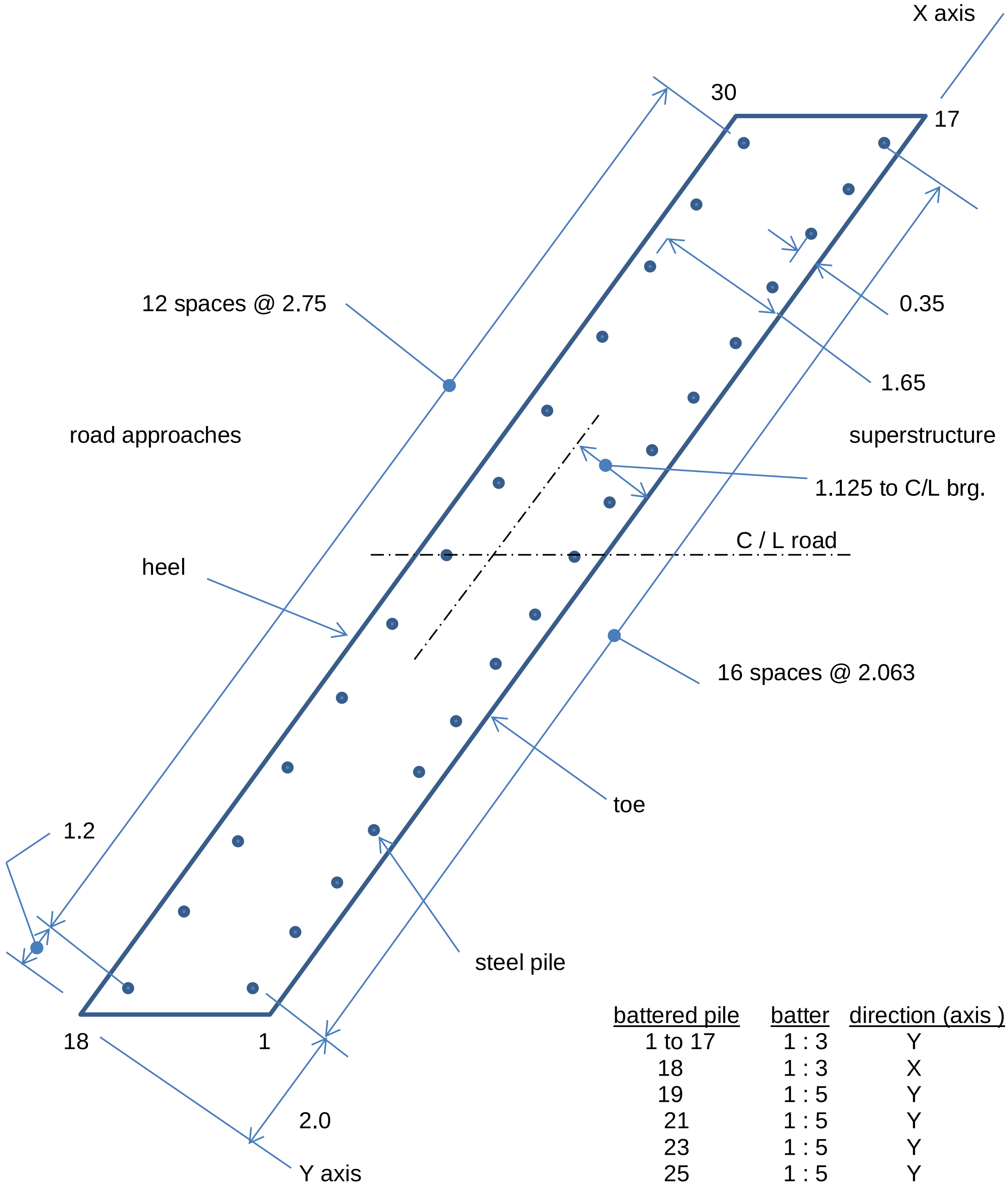
<u>Note:</u> abutment wall is assumed to be centred along length of footing

Structure density = 24.0 kN/m^3

Forces on Bearing Seats at 'p' :

SLS:	Max. Fv transitory load (excl. DLA) =	0.0	kN
	Max. Fv remaining loads =	0.0	kN
	Min. Fv transitory load (excl. DLA) =	0.0	kN
	Min. Fv remaining loads =	0.0	kN
	Max. Fh force =	0.0	kN
	Min. Fh force =	0.0	kN
	Corresp. Max. Fh_y force (from Fh) =	0.0	kN
	Corresp. Max. Fh_x force (from Fh) =	0.0	kN
	Corresp. Min. Fh_y force (from Fh) =	0.0	kN
	Corresp. Min. Fh_x force (from Fh) =	0.0	kN
	Additional transverse Fh_x =	0.0	kN
	Mh_x from additional transverse Fh_x =	0.0	kN.m
	Mh_x using Max. Fv transitory loads =	0.0	kN.m
	Mh_x using Max. Fv remaining loads =	0.0	kN.m
	Mh_x using Min. Fv transitory loads =	0.0	kN.m
	Mh_x using Min. Fv remaining loads =	0.0	kN.m
ULS:	Max. Fv transitory load (excl. DLA) =	2713.0	kN
	Max. Fv remaining loads =	4497.0	kN
	Min. Fv transitory load (excl. DLA) =	-697.0	kN
	Min. Fv remaining loads =	3181.0	kN
	Max. Fh force =	868.0	kN
	Min. Fh force =	0.0	kN
	Corresp. Max. Fh_y force (from Fh) =	751.7	kN
	Corresp. Max. Fh_x force (from Fh) =	434.0	kN
	Corresp. Min. Fh_y force (from Fh) =	0.0	kN
	Corresp. Min. Fh_x force (from Fh) =	0.0	kN
	Additional transverse Fh_x =	22.0	kN
	Mh_x from additional transverse Max. Fh_x =	52.8	kN.m
	Mh_x using Max. Fv transitory loads =	110.0	kN.m
	Mh_x using Max. Fv remaining loads =	0.0	kN.m
	Mh_x using Min. Fv transitory loads =	90.0	kN.m
	Mh_x using Min. Fv remaining loads =	0.0	kN.m

Assumed Pile Layout:



battered pile	batter	direction (axis)
1 to 17	1 : 3	Y
18	1 : 3	X
19	1 : 5	Y
21	1 : 5	Y
23	1 : 5	Y
25	1 : 5	Y
27	1 : 5	Y
29	1 : 5	Y
30	1 : 3	X

Conservatively assume unsupported length of pile = 6000 mm.

STRUCTURAL DESIGN (Str 1)

- perm. udl + live udl 1 surcharge or perm. udl + seismic
- this worksheet assumes max. Fh and max. Fv
- additional transverse Mh_x

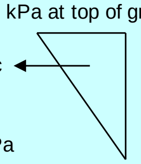
ULS Load Factors:

LH / α_L live surcharge	1.70
LV / α_L live surcharge	1.70
EH / α_E overturning	1.25
EH / α_E righting	0.80
EV / α_D earth fill	1.25
DC / α_D structure	1.20
EQ overturning	1.00

Retained Soil: **max. horizontal earth and max. surcharge**

Compaction Surcharge (CHBDC only) cl.6.12.3

Distance between top of road and top of abutment "h2" = 0.700 m



h1 = 1.700 m
h1 x 12 / 2 = Pc = 10.2 kN

depth of compaction surcharge on abutment = 1.000 m
comp. surcharge pressure at top of abut. = 7.1 kPa

"Pc" on abutment = 3.5 kN/m

Unfactored Overturning Moment from Surcharge = 9.2 kN.m/m

SLS:

$Pa_y = K_a$ (0.5 x density soil x H^2+u.d.l. x H) x L1 = 1554.8 kN

$Ph_y = Pa_y$ x Sin ($\alpha_1+\delta$) + Pc = 1676.9 kN

Pv_y = (Pa_y + Pc) x Sin (α_1-90+δ) = N/A kN

Vertical distance from X to Pa_y or Ph_y = 1.230 m

Horizontal distance from X to Pv_y = N/A m

ULS:

$Pa_{y1} = K_a$ (0.5 x density soil x H^2+u.d.l. x H) x L1 = 1943.5 kN

Pa_{y2} = (K_a (0.5 x density soil x H^2 + perm. udl x H)+seismic udl x H) x L1 = N/A kN

use Pa_y = 1943.5 kN

$Ph_y = Pa_y$ x Sin ($\alpha_1+\delta$) + Pc = 2096.1 kN

Pv_y = (Pa_y + Pc) x Sin (α_1-90+δ) = N/A kN -USED FOR GRAVITY WALL ONLY

Vertical distance from X to Pa_y or Ph_y = 1.230 m

Horizontal distance from X to Pv_y = N/A m

Resisting Soil: **min. horizontal earth**

SLS:

$P_o h_y = K_o$ (0.5 x density soil x H^2) x L1 = 199.2 kN

ULS:

$P_o h_y = K_o$ (0.5 x density soil x H^2) x L1 = 159.4 kN

Vertical distance from X to $P_o h_y$ = 0.400 m

CANTILEVER WALL *

Sum of Horizontal Forces "P_{Hy}" =	1477.7	kN	SLS
Sum of Horizontal Forces "P_{Hy}" =	2688.4	kN	ULS
Sum of Horizontal Forces "P_{Hx}" =	0.0	kN	SLS
Sum of Horizontal Forces "P_{Hx}" =	456.0	kN	ULS
Moment Righting "M_{Ry} " =	5411.2	kN.m	SLS
Moment Righting "M_{Ry} " =	15087.8	kN.m	ULS
Moment Righting "M_{Rx} " =	71689.0	kN.m	SLS
Moment Righting "M_{Rx} " =	216404.4	kN.m	ULS
Moment Overturning "Mo_y" =	2063.1	kN.m	SLS
Moment Overturning "Mo_y" =	4383.0	kN.m	ULS
Moment about C/L of footing "Mo_x" =	0.0	kN.m	SLS
Moment about C/L of footing "Mo_x" =	1204.4	kN.m	ULS
Sum of Vertical Loads "V" =	4145.7	kN	SLS
Sum of Vertical Loads "Q" =	12514.4	kN	ULS

Mx1 = X direction moments about Y axis from Gravity loads.

Note: if the center of the gravity loads about the Y axis passes through the centroid of the piles about the Y axis, the above Mx1 is not required. This example will include it regardless.

Therefore, Mx1 = 12514.4 kN x 17.293 m = 216412 kN.m

Torsion:

Torsion is caused by the longitudinal or transverse loads acting at a distance from the centroid of the piles. For transverse force, the location of the force along the Y axis would be the centroid of the bearing.

Distance between centroid of bearing and centroid of piles:

Distance from X axis to centroid of bearing = 1.125 m

From the Design 2 worksheet (after completing pile layout tables, the 'y' for torsional moment of inertia = 1.650 m.

1.650 – 1.125 = 0.525 m

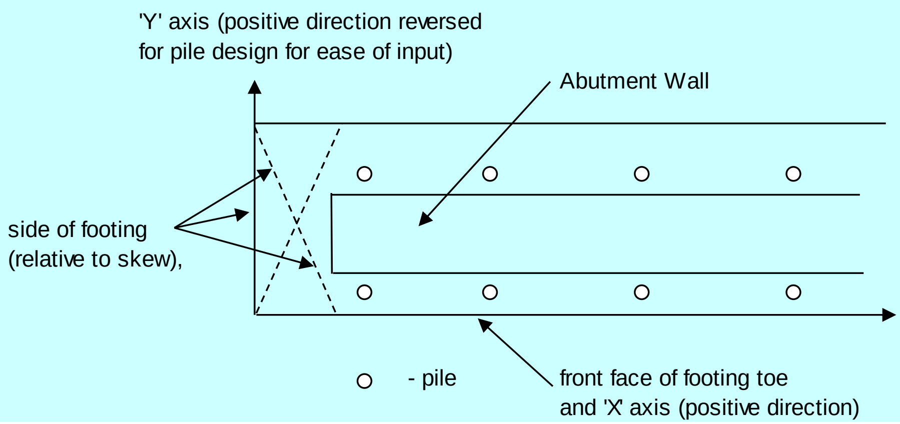
Say wind is acting in same direction as Fhx. Torsion is counterclockwise.

Ty = 2688.4 kN x 0.0 m = 0 kN.m (resultant force acts through centroid of piles)
Tx = (434.0 + 22.0) kN x 0.525 = -239.4 kN.m (counterclockwise)

WORKSHEET FOR DEEP PILE FOUNDATION USING CSA-S6-19

Note: For design of piles, set minimum load factor on the Loads 3 Input tab to 1.0 for Dead / SIDL and Vertical Earth Loads

PILE LAYOUT



IN Y DIRECTION (ABOUT X AXIS) Y direction batters resisting Y neg. movement only in table below
Remaining piles to be input with no batter.

N° of piles ' y '	pile I.D.	dist. from X axis (m)	Inertia ' y ' of piles	Y batter Y = 'yes'	battered ie., 4	rot. from Y axis	rot. from X axis
1	1	0.350	0.317	Y	3.0	0.0	90.0
1	2	0.350	0.317	Y	3.0	0.0	90.0
1	3	0.350	0.317	Y	3.0	0.0	90.0
1	4	0.350	0.317	Y	3.0	0.0	90.0
1	5	0.350	0.317	Y	3.0	0.0	90.0
1	6	0.350	0.317	Y	3.0	0.0	90.0
1	7	0.350	0.317	Y	3.0	0.0	90.0
1	8	0.350	0.317	Y	3.0	0.0	90.0
1	9	0.350	0.317	Y	3.0	0.0	90.0
1	10	0.350	0.317	Y	3.0	0.0	90.0
1	11	0.350	0.317	Y	3.0	0.0	90.0
1	12	0.350	0.317	Y	3.0	0.0	90.0
1	13	0.350	0.317	Y	3.0	0.0	90.0
1	14	0.350	0.317	Y	3.0	0.0	90.0
1	15	0.350	0.317	Y	3.0	0.0	90.0
1	16	0.350	0.317	Y	3.0	0.0	90.0
1	17	0.350	0.317	Y	3.0	0.0	90.0
1	18	1.650	0.543			90.0	0.0
1	19	1.650	0.543	Y	5.0	0.0	90.0
1	20	1.650	0.543			0.0	0.0
1	21	1.650	0.543	Y	5.0	0.0	90.0
1	22	1.650	0.543			0.0	0.0
1	23	1.650	0.543	Y	5.0	0.0	90.0
1	24	1.650	0.543			0.0	0.0
1	25	1.650	0.543	Y	5.0	0.0	90.0
1	26	1.650	0.543			0.0	0.0
1	27	1.650	0.543	Y	5.0	0.0	90.0
1	28	1.650	0.543			0.0	0.0
1	29	1.650	0.543	Y	5.0	0.0	90.0
1	30	1.650	0.543			90.0	0.0
	31						
	32						

30 = Total piles

y' = Sum piles * dist. from X axis / Sum piles = 0.913 m

e_y = dist. from X axis

Inertia of a single pile in the Y direction = $1 * (e_y - y')^2$

Inertia of piles ' y ' in the Y direction = 12.450 m^4

<u>IN X DIRECTION (ABOUT Y AXIS)</u> X direction batters resisting -X OR X movement only, in table below. Remaining piles to be input with no batter.

N^o of piles ' x '	pile I.D.	dist. from Y axis (m)	Inertia ' x ' of piles	X batter Y = 'yes'	battered ie., 4	actual batter in 'xy' direction
1	1	2.000	261.026			
1	2	4.063	198.621			
1	3	6.126	144.728			
1	4	8.189	99.347			
1	5	10.252	62.478			
1	6	12.315	34.121			
1	7	14.378	14.276			
1	8	16.441	2.942			
1	9	18.504	0.121			
1	10	20.567	5.811			
1	11	22.630	20.014			
1	12	24.693	42.728			
1	13	26.756	73.955			
1	14	28.819	113.693			
1	15	30.882	161.943			
1	16	32.945	218.706			
1	17	35.008	283.980			
1	18	1.200	287.516	Y	3.0	
1	19	3.950	201.819			
1	20	6.701	131.224			
1	21	9.451	75.782			
1	22	12.201	35.466			
1	23	14.951	10.274			
1	24	17.702	0.206			
1	25	20.452	5.270			
1	26	23.202	25.459			
1	27	25.952	60.773			
1	28	28.703	111.233			
1	29	31.453	176.802			
1	30	34.203	257.497	Y	3.0	
	31					
	32					

30 = Total piles

x' = Sum piles * dist. from Y axis / Sum piles = 18.156 m

e_X = dist. from Y axis

Inertia of a single pile in the X direction = 1 * (e_X - x')^2

Inertia of piles ' x ' in the X direction = 3117.812 m^4

TORSIONAL MOMENT OF INERTIA - using battered piles only

Y BATTERED PILES

x' = Sum piles x dist. X / Sum piles = 18.295 m

e_y = dist. from Y axis

Inertia of a single pile in the Y direction = 1 * (x' - e_y)^2

Inertia of all piles in the Y direction = 2268.771 m^4

X BATTERED PILES

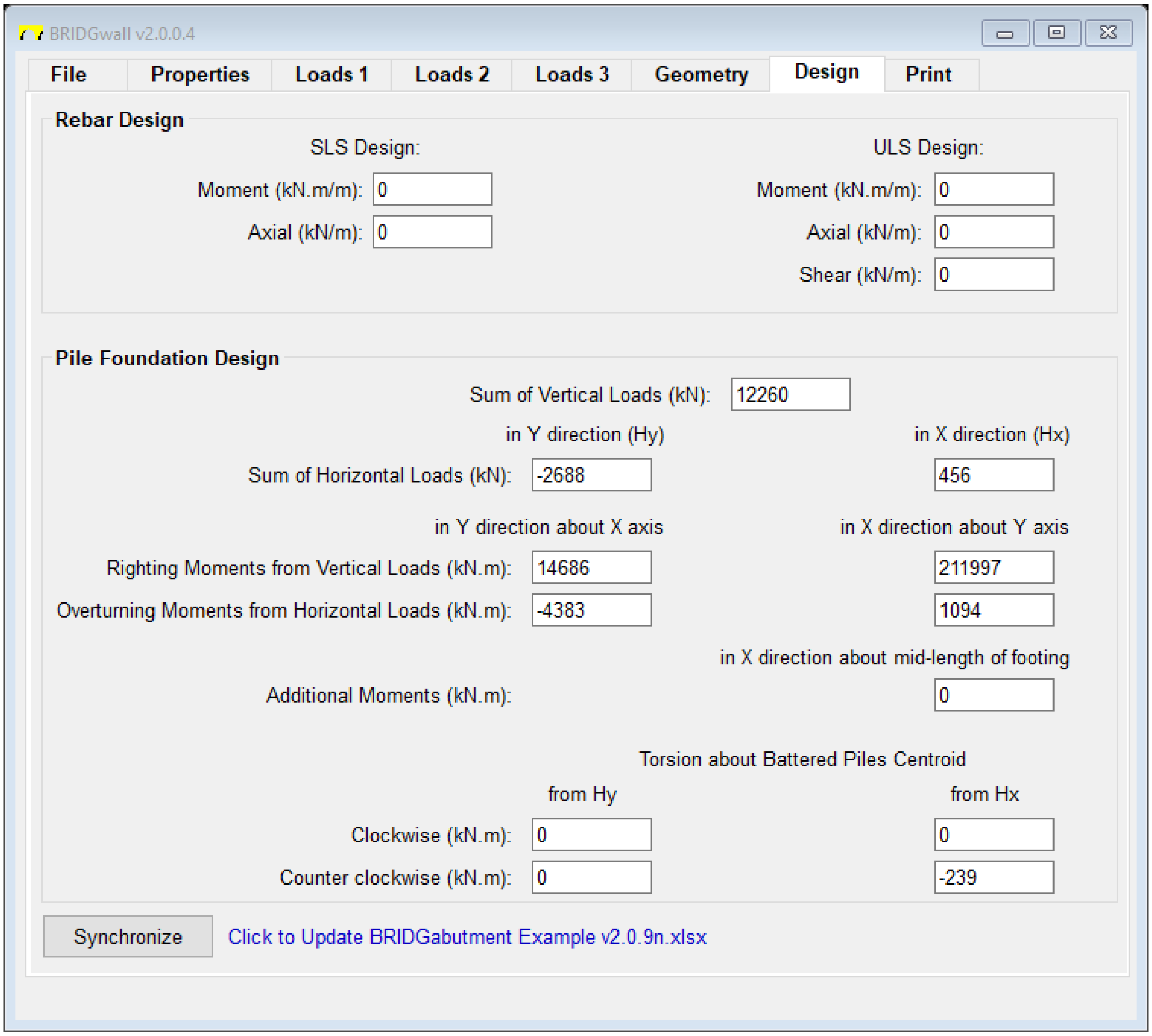
y' = Sum piles x dist. Y / Sum piles = 1.650 m

e_x = dist. from X axis

Inertia of a single pile in the X direction = 1 * (y' - e_x)^2

Inertia of all piles in the X direction = 0.000 m^4

Therefore J = $I_x + I_y$ = 2268.771 m^4



- The sign convention in the Y direction has been reversed from that in the remainder of the program for ease of not inputting numerous pile offsets as negative values. Therefore, force direction in the Y direction has changed accordingly.
- Sign convention of horizontal forces should be entered relative to the direction of skew. For clockwise skew, the forces in the X direction will be positive; and for counterclockwise skew, the forces in the X direction will be negative.

PILE DESIGN

LOAD DATA - total loads on pile group

Note: V, H, and M forces must be input using program (VB interface)

V =	sum of vertical loads =	12514.0	kN (V or Q from Str 1 to 4)

Do not include horizontal load from opposite battered piles in H_x and H_y below.

H_y =	sum of horizontal loads in the Y direction =	-2688.0	kN (Phy from Str 1 to 4)
H_x =	sum of horizontal loads in the X direction =	456.0	kN

Hx is the sum of Fh_x (component of Fh plus Additional transverse Fh_x from Input worksheet)

Note: Starting point used for lever arm length for M_{x1} and M_{y1} should correspond with point for "dist. from axis" for pile layout data.

M_{y1} =	Y direction moments about X axis from gravity lds. =	15088.0	kN.m (Mry from Str 1 to 4)
M_{x1} =	X direction moments about Y axis from gravity lds. =	216412.0	kN.m (Mrx from Str 1 to 4)
M_{y2} =	Y direction moments about X axis from horiz. lds. =	-4383.0	kN.m (Moy from Str 1 to 4)
M_{x2} =	X direction moments about Y axis from horiz. lds. =	1204.0	kN.m (Mox from Str 1 to 4)

M_{x3} = additional moments in X direction about mid-length of footing = 0.0 kN.m

$M_y = M_{y1}+M_{y2}$ = sum of moments in the Y direction about X axis = 10705.0 kN.m

$M_{x1\_x2} = M_{x1}+M_{x2}$ = sum of moments in the X direction about Y axis = 217616.0 kN.m

d_y = distance to centroid of load from the X axis = M_y / V =	0.855	m
d_x = distance to centroid of load from the Y axis = M_{x1_x2} / V =	17.390	m

Torsion - Clockwise:

T_y = torsional moments from H_y =	0.0	kN.m
T_x = torsional moments from H_x =	0.0	kN.m

Torsion - Counterclockwise:

T_y = torsional moments from H_y =	0.0	kN.m
T_x = torsional moments from H_x =	-239.0	kN.m

Design of Pile 1: % of Hy load pile = 1 / 23 Y battered piles x 100 = 4.3 %

Single Pile Design — Pile I.D.: 1 (1 to 86) *

DATA

Compressive Resistance of Vertical Piles =	620.0	kN
Compressive Resistance of Battered Piles =	620.0	kN
Is pile battered in Y direction	Yes	
Batter of pile =	3.0	vertical to 1 horizontal
Is pile battered in X direction	No	
Batter of pile =	0.0	vertical to 1 horizontal

GRAVITY LOAD EFFECTS:

$$\text{Vert. ld / pile} = \text{gravity ld on a pile} + \Sigma \frac{M_y' \text{ and } M_x' \text{ about the c.g of piles} * c_y \text{ and } c_x}{\text{Inertia ' y ' and Inertia ' x '}}$$

-gravity ld may be the total ld / N^o of piles if the structure is considered rigid such as a bridge abutment or the gravity ld shall be determined per pile based on the ld from the contributing area.

gravity load from V per pile = v =	417.0	kN
y' = distance from X axis to pile =	0.350	m
x' = distance from Y axis to pile =	2.000	m
M_y' = moment in Y direction = V * (d_y - y') =	-724.5	kN.m
M_x' = moment in X direction = V * (d_x - x') =	-9591.9	kN.m
c_y = dist from c.g. of piles to design pile =	-0.563	m
c_x = dist from c.g. of piles to design pile =	-16.156	m
v_y = Vertical ld / pile in Y direction (excl. gravity) =	32.8	kN
v_x = Vertical ld / pile in X direction (excl. gravity) =	49.7	kN
d_x = dist from M_{x3} to pile ' x ' =	-15.293	m
Vertical ld / pile ' x ' from M_{x3} = v_{x3} =	0.0	kN
Vertical Load in Pile = v + v_y + v_x + v_{x3} =	499.5	kN
Horizontal component / pile in Y direction from Vertical ld. =	166.5	kN
Horizontal component / pile in X direction from Vertical ld. =	0.0	kN

TORSION DATA:

$c1_y$ = dist from c.g. of battered piles from Y axis to battered pile along x axis = 0.350 m

$c1_x$ = dist from c.g. of battered piles from X axis to battered pile along y axis = 17.945 m

c = straight line dist from c.g. of battered piles to battered pile = 17.948 m

Applicable J = 2268.77 m^2

Horizontal component / pile from Torsion ld. = 0.0 kN

Include Torsion ld. in further design Yes

AXIAL DESIGN CHECK:

Axial Force in Pile = 526.5 kN **< compr. resist of pile, therefore OK**

Horizontal Stability Check of battered pile in Y direction:

Horizontal component / pile in Y direction =	166.5	kN
Passive resistance of pile in Y direction =		kN
Structural resistance (assumed fixed at a depth) =		kN
	166.5	kN

Percentage of H_y loading pile =	4.30	%
Horizontal force / battered pile ' y ' from H_y =	115.6	kN
Horizontal force from opposite battered pile from V =		kN (pos)
Total including Horizontal component / pile from Torsion ld. =	115.5	kN

166.5 kN >/= 115.5 kN **therefore OK**

Horizontal Stability Check of battered pile in X direction:

Horizontal component / pile in X direction =	0.0	kN
Passive resistance of pile in X direction =		kN
Structural resistance (assumed fixed at a depth) =		kN
	0.0	kN

Percentage of H_x loading pile =		%
Horizontal force / battered pile ' x ' from H_x =	0.0	kN
Horizontal force from opposite battered pile from V =		kN (pos)
Total including Horizontal component / pile from Torsion ld. =	0.0	kN

0.0 kN >/= 0.0 kN **therefore OK**