Paia Retain Overview

Paia means "wall" in the Hawaiian language. Paia Retain is software developed to design cantilever concrete walls based on AASHTO LRFD and IBC design codes.

Hardware Requirements
Minimum
Any Windows compatible computer with a Pentium 3 Processor or better
Windows XP/Vista/7/8
256MB of RAM

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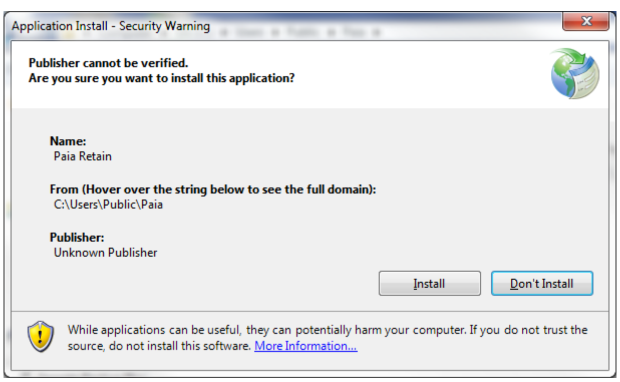
Installation:

Installation of this program uses ClickOnce process which is designed to work for non-administrative accounts, and is installed in the user's profile folders. One of the design goals of ClickOnce is to provide a deployment technique that allows customers to install applications without elevated privileges. However, if multiple users are using one computer the program should be installed for each user because in this method the files are stored in the user’s profile. Another design goal is to protect the client machine from problems caused by software installations such as “dll” system files.

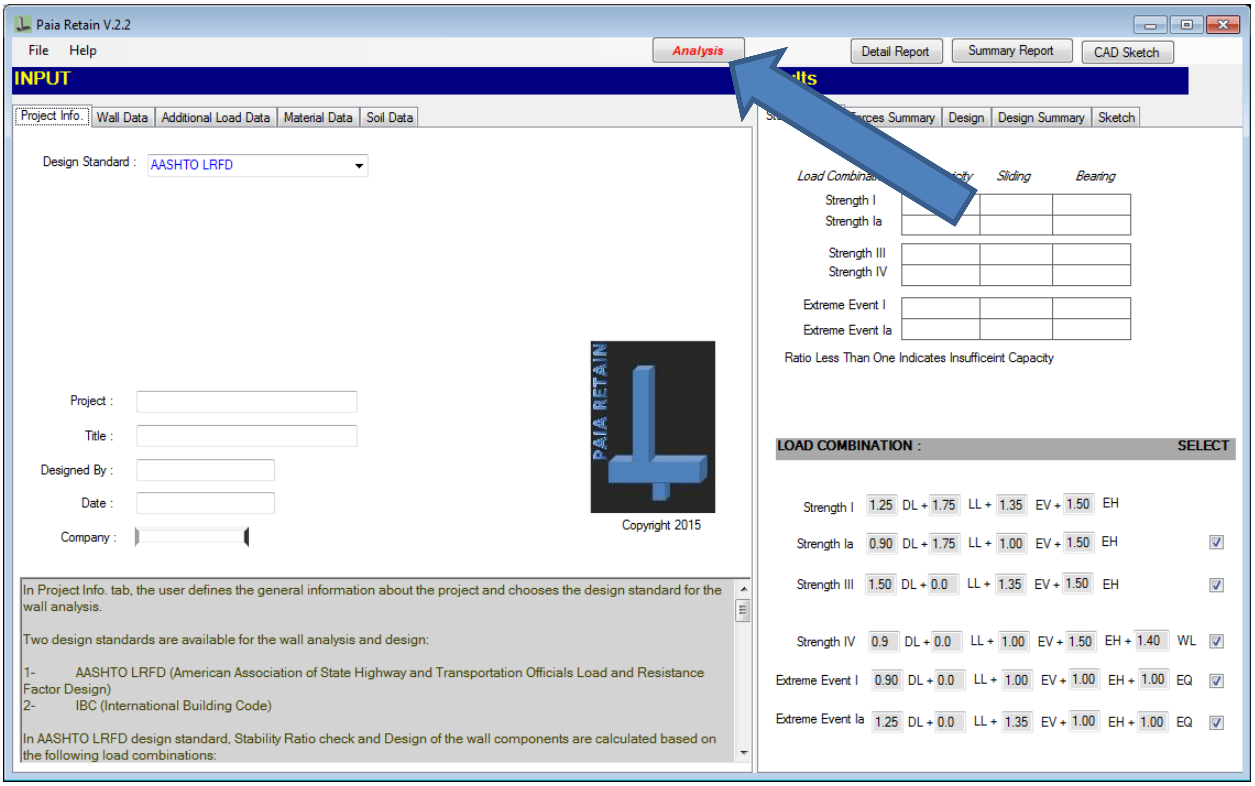
To start the installation unzip the installation file and run “setup.exe” file. The following screen appears:



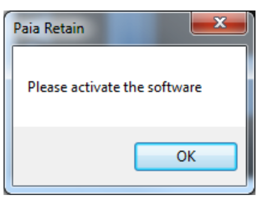
Click “Install”

Program Activation:

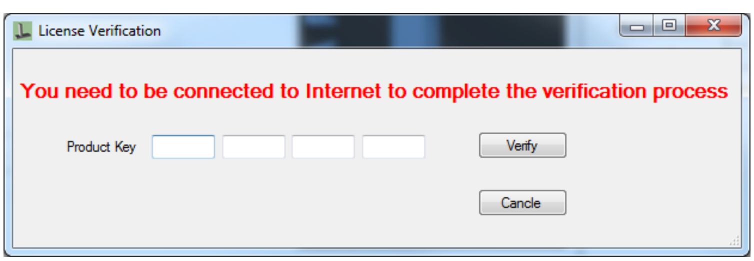
Run Paia Retian Program



Click on "Analysis" button



Click "OK". Make sure you are connected to internet



Enter the code which was provided to you. Click Verify. You are ready to use the program. A confirmation email will be sent to the email address which was provided in the account.

Paia Retain Tutorial

INPUT SECTION:

1-Project Info.

In Project Info. tab, the user defines the general information about the project and chooses the design standard for the wall analysis.

Two design standards are available for the wall analysis and design:

1- AASHTO LRFD (American Association of State Highway and Transportation Officials Load and Resistance Factor Design)
2- IBC (International Building Code)

In AASHTO LRFD design standard, Stability Ratio check and Design of the wall components are calculated based on the following load combinations:

Strength I	= 1.25 DL+1.75LL+1.35 EV+1.5EH
Strength Ia	= 0.9 DL+1.75LL+1.0 EV+1.5EH
Strength III	= 0.9DL+EV+1.4W
Strength IV	= 1.5DL+1.75LL+1.35EV+1.5EH
Extreme Event I	= 0.9DL+EV+1.0EH+EQ
Extreme Event Ia	= 1.25DL+1.35EV+1.0EH+EQ

Where:

DL = Dead Load
LL = Live Load
EV = Vertical Component of Soil Pressure
EH = Horizontal Component of Soil Pressure
W = Wind load
EQ = Seismic Load

In IBC design standard, Stability Ratio check and design of the wall are calculated based on the following load combinations:

Stability Ratio Check:

LC1 = DL + LL + EV +EH
LC2 = DL + EV + WL
LC3 = DL + EH +EV+ 0.7 EQ

LC3 represents the load combination for seismic loads. In IBC, the seismic loads are determined at strength level. A load factor of 0.7 on EQ is applied to reduce the seismic loads to allowable stress design level.

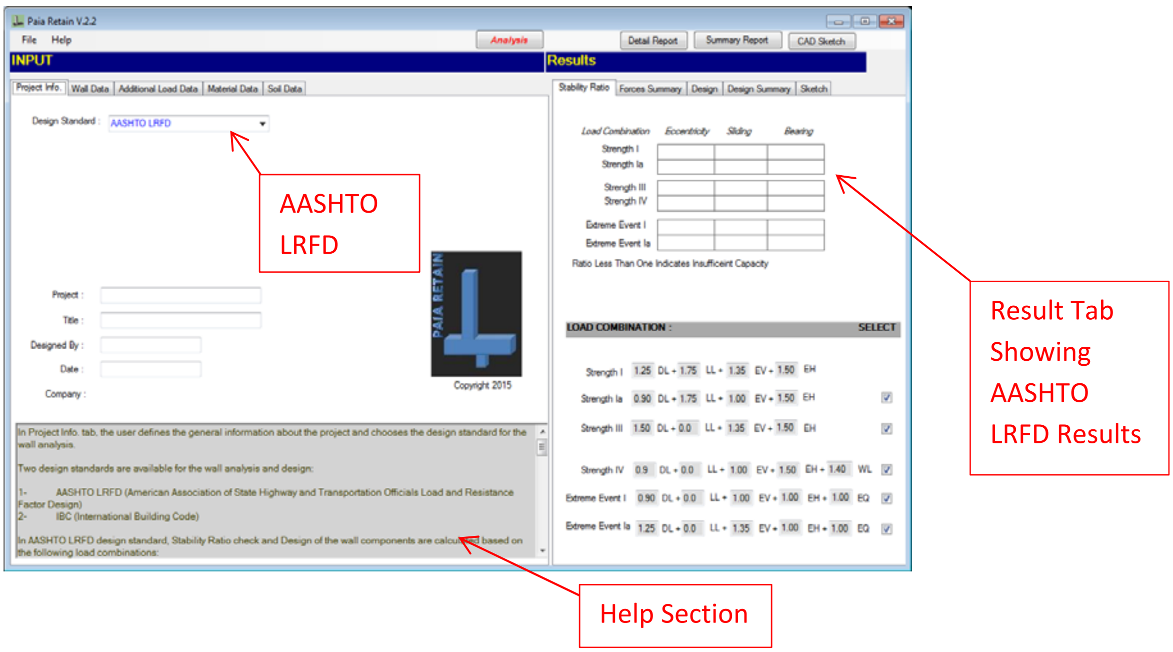
Wall Component Design:

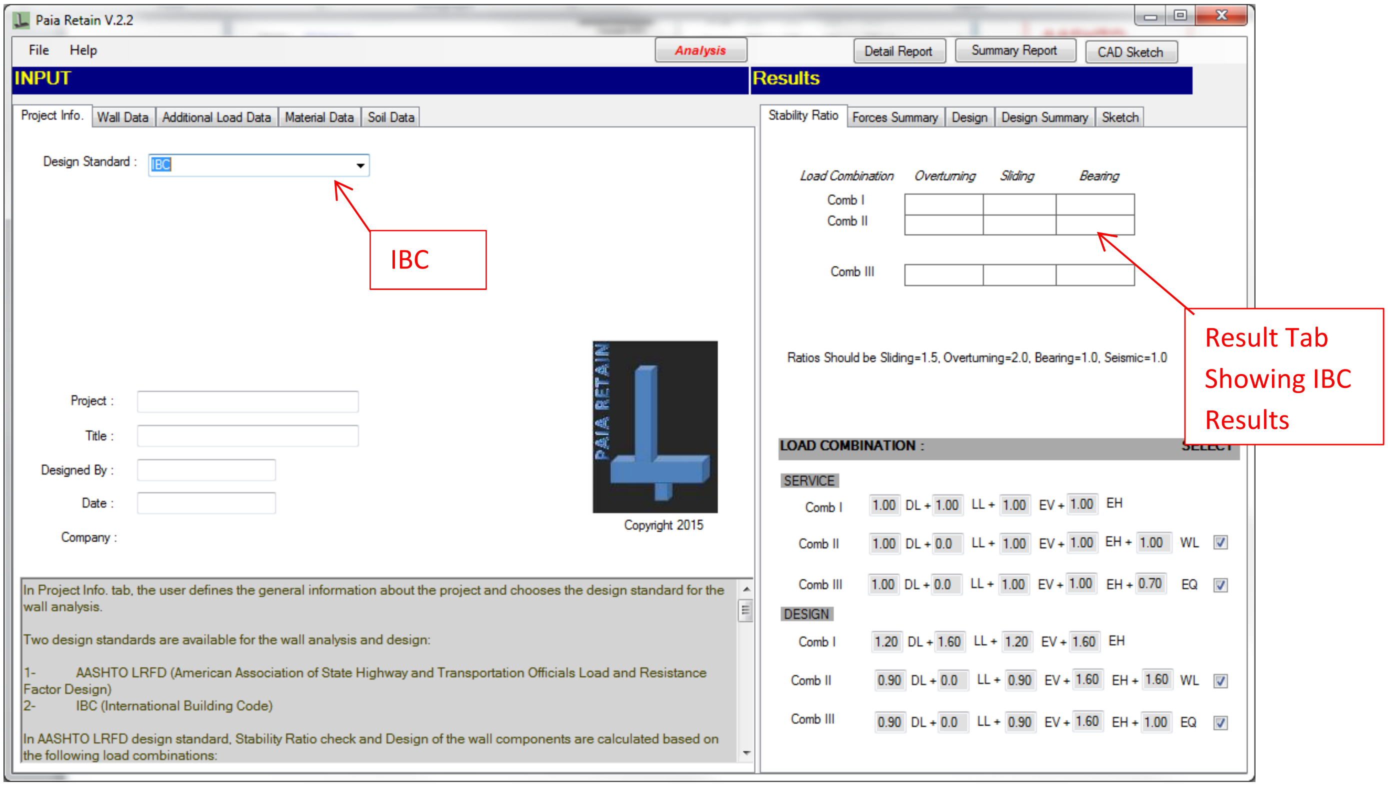
LC1 = 1.2 DL+1.6LL+1.2EV+1.6EH
LC2 = 0.9 DL+1.6WL+0.9EV+1.6EH
LC3 = 0.9 DL+0.9EV+1.6EH+1.0EQ

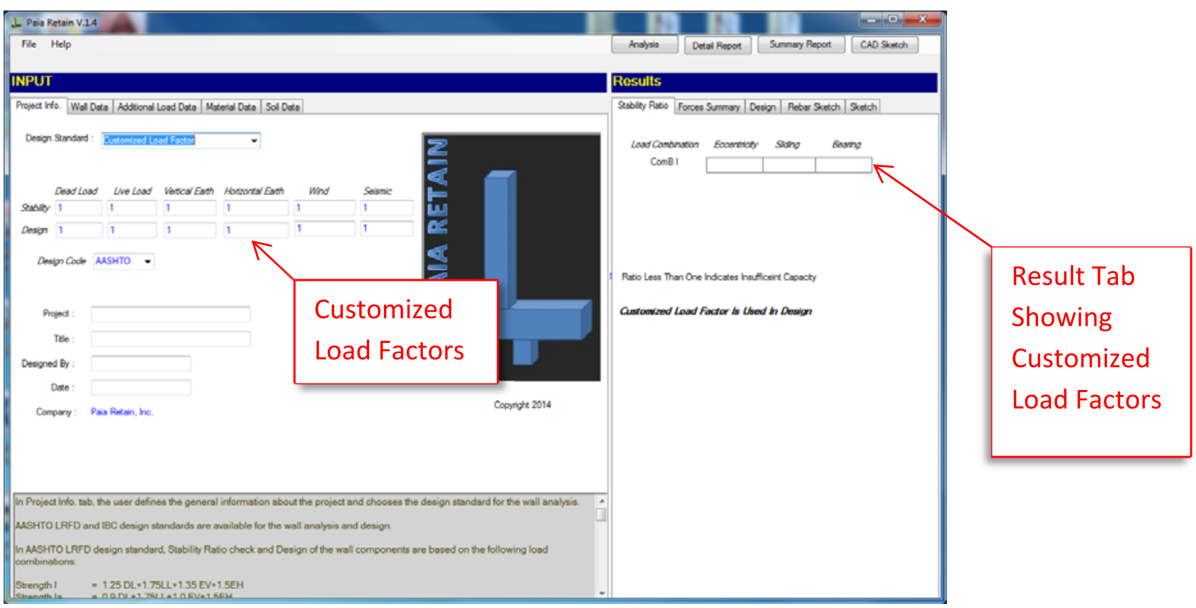
Where:

DL = Dead Load
LL = Live Load
EV = Vertical Component of Soil Pressure
EH = Horizontal Component of Soil Pressure
WL = Wind load
EQ = Seismic Load

The user is given “Customized Load Factor” Option for analysis and design of the wall. Since concrete design process in AASHTO LRFD and IBC is different, the user should define the design load factors and the stability ratio load factors for this option. The following pictures show the options in project info tab:



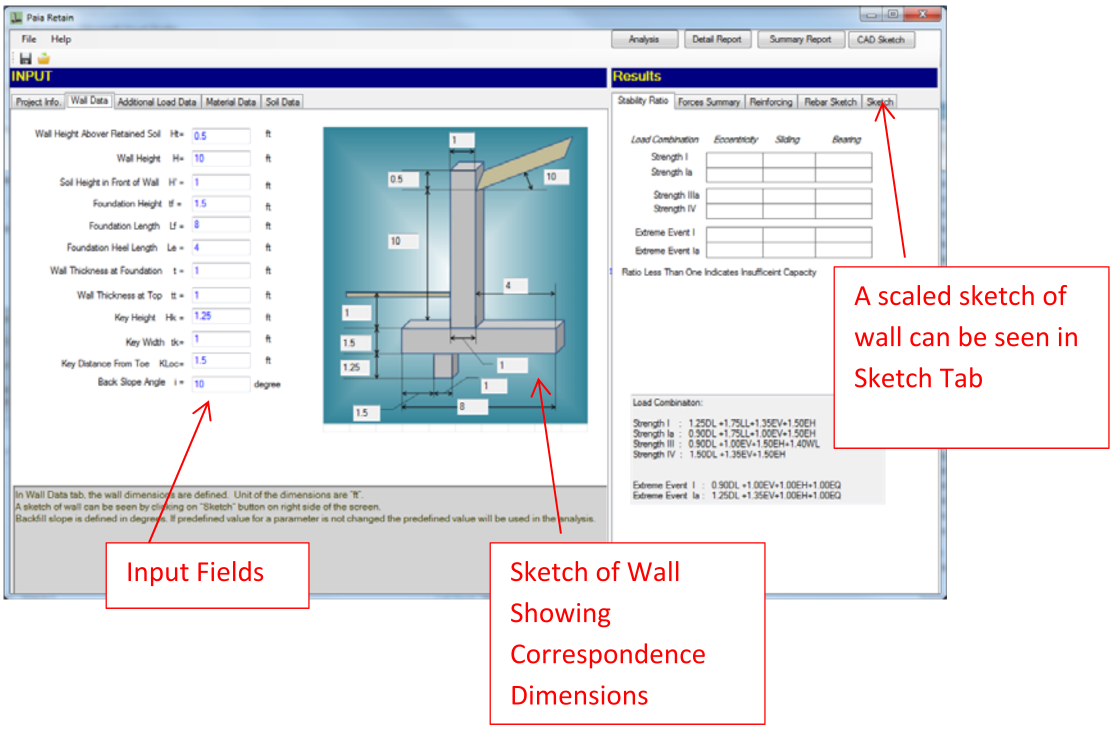




2-Wall Data

In Wall Data tab, the wall dimensions are defined. Unit of the wall dimensions is “foot”.
The input data are presented on a sketch of the wall in this tab for clarification. Changing a field value would update the dimensions shown in the sketch.

Backfill slope is defined in degrees. All the wall dimensions have a predefined value, if predefined value for a parameter is not changed, the predefined value will be used in the analysis.



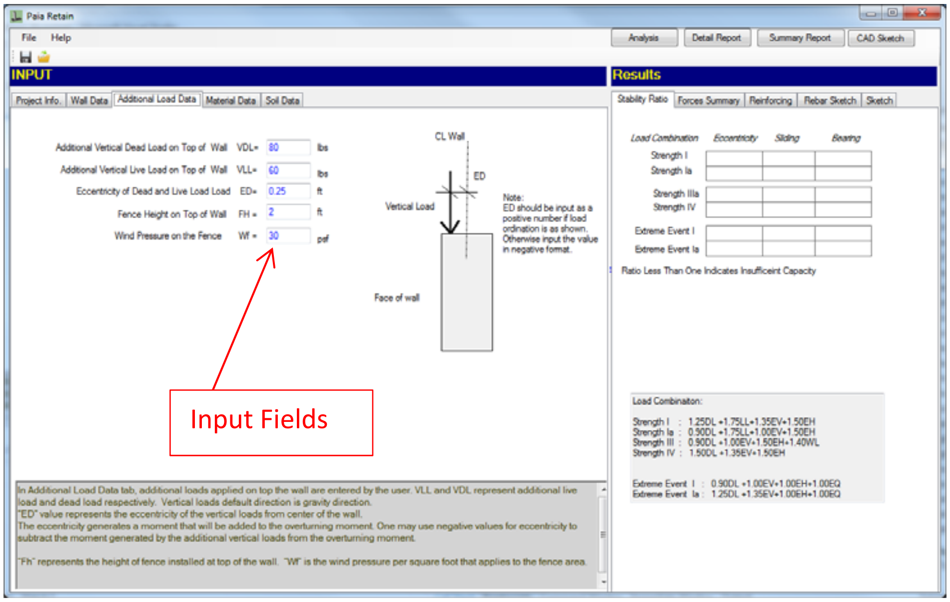
3-Additional Load Data

In Additional Load Data tab, additional loads applied top of the wall are entered by the user. VLL and VDL represent additional live load and dead load respectively. Vertical loads default direction is gravity direction.

“ED” value represents the eccentricity of the vertical loads from the center of the wall.

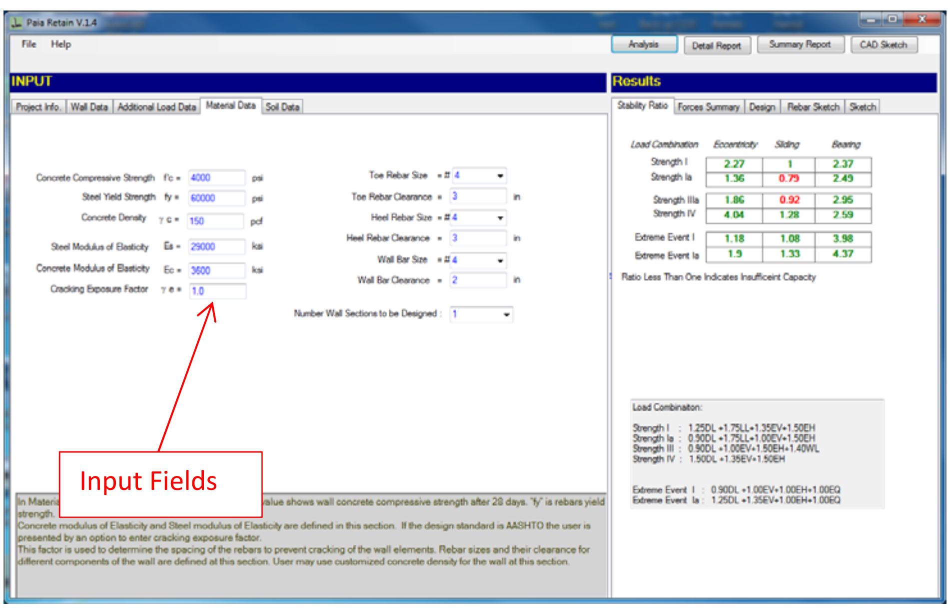
The eccentricity generates a moment that will be added to the overturning moment. One may use negative values for eccentricity to subtract the moment generated by the additional vertical loads from the overturning moment.

“Fh” represents the height of a fence installed at the top of the wall. “Wf” is the wind pressure per square foot that applies to the fence area.



4-Material Data

In Material Data tab, the wall materials are defined. “f’c” value shows wall concrete compressive strength after 28 days. “fy” is rebars yield strength.
Rebar sizes and their clearance for different components of the wall are defined at this section. User may use customized concrete density for the wall at this section as well.
Concrete modulus of Elasticity and Steel modulus of Elasticity are defined in this section. If the design standard is AASHTO the user is presented with an option to enter cracking exposure factor.
This factor is used to determine the spacing of the rebars to prevent cracking of the wall elements. The user may define up to three sections along the wall height to be designed.



5-1 Soil Data

In Soil Data tab, soil information is defined as follows:

***Pp*: Passive earth pressure**

Passive earth pressure is used to calculate earth passive resisting force. If AASHTO LRFD design standard is used, the program will multiply the defined passive pressure value by a resistance factor (predefined equal to 0.5) to check the stability of the wall in strength limit state load combinations. For extreme event load combination, the resistance factor is equal to one. The user may eliminate some or all of the soil height in front of the wall for passive resistance.

***qua*: Soil bearing pressure**

"qua" value represents soil bearing pressure. If the design standard is AASHTO LRFD then the value would be bearing pressure at strength limit estate. If the design standard is IBC then the value represents allowable bearing pressure.

***Soil Density*:**

This value is used to calculate the soil weight on top of the wall foundation.

fr: Foundation Friction factor,

"fr" is used to calculate foundation friction resistance load. This value will not be used in seismic load combination. A separate value will be used to define the foundation friction factor in a seismic event

***he*: Live load surcharge**

Live load surcharge behind the retaining wall is defined through "he" value. For AASHTO LRFD design standard, "he" represents equivalent height of soil for live load, and the surcharge is calculated based on the following equations:

Hsur = k * g * he * (H + tf) Wsur = g * he * Le

Where

Hsur is the horizontal force on the wall caused by surcharge

k is the active lateral pressure coefficient

H is wall height

tf is foundation height

Wsur is the vertical component of surcharge on heel of the foundation

Le is foundation heel length

In IBC design standard the effects of the surcharge are calculated based on the following equations:

Hsur = k * he * (H + tf)

Wsur = he * Le

It is important to note that "he" unit changes from equivalent soil height to a distributed load in IBC design standard.

***Bearing Condition*:**

In AASHTO LRFD design standard the user should define the bearing conditions for the wall foundation; i.e. Soil or Rock bearing condition. In IBC design standard, this option does not apply.

Soil Active Pressure Calculation Method:

The program provides the user two methods to calculate soil active pressure: Equivalent Fluid Pressure and Coulomb.

If Equivalent Fluid Pressure method is chosen, value of "Pa", active earth pressure, in pcf should be determined. If Coulomb method is chosen, the following values should be determined:

Angle of friction of soil in degree

Angle of friction between soil and wall in degree

Slope of Wall to the Vertical, Negative as Shown

5-2 Seismic Data

In Soil Data tab, user may define seismic loads calculation method.

Three different options for seismic load are provided in this program:

A-Uniform Distributed Load

In this option, the user defines a unformed seismic pressure, Eq. The result force, Heq, caused by this pressure will be applied at mid height of the wall as shown in Figure 2.

In this option, the seismic pressure is applied in addition to active pressure of soil, Ha.

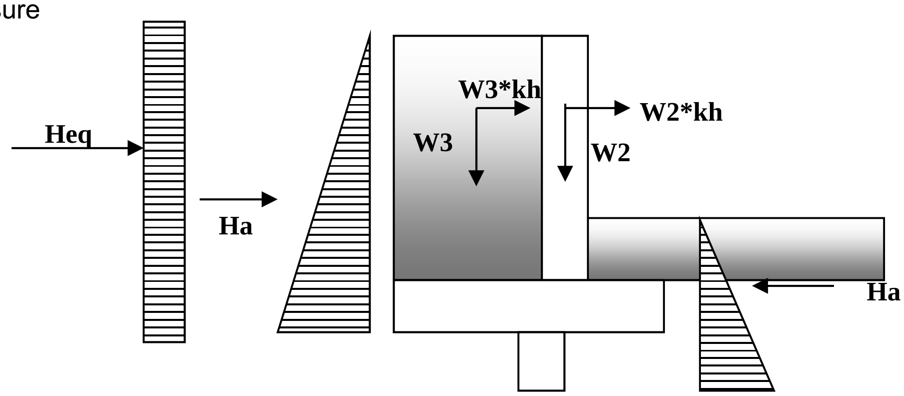


Figure 1

Other parameters that are defined for this option are:

"fe" ; friction factor of foundation for seismic load condition.

“que”; soil bearing pressure for seismic load condition.

“kh”; Horizontal Acceleration Coefficient for the retaining wall site.

B- Mononobe-Okabe (M-O)

In this option the seismic load is calculated based on the Mononobe-Okabe equation. This method calculates active soil pressure, PAE, from the equation below:

$$PAE = \frac{1}{2} * KAE * \gamma * H^2 * (1 - K_V)$$

Where

$$KAE = \frac{Cos^2(\emptyset - \theta - \beta)}{Cos\,\theta * Cos^2\beta * Cos\,(\delta + \beta + \theta) * \left[1 + \sqrt{\frac{Sin\,(\emptyset + \delta) * Sin(\emptyset - \theta - i)}{Cos(\delta + \beta + \theta) * Cos(i - \beta)}}\right]^2}$$

And

$$\theta = \tan^{-1}\frac{Kh}{1 - Kv}$$

H = height of wall
γ = unit weight of soil
φ = angle of friction of soil
δ = angle of wall friction
i = slope of ground surface behind the wall
β = slope of back wall to the vertical
Kh= horizontal ground acceleration /g
Kv= vertical ground acceleration /g (which is considered equal to zero on this program)

PAE represent earth pressure developed on the wall by dynamic and static loads. The program separates this pressure into two components – the initial static pressure calculated from soil active pressure defined previously in this tab, PA, and the dynamic pressure calculated from the following equation:

Peq= PAE- PA, where Peq is dynamic pressure caused by seismic loads.
The static pressure is applied at the height of H/3 above the base and the dynamic pressure is applied at the height of 0.5H above the base by default. However, the program gives the user the option to change this height to a different height by changing the height factor.

When the user selects this option, the following parameters need to be defined:

Angle of friction of soil in degree

Angle of friction between soil and wall in degree

Slope of wall to the vertical in degree

C- Trail Wedge Method

In this option, the seismic load is calculated based on the Trail Wedge Method. This method is an interactive process where the failure plane angles varies until maximum dynamic and static loads are computed based on the following equation:

$$PAE = \frac{WT - COH - ADH - Wa}{[1 + \tan(\delta + \omega) * \tan(\alpha - \emptyset)] * Cos\ (\delta + \omega)}$$

$$WT = W * [(1 - kv) * \tan(\alpha - \emptyset) + kh)]$$

$$COH = Cn * Ln * [Sin\alpha * Tan\ (\alpha - \emptyset) + Cos\alpha]$$

$$ADH = Ca * La * [\tan(\alpha - \emptyset) * Cos\omega - Sin\omega]$$

$$Wa = (Usl + Ush)[\tan(\alpha - \emptyset) * Cos\alpha - Sin\alpha]$$

When the user selects this option, the following parameters need to be defined:

Angle of friction of soil in degree

Angle of friction between soil and wall in degree

Slope of wall to the vertical in degree

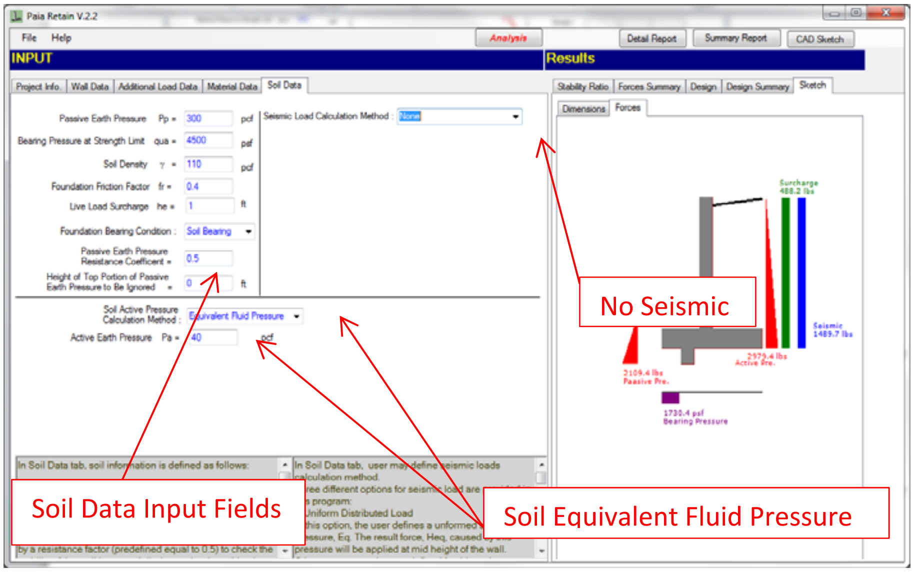
Soil Cohession

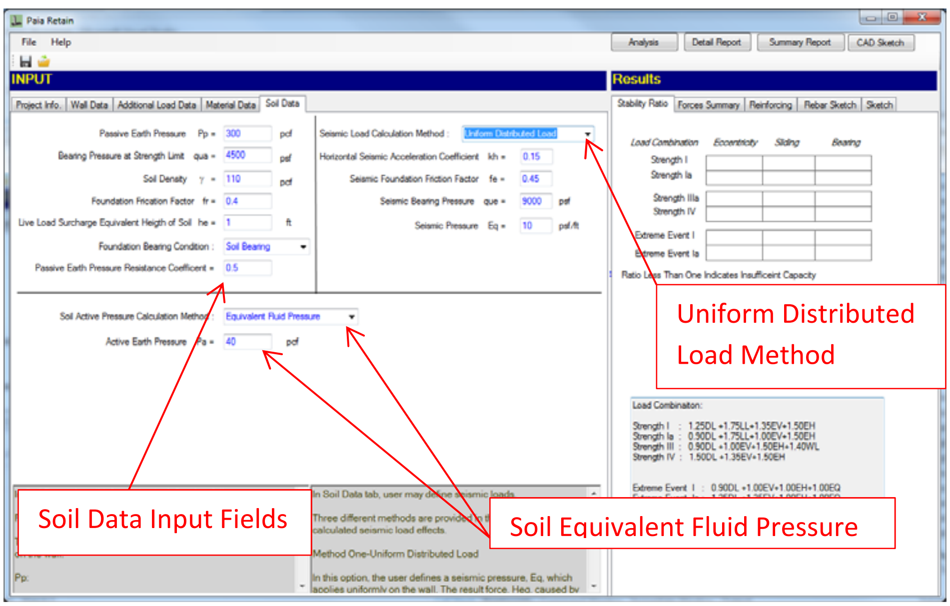
Soil and Wall Cohession

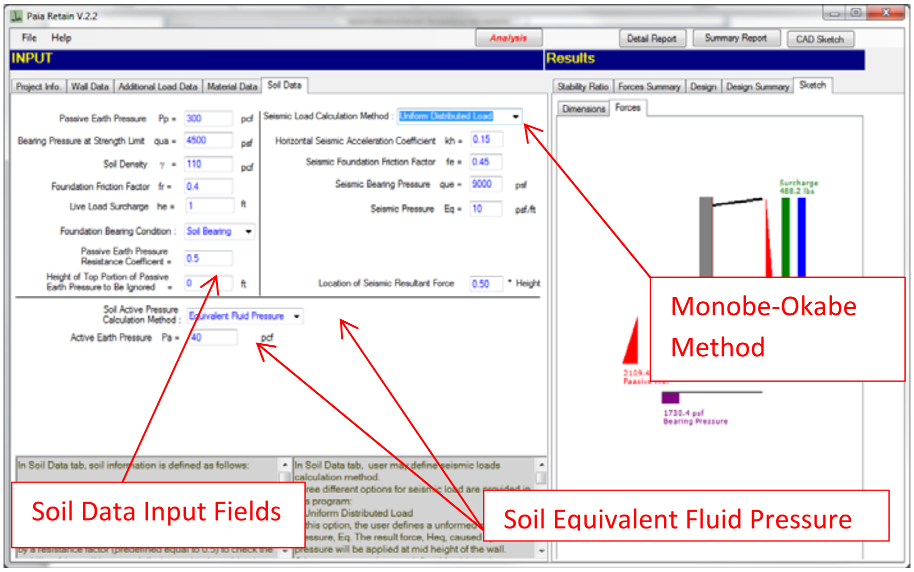
PAE represent earth pressure developed on the wall by dynamic and static loads. The previously defined active soil pressure will not be used in seismic load combination analysis. However, this active soil pressure will be used in other load combination analysis.

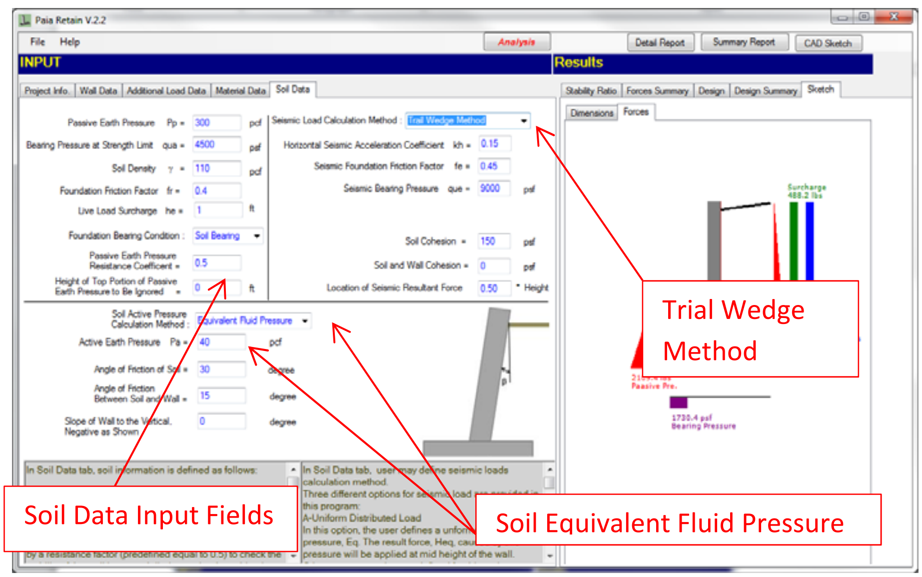
The resultant force caused by dynamic and static loads will be applied at mid height of the wall. However, the program gives the user the option to change this height to a different height by changing the height factor.

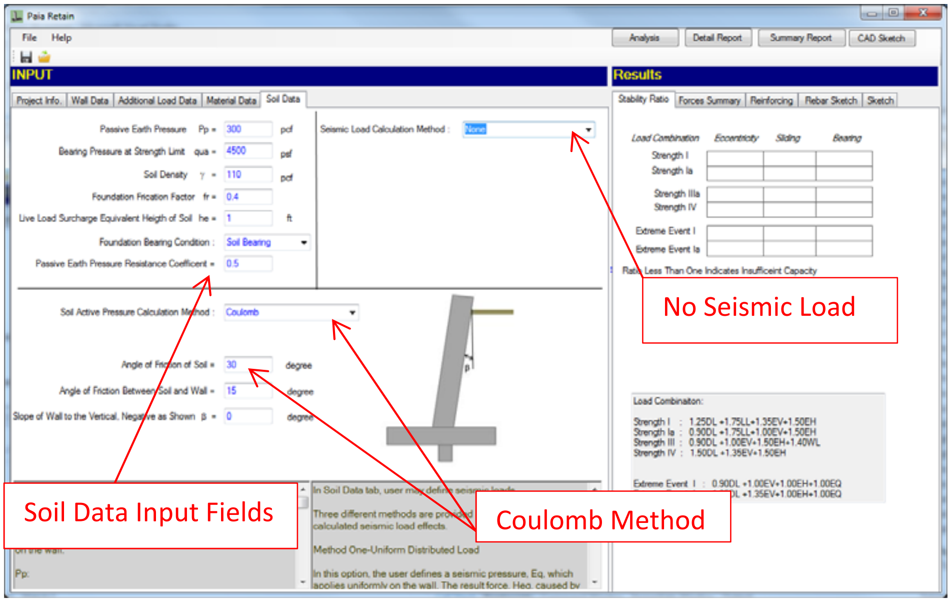
The following screen shots show the different seismic calculation forces:


INPUT
Results
No Seismic
Soil Data Input Fields
Soil Equivalent Fluid Pressure


INPUT
Results
Uniform Distributed Load Method
Soil Data Input Fields
Soil Equivalent Fluid Pressure


Monobe-Okabe Method
Soil Data Input Fields
Soil Equivalent Fluid Pressure


Trial Wedge Method
Soil Data Input Fields
Soil Equivalent Fluid Pressure

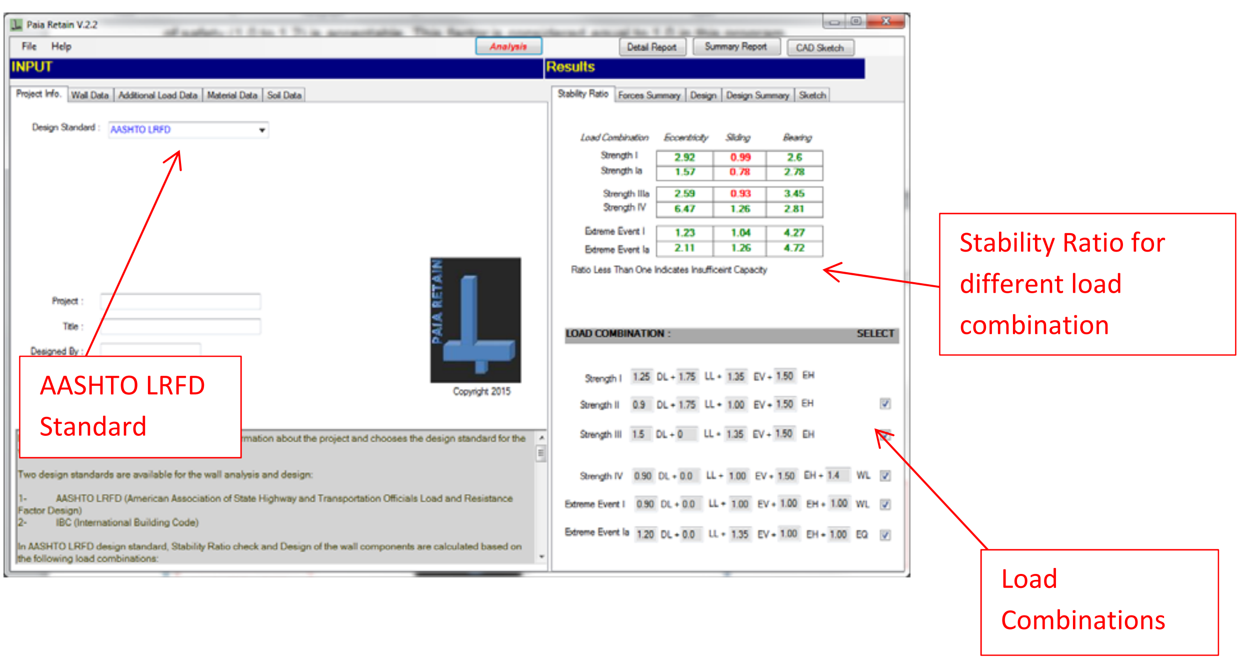


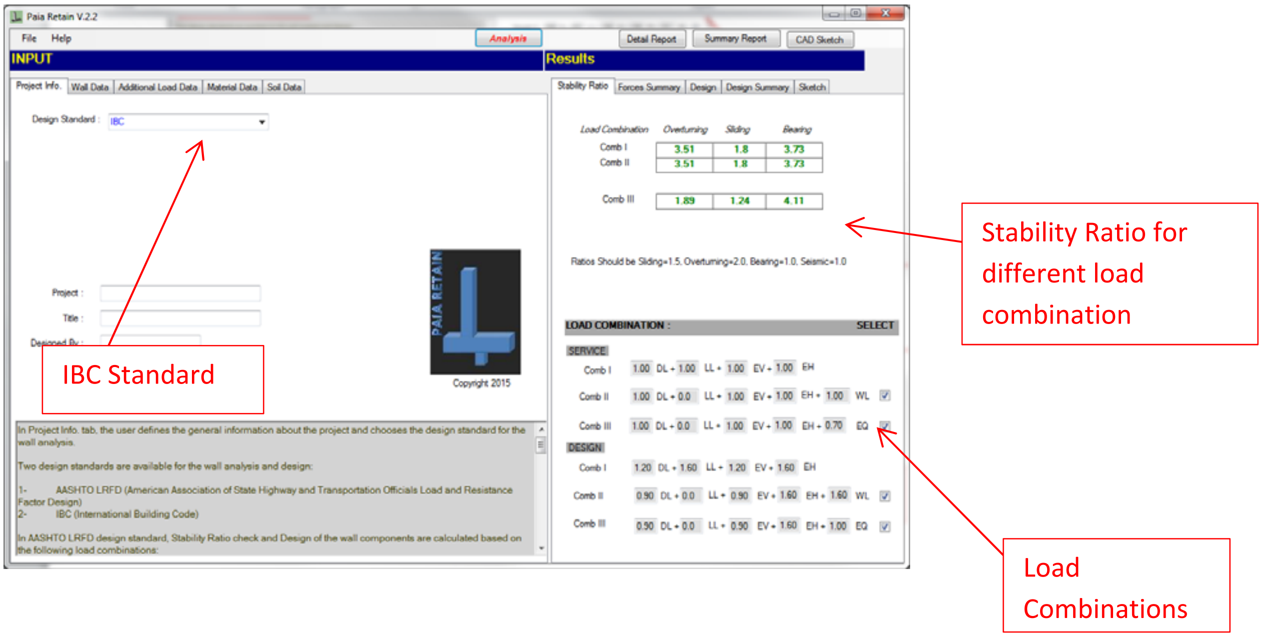
RESULTS SECTION:

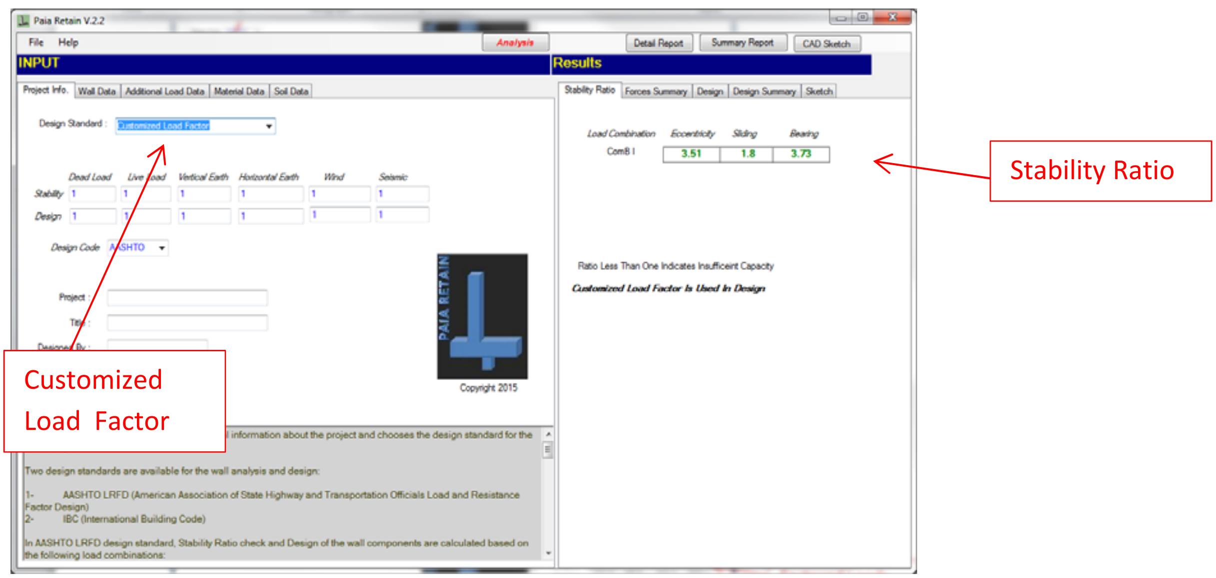
In this section, the result of analysis is presented. The user needs to click on “Analysis” button to execute the program. The following pictures represent different result sections.

1- Stability Ratio

In the Stability Ratio tab, the ratio for each load combination is shown. For AASHTO LRFD, a ratio less than one indicates insufficient capacity. When IBC design code is chosen the governing ratio is 1.5 for sliding, 2.0 overturning, and 1.0 for bearing. For the combined static and earthquake loads a lower factor of safety (1.0 to 1.2) is acceptable. This factor is considered equal to 1.0 in this program.

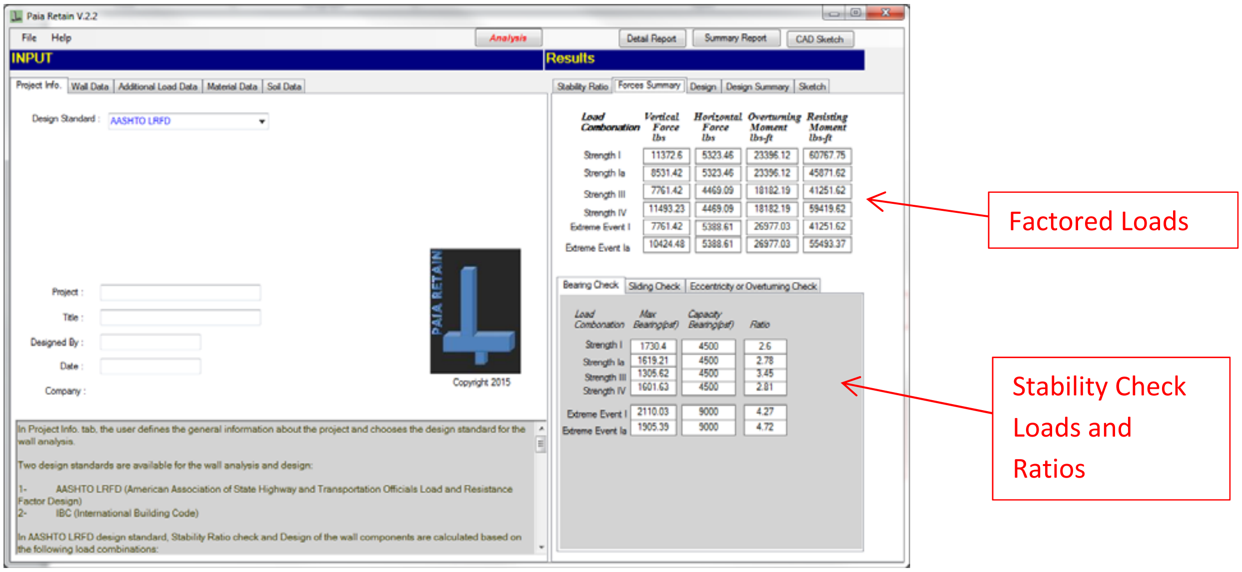






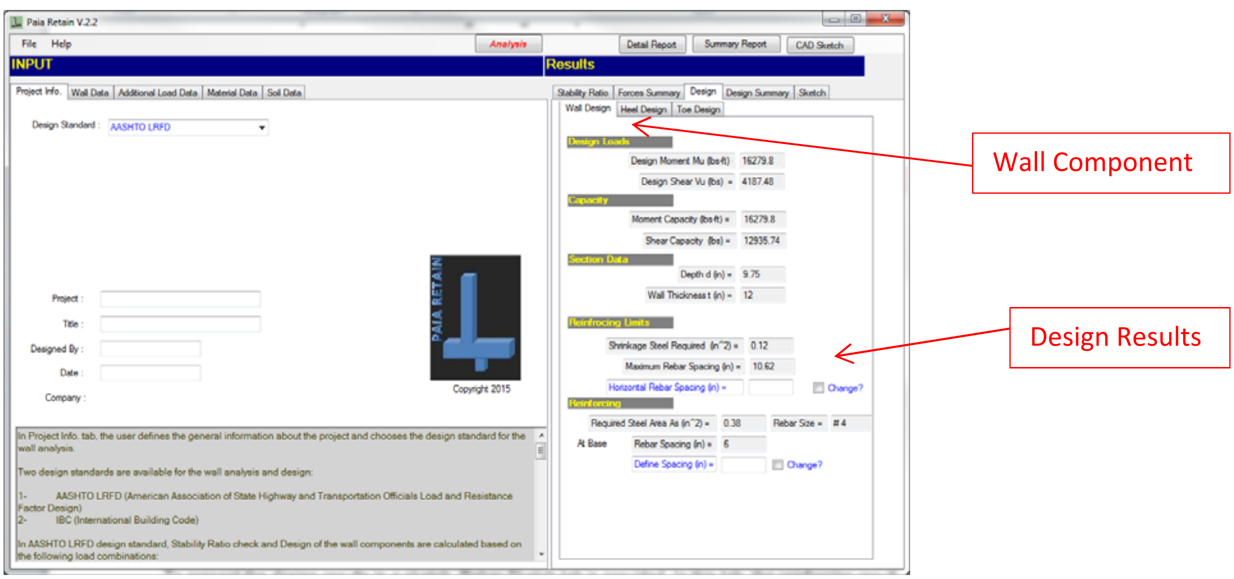
2- Force Summary

In Force Summary tab, factored loads and stability check loads and ratios are presented. The user may modify the design of the wall based on this information to a reach optimum design.



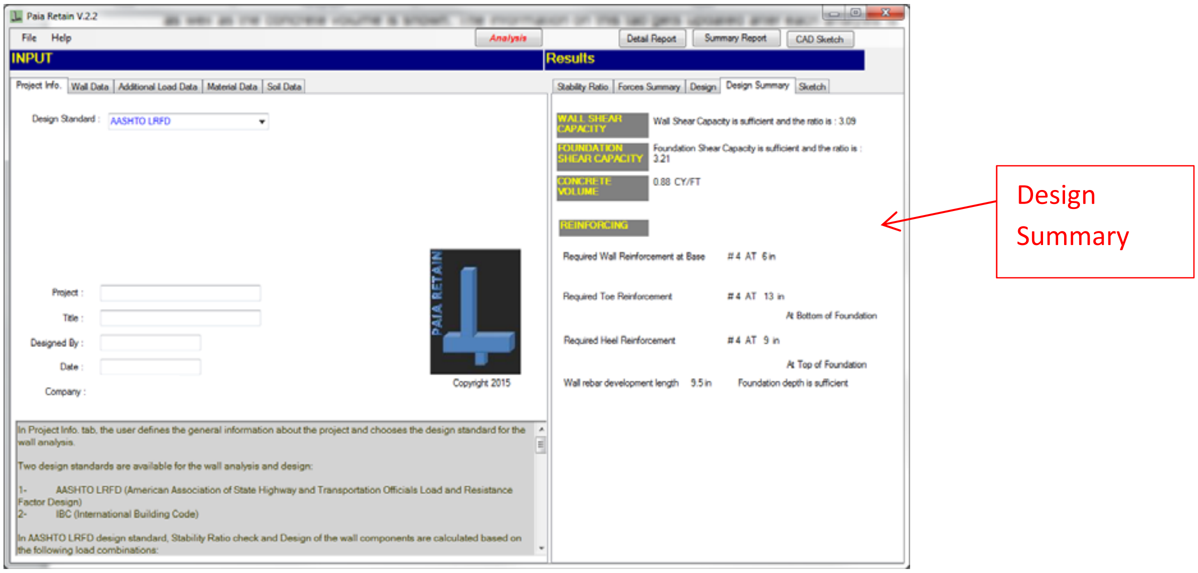
3- Reinforcing:

Concrete design results are shown under the reinforcing tab for different components of the wall. The design moments as well as the design results are shown in this tab. The user may define a rebar spacing less than required by the program to be presented in the calculation print out. In addition, the design results of the wall up to three sections along its height are presented here.



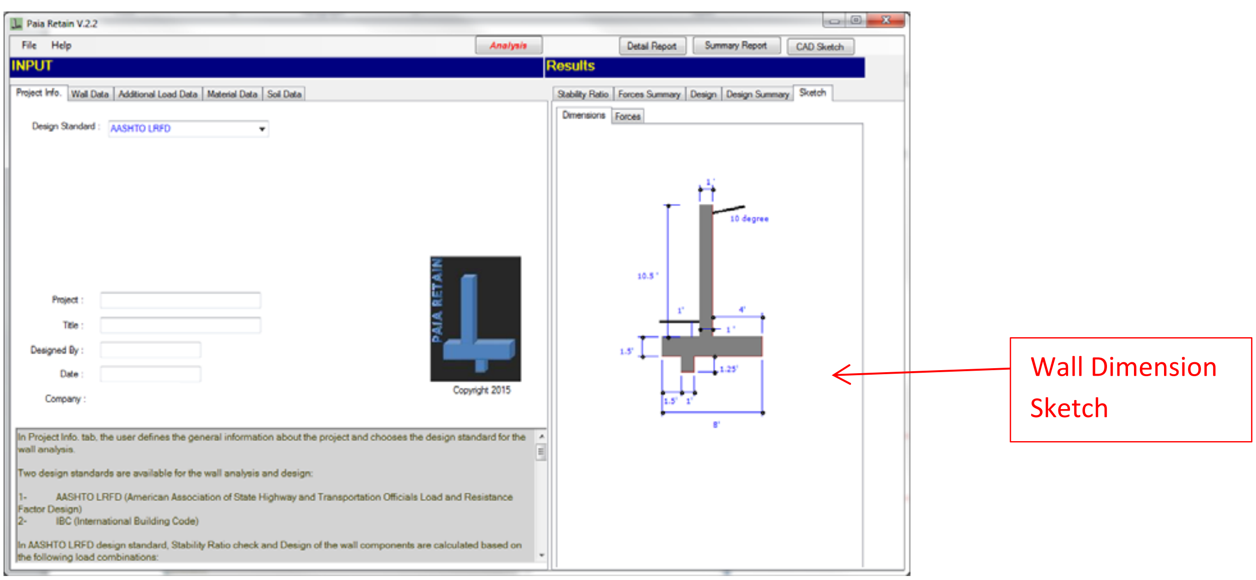
4- Design Summary:

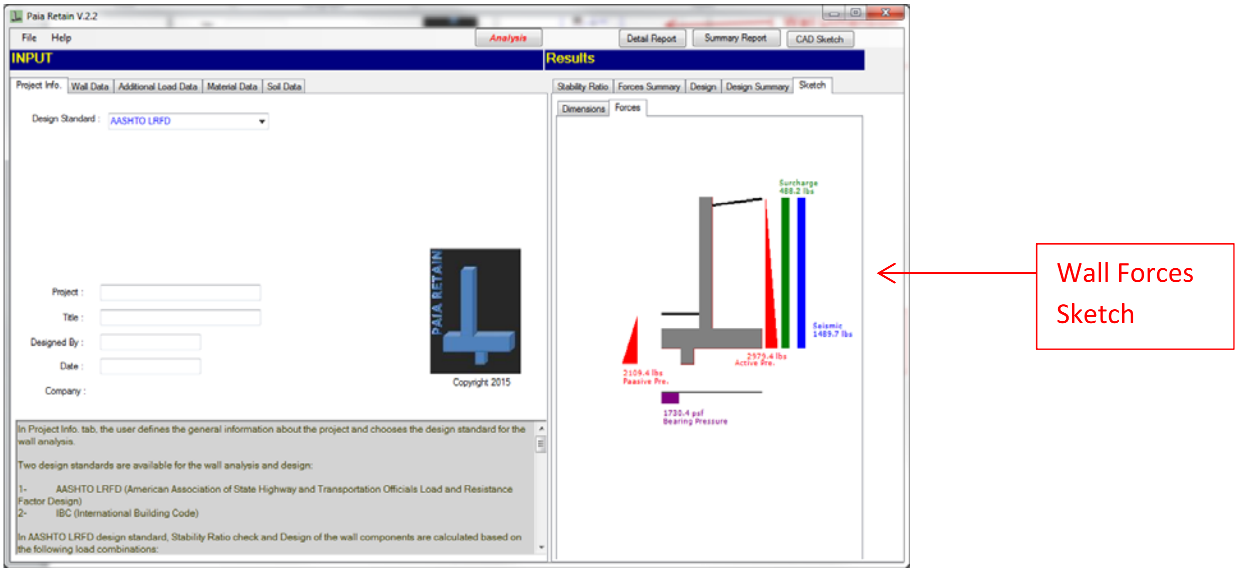
In this tab, the reinforcing result as well as the concrete volume is shown. The information on this tab gets updated after each analysis is executed.



5- Wall Sketch:

In Sketch tab, the user can see the wall dimensions and the applied forces to the wall. The information on these tabs can be updated by leaving and returning to the tabs.





PRINT SECTION:

The user may print the results using, Summary Report, Detail Report, and CAD Sketch buttons. An example of Summary Report is shown below. Detail Report, generates an editable word document file. CAD Sketch, generates a .DXF file which presents the wall and the reinforcing design results.