Stantec Engineering Standard-Structural

STAAD.*foundation* User Tip Manual and Deliverable

Standard Number: ES-S-

Revision:

Approved By: ____________________

Issue Date: ____________________

Subject: ES-S-

1.0 References

Contents

2.0 Purpose

The purpose of this guideline is to investigate STAAD.*foundation* to determine the range of applicability and reliability within the software package. The MQP team quantified the effectiveness and reliability of STAAD.*foundation* through hand calculations and then verified this through the STAAD.*foundation* program's output.

3.0 Applicable Codes and Standards

AISC 9-1

AISC 9-2

AISC 9-3

ACI 318-05

ASCE 7-05

4.0 Definitions

Combined Footings
Data Input and Load Pane
Foundation Design
Isolated Spread Footings
Main Navigator Pane
Output Pane
Quick Access Toolbar
Ribbon Toolbar
Spread Footings
Strap Footings
Tabbed View Window

4.1 Combined Footings

Combined Footings receive loading from more than one column or load-supporting element. Each column applies their own individual loading to the footing. The columns can be located at any distance from the footing ends, however, they must lie on the centerline along the longer axis of the footing.

Determination of shear, service loading, soil bearing pressure, bending moments, and reinforcement need to be looked at to determine design capability. Combined footings are usually designed in a rectangular or trapezoidal fashion

4.2 Data Input and Load Pane

The data input and load pane is the primary window for input and option selections for foundation jobs in the General Foundation mode. All global data that is not imported is entered in this window pane. The input is done through a series of tables and forms which is opened on the right side of the program's main window through the main navigator pane. Only the necessary pane is displayed for the current form being designed in the program.

4.3 Foundation Design

Foundations are the base and support in the structural system that transmit the superstructure's loads directly to the earth. All civil engineering structures require foundations to keep the structure from leaning or buckling. Buildings bestow their weight and loadings onto their foundations; therefore, the footing needs to be designed to withstand the weight of the building. The foundation design process cannot begin until the loads have been calculated. There are several different types of design loads including: normal loads, shear loads, moment loads, and torsion loads. Where weather is applicable, the bottom of the foundation must be constructed below the frost line to prevent cracking from freeze-thaw cycles.

4.4 Isolated Spread Footings

Isolated Spread footings are one type of spread footings. They support the structural system of small to medium structures. These footings are used to transmit a load from columns to the soil beneath it. If the soil supporting the column is weak or the column loading is too heavy, the isolated spread footing needs to be designed a lot larger. Isolated spread footings are more economical because less material is needed to create the footing than a normal spread footing.

Determination of soil bearing pressure and bearing capacity needs to be looked at to determine the design capability. If the soil has a higher bearing capacity, then the isolated spread footing is sufficient for the design.

4.5 Main Navigator Pane

The main navigator pane incorporates the general foundation design into a display of forms and tables to input project data. It is displayed in a tree-styled cohesive order to complete the project design from top to bottom. Through the tree the designer can input global data column positions, column dimensions, and loading. Local data such as design parameters and footing geometry are also available to input specific variables for the project's design. By selecting a branch of the tree, a form or table opens up on the right side of the page in the Data Input and Load pane to perform an action within the program. Depending on your specific project, whether it be isolated, combined, or mat footing, the tree will contain different parameters for the project's design (i.e. soil parameters for mat footing).

4.6 Output Pane

The output pane provides the designer with a list of the design progress while analyzing a foundation and displays the output tables when the program deems the analysis successful.

4.7 Quick Access Toolbar

The quick access toolbar is located directly under the Ribbon Toolbar. This toolbar allows the designer to make the program more designer specific as it allows the designer to add tools that are more regularly used. To do this, select any tool from the ribbon tab, right click, and then select "add to quick access toolbar" from the pop-up menu.

4.8 Ribbon Toolbar

The Ribbon Toolbar shows relevant commands for a given action. The specific tools for the current task you are trying to accomplish are given to the designer in different Groups. It is located horizontally across the top of the STAAD.*foundation* program's window. The Ribbon essentially serves a visual menu tabs. Therefore, the program's functionality is brought to this menu bar and helps organize specific features into specific Groups.

4.9 Spread Footings

Spread footings are normally used to support the structural system of small to medium structures with moderate to good soil conditions. They can be used in high-rise buildings where the soil conditions are exceptional and can bear the load. Individual columns of the building are constructed on top of the spread footing because of its ability to bear extremely heavy loading. Many low-rise residential buildings consist of spread footings that support the load over a larger area. The foundation of residential homes, for example, is often used as a basement that supports the infrastructure of the house above it. Spread footings are the most common type of foundation due to its low cost and quick construction. They are built in different shapes and sized to accommodate each project's scenario. The shape of the footing is generally a rectangle and larger in lateral dimensions than the load it is supporting.

Determination of soil pressures, shear forces, and bending moments then need to be looked at to determine design capability[5]. The design and layout of the footing is controlled by several factors: the load of the structure, penetration of soft layers near the surface, and penetration of layers near the surface due to the effects freezing and thawing. These foundations are more commonly found in residential construction buildings that have a basement. These footings are not sufficient for high-rise buildings. Three types of spread footings, isolated, combined and strap, are discussed below and can be seen in Figure 1.

4.10 Strap Footings

Strap footings are generally used when one of the columns the footing is supporting undergoes extreme loading. When two columns are far apart, the strap is designed to transfer the large moment between the two columns. The strap does not provide any weight bearing; it is simply there to transfer the moment of one footing to the other. Strap footings are more economic than combined footings because it uses less material to construct the footing.

Determination of loading, soil bearing capacity, and characteristic of the footing need to be looked at to determine design capability.

4.11 Tabbed View Window

The tabbed view window contains tabbed pages to display graphics as well as design calculation output in the center of the program's main window; it is permanently fixed there. The tabs are as follows; Start Page, Geometry Page, Detail and Schedule Drawing, GA Drawing, Calculation Sheet, and Graphs. The start page tab provides the designer with access to common file operations for creating new projects, opening existing projects, and exploring the program. The Geometry page tab is used as the main graphical input for foundation models. The Detail and Schedule Drawing tab visually shows the detail drawing of a schematic diagram of the footing elevation and reinforcement plan once the design has been deemed successful by the program. The GA Drawing tab shows the designer a footing plan layout of analyzed footing that are drawn to scale, complete with a title block. The Calculation Sheet tab provides the designer with a detailed set of foundation calculations and code checks once the program deems the design successful. Each footing element is provided by the program with step by step calculations with relevant code numbers and equations. The Graphs tab is used to display internal force graphs for a strip footing beam.

5.0 Design Criteria

5.1 RESPONSIBILITIES

5.1.1

The Department Manager has the overall responsibility of implementing this procedure, and only the Department Manager can waive any part of this procedure.

5.1.2

The Lead Structural Engineer has the responsibility of making sure all engineers assigned to him are familiar with this procedure and adhere to it. The Lead Engineer shall be responsible for ensuring that calculations are checked prior to drawing issue.

5.1.3

The Lead Engineer is responsible for coordinating the checking procedure of all calculations and resolving any comments made by the Checking Engineer on the calculations.

5.1.4

The Lead Engineer shall assign Checking Engineers from personnel assigned to the project or request resources from the Department Manager. The designated Checking Engineer may not be the engineer who carried out the original work. The Checking Engineer’s experience and qualifications must be consistent with the technical requirements of the documentation being checked.

5.1.5

The Design Engineer and Checking Engineer are responsible for preparing and checking the calculations in accordance with the guidelines in this procedure.

5.1.6

The Checking Engineer is responsible for checking all the drawings associated with the checked calculations to ensure that all relevant comments on the checked calculations have been incorporated before the drawings are issued for construction.

5.1.7

It is the responsibility of the Design Engineer to ensure that the checking activity is conducted on the most relevant issue of project documentation.

5.2 REQUIREMENTS

5.2.1

Unless otherwise specified in 5.2.3, calculations shall be prepared for all elements on the project including, but not limited to, structures and foundations for equipment, building, utility/pipe rack, bridges, miscellaneous structures and foundations. Construction types include reinforced concrete, masonry, structural slabs and slabs on grade, structural steel, timber and shoring systems.

5.2.2

All calculations shall be reviewed and checked by an engineer before the drawings are issued for bid, material order or construction. Checking shall be scheduled to provide adequate time for completion prior to drawing issues.

5.2.3

Calculations will not be required for standard items such as ladders, handrails, miscellaneous support, small pumps, catch basins and other designed items where shown on the Department Standard Drawings.

5.2.4

The Checking Engineer shall request a detailed calculation for questionable items that are being engineered without calculations.

5.2.5

Calculations shall be numbered using the task code and a three digit number as follows:

203YY-XXX for Foundation Calculations

204YY-XXX for all other Structural Calculations

YY = 2 digit extension to identify task code for structure or area

XXX = 3 digit extension identifying calculation number - 001…

5.2.6

A calculation log shall be completed by the Lead Engineer for projects containing multiple calculations.

5.3 PREPARATION OF CALCULATIONS

5.3.1

The calculations shall include the following information on a cover sheet: (See Appendix B for Cover Sheet Document)

• Listing of referenced drawings, (vendor and other disciplines).

• Reference to any engineering codes and standards utilized in the design (IBC, SBC, UBC, BOCA, NFPA, OSHA, ASCE, etc.).

• Specific design basis that applies from Design Criteria.

• Listing of all assumptions.

5.3.2

The following relevant information shall be included with the calculations:

• Copy of any memos or instructions from client, project or vendor regarding any special instructions affecting the design.

• Complete set of sketches showing all necessary information for the development of the final drawings.

• References to code sections shall be incorporated in to the calculations where applicable.

• Clear and reproducible copies of charts, sketches, data sheets, vendor drawings and other reference sources used in the calculations.

5.3.3

Calculations shall be presented in a neat and organized presentation where design results are clearly indicated to facilitate an efficient checking process.

5.3.4

Each calculation sheet shall be initialed, numbered and dated, and shall have the project number and area of design completed in the title block before checking commences.

5.3.5

Computer calculations shall meet the requirements specified in section 5.3.1 and the following:

a) Calculations and sketches clearly indicating how all of the input loads were developed and how they are to be applied.

b) Department approved spreadsheets are authorized for use as calculations as applicable. See ES-S-102 for more information.

5.4 CHECKING OF CALCULATIONS

5.4.1

The purpose for checking the engineering calculations is to insure a design that is safe for personnel, economical, meets specific project requirements and is in compliance with applicable codes, standards and statutory regulations.

5.4.2

The Checking Engineer shall not modify the design if the design meets the requirements of section 5.4.1.

5.4.3

The Checking Engineer shall review all the assumptions, references, sketches and the design criteria to insure a complete overall understanding of the design.

5.4.4

The Checking Engineer must highlight any major design or redesign that results from the checking process and ensure that subsequent work is correct as compared to the appropriate design or project procedures. Prior to a major redesign refer to section 5.5.1.

5.4.5

Input for computer generated calculations shall be checked for accuracy. Results from the computer generated calculations shall be reviewed for accuracy, logic and consistency. The Checking Engineer shall supplement the check with hand calculations if accuracy of output is in question.

5.4.6

Where applicable, a statics load check for all basic load cases in computer generated calculations shall be performed to verify the overall magnitude and directions of applied loads.

5.4.7

Field notes shall be reviewed and a field trip may be required to verify what is being checked.

5.4.8

Applicable checklists shall be completed for each set of calculations. Check lists are included as Appendix A to this procedure.

5.4.9

The Calculation Cover Sheet for all checked calculations shall be clearly identified by the words "Check Calculations" and the checked calculation sheets shall be stapled or otherwise bound to this cover sheet.

5.4.10

The Checking Engineer shall initial and date each sheet checked.

5.4.11

Color Coding

All corrections or notations to checked documents shall be made in accordance with the Company's color coding system, as follows:

- Red indicates additions, corrections or deletions.
- Yellow indicates correct content
- Blue indicates check comments have been incorporated
- Black (lead) indicates calculations and non-record comments

This standard shall be applied consistently on all projects.

5.5 IMPLEMENTATION OF CHECKERS COMMENTS

5.5.1

The Design Engineer and Checking Engineer should discuss all comments and agree upon any revisions. Where agreement is not reached and either person feels that an item is of critical importance, the matter shall be referred to the Lead Engineer for resolution. If the Lead Engineer is also the originator, then the matter is referred to the Department Manager.

5.5.2

The Design Engineer initiates the checking process by completing the project information and the engineer's check boxes (Labeled "E") on the calculation check list. The checklist and a copy of the calculations with the cover sheet labeled "Check Calculations" shall than be forwarded to the Checking Engineer.

5.5.2

The Checking Engineer completes a check of the calculations, initials and dates the checked calculation sheets. The Design Engineer ensures that required changes are made. The revised calculations shall be backchecked by the Checking Engineer to ensure that all required changes have been correctly incorporated.

5.5.3

Once the Checking Engineer is satisfied that all agreed changes have been incorporated into the design, the Checker shall complete the check boxes(labeled "C") on the calculation check list and sign and date the coversheet of the master copy of the completed calculations and the calculation check list. The Checker will then transfer the master copy and check prints to the Lead Engineer for review.

5.5.4

The Lead Engineer or Department Manager conducts a random review or a second check to ensure (to the degree practical) that the calculations have been properly checked. The Lead Engineer or Department Manager will then sign and date the calculation check list. This completes the departmental approval process. Copies of calculations are then issued if required using the document control procedures relevant to the project.

5.6 CALCULATION FILES AND RECORDS

5.6.1

The final calculations signed by the Design Engineer and Checking Engineer and the completed check list shall be scanned and filed in the appropriate foundation or structural folder in the project directory. The original hard copy shall be maintained by the Design Engineer or Lead Engineer until the project is complete and then turned over the Project Manager for retention in the project file.

5.6.2

A clearly labeled native file and a pdf of the final version of all computer calculations showing the input and results files shall be filed in the appropriate foundation or structural calculations folder in the project directory.

5.6.3

The Lead Engineer shall set up the foundation (20300) and/or structural (20400) folders in the project directory to provide sub folders for each structure or foundation as appropriate for the project. The folders shall be numbered to match the calculation log and named to identify the structure.

5.7 APPROVAL

5.7.1

Engineering deliverables that have been checked require the appropriate approval prior to issue. This approval signifies that the document is "fit for issue." The Department Manager or his designee shall approve all engineering deliverables prior to issue.

Regulations regarding approval or “signing and sealing” calculations by licensed engineers vary from state to state and country to country. Clients may also have special approval requirements. A schedule of authorized approvers and approval requirements shall be developed as appropriate for the legal and Client requirements governing the project scope of work and incorporated in the project plan. The Structural Engineer of Record shall ensure that the project plan is in accordance with the laws of the governing Professional Engineers board for the project.

6.0 Appendices

The following appendices document the design process for several types of foundation types as well as results and finding of testing optimization within STAAD.foundation

Appendix A ……………………………………………………………Structural Calculation Check List

APPENDIX A – STRUCTURAL CALCULATION CHECK LIST

Project No.: ________________Project Name: ________________________Calculation No.__________

SIGNATURES:

Preparing Engineer________________Checking Engineer ________________Date: ____________

Lead Engineer or Department Manager ________________________________Date: ____________

Description of Calculation Package: ____

____

No.	Item	E	C	NA	Status/Action Required:
1	Title block complete, cover sheet complete, listing references, applicable codes, design criteria, and assumptions as applicable.	☐	☐	☐	
2	Are the calculations clear, orderly and easy to follow by the checking engineer? Are code references, formulas and material properties noted where applicable?	☐	☐	☐	
3	Have appropriate sketches been provided where required to document the calculations?	☐	☐	☐	
4	Have reference documents or appropriate links to structural, mechanical, electrical or vendor calculations or documents used for a basis of the calculations been provided?	☐	☐	☐	
5	Have the recommendations in the geotechnical report been incorporated in the design and documented in the calculations and on the drawings?	☐	☐	☐	
6	Have computer input and output been checked? (See Structural STAAD Check list if appropriate)	☐	☐	☐	
7	Have appropriate horizontal and vertical load paths been provided for global stability of the structure?	☐	☐	☐	
8	Has adequate local bracing of individual beams, columns and bracing been provided to match the design assumptions?	☐	☐	☐	
9	Have second order affects been considered where required?	☐	☐	☐	
10	Have appropriate dead, live, snow, wind and seismic loads been applied and documented in the calculations and on the drawings?	☐	☐	☐	

APPENDIX A – STRUCTURAL CALCULATION CHECK LIST

Project No.: ________________ Project Name: ______________________ Calculation No.__________

No.	Item	E	C	NA	**Status/Action Required:**
11	Have snow drift, impact, operating, dynamic and torsional loads been considered?	☐	☐	☐	
12	Were future loads considered and documented in calculations and on the drawings?	☐	☐	☐	
13	Have appropriate load combinations been used and documented? Are removable loads appropriately combined to provide maximum compression and uplift?	☐	☐	☐	
14	Are splice, bracing, truss axial and transfer loads indicated for inclusion on drawings?	☐	☐	☐	
15	If provided, do "Not to Exceed" load tables provide appropriate load breakdown and descriptions to ensure the foundation designer is able to develop worst case load combinations for both compression and uplift.	☐	☐	☐	
16	Are member sizes and load capacities as shown on the drawings documented in the calculations?	☐	☐	☐	
17	Has deflection and/or drift criteria been satisfied?	☐	☐	☐	
18	Has vibration criteria been satisfied?	☐	☐	☐	
19	Have steel connections been designed and detailed where not covered by AISC standard framed tables?	☐	☐	☐	
20	Have details appropriate for seismic design been included?	☐	☐	☐	

APPENDIX A – STRUCTURAL STAAD CALCULATION CHECK LIST

Project No.: ________________ Project Name: ____________________________ Calculation No.________

SIGNATURES:

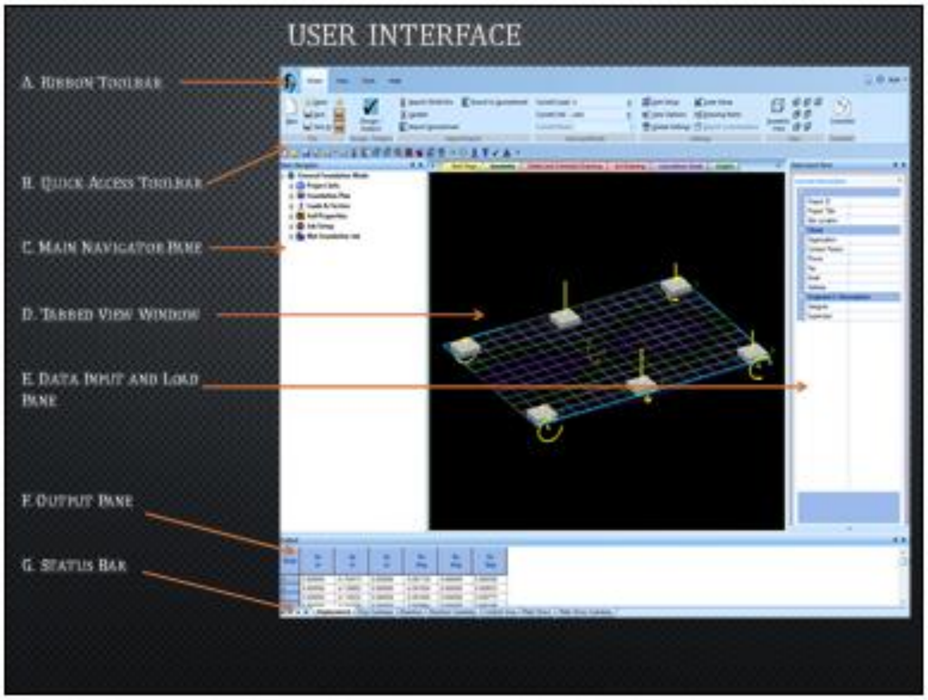
Preparing Engineer________________ Checking Engineer ________________ Date: ____________

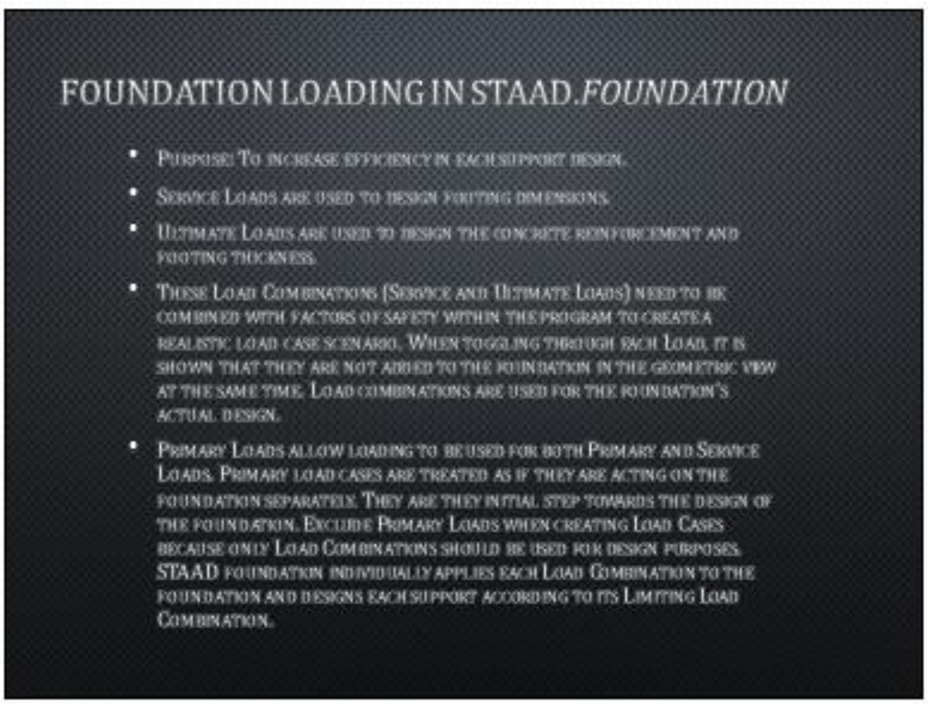
Lead Engineer or Department Manager ____________________________________ Date: ____________

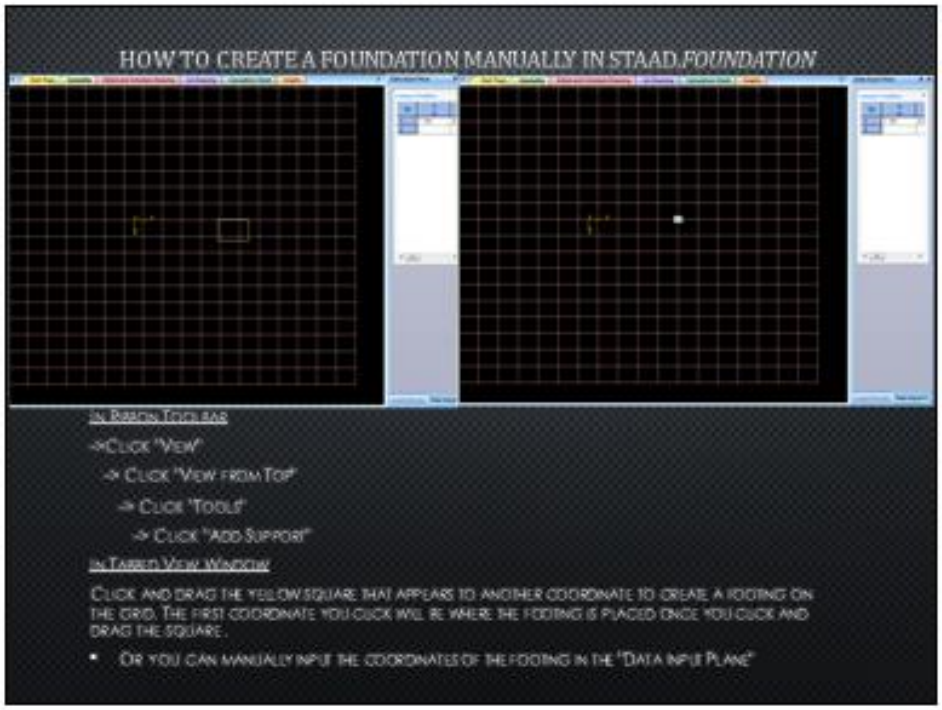
Description of Calculation Package: ____

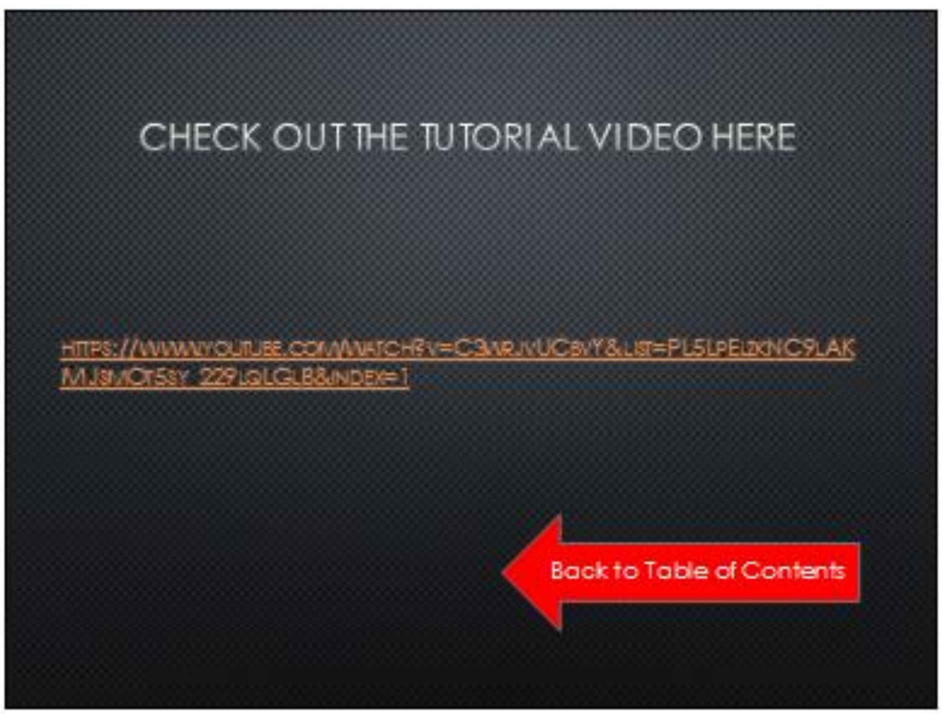
No.	Item	E	C	NA	Status/Action Required:
1	**Modeling – Setup**				
	a.) Is "Job" tab filled out?				
	b.) Is North Direction identified in "Comment" box				
2	**Modeling – Geometry**				
	a.) Check model geometry				
	b.) No Duplicate, Zero Length, Co-Linear Members				
3	**Modeling – General**				
	a.) Check member Properties and Orientations				
	b.) Check end releases and member specifications				
	c.) Check supports are modeled correctly				
	d.) Check primary loads				
	1.) Are they documented in the input file?				
	2.) Are they applied correctly?				
	e.) Check load combinations				
	1.) Are they documented in the input file?				
	2.) Is the repeat load command used?				
	f.) Check proper materials have been assigned				
4	**Modeling – Analysis**				
	a.) Verify results of Statics load check				
	b.) Has a 2nd Order Analysis been specified?				
	1.) Are notional loads applied correctly?				
	2.) Are stiffness reductions applied correctly?				
	3.) Are the correct commands specified?				
5	**Modeling – Design**				
	a.) Check default and Member parameters				
	b.) Is the correct method specified(ASD or LRFD)				
6	**Post Processing**				
	a.) Deflection and drift criteria met				
	b.) Utilization ratios met				
	c.) Eccentricities for angles & WT's Considered				
	d.) Pass-thru loads for connections calculated				
7	**Project Coordination**				
	a.) Models archived to match drawing revision				
	b.) Member sizes on drawings match Staad Model				
	c.) Geometry on drawings match Staad Model				
	d.) Connection, splice, axial, pass-thru loads labeled				

Appendix B………………………………………………………… User Tips Manual

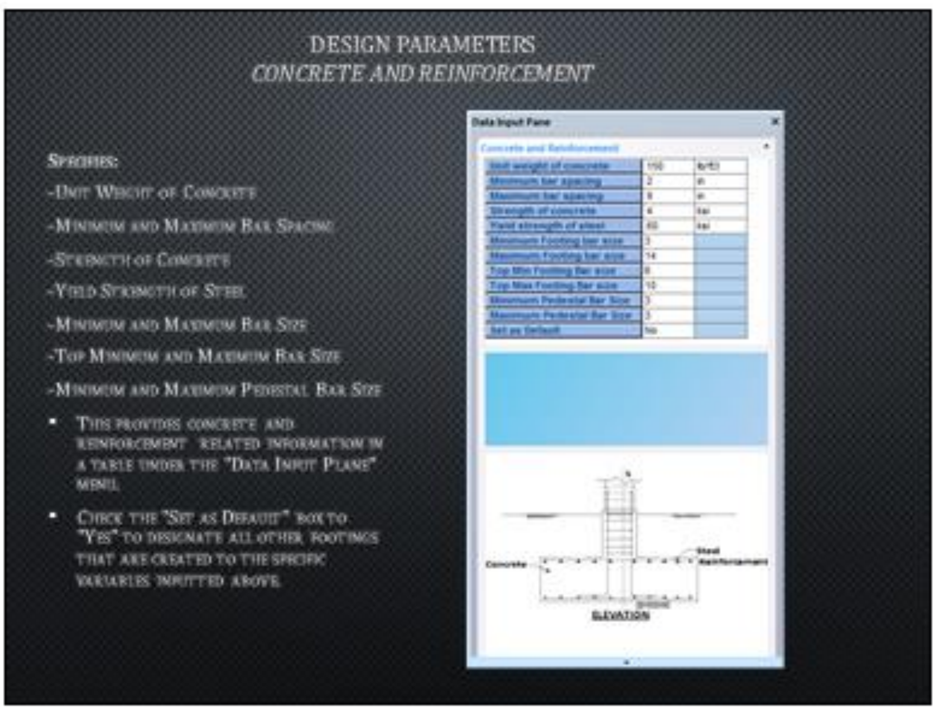

USER INTERFACE
A. Ribbon Toolbar
B. Quick Access Toolbar
C. Main Navigator Pane
D. Tabbed View Window
E. Data Input and Load Pane
F. Output Pane
G. Status Bar

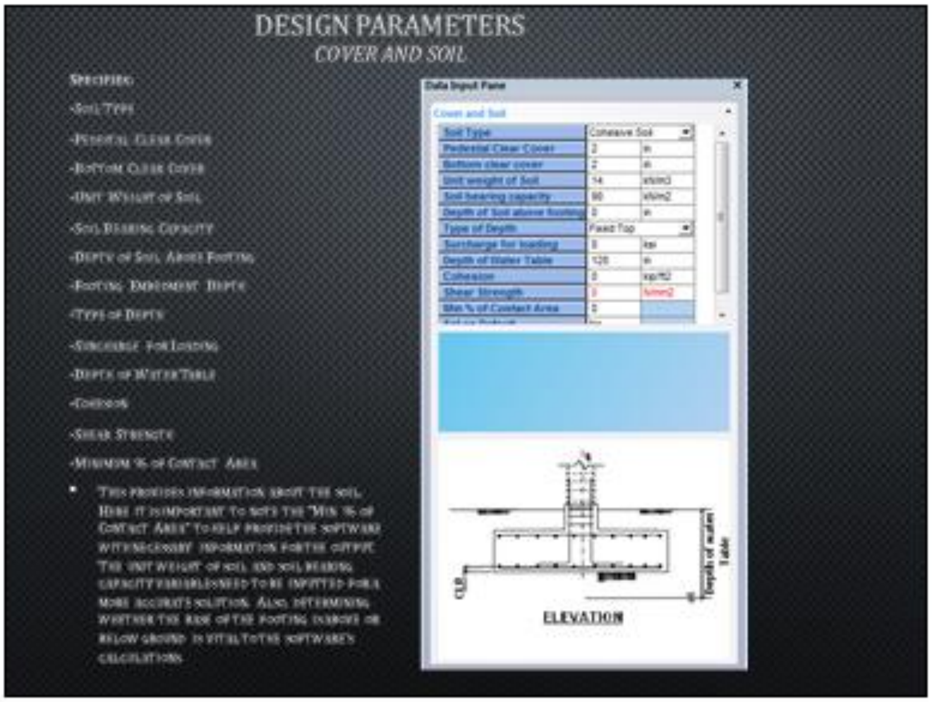

FOUNDATION LOADING IN STAAD.FOUNDATION
Purpose: To increase efficiency in each support design.
Service Loads are used to design footing dimensions.
Ultimate Loads are used to design the concrete reinforcement and footing thickness.
These Load Combinations (Service and Ultimate Loads) need to be combined with factors of safety within the program to create a realistic load case scenario. When toggling through each Load, it is shown that they are not added to the foundation in the geometric view at the same time. Load combinations are used for the foundation's actual design.
Primary Loads allow loading to be used for both Primary and Service Loads. Primary load cases are treated as if they are acting on the foundation separately. They are they initial step towards the design of the foundation. Exclude Primary Loads when creating Load Cases because only Load Combinations should be used for design purposes. STAAD foundation individually applies each Load Combination to the foundation and designs each support according to its Limiting Load Combination.

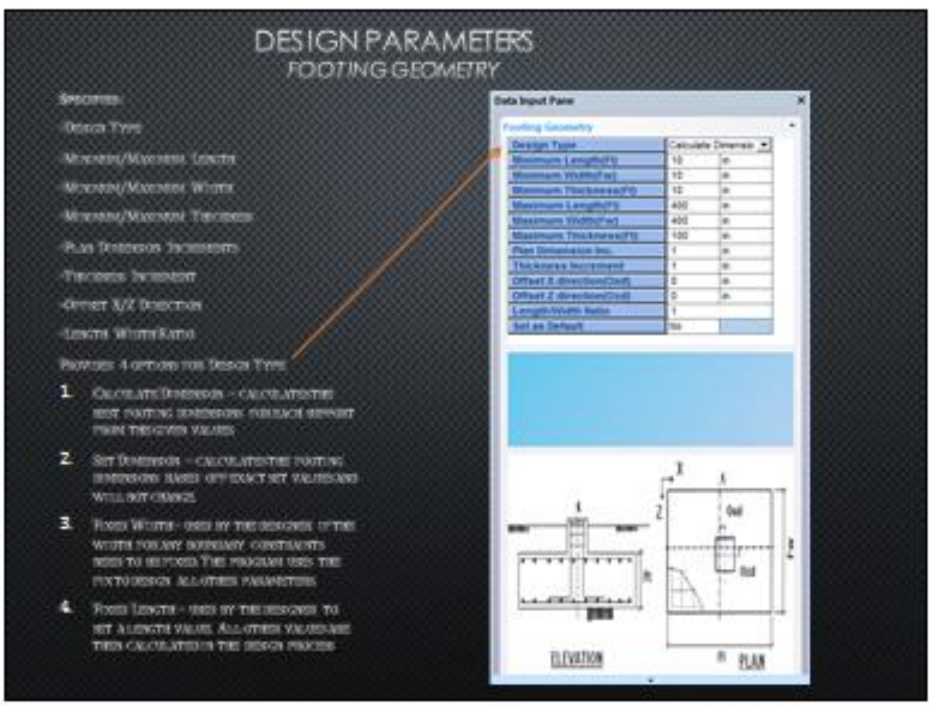

HOW TO CREATE A FOUNDATION MANUALLY IN STAAD.FOUNDATION
IN RIBBON TOOLBAR
->CLICK "VIEW"
-> CLICK "VIEW FROM TOP"
-> CLICK "TOOLS"
-> CLICK "ADD SUPPORT"
IN TABBED VIEW WINDOW
CLICK AND DRAG THE YELLOW SQUARE THAT APPEARS TO ANOTHER COORDINATE TO CREATE A FOOTING ON THE GRID. THE FIRST COORDINATE YOU CLICK WILL BE WHERE THE FOOTING IS PLACED ONCE YOU CLICK AND DRAG THE SQUARE.
• OR YOU CAN MANUALLY INPUT THE COORDINATES OF THE FOOTING IN THE "DATA INPUT PLANE"

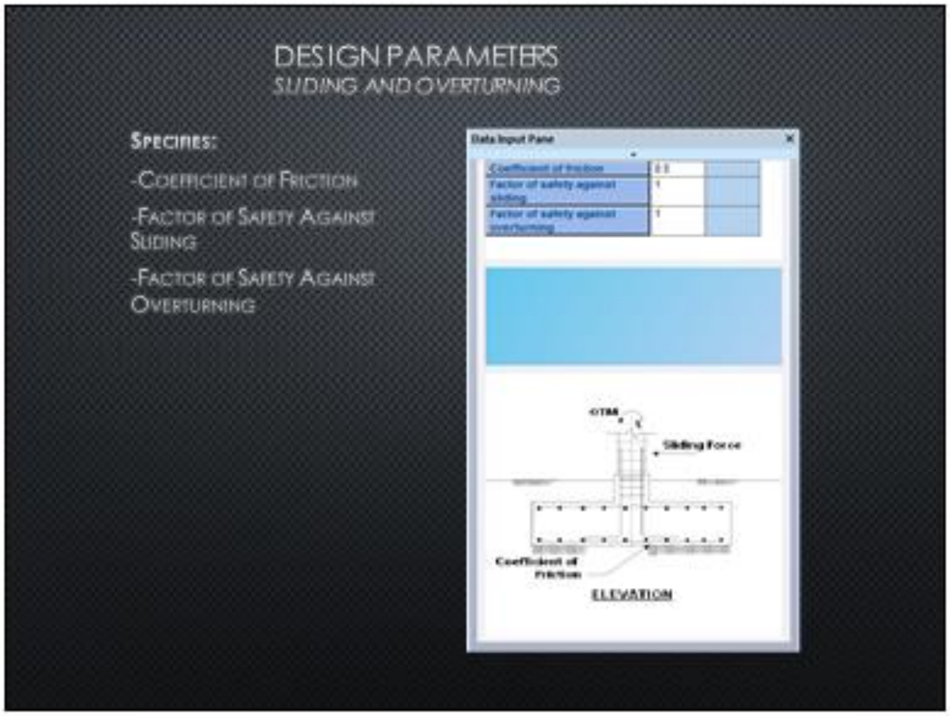

CHECK OUT THE TUTORIAL VIDEO HERE
HTTPS://WWW.YOUTUBE.COM/WATCH?V=C3WRJVUCBVY&LIST=PL5LPELZKNC9LAKMJSMOT5SY_229LGLGLB&INDEX=1
Back to Table of Contents

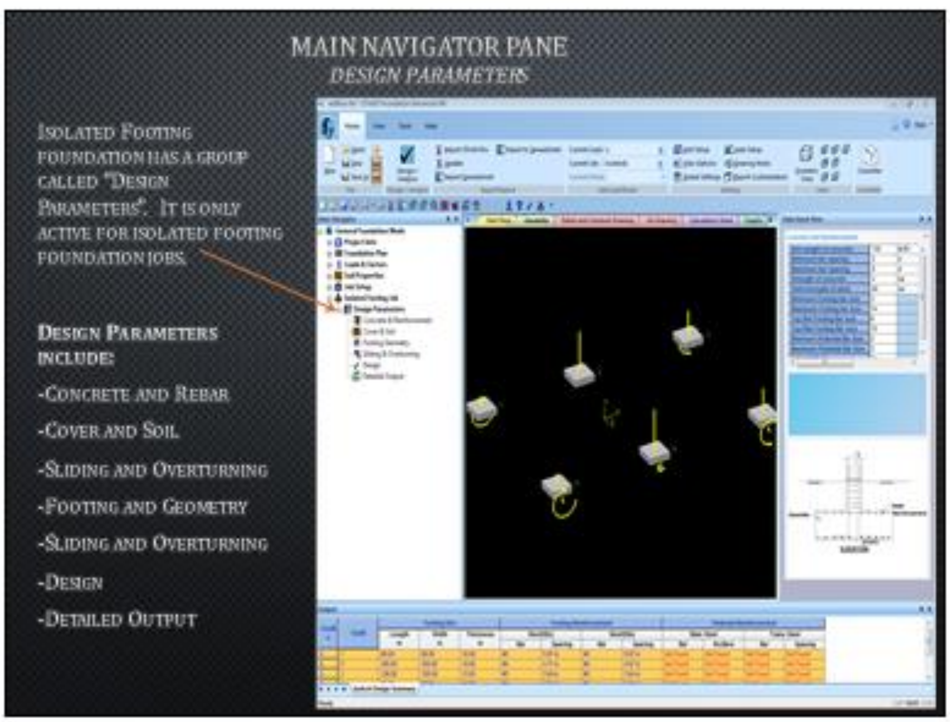

ISOLATED SPREAD FOOTING

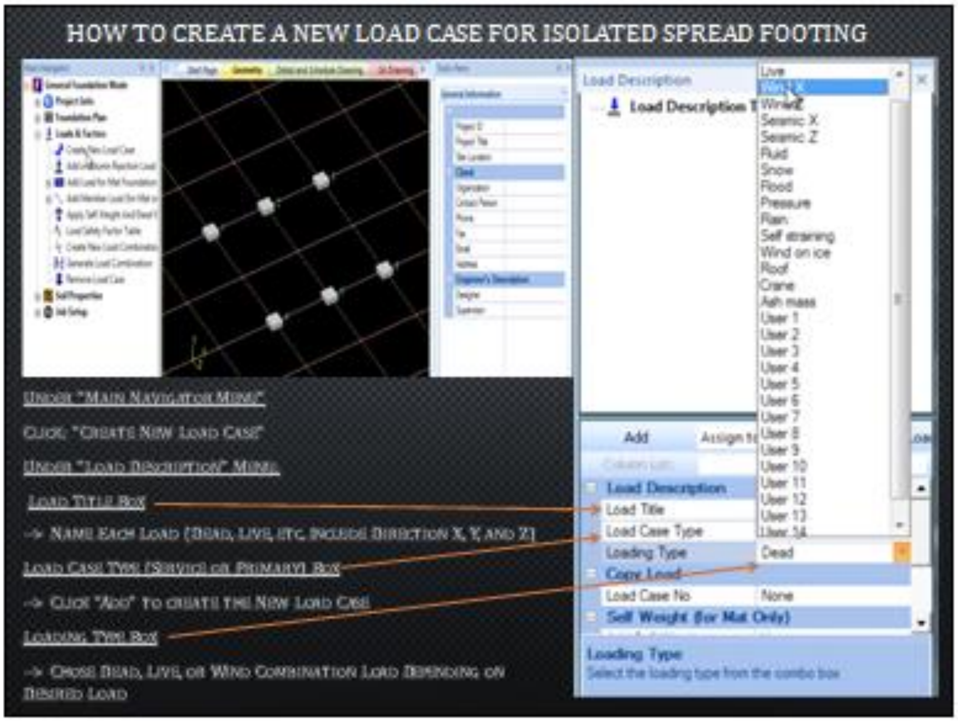

DESIGN PARAMETERS
CONCRETE AND REINFORCEMENT
Specifies:
-Unit Weight of Concrete
-Minimum and Maximum Bar Spacing
-Strength of Concrete
-Yield Strength of Steel
-Minimum and Maximum Bar Size
-Top Minimum and Maximum Bar Size
-Minimum and Maximum Pedestal Bar Size
This provides concrete and reinforcement related information in a table under the "Data Input Plane" menu.
Check the "Set as Default" box to "Yes" to designate all other footings that are created to the specific variables inputted above.
Data Input Pane
ELEVATION

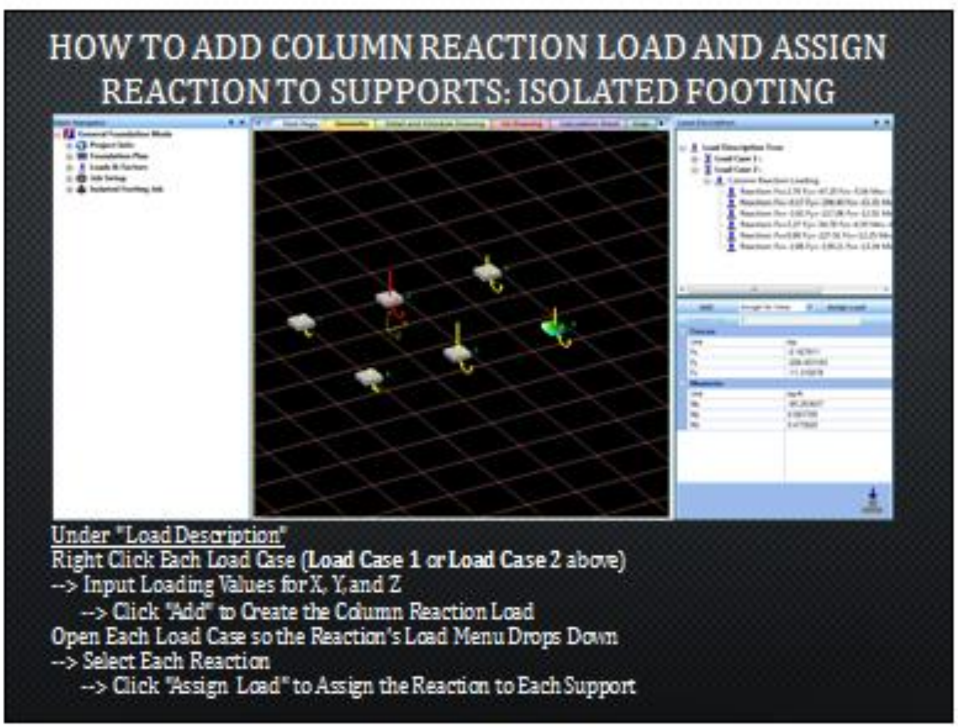

DESIGN PARAMETERS
COVER AND SOIL
-Soil Type
-Depth of Water Table
-Shear Strength
-Minimum % of Contact Area
ELEVATION

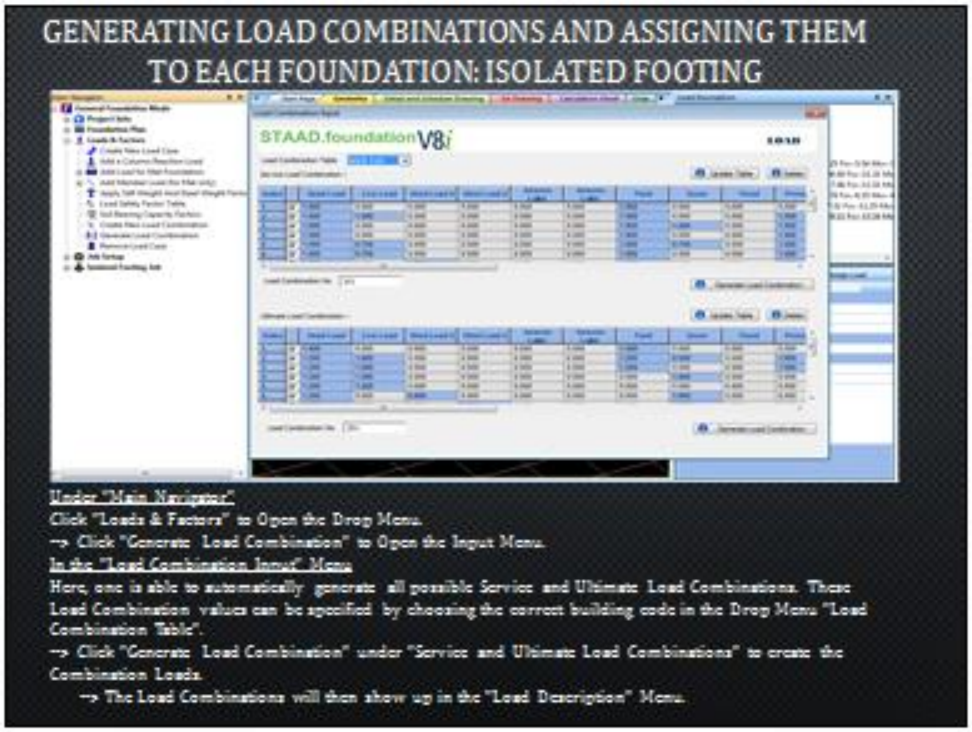

DESIGN PARAMETERS
FOOTING GEOMETRY
-Design Type
-Offset X/Z Direction
Provides 4 options for Design Type
ELEVATION
PLAN

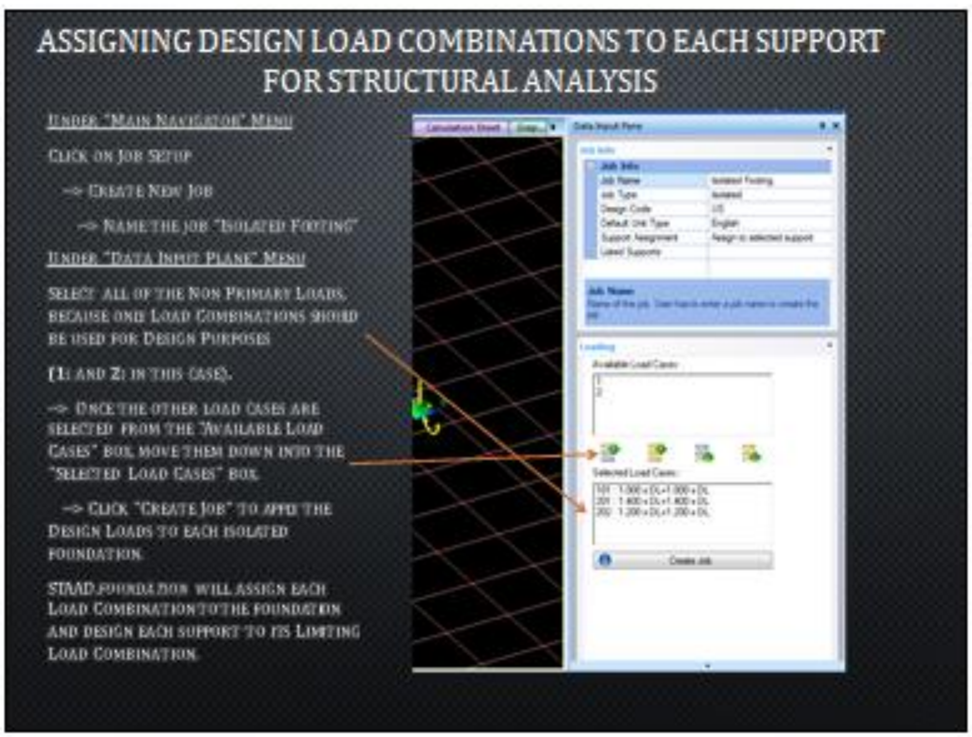

DESIGN PARAMETERS
SLIDING AND OVERTURNING
Specifies:
-Coefficient of Friction
-Factor of Safety Against Sliding
-Factor of Safety Against Overturning
Data Input Pane
Coefficient of friction
Factor of safety against sliding
Factor of safety against overturning
OTM
Sliding Force
Coefficient of Friction
ELEVATION

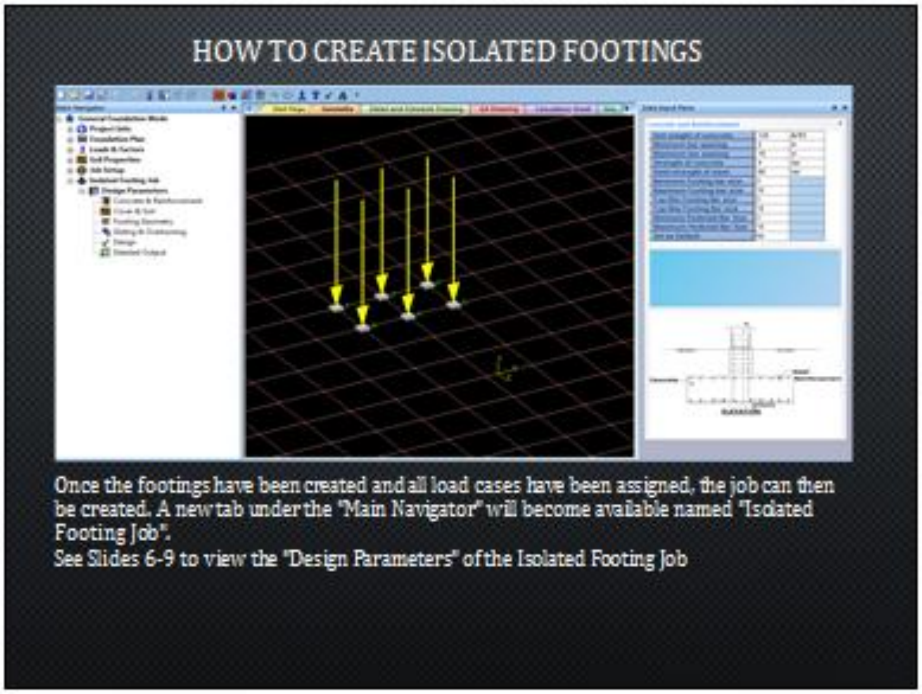

MAIN NAVIGATOR PANE
DESIGN PARAMETERS
Isolated Footing foundation has a group called "Design Parameters". It is only active for isolated footing foundation jobs.
Design Parameters include:
-Concrete and Rebar
-Cover and Soil
-Sliding and Overturning
-Footing and Geometry
-Sliding and Overturning
-Design
-Detailed Output

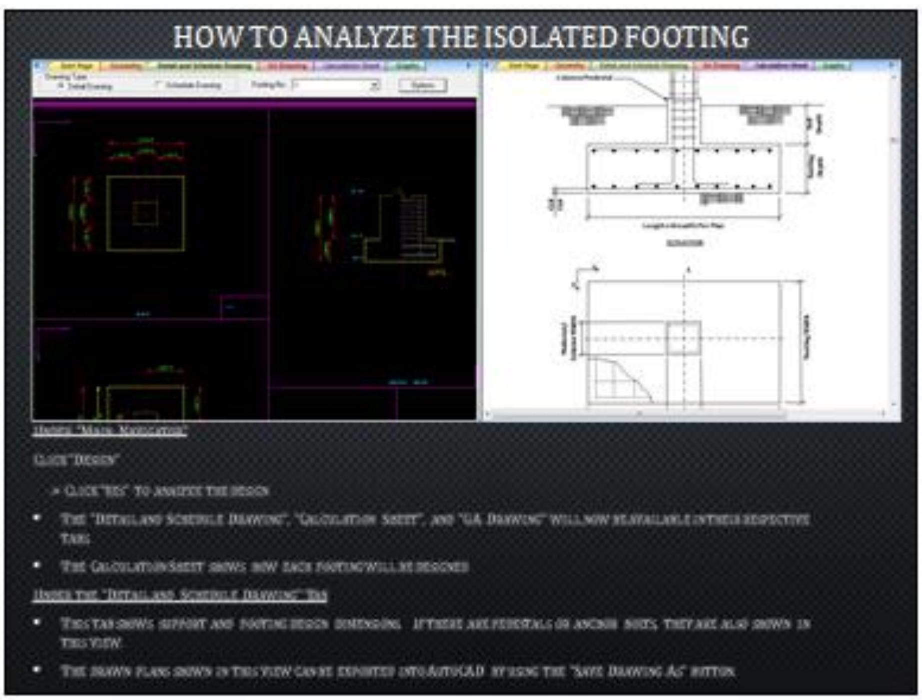

HOW TO CREATE A NEW LOAD CASE FOR ISOLATED SPREAD FOOTING
UNDER "MAIN NAVIGATOR MENU"
CLICK: "CREATE NEW LOAD CASE"
UNDER "LOAD DESCRIPTION" MENU:
LOAD TITLE BOX
--> NAME EACH LOAD (DEAD, LIVE, ETC. INCLUDE DIRECTION X, Y, AND Z)
LOAD CASE TYPE (SERVICE OR PRIMARY) BOX
--> CLICK "ADD" TO CREATE THE NEW LOAD CASE
LOADING TYPE BOX
--> CHOSE DEAD, LIVE, OR WIND COMBINATION LOAD DEPENDING ON DESIRED LOAD
Load Description
Load Title
Load Case Type
Loading Type
Dead
Copy Load
Load Case No
None
Self Weight (for Mat Only)
Loading Type
Select the loading type from the combo box

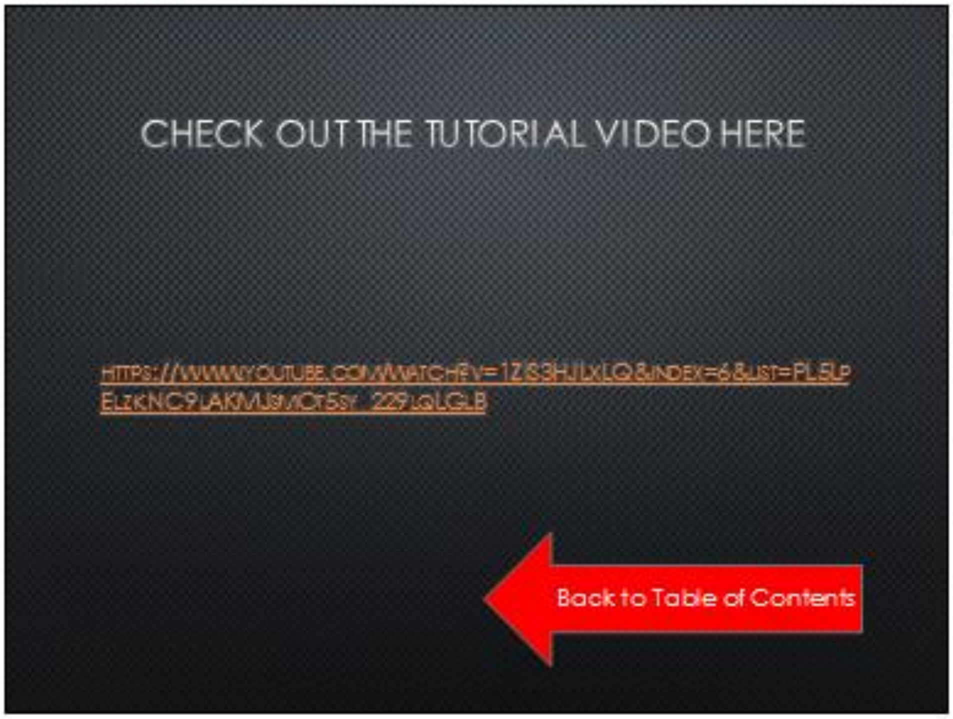

HOW TO ADD COLUMN REACTION LOAD AND ASSIGN REACTION TO SUPPORTS: ISOLATED FOOTING
Under "Load Description"
Right Click Each Load Case (Load Case 1 or Load Case 2 above)
--> Input Loading Values for X, Y, and Z
--> Click "Add" to Create the Column Reaction Load
Open Each Load Case so the Reaction's Load Menu Drops Down
--> Select Each Reaction
--> Click "Assign Load" to Assign the Reaction to Each Support


GENERATING LOAD COMBINATIONS AND ASSIGNING THEM TO EACH FOUNDATION: ISOLATED FOOTING
STAAD.foundation V8i
Under "Main Navigator"
Click "Loads & Factors" to Open the Drop Menu.
--> Click "Generate Load Combination" to Open the Input Menu.
In the "Load Combination Input" Menu
Here, one is able to automatically generate all possible Service and Ultimate Load Combinations. These Load Combination values can be specified by choosing the correct building code in the Drop Menu "Load Combination Table".
--> Click "Generate Load Combination" under "Service and Ultimate Load Combinations" to create the Combination Loads.
--> The Load Combinations will then show up in the "Load Description" Menu.

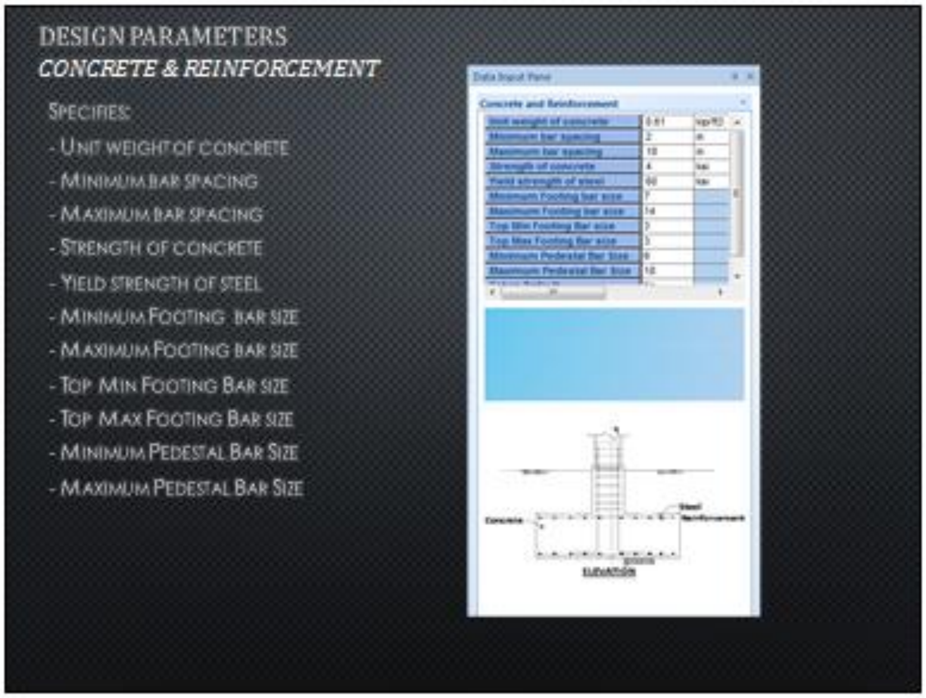

ASSIGNING DESIGN LOAD COMBINATIONS TO EACH SUPPORT FOR STRUCTURAL ANALYSIS
Under "Main Navigator" Menu
Click on Job Setup
--> Create New Job
--> Name the job "Isolated Footing"
Under "Data Input Plane" Menu
Select all of the Non Primary Loads, because only Load Combinations should be used for Design Purposes
(1 and 2 in this case).
--> Once the other load cases are selected from the "Available Load Cases" box, move them down into the "Selected Load Cases" box.
--> Click "Create Job" to apply the Design Loads to each isolated foundation.
STAAD.foundation will assign each Load Combination to the foundation and design each support to its Limiting Load Combination.
Create Job

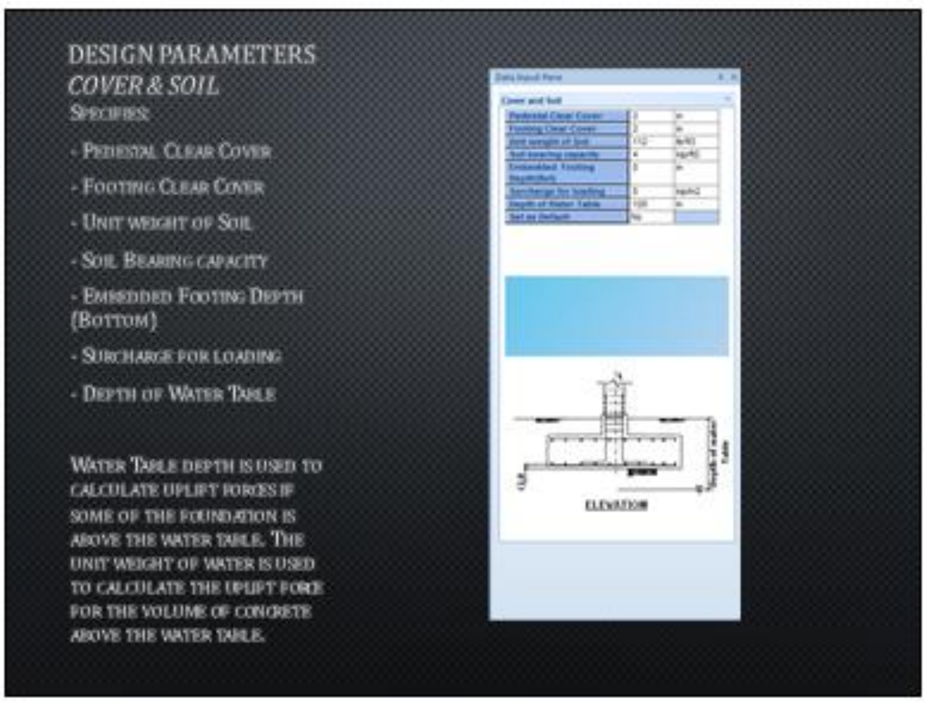

HOW TO CREATE ISOLATED FOOTINGS
Once the footings have been created and all load cases have been assigned, the job can then be created. A new tab under the "Main Navigator" will become available named "Isolated Footing Job".
See Slides 6-9 to view the "Design Parameters" of the Isolated Footing Job

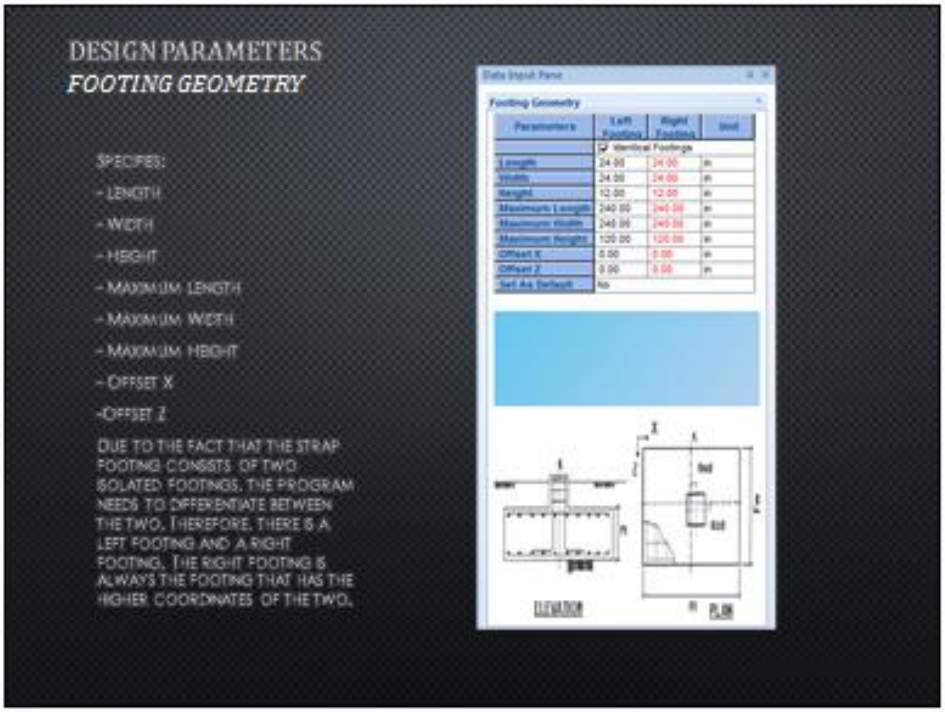

HOW TO ANALYZE THE ISOLATED FOOTING
Under "Main Navigator"
Click "Design"
Click "Yes" to analyze the design
The "Detail and Schedule Drawing", "Calculation Sheet", and "GA Drawing" will now be available in their respective tabs
The Calculation Sheet shows how each footing will be designed
Under the "Detail and Schedule Drawing" Tab
This tab shows support and footing design dimensions. If there are pedestals or anchor bolts, they are also shown in this view.
The drawn plans shown in this view can be exported into AutoCAD by using the "Save Drawing As" button

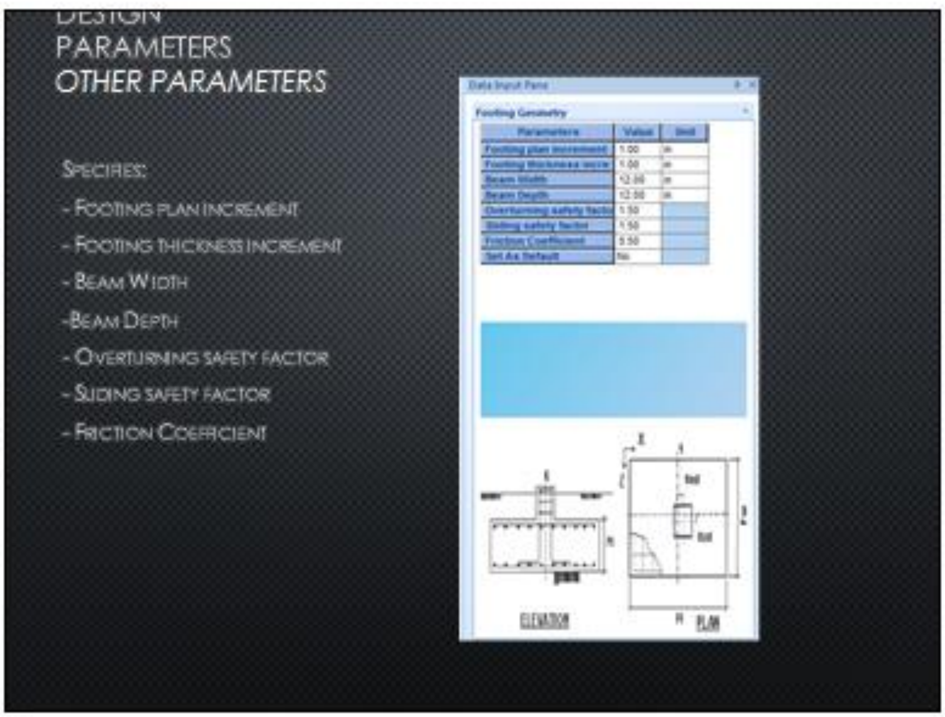

CHECK OUT THE TUTORIAL VIDEO HERE
HTTPS://WWW.YOUTUBE.COM/WATCH?V=1ZIS3HJ1LXLQ&INDEX=6&LIST=PL5LP
ELZKNC9LAKMJSMCT5SY_229LQLGLB
Back to Table of Contents

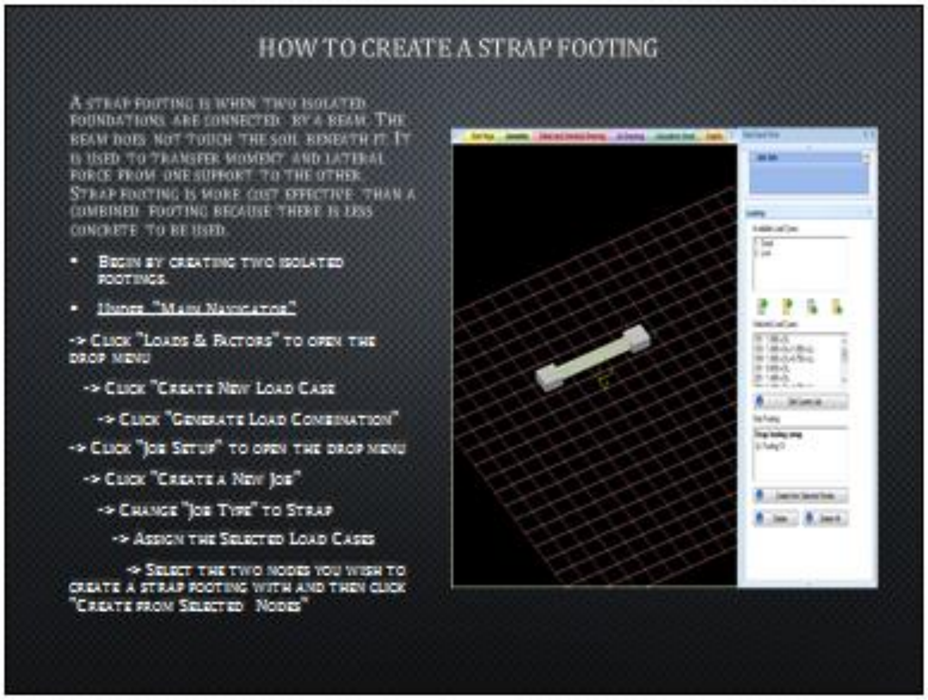

STRAP FOUNDATION

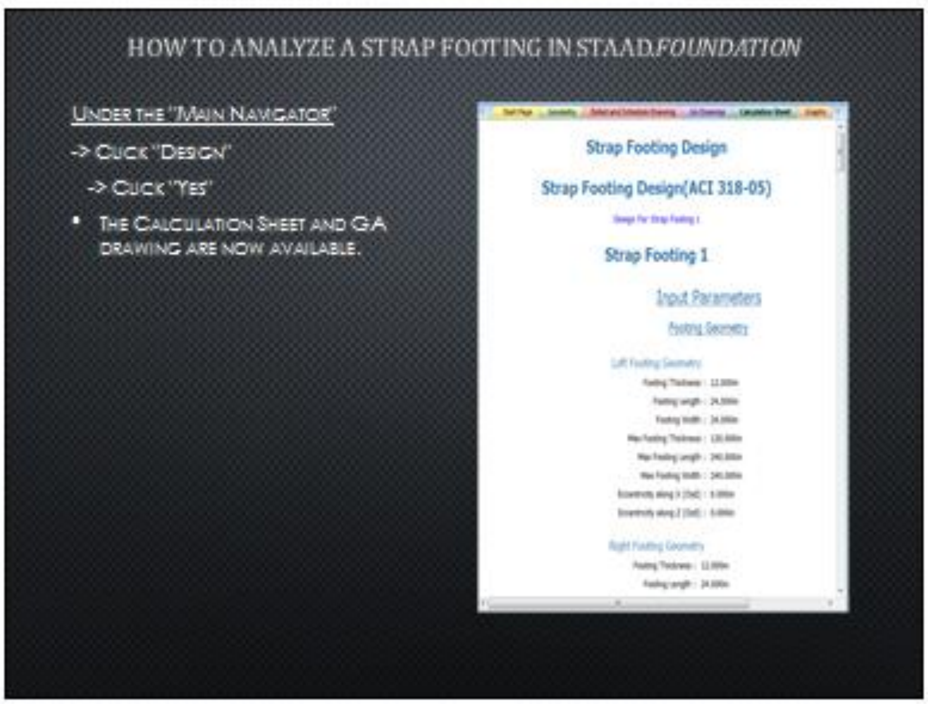

DESIGN PARAMETERS
CONCRETE & REINFORCEMENT
SPECIFIES:
- UNIT WEIGHT OF CONCRETE
- MINIMUM BAR SPACING
- MAXIMUM BAR SPACING
- STRENGTH OF CONCRETE
- YIELD STRENGTH OF STEEL
- MINIMUM FOOTING BAR SIZE
- MAXIMUM FOOTING BAR SIZE
- TOP MIN FOOTING BAR SIZE
- TOP MAX FOOTING BAR SIZE
- MINIMUM PEDESTAL BAR SIZE
- MAXIMUM PEDESTAL BAR SIZE


DESIGN PARAMETERS
COVER & SOIL
SPECIFIES:
- PEDESTAL CLEAR COVER
- FOOTING CLEAR COVER
- UNIT WEIGHT OF SOIL
- SOIL BEARING CAPACITY
- EMBEDDED FOOTING DEPTH (BOTTOM)
- SURCHARGE FOR LOADING
- DEPTH OF WATER TABLE
WATER TABLE DEPTH IS USED TO CALCULATE UPLIFT FORCES IF SOME OF THE FOUNDATION IS ABOVE THE WATER TABLE. THE UNIT WEIGHT OF WATER IS USED TO CALCULATE THE UPLIFT FORCE FOR THE VOLUME OF CONCRETE ABOVE THE WATER TABLE.


DESIGN PARAMETERS
FOOTING GEOMETRY
SPECIFIES:
- LENGTH
- WIDTH
- HEIGHT
- MAXIMUM LENGTH
- MAXIMUM WIDTH
- MAXIMUM HEIGHT
- OFFSET X
-OFFSET Z
DUE TO THE FACT THAT THE STRAP FOOTING CONSISTS OF TWO ISOLATED FOOTINGS, THE PROGRAM NEEDS TO DIFFERENTIATE BETWEEN THE TWO. THEREFORE, THERE IS A LEFT FOOTING AND A RIGHT FOOTING. THE RIGHT FOOTING IS ALWAYS THE FOOTING THAT HAS THE HIGHER COORDINATES OF THE TWO.
Footing Geometry
ELEVATION
PLAN

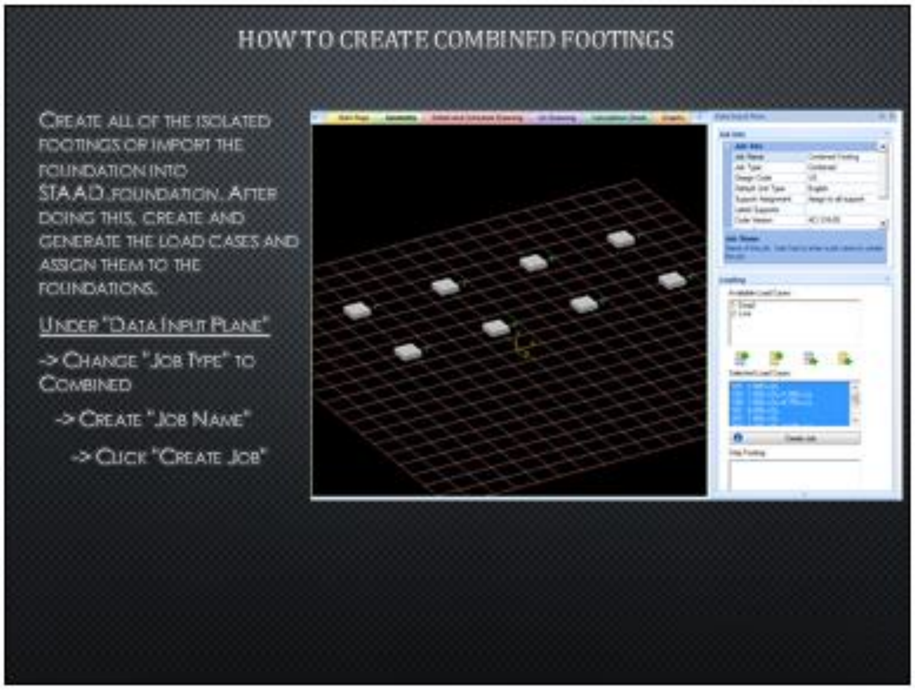

DESIGN
PARAMETERS
OTHER PARAMETERS
SPECIFIES:
- FOOTING PLAN INCREMENT
- FOOTING THICKNESS INCREMENT
- BEAM WIDTH
-BEAM DEPTH
- OVERTURNING SAFETY FACTOR
- SLIDING SAFETY FACTOR
- FRICTION COEFFICIENT
Footing Geometry
ELEVATION
PLAN

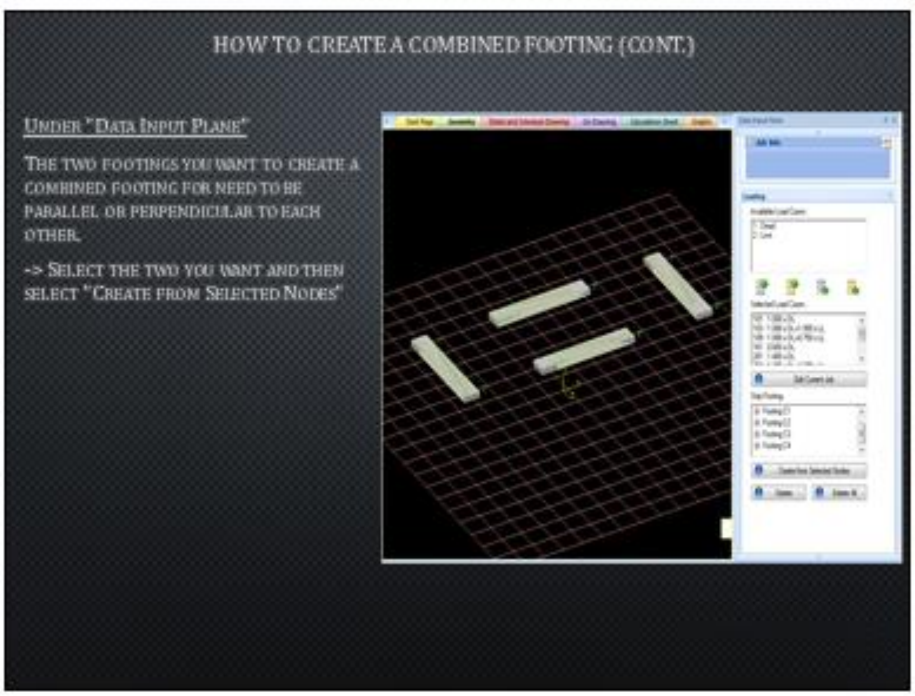

HOW TO CREATE A STRAP FOOTING
A strap footing is when two isolated foundations are connected by a beam. The beam does not touch the soil beneath it. It is used to transfer moment and lateral force from one support to the other. Strap footing is more cost effective than a combined footing because there is less concrete to be used.
Begin by creating two isolated footings.
Under "Main Navigator"
-> Click "Loads & Factors" to open the drop menu
-> Click "Create New Load Case
-> Click "Generate Load Combination"
-> Click "Job Setup" to open the drop menu
-> Click "Create a New Job"
-> Change "Job Type" to Strap
-> Assign the Selected Load Cases
-> Select the two nodes you wish to create a strap footing with and then click "Create from Selected Nodes"

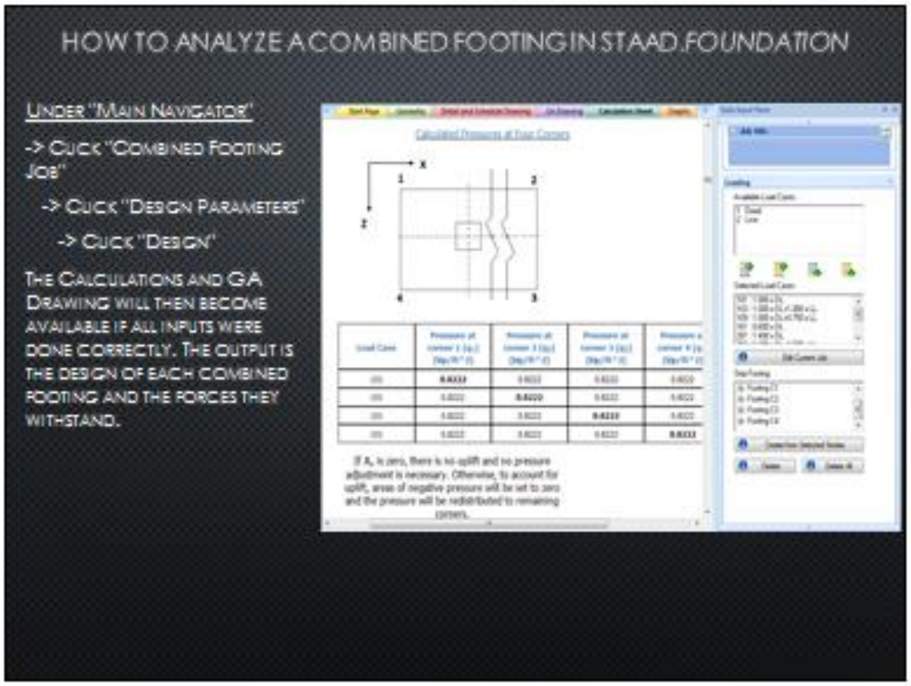

HOW TO ANALYZE A STRAP FOOTING IN STAAD.FOUNDATION
Under the "Main Navigator"
-> Click "Design"
-> Click "Yes"
The Calculation Sheet and GA drawing are now available.
Strap Footing Design
Strap Footing Design(ACI 318-05)
Strap Footing 1
Input Parameters
Footing Geometry

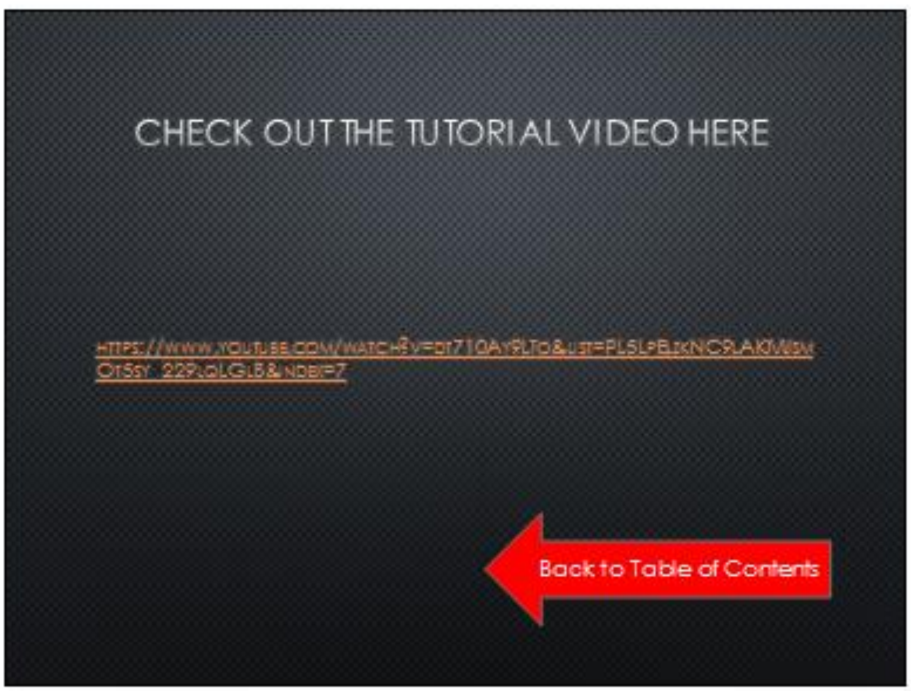

CHECK OUT THE TUTORIAL VIDEO HERE
HTTPS://WWW.YOUTUBE.COM/WATCH?V=E2ASWWBK74D&LIST=PL5LPELZKNC9LAKMJBMOT5SY_229LQLGL6&INDEX=16
Back to Table of Contents


COMBINED FOOTING

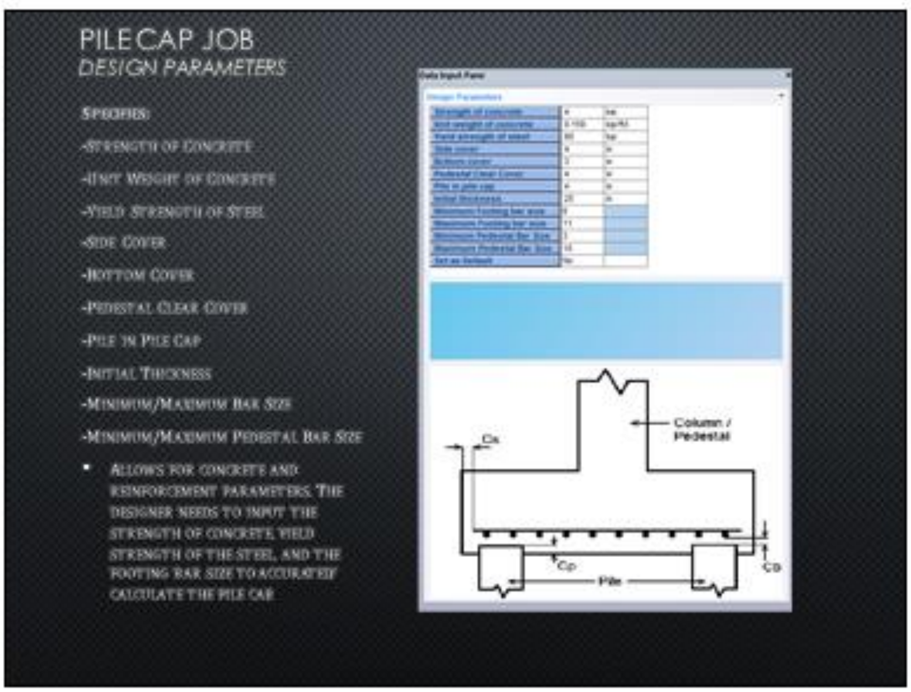

HOW TO CREATE COMBINED FOOTINGS
Create all of the isolated footings or import the foundation into STAAD.foundation. After doing this, create and generate the load cases and assign them to the foundations.
Under "Data Input Plane"
-> Change "Job Type" to Combined
-> Create "Job Name"
-> Click "Create Job"

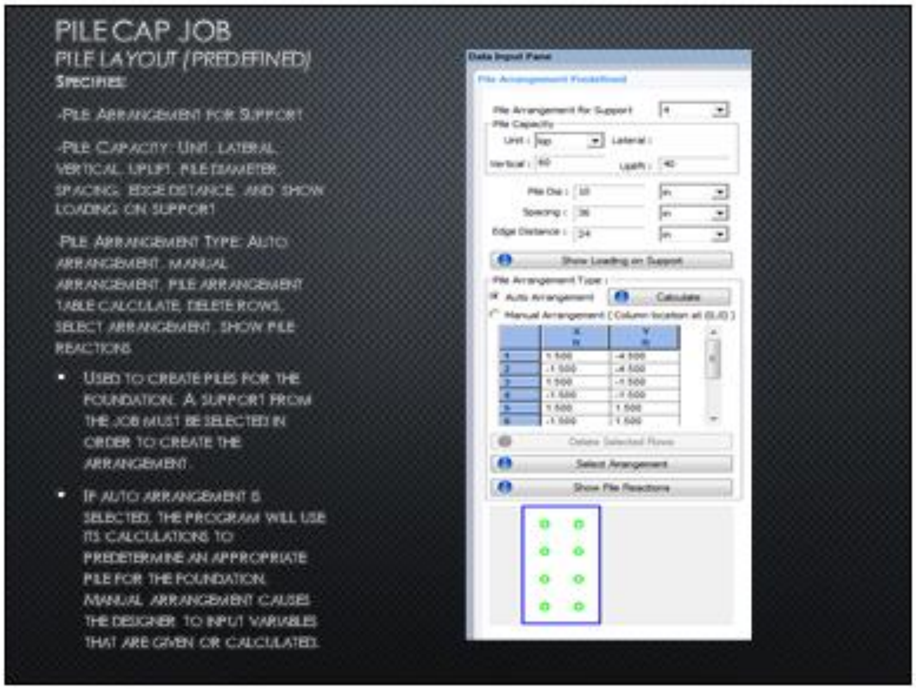

HOW TO CREATE A COMBINED FOOTING (CONT.)
Under "Data Input Plane"
The two footings you want to create a combined footing for need to be parallel or perpendicular to each other.
-> Select the two you want and then select "Create from Selected Nodes"

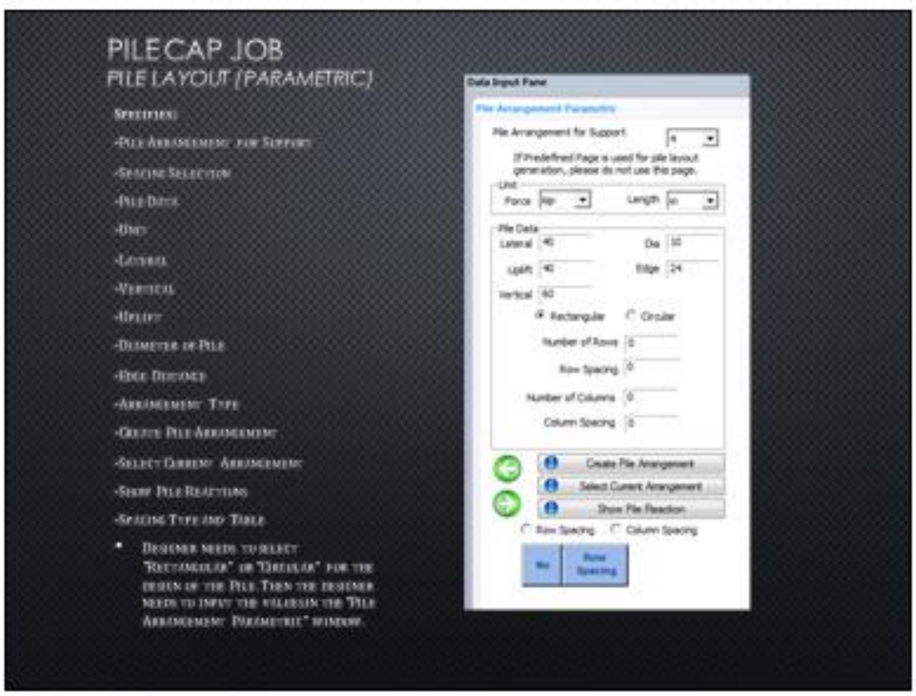

HOW TO ANALYZE A COMBINED FOOTING IN STAAD.FOUNDATION
UNDER "MAIN NAVIGATOR"
-> CLICK "COMBINED FOOTING JOB"
-> CLICK "DESIGN PARAMETERS"
-> CLICK "DESIGN"
THE CALCULATIONS AND GA DRAWING WILL THEN BECOME AVAILABLE IF ALL INPUTS WERE DONE CORRECTLY. THE OUTPUT IS THE DESIGN OF EACH COMBINED FOOTING AND THE FORCES THEY WITHSTAND.

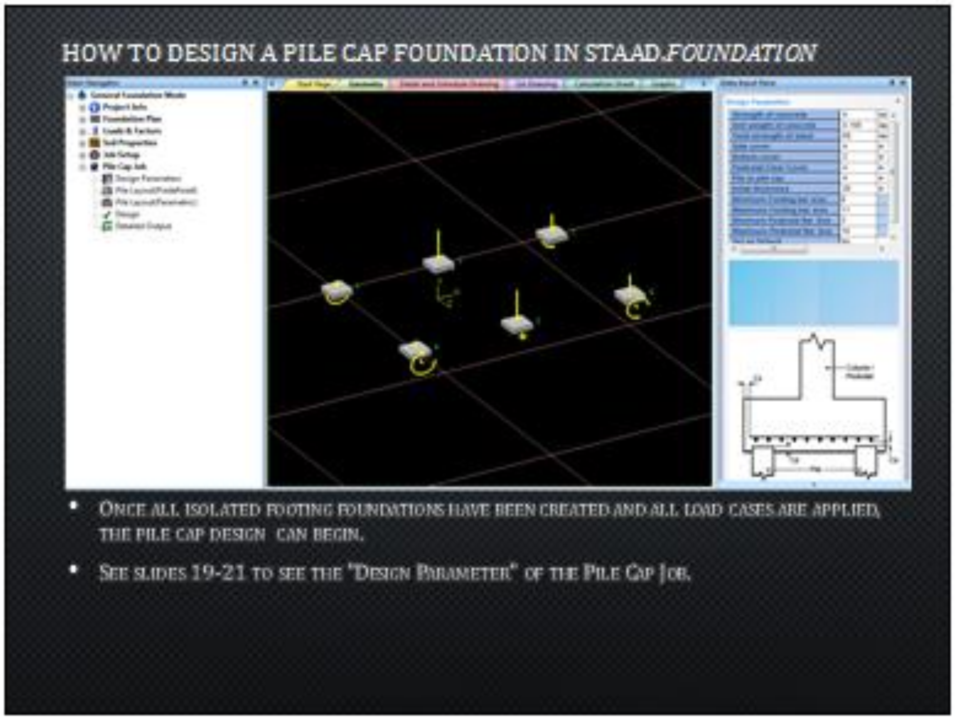

CHECK OUT THE TUTORIAL VIDEO HERE
Back to Table of Contents

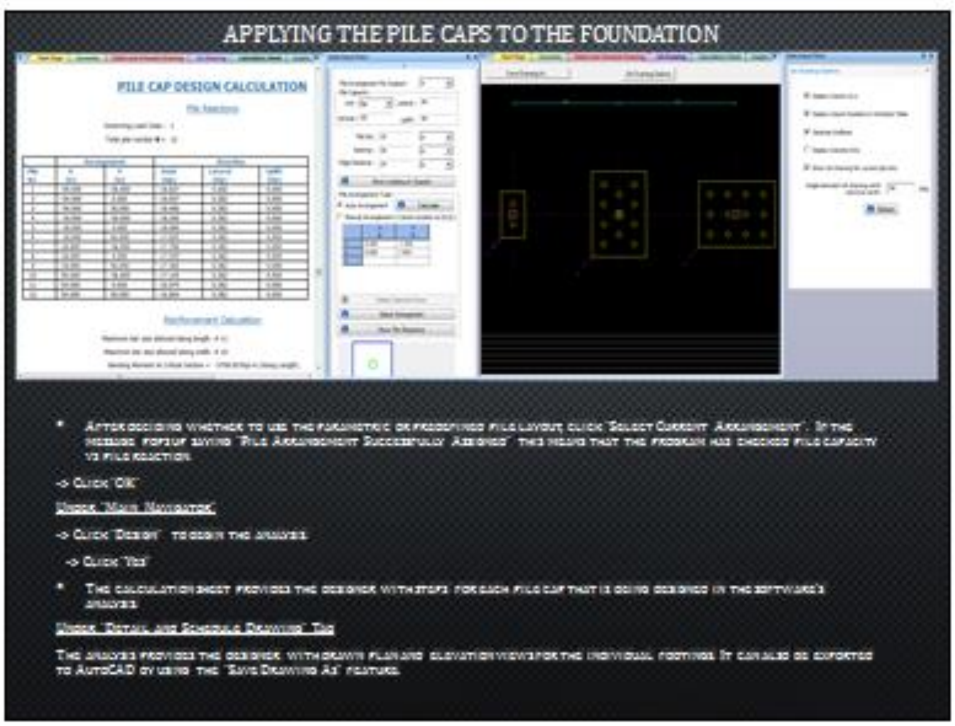

PILE CAP FOUNDATION

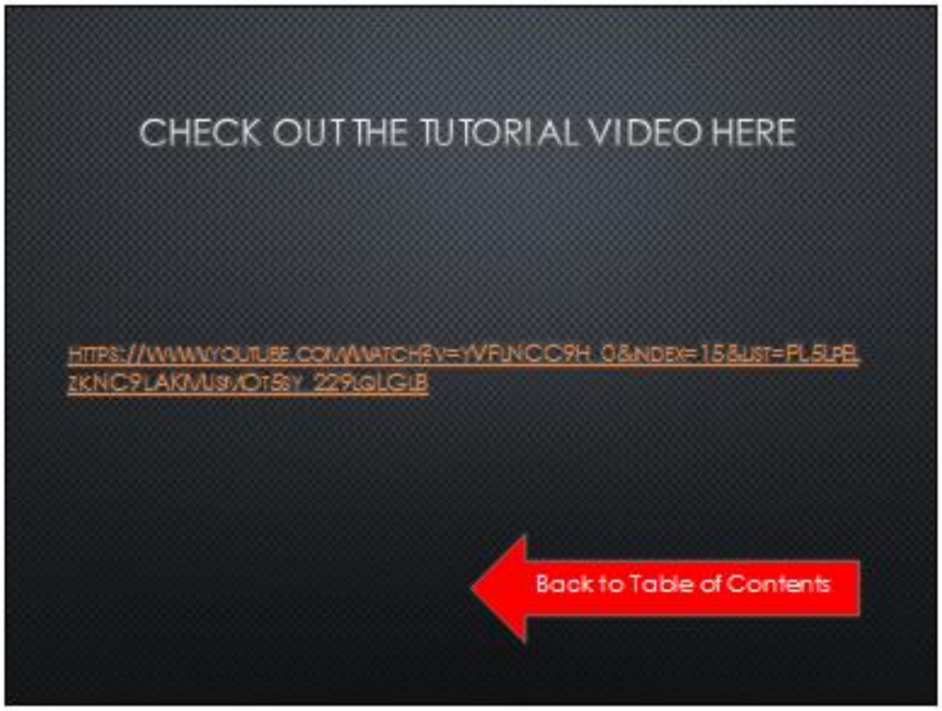

PILE CAP JOB
DESIGN PARAMETERS
SPECIFIES:
-STRENGTH OF CONCRETE
-UNIT WEIGHT OF CONCRETE
-YIELD STRENGTH OF STEEL
-SIDE COVER
-BOTTOM COVER
-PEDESTAL CLEAR COVER
-PILE IN PILE CAP
-INITIAL THICKNESS
-MINIMUM/MAXIMUM BAR SIZE
-MINIMUM/MAXIMUM PEDESTAL BAR SIZE
ALLOWS FOR CONCRETE AND REINFORCEMENT PARAMETERS. THE DESIGNER NEEDS TO INPUT THE STRENGTH OF CONCRETE, YIELD STRENGTH OF THE STEEL, AND THE FOOTING BAR SIZE TO ACCURATELY CALCULATE THE PILE CAP.
Column / Pedestal
Cs
Cp
Pile
Cb


PILE CAP JOB
PILE LAYOUT (PREDEFINED)
SPECIFIES:
-PILE ARRANGEMENT FOR SUPPORT
-PILE CAPACITY: UNIT, LATERAL, VERTICAL, UPLIFT, PILE DIAMETER, SPACING, EDGE DISTANCE, AND SHOW LOADING ON SUPPORT
-PILE ARRANGEMENT TYPE: AUTO ARRANGEMENT, MANUAL ARRANGEMENT, PILE ARRANGEMENT TABLE CALCULATE, DELETE ROWS, SELECT ARRANGEMENT, SHOW PILE REACTIONS
USED TO CREATE PILES FOR THE FOUNDATION. A SUPPORT FROM THE JOB MUST BE SELECTED IN ORDER TO CREATE THE ARRANGEMENT.
IF AUTO ARRANGEMENT IS SELECTED, THE PROGRAM WILL USE ITS CALCULATIONS TO PREDETERMINE AN APPROPRIATE PILE FOR THE FOUNDATION. MANUAL ARRANGEMENT CAUSES THE DESIGNER TO INPUT VARIABLES THAT ARE GIVEN OR CALCULATED.
Data Input Pane
Pile Arrangement Predefined
Pile Arrangement for Support
Pile Capacity
Unit :
Lateral :
Vertical :
Uplift :
Pile Dia :
Spacing :
Edge Distance :
Show Loading on Support
Pile Arrangement Type :
Auto Arrangement
Calculate
Manual Arrangement
Delete Selected Rows
Select Arrangement
Show Pile Reactions

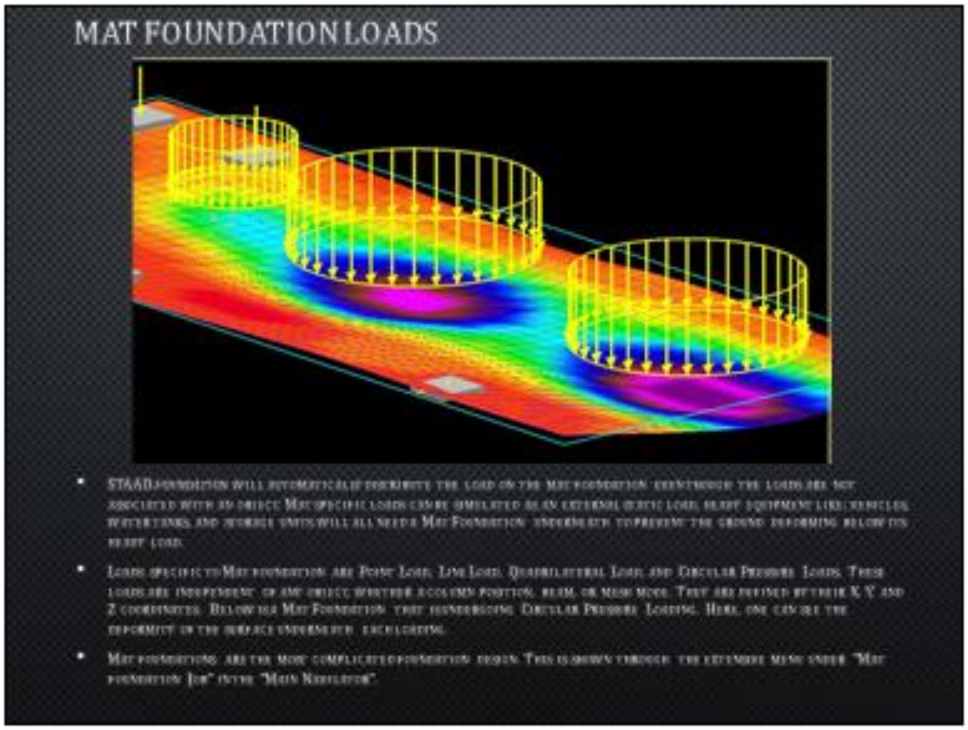

PILE CAP JOB
PILE LAYOUT (PARAMETRIC)


HOW TO DESIGN A PILE CAP FOUNDATION IN STAAD.FOUNDATION
Once all isolated footing foundations have been created and all load cases are applied, the pile cap design can begin.
See slides 19-21 to see the "Design Parameter" of the Pile Cap Job.

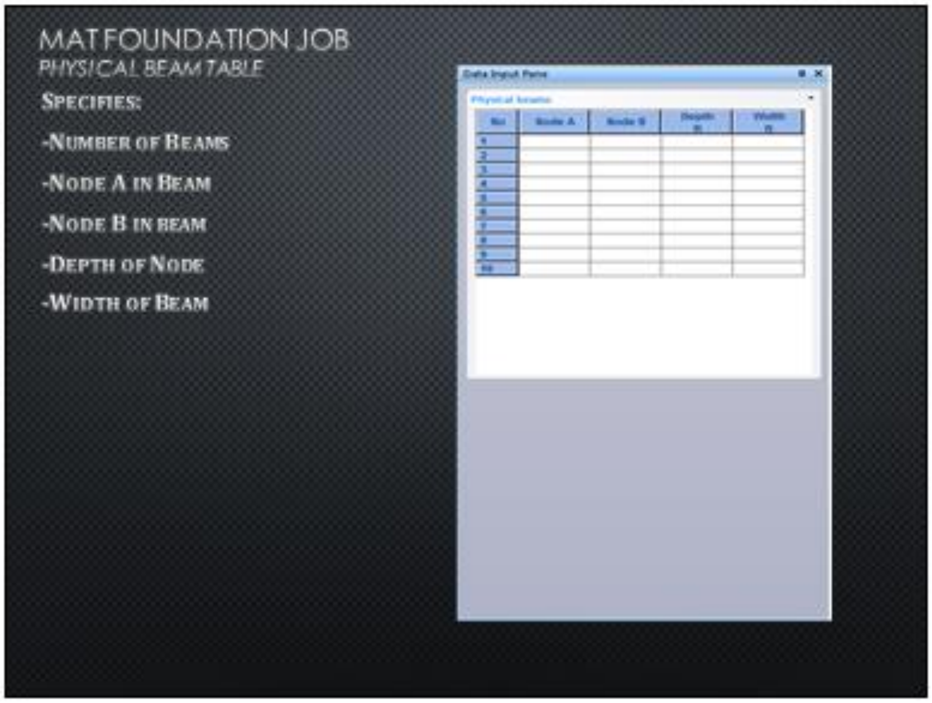

APPLYING THE PILE CAPS TO THE FOUNDATION
PILE CAP DESIGN CALCULATION
After deciding whether to use the parametric or predefined pile layout, click 'Select Current Arrangement'. If the message popup saying 'Pile Arrangement Successfully Assigned' this means that the program has checked pile capacity vs pile reaction.
-> Click 'OK'
Under 'Main Navigator'
-> Click 'Design' to begin the analysis.
-> Click 'Yes'
The calculation sheet provides the designer with steps for each pile cap that is being designed in the software's analysis.
Under 'Detail and Schedule Drawing' Tab
The analysis provides the designer with drawn plan and elevation views for the individual footings. It can also be exported to AutoCAD by using the 'Save Drawing As' feature.

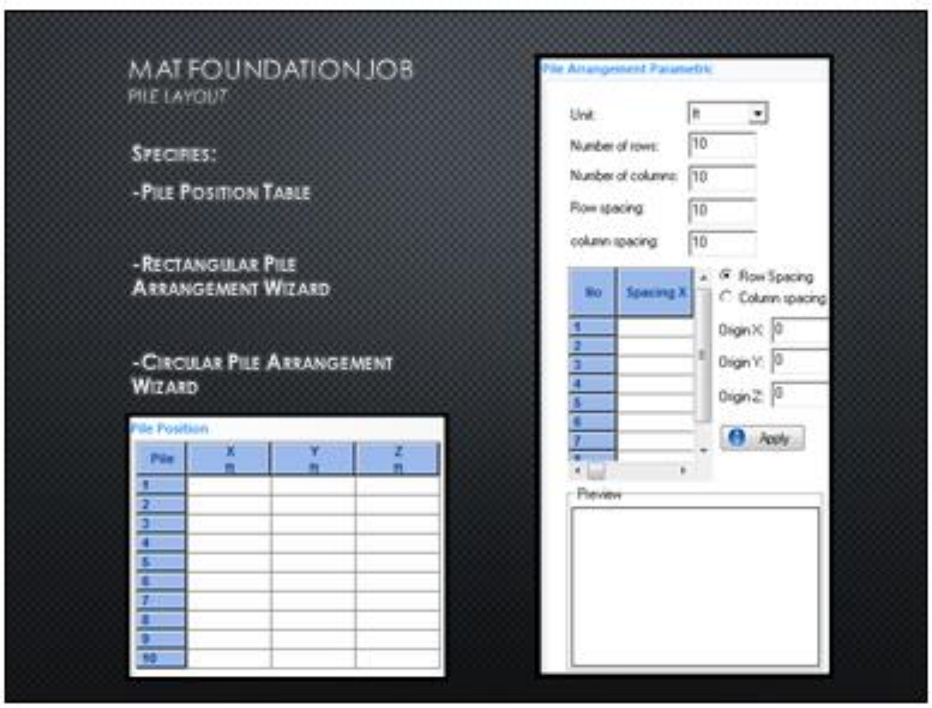

CHECK OUT THE TUTORIAL VIDEO HERE
Back to Table of Contents

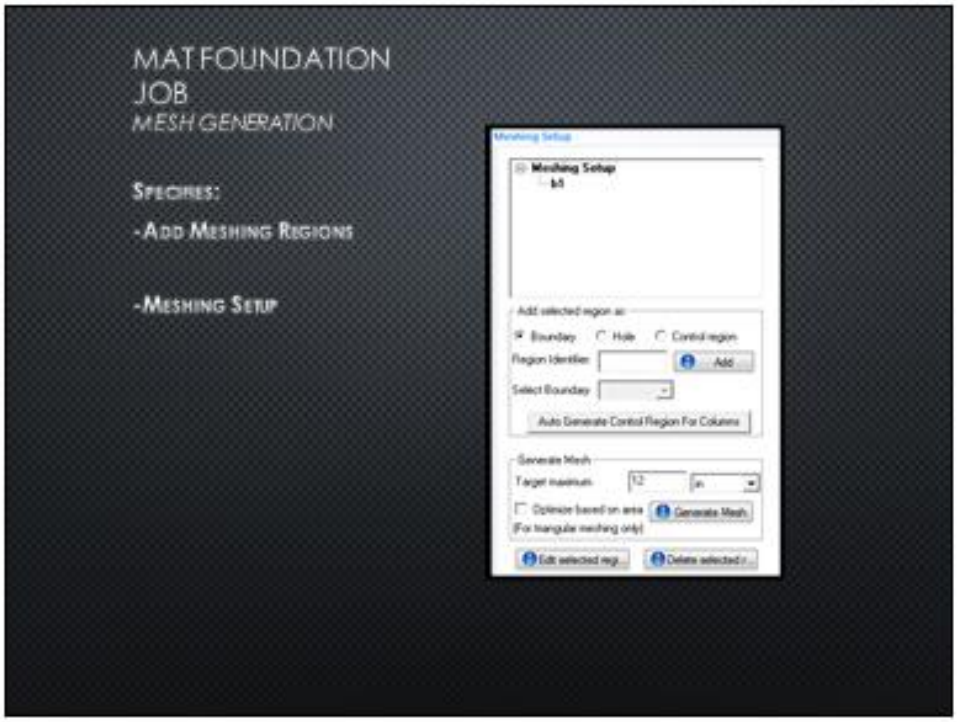

MAT FOUNDATION DESIGN

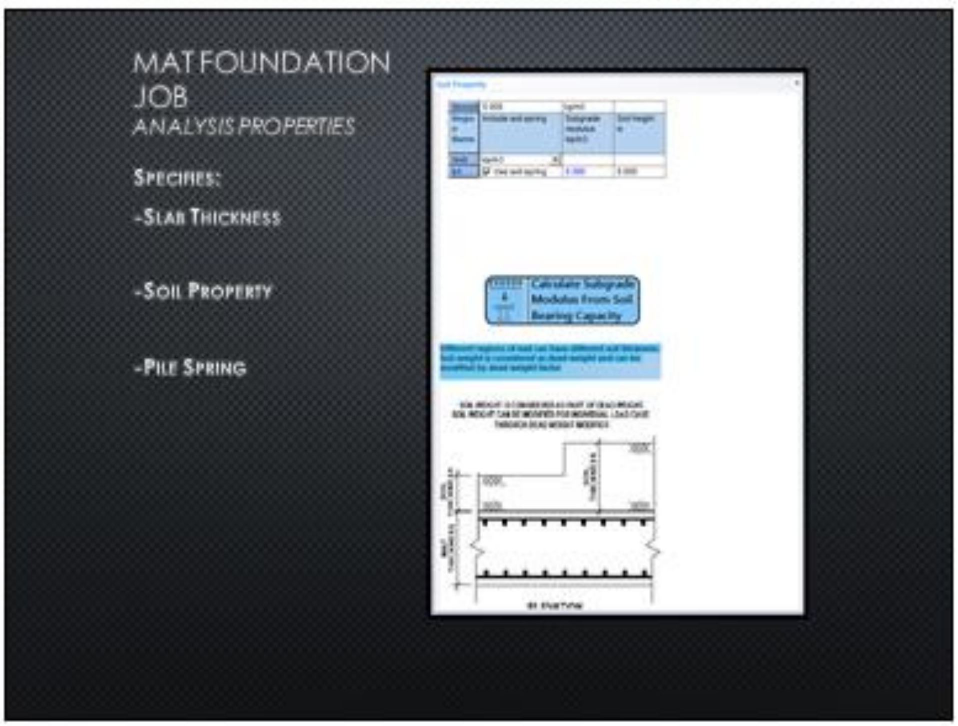

MAT FOUNDATION LOADS

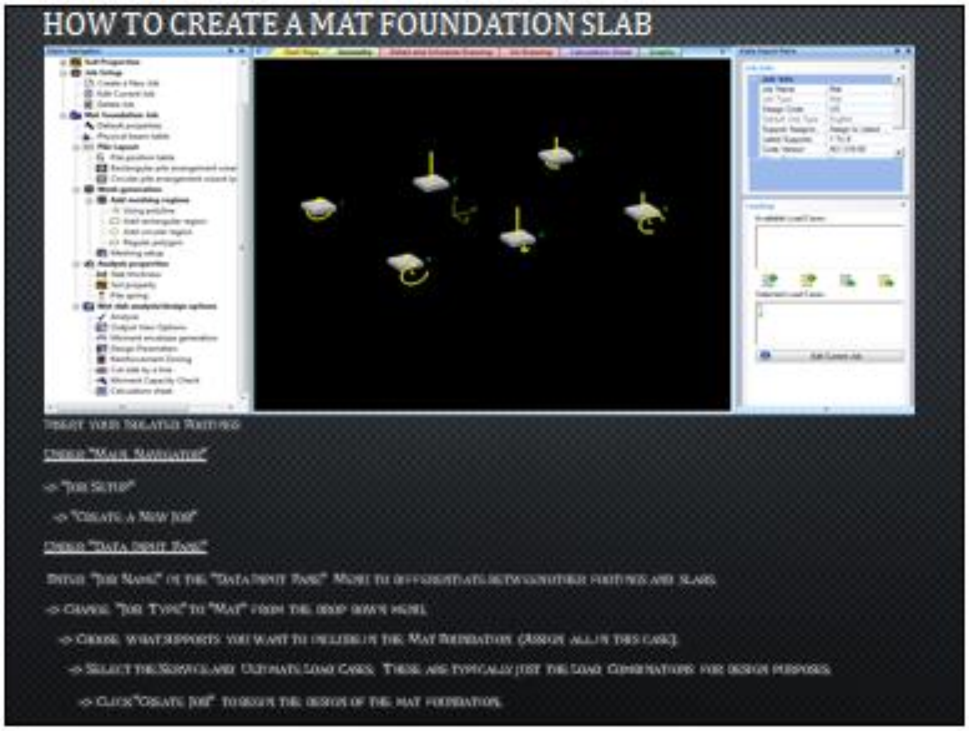

MAT FOUNDATION JOB
DEFAULT PROPERTIES
SPECIFIES:
-SLAB ANALYSIS THICKNESS
-SLAB DESIGN THICKNESS
-SUBGRADE MODULUS
-SOIL PROPERTY
-BEAM SECTIONAL PROPERTY
-PILE SPRING VALUES
Default properties
Slab analysis thickness
Unit
in
Thickness
12.000000
Slab design thickness
Unit
in
Thickness
12.000000
Subgrade modulus
Unit
Subgrade modulus
0.040000
Soil Property
Unit
Soil Density
110.000000
Beam sectional property
Unit
in
Depth
12.000000
Width
12.000000
Pile spring values
Unit
Spring along X (Kx)
30.000000
Spring along Y (Ky)
300.000000

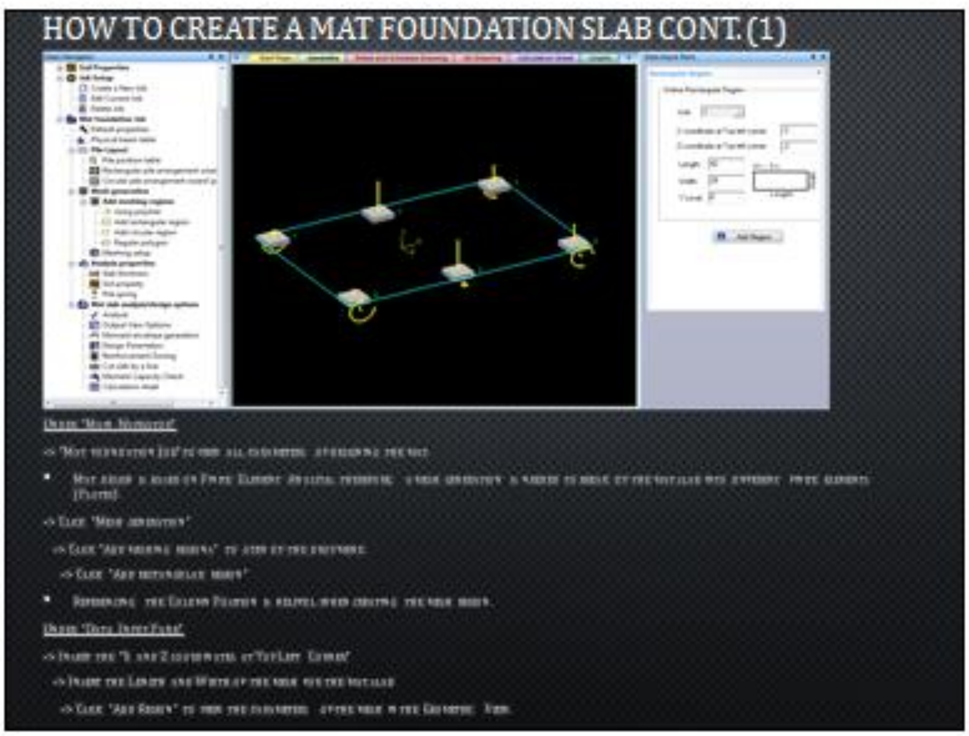

MAT FOUNDATION JOB
PHYSICAL BEAM TABLE
SPECIFIES:
-NUMBER OF BEAMS
-NODE A IN BEAM
-NODE B IN BEAM
-DEPTH OF NODE
-WIDTH OF BEAM


MAT FOUNDATION JOB
PILE LAYOUT
SPECIFIES:
-PILE POSITION TABLE
-RECTANGULAR PILE ARRANGEMENT WIZARD
-CIRCULAR PILE ARRANGEMENT WIZARD
Pile Position
Pile Arrangement Parametric
Unit:
Number of rows:
Number of columns:
Row spacing
column spacing
Row Spacing
Column spacing
Origin X:
Origin Y:
Origin Z:
Apply
Preview

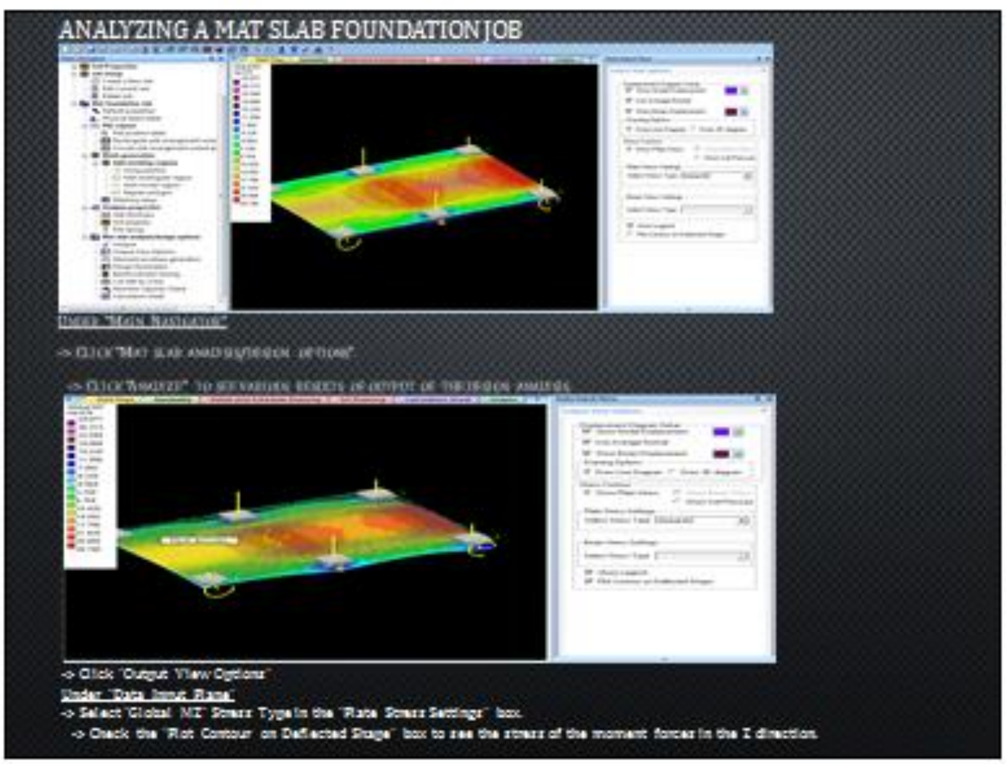

MAT FOUNDATION
JOB
MESH GENERATION
Specifies:
-Add Meshing Regions
-Meshing Setup
Meshing Setup
Add selected region as
Boundary
Hole
Control region
Region Identifier
Add
Select Boundary
Auto Generate Control Region For Columns
Generate Mesh
Target maximum
12
in
Optimize based on area
Generate Mesh
(For triangular meshing only)

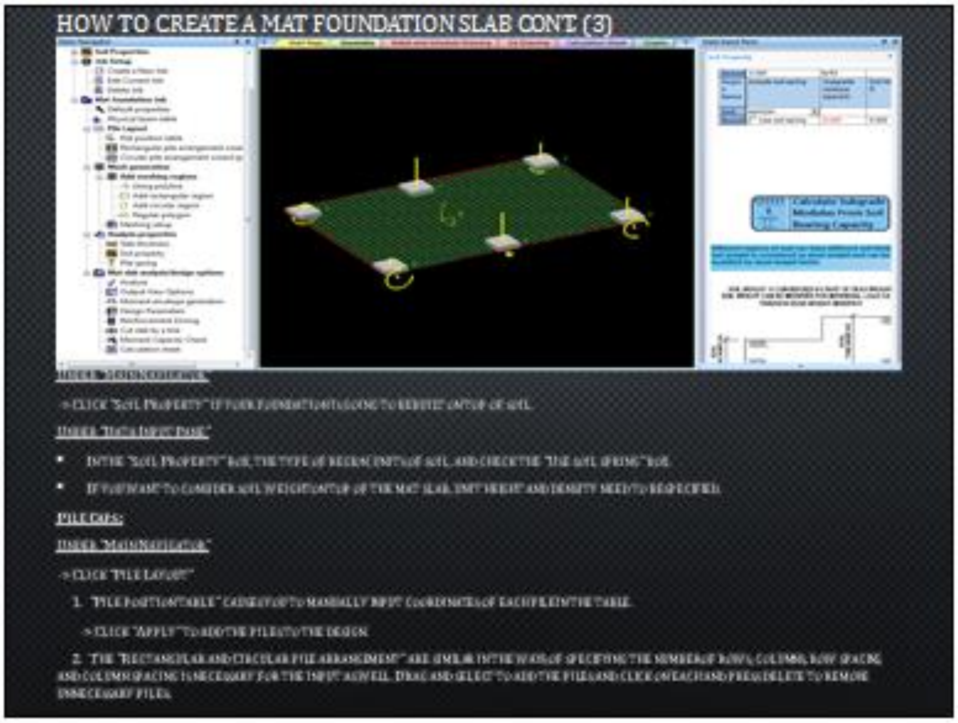

MAT FOUNDATION
JOB
ANALYSIS PROPERTIES
Specifies:
-Slab Thickness
-Soil Property
-Pile Spring
Calculate Subgrade Modulus From Soil Bearing Capacity

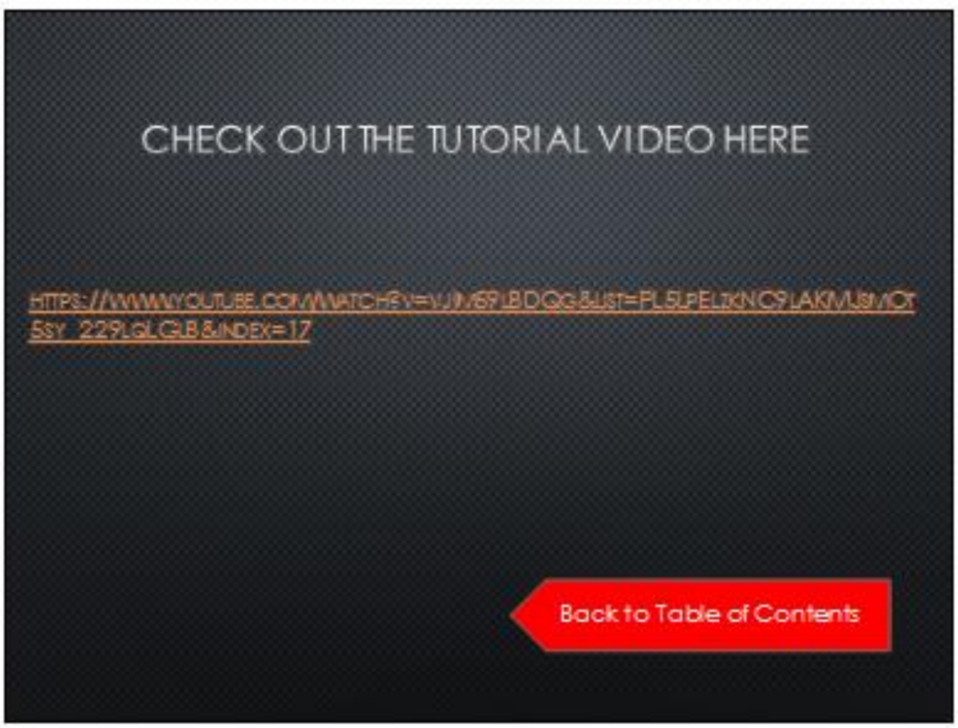

HOW TO CREATE A MAT FOUNDATION SLAB

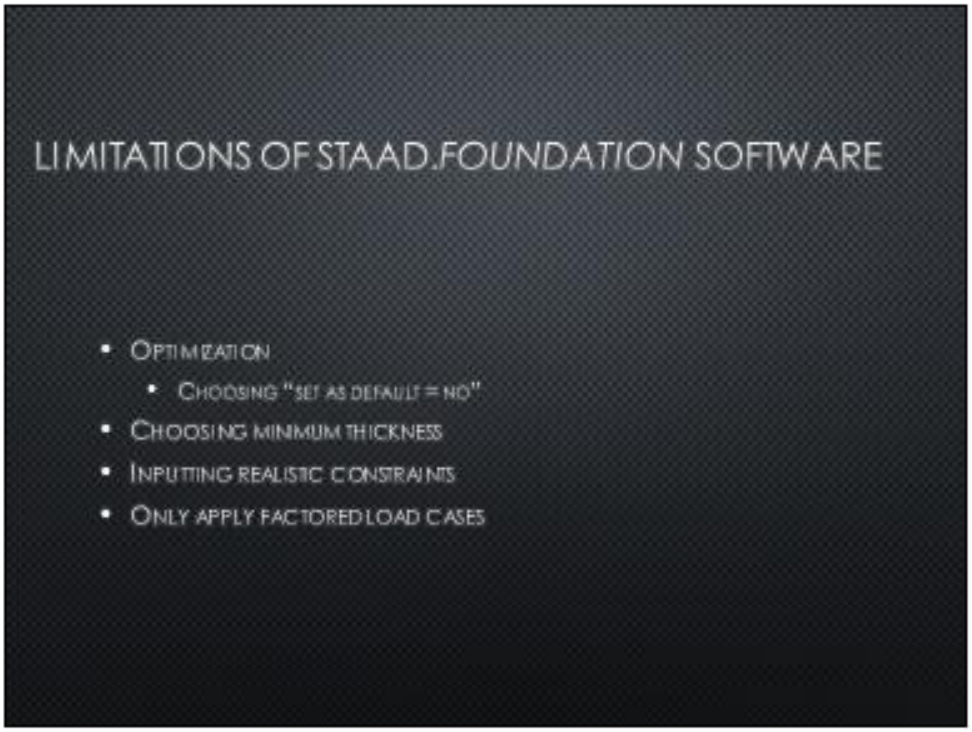

HOW TO CREATE A MAT FOUNDATION SLAB CONT.(1)

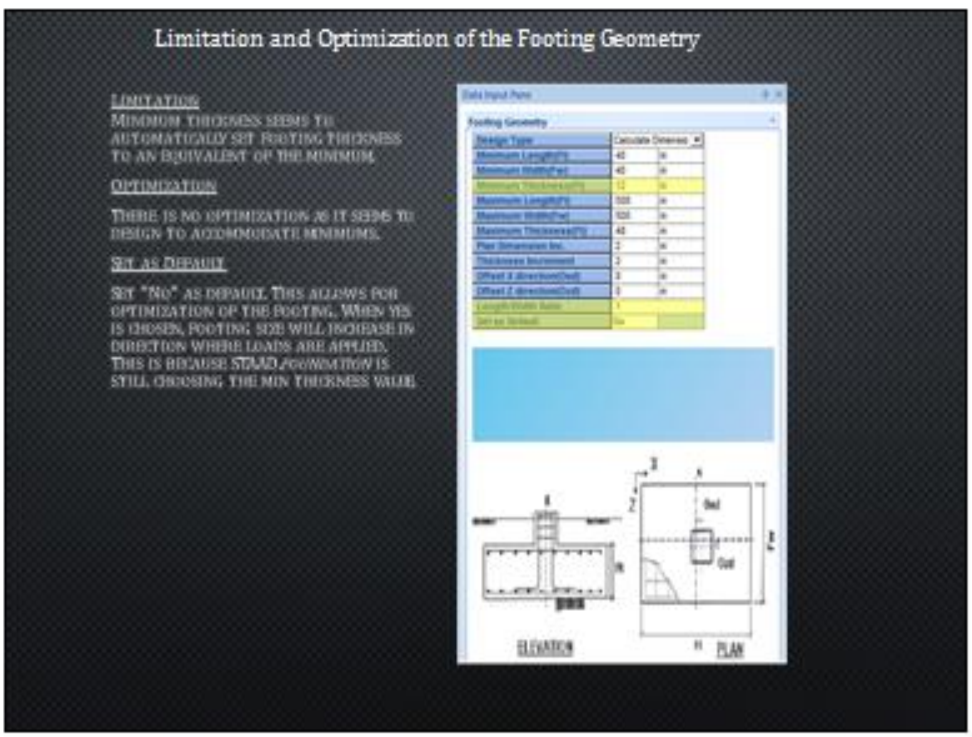

HOW TO CREATE A MAT FOUNDATION SLAB CONT (2)

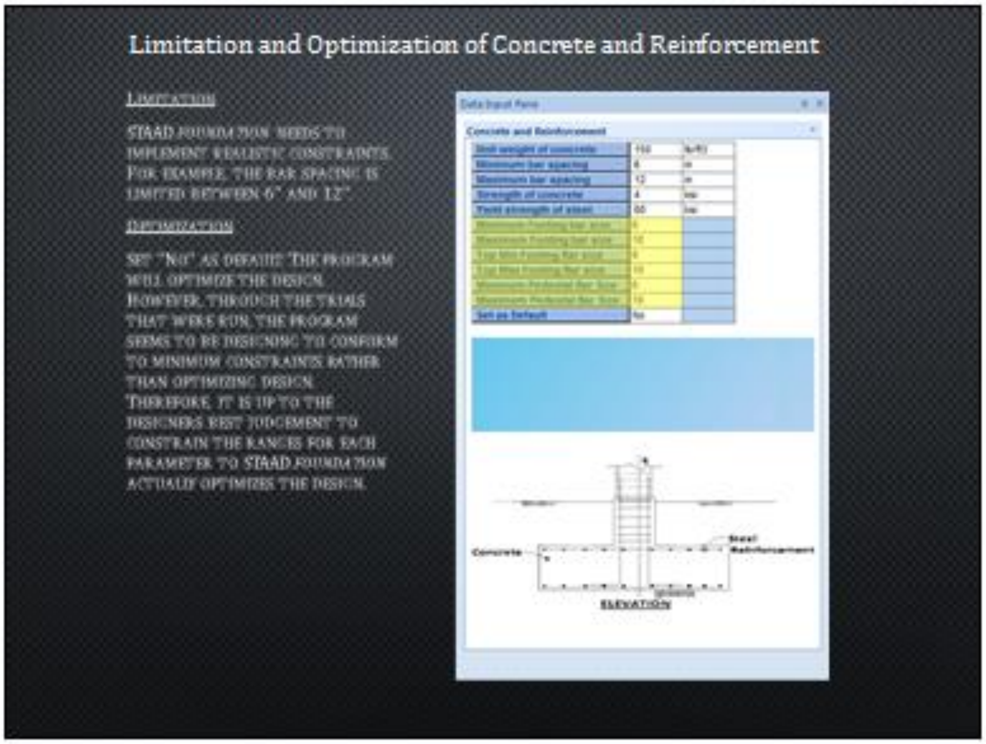

ANALYZING A MAT SLAB FOUNDATION JOB
Under "Main Navigator"
-> Click "Output View Options"
Under "Data Input Pane"
-> Select "Global MZ" Stress Type in the "Plate Stress Settings" box.
-> Check the "Plot Contour on Deflected Shape" box to see the stress of the moment forces in the Z direction.

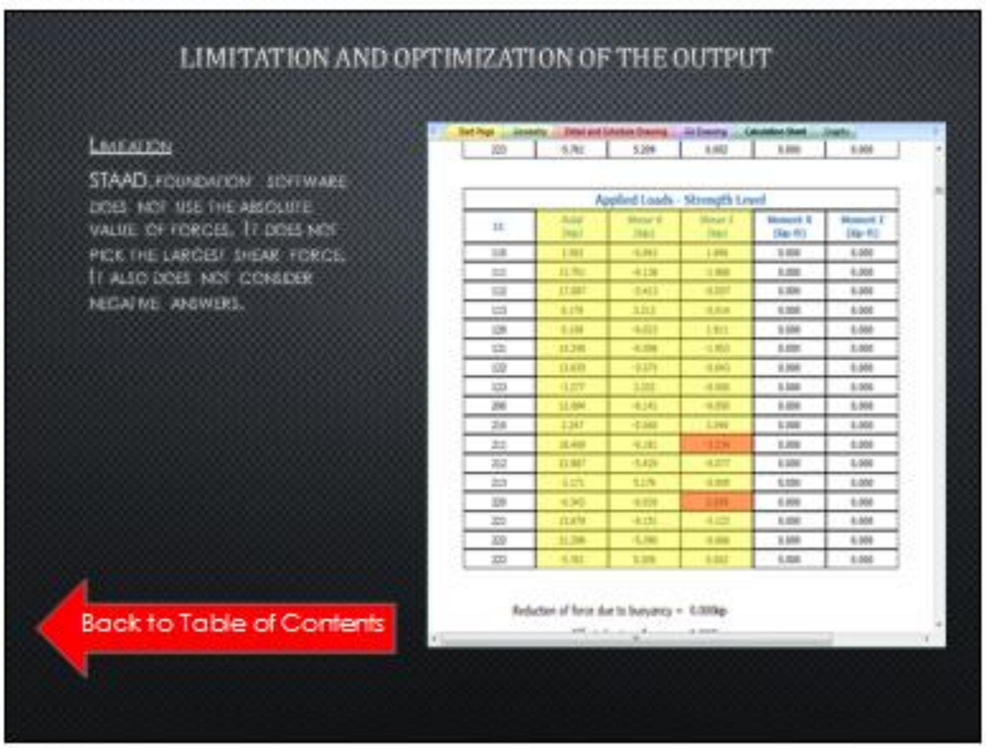

HOW TO CREATE A MAT FOUNDATION SLAB CONT (3)
PILE CAPS:
UNDER "MAIN NAVIGATOR"
->CLICK "PILE LAYOUT"
->CLICK "APPLY" TO ADD THE PILES TO THE DESIGN.


CHECK OUT THE TUTORIAL VIDEO HERE
HTTPS://WWW.YOUTUBE.COM/WATCH?V=VJIM69LBDQG&LIST=PL5LPELZKNC9LAKMUSMCT5SY_229LGLGLB&INDEX=17
Back to Table of Contents

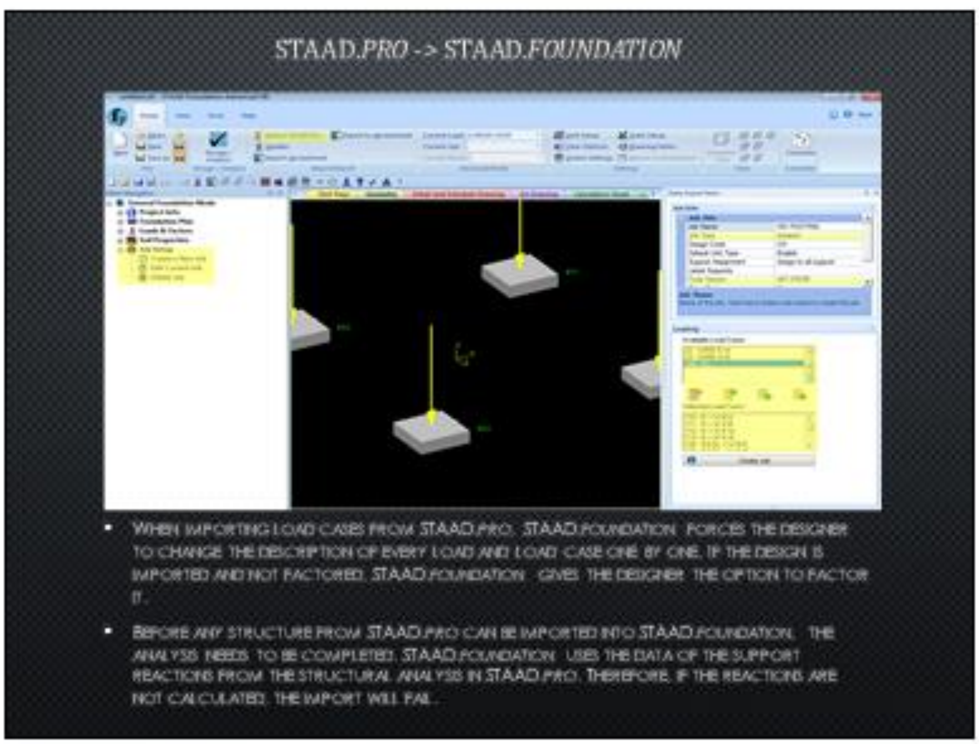

LIMITATIONS OF STAAD.FOUNDATION SOFTWARE
Optimization
Choosing "set as default = no"
Choosing minimum thickness
Inputting realistic constraints
Only apply factored load cases

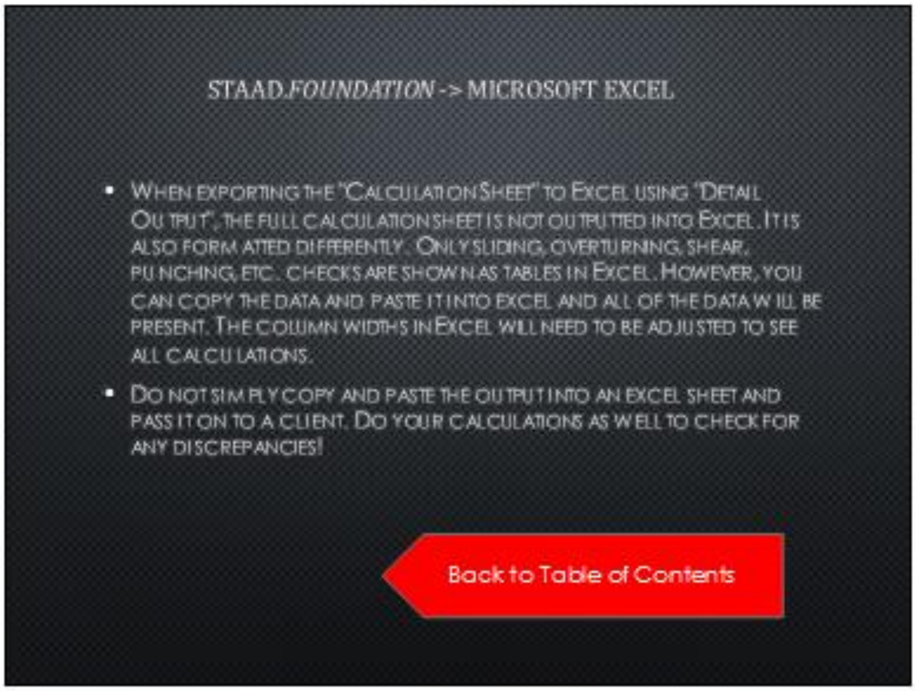

Limitation and Optimization of the Footing Geometry
Limitation
Minimum thickness seems to automatically set footing thickness to an equivalent of the minimum.
Optimization
There is no optimization as it seems to design to accommodate minimums.
Set as Default
Set "No" as default. This allows for optimization of the footing. When yes is chosen, footing size will increase in direction where loads are applied. This is because STAAD.foundation is still choosing the min thickness value.
ELEVATION
PLAN


Limitation and Optimization of Concrete and Reinforcement
LIMITATION
STAAD.FOUNDATION NEEDS TO IMPLEMENT REALISTIC CONSTRAINTS. FOR EXAMPLE, THE BAR SPACING IS LIMITED BETWEEN 6" AND 12".
OPTIMIZATION
SET "NO" AS DEFAULT. THE PROGRAM WILL OPTIMIZE THE DESIGN. HOWEVER, THROUGH THE TRIALS THAT WERE RUN, THE PROGRAM SEEMS TO BE DESIGNING TO CONFIRM TO MINIMUM CONSTRAINTS RATHER THAN OPTIMIZING DESIGN. THEREFORE, IT IS UP TO THE DESIGNERS BEST JUDGEMENT TO CONSTRAIN THE RANGES FOR EACH PARAMETER TO STAAD.FOUNDATION ACTUALLY OPTIMIZES THE DESIGN.
Concrete
ELEVATION

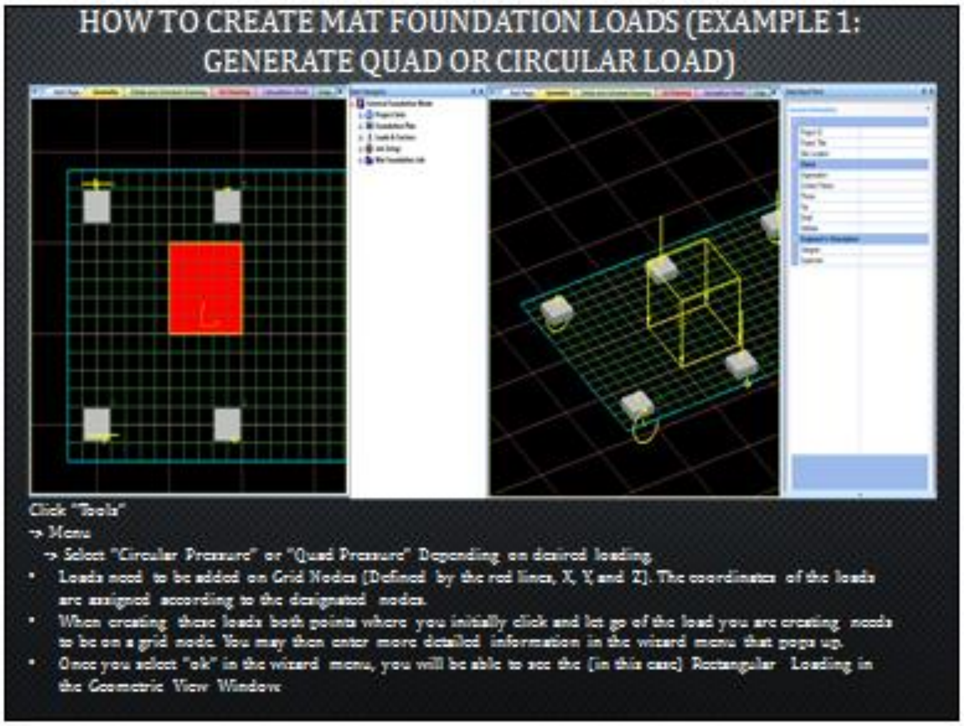

LIMITATION AND OPTIMIZATION OF THE OUTPUT
LIMITATION
STAAD.FOUNDATION SOFTWARE DOES NOT USE THE ABSOLUTE VALUE OF FORCES. IT DOES NOT PICK THE LARGEST SHEAR FORCE. IT ALSO DOES NOT CONSIDER NEGATIVE ANSWERS.
Applied Loads - Strength Level
Back to Table of Contents

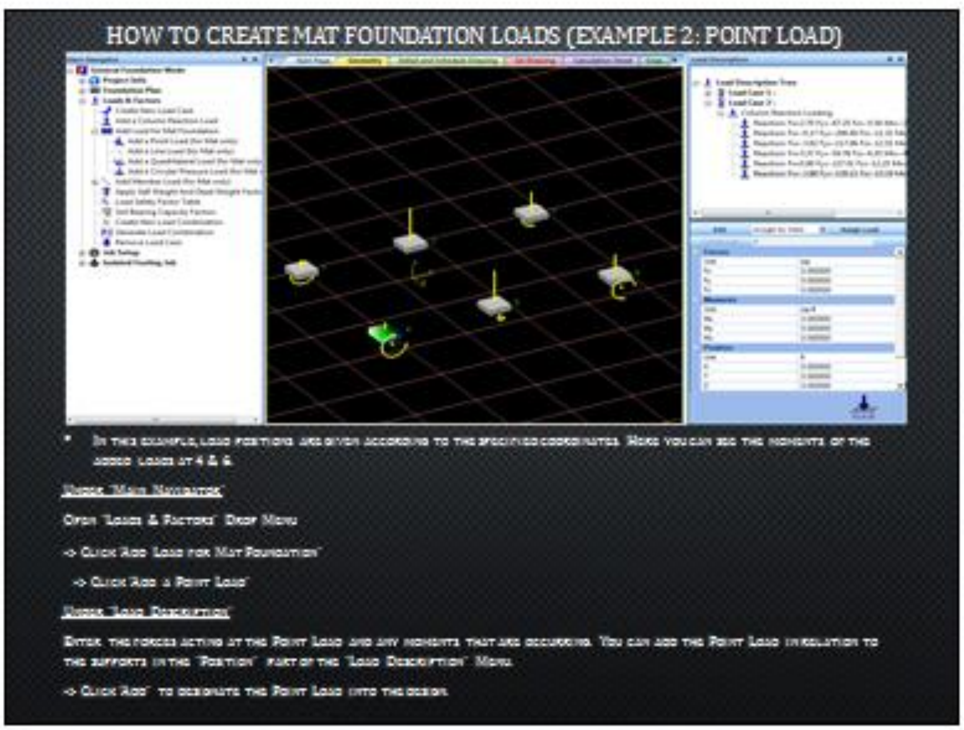

Importing and Exporting
with STAAD.foundation

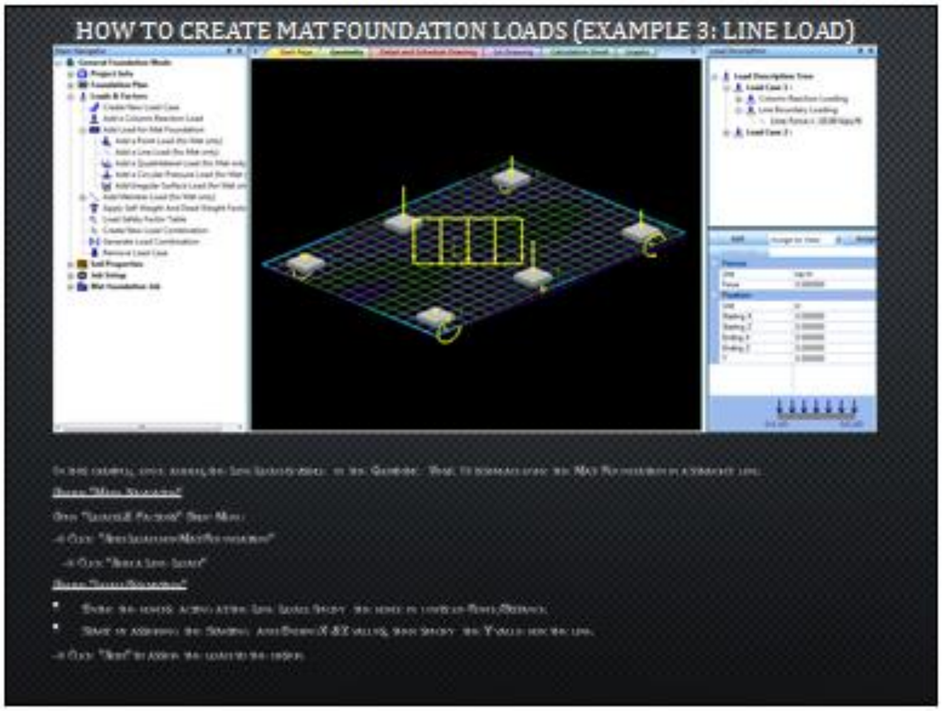

STAAD.PRO -> STAAD.FOUNDATION
When importing load cases from STAAD.Pro, STAAD.foundation forces the designer to change the description of every load and load case one by one. If the design is imported and not factored, STAAD.foundation gives the designer the option to factor it.
Before any structure from STAAD.Pro can be imported into STAAD.foundation, the analysis needs to be completed. STAAD.foundation uses the data of the support reactions from the structural analysis in STAAD.Pro. Therefore, if the reactions are not calculated, the import will fail.

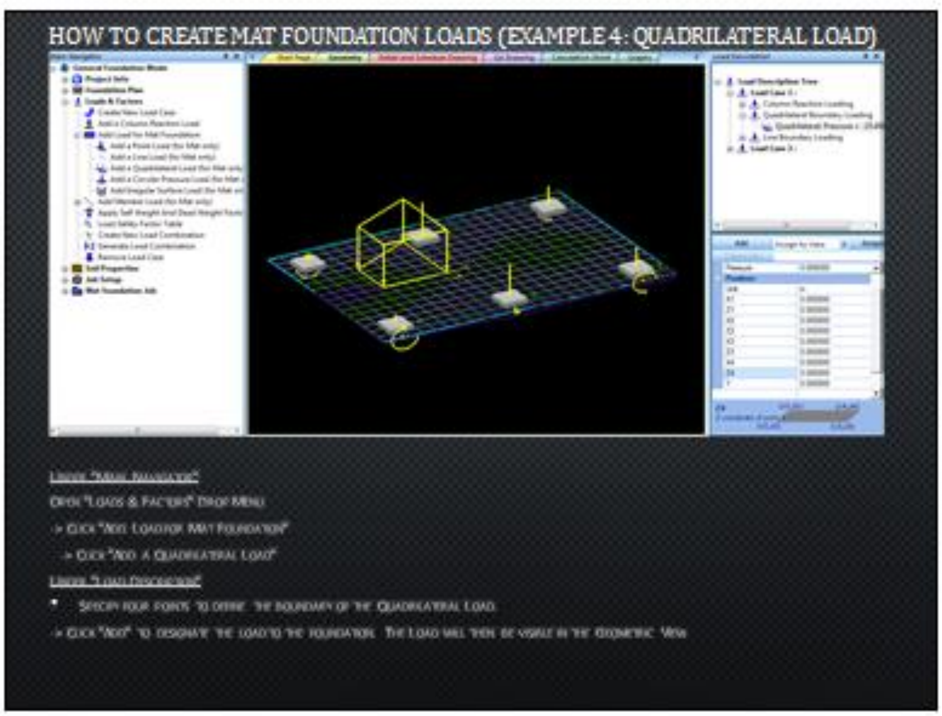

STAAD.FOUNDATION -> MICROSOFT EXCEL
• When exporting the "Calculation Sheet" to Excel using "Detail Output", the full calculation sheet is not outputted into Excel. It is also formatted differently. Only sliding, overturning, shear, punching, etc. checks are shown as tables in Excel. However, you can copy the data and paste it into Excel and all of the data will be present. The column widths in Excel will need to be adjusted to see all calculations.
• Do not simply copy and paste the output into an Excel sheet and pass it on to a client. Do your calculations as well to check for any discrepancies!
Back to Table of Contents

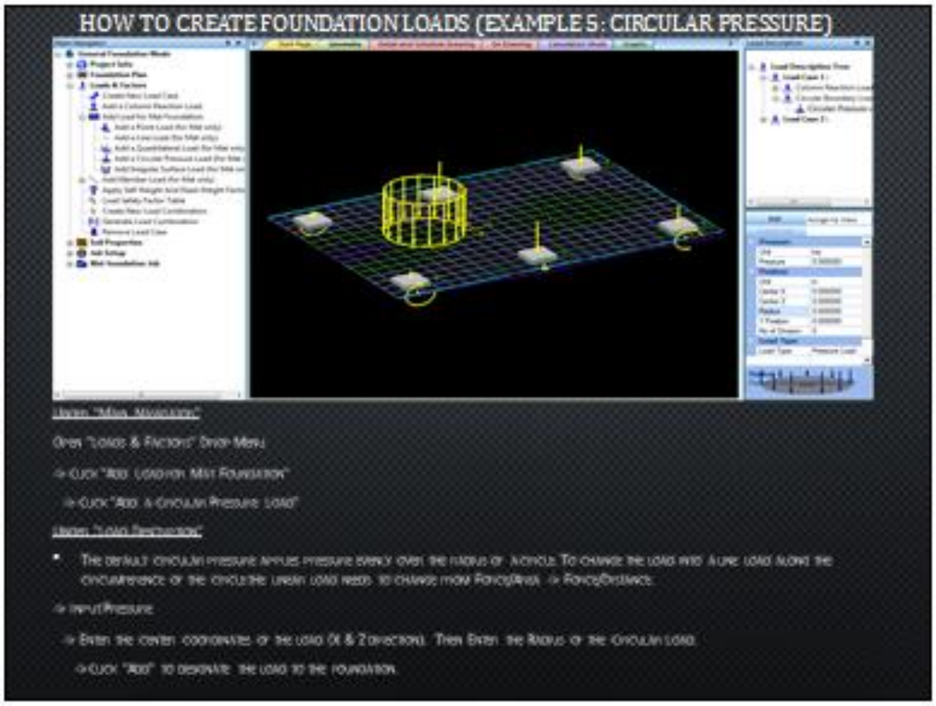

HOW TO STREAMLINE PROGRAM USE
HELPFUL TIPS AND TRICKS

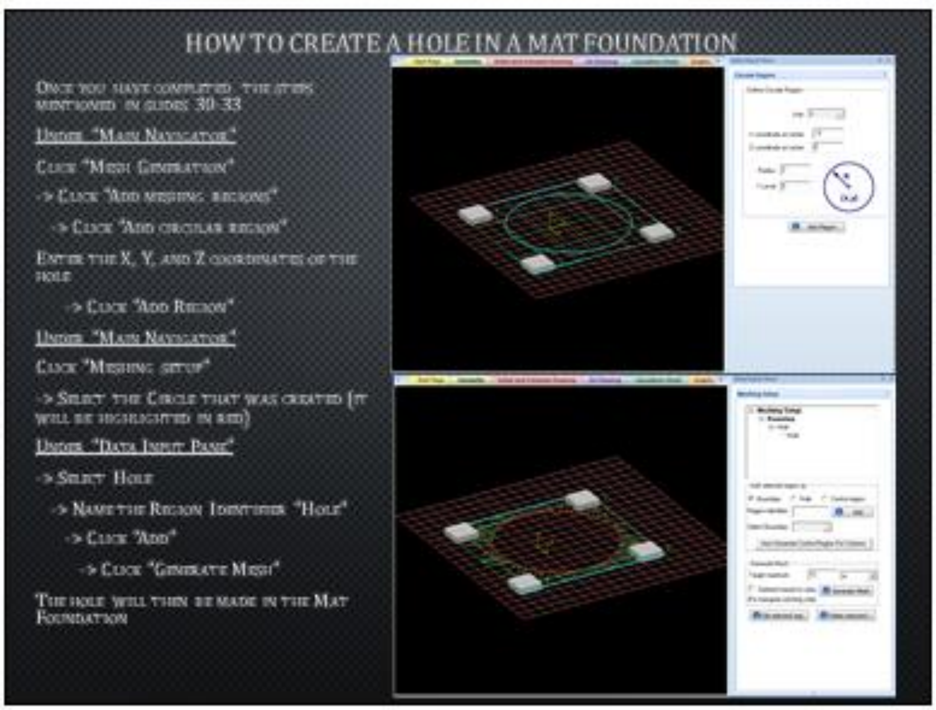

HOW TO CREATE MAT FOUNDATION LOADS (EXAMPLE 1: GENERATE QUAD OR CIRCULAR LOAD)
Click "Tools"
→ Menu
→ Select "Circular Pressure" or "Quad Pressure" Depending on desired loading.
• Loads need to be added on Grid Nodes (Defined by the red lines, X, Y, and Z). The coordinates of the loads are assigned according to the designated nodes.
• When creating these loads both points where you initially click and let go of the load you are creating needs to be on a grid node. You may then enter more detailed information in the wizard menu that pops up.
• Once you select "ok" in the wizard menu, you will be able to see the (in this case) Rectangular Loading in the Geometric View Window

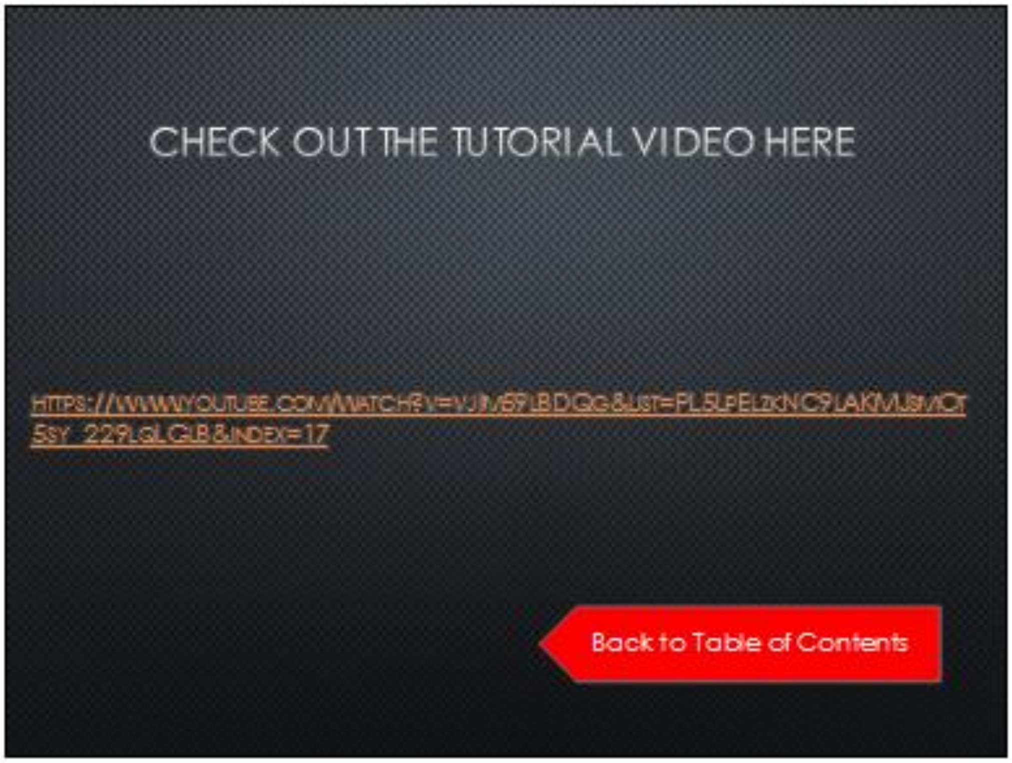

HOW TO CREATE MAT FOUNDATION LOADS (EXAMPLE 2: POINT LOAD)
• In this example, load positions are given according to the specified coordinates. Here you can see the moments of the added loads at 4 & 6.
Under 'Main Navigator'
Open 'Loads & Factors' Drop Menu
-> Click 'Add Load for Mat Foundation'
-> Click 'Add a Point Load'
Under 'Load Description'
Enter the forces acting at the Point Load and any moments that are occurring. You can add the Point Load in relation to the supports in the 'Position' part of the 'Load Description' Menu.
-> Click 'Add' to designate the Point Load into the design.


HOW TO CREATE MAT FOUNDATION LOADS (EXAMPLE 3: LINE LOAD)

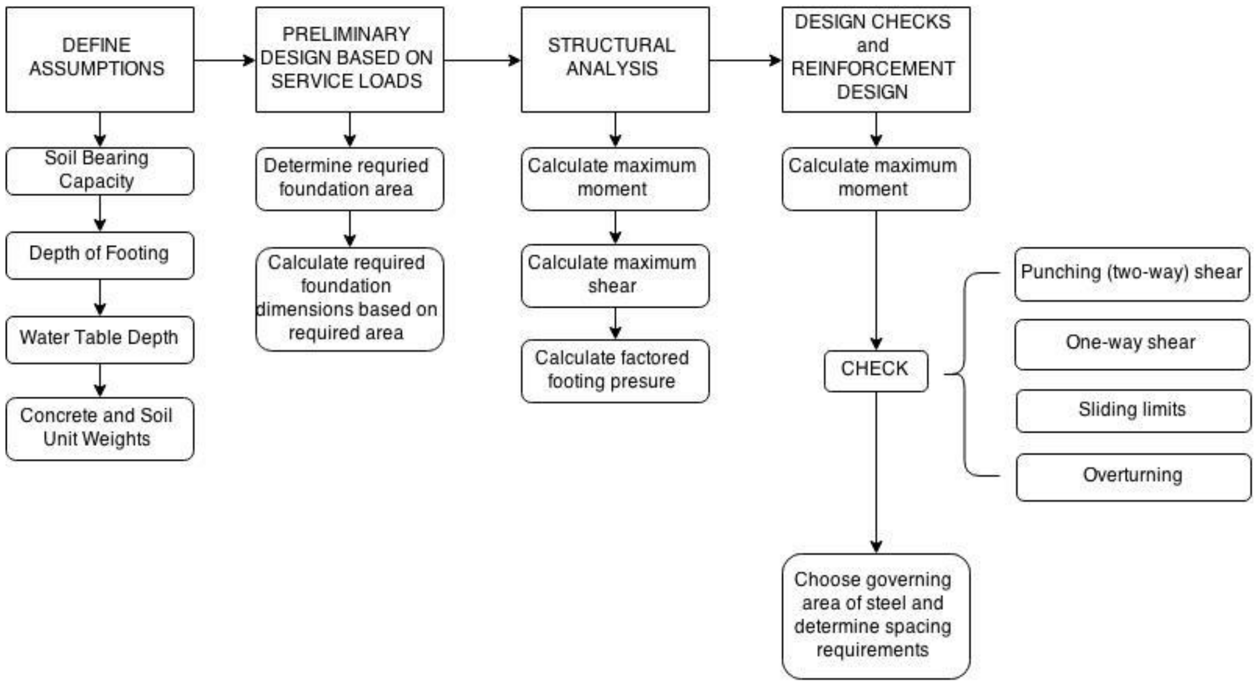

HOW TO CREATE MAT FOUNDATION LOADS (EXAMPLE 4: QUADRILATERAL LOAD)
Open "Loads & Factors" Drop Menu
-> Click "Add Load for Mat Foundation"
-> Click "Add A Quadrilateral Load"
Specify four points to define the boundary of the Quadrilateral Load.
-> Click "Add" to designate the load to the foundation. The Load will then be visible in the Geometric View


HOW TO CREATE FOUNDATION LOADS (EXAMPLE 5: CIRCULAR PRESSURE)
Under "Main Navigator"
Open "Loads & Factors" Drop Menu
-> Click "Add Load for Mat Foundation"
-> Click "Add a Circular Pressure Load"
Under "Load Description"
The default circular pressure applies pressure evenly over the radius of a circle. To change the load into a line load along the circumference of the circle the unit load needs to change from Force/Area -> Force/Distance.
-> Input Pressure
-> Enter the center coordinates of the load (X & Z directions). Then Enter the Radius of the circular load.
-> Click "Add" to designate the load to the foundation.


HOW TO CREATE A HOLE IN A MAT FOUNDATION
Once you have completed the steps mentioned in slides 30-33
Under "Main Navigator"
Click "Mesh Generation"
-> Click "Add meshing regions"
-> Click "Add circular region"
Enter the X, Y, and Z coordinates of the hole
-> Click "Add Region"
Under "Main Navigator"
Click "Meshing setup"
-> Select the Circle that was created (it will be highlighted in red)
Under "Data Input Pane"
-> Select Hole
-> Name the Region Identifier "Hole"
-> Click "Add"
-> Click "Generate Mesh"
The hole will then be made in the Mat Foundation


CHECK OUT THE TUTORIAL VIDEO HERE
HTTPS://WWW.YOUTUBE.COM/WATCH?V=VJIM69LBDQG&LIST=PL5LPELZKNC9LAKMJSMCT5SY_229LGLGLB&INDEX=17
Back to Table of Contents

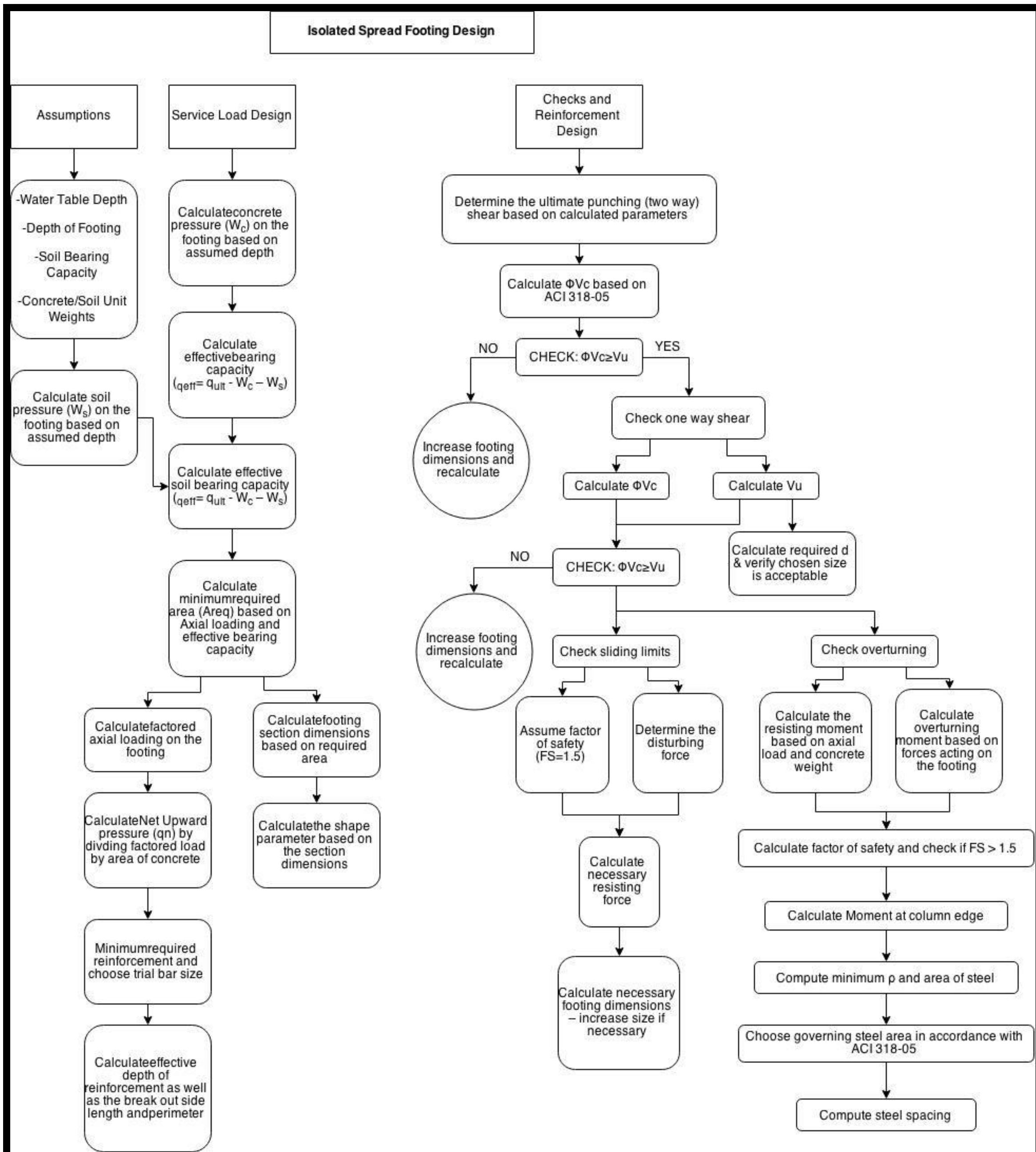
Appendix C.. Design Procedure



Appendix D……………………………………………………………………Isolated Footing Design Verification

Several steps were taken in order to verify the automated calculations run within STAAD.foundation. This process was aided by the use of an excel spreadsheet in order to iterate several designs quickly. The functionality and accuracy of the spreadsheet was verified against hand calculations. When designing these footings, checks against sliding, overturning, and direct and punching shear were considered. Examples of this procedure can be seen below in the following sections.

Isolated Footing Design Procedure



Excel Spreadsheet – Isolated Spread Footing Design

Spread Footing Design

DATE:	2/6/2015	**DESIGN #:**	1
PASS:	**YES**	**CHECK:**	DH

Footing

Length	7 ft
Width	7 ft
Thickness	3 ft
Depth to base	3 ft
Column Spacing	0 ft

Pedestal *PEDESTAL NOT USED*

Height	0 ft
Length	0 ft
Width	0 ft

Reinforcement

Size	# 7
Number	16
Spacing	5 in
Reinforcement	Bottom Reinforcement Only

Spread Footing Design

DATE:	2/6/2015	DESIGN #:	1
PASS:	YES	CHECK:	DH

CHECKS:

1.0 Load & Sizing

NODE: 642

Check 1:	OKAY!
Check 2:	OKAY!
Check 3:	OKAY!

1.1 Shear

Check 1:	OKAY!
Check 2:	OKAY!

1.2 Overturning

Check 1:	OKAY!

1.3 Sliding

Check 1:	OKAY!

		Spread Footing Design			
DATE:	2/6/2015			**DESIGN #:**	1
PASS:	**YES**			**CHECK:**	DH

Data

1.0 Loads

Axial Load	23.887	kip	Downward Loading
Factored	28.6644		Downward Loading LRFD

1.1 Material Properties

f'c	4000	psi	Concrete Compressive Strength
f_y	60	ksi	Steel Yield Strength
λ	1		Normal Weight Concrete
Wc	150	pcf	Density of Concrete
γ	120	pcf	Unit Weight of Soil
μ	0.5		Coefficient of Friction

1.2 Allowable Soil-Bearing Pressure

q_{all}	4000	psf	Allowable Soil Pressure
q_{eff}	3550		Effective Soil Pressure

1.3 Type of Footing

h	3	ft	Depth to base of Footing
Type	Shallow		Shallow or Deep Footing

Footing Dimensions

2.0 Determine Control Footing Area*

Area 1	7	ft^2	
$Length_{Area1}$	2.6	ft	Minimum length of side Req'd from Area1
Length Reqd	6.813		Largest Req'd Length from Checks
Length Side 1	7	ft	
Length Side 2	7	ft^2	
Area Used	49	ft^2	

Thickness of Footing & Pedestal - Uplift Check

3.0 Initial Data

t_{min}		ft	Minimum thickness Hand Calced
t	3	ft	Selected thickness
D_{bew}	0	ft	Depth below water to top footing

γ_w	62.4	pcf	Unit weight of Water
FS_{up}	1.1		Factor of Safety for Uplift
u	187.2	lbs	Uplift Pressure
P_{up}	9.17	ksf	Uplift force
FP_{up}	11.01		Factored Uplift Force (1.2DL) LRFD
h_{soil}	0	ft	

3.1 Pedestal Size (Assumed-Can equal zero unless underground)

B_{tp}		ft	Transverse Width of Pedestal
B_{lp}		ft	Longtitudinal Width of Pedestal
h_{ped}		ft	Height of Pedestal
W_{soil}	0	kips	Weight of soil above footing

Rebar

4.0 Material

ϕ_t =	0.9		Strength Reduction Factor in Tension
MinShrink	0.0018	x b x h	Min. Shrinkage & Temp. Reinf.

4.1 Loads

qn	0.5850		
M_u =	19.47	ft - kips / b_w	Applied Moment

4.2 Reinforcing

	Layers	Bottom Reinforcement Only		
	Cover	3	in	Clear Cover - All Sides
	Width	12	in	
	As_1	8.650	in^2	Area of Steel 1
	As_2	9.1175	in^2	Area of Steel 2
	Ru	0.003	ksi	
	w	5.14E-05		
	ρ	0.000003		
	As_3	0.010	in^2	Area of Steel 3
	As_{min}	9.1175	in^2	Minimum Area of Steel
	Size	# 7		Size of Steel Reinforcing
	n	15.196		Number of Bars used to achieve Asmin
	n_{used}	16		Number of Bars used
	S_{max}	5.2	in	Maximum Allowable Spacing
Check	Spacing	5	in	
	Check:	OKAY!		Spacing<Smax

4.3 Rebar Provided

d =	32.56	in
As / b_w =	1.44	in^2

4.4 Moment Design

a =	2.12	in
ΦMn =	204.14	ft - kips / b_w
	CHECK:	Moment Design Acceptable

4.5 Minimum Reinforcement Requirements

Reinf **Yes** Reinf. Prov'd 1/3 Greater than Req'd

$A_{s\ t\&s}$	0.78	in^2	Temp. & Shrinkage Steel
$A_{s\ flex}$		in^2	Flexural
$As / b_{w\ prov'd}$	1.44	in^2	
$As / b_{w\ req'd}$	0.78	in^2	

		Spread Footing Shear Check			
DATE:	2/6/2015			**DESIGN #:**	1
PASS:	**YES**			**CHECK:**	DH

Data Input

1.0 Loading

Col_{wt}	0.15	kips	Column Weight
P_{uShear}	28.8444	kips	Factored Loads (LRFD)
Net_{Up}	0.589	ksf	Net Upward Pressure

1.1 Reinforcement

Size	0.875	in	Bar Size
Cover	3.00	in	Cover Depth
d	32.56	in	Reinforcement Depth

1.2 Critical Section

Cs	10	in	Column Side
c_s+d	42.5625	in	Critical Section
c_s+d	3.547	ft	Critical Section
b_0	170.25	in	

Shear

2.0 Shear & Footing Thickness

β	1		Shape Parameter
Vu	21.44	kips	
Φ	0.85		
αs	40		Select Column Location
d_1	0.390	inch	Acceptable depth from 2 Way Shear
d_2	0.306	inch	Acceptable depth from 2 Way Shear
d_3	0.586	inch	Acceptable depth from 2 Way Shear

CHECK **CHECK:** **OKAY!**

2.1 One Way Shear

d_4	0.370	ft	Acceptable Depth from 1 Way Shear
V_{u1}	1.5	kips	
d_{OneWay}	0.169	inch	

CHECK **CHECK:** **OKAY!**

2.2 Bending Moment

B_{MEdge}	3.083	ft
M_{uBend}	19.6	k-ft

Spread Footing Overturning Check

DATE:	2/6/2015		**DESIGN #:**	1
PASS:	**YES**		**CHECK:**	DH

Overturning

1.0 Initial Conditions

V_z	3.134	kip	Governing Load Case
μ	0.5		
$Load_{Total}$	45.937	kip	
$FS_{Overturning}$	1.5		

1.1 Overturning Calculations

M_x	9.402	k-ft	Governing Moment
M_r	160.780	k-ft	Resisting Moment
Mr/Mx	17.101		
Check:	**OKAY!**		

Spread Footing Sliding Check

DATE:	2/6/2015		DESIGN #:	1
PASS:	YES		CHECK:	DH

DATA INPUT

1.0 Forces

DF_{shear}	5.42	kips	Disturbing Force (x-shear)
$FS_{sliding}$	1.5		Factor of Safety - Sliding
$Axial_{sliding}$	23.887	kips	Axial Downward Force
μ	0.5		Coefficient of Friction
Wc	0.15	kips	Self Weight

1.1 Sliding Calculations

	Fs_{force}	8.13	kips	
	$b^2_{sliding}$	46.416		Area of footing - Minimum
	$bmin_{sliding}$	6.813		
CHECK	$b_{sliding}$	7		Selected length of footing

CHECK: **OKAY!**

Reinforcement Reference

ASTM STANDARD REINFORCING BARS			
SIZE #	Nominal Dia. (in)	Nominal Area (in^2)	Nominal Weight (lb/ft)
# 3	0.375	0.11	0.376
# 4	0.5	0.2	0.668
# 5	0.625	0.31	1.043
# 6	0.75	0.44	1.502
# 7	0.875	0.6	2.044
# 8	1	0.79	2.67
# 9	1.278	1	3.4
# 10	1.27	1.27	4.303
# 11	1.41	1.56	5.313
# 14	1.693	2.25	7.65
# 18	2.257	4	13.6

N/A

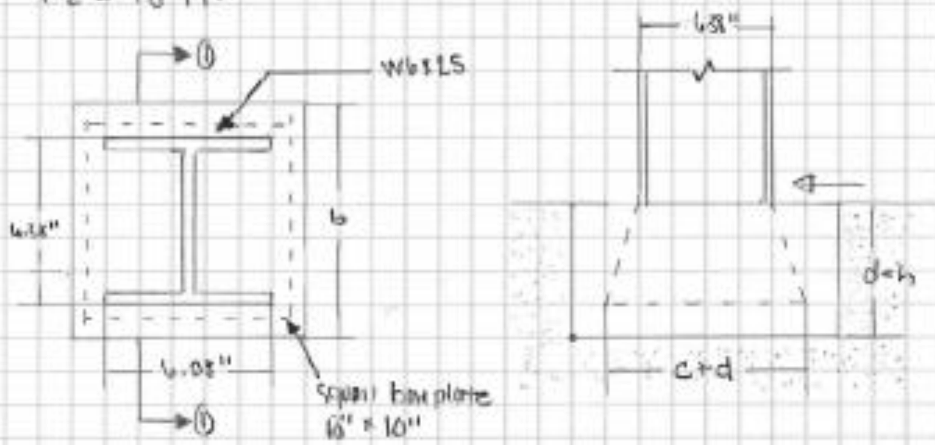
Top & Bottom Reinforcement	T & B	2
Bottom Reinforcement Only	Bott.	1

Hand Calculations – Isolated Spread Footing

Stantec

ISOLATED FOOTING DESIGN: #642
→ ASSUME SQUARE FOOTING
→ GOVERNING LOAD CASE 212: 1.2DL + 1.6W (E-W)

$F_x = 5.420$ k   Column weight = 25 lb/ft (6 ft) = 150 lb
$F_y = 23.867$ k
$F_z = .077$ k



ASSUME → FOOTING DEPTH = 3'
→ TOP OF FOOTING @ GROUND LEVEL
→ SOIL BEARING CAPACITY, $q_{ult} = 4$ ksf
→ 150 lb/ft³ concrete
→ 6" from steel column to edge of footing

$$W_c = 150 \frac{lb}{ft^3}(36\,in)\left(\frac{1\,ft}{12\,in}\right)\left(\frac{1\,k}{1000\,lb}\right) = .45\ k/ft^2$$

$$q_{eff} = q_{ult} - W_c = 4 - .45 = 3.55\ k/ft^2$$

$$A_{min} = (10 + 6)(10 + 6) = 256\ in^2 = 1.78\ ft^2$$

MQP FOUNDATION DESIGN – ISOLATED FOOTING
STAAD.FDN REFERENCE: FOOTING #642
Designed by: DJH   Checked by:

Stantec

$A_{req} = \frac{P_{axial}}{q_{eff}} = \frac{23.887}{3.55} = 6.73\ ft^2 \rightarrow$ governs

$b = \sqrt{6.73} = 2.60\ ft \rightarrow$ round up to 3', for breakout perimeter > 4'

NET UPWARD PRESSURE: (b = 7' due to sliding)

FACTORED LOAD: $1.2DL = 1.2(23.887 + .150) = 28.84^k$

$q_n = \frac{DL}{A_c} = \frac{28.84^k}{(7^2)} = .589\ k/ft^2$

MINIMUM REINFORCEMENT

$A_g = (7 \times 7)(144) = 7056\ in^2$

$A_{se\,min} = .005A_g = 35.28\ in^2$

$A_{s\,min} = \rho bh = .0018\ bh = .0018(84)(36) = 5.4\ in^2$ (shrinkage)

∴ try 9 #7, $d_b = .875"$, $a = .6\ in^2$

DEPTH OF REINFORCEMENT (

$d = h - cover - .5d_b = 36 - 3 - .5(.875) = 32.56"$

breakout perimeter: $c + d = 32.56 + 10 = 42.56$

side length: $b_o = 4(c+d) = 170.24"$

TWO WAY SHEAR

$V_u = P_u - q_n(c+d)^2$

$= 28.84 - .589(42.56/12)^2 = 21.41^k$

$\beta_c = 1$, square column

Designed by: Checked by:

Stantec

ACI 318-05 Ch. 10.5.1

$$A_{s\,min} = \frac{3\sqrt{f'c}\,b_w d}{f_y} = \frac{3\sqrt{4000}}{60000}(84)(32.56) = 8.65\ in^2$$

$A_s = 5.4\ in^2$

$$A_{s\,min} = \frac{200 b_w d}{f_y} = \frac{200(84)(32.56)}{60{,}000} = 9.11\ in^2 \Rightarrow \text{governs}$$

$\therefore 5\#10$

$$\rho_b = .85\left[\frac{87{,}000\,\beta_1 f'c}{f_y(87000 + f_y)}\right] = .85\left[\frac{87000(.85)(4000)}{60000(87000+60000)}\right] = .0285$$

$\rho max = .75\rho_b = .2138$

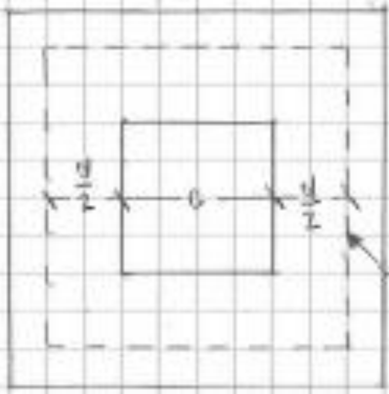
$\rho min = .0018 > \rho calc \Rightarrow$ governs

$$S = \frac{L - 2(cover)}{(n-1)} = \frac{84 - 6}{4} = 5.57 \Rightarrow 19'' \text{ spacing}$$

Designed by: Checked by:

Stantec

TWO WAY SHEAR:



* from previous pages:

$c = 10''$

$d = 32.56''$

$c + d = 42.56''$

$b_o = 4(c+d) = 170.24''$

breakout perimeter

$V_u = 21.41^K$

$$\phi V_c = \left[2 + \frac{4}{1}\right]\sqrt{4000}\,(.85)(170.24)(32.56) = \qquad > V_u \checkmark$$

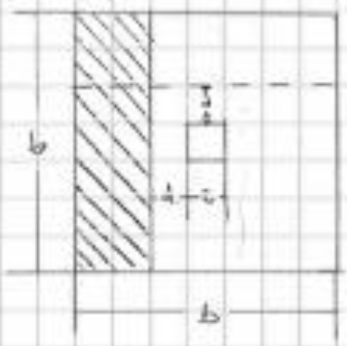
$$\phi V_c = \left[\frac{(32.56)}{170.24} + 2\right]\sqrt{4000}\,(170.24)(32.56)(.85) = \qquad > V_u \checkmark$$

$$\phi V_c = 4\sqrt{4000}\,(170.24)(32.56)(.85) = \qquad > V_u \checkmark$$

Designed by: Checked by:

Stantec

ONE WAY SHEAR:



$$\left[\frac{b}{2} - \frac{c}{2} - d\right] = \left[\frac{84}{2} - \frac{10}{2} - 32.56\right] = 4.44''$$

$$V_u = q_n(b)\left[\frac{b}{2} - \frac{c}{2} - d\right] = .589(7)(4.44) = 1.526^K$$

$$d = \frac{V_u}{\phi 2\sqrt{f'c}\, b} = \frac{1526.16}{.75(2)\sqrt{4000}\,(72)} = .15$$

Since square footing & square baseplate → Transverse = Longitudinal

$$\phi V_c = .75(2)\sqrt{f'c}\, b d$$
$$= .75(2)(4000)(84)(32.56) = 259.47^K > V_u \checkmark$$

Designed by: Checked by:

Stantec

Overturning

governing moment: (220) $M_x = h_t(V_x) = 3(3.059) = 9.177$ k-ft

resisting moment: $M_r = (.M)(W_c)b$

$= .5[(.150(7^2)(3)) + 28.66](7)$

$=$ k-ft

$$\frac{M_r}{M_x} = \frac{75.9745}{9.177} = 8.28 > 1.5 ✓$$

Moment @ column edge

$$\left[\frac{L-c}{2}\right] = \frac{7-(10/12)}{2} = 3.083' \qquad q_n = .589$$

$$M_u = q_n(3.083)\left(\frac{3.083}{2}\right)b = .589(3.083)\left(\frac{3.083}{2}\right)7$$

$M_u = 19.59$ k-ft

$$R_u = \frac{M_u}{bd^2} = \frac{19.59(12)}{(84)(32.56)^2} = .0026 \text{ ksi}$$

$$\omega = \frac{1.7 - \sqrt{(1.7^2) - 4\left[1.7\left(\frac{R_u}{\Phi f_y}\right)\right]}}{2} = \frac{1.7 - \sqrt{1.7^2 - 4\left(1.7\left(\frac{.0026}{.9(60)}\right)\right)}}{2}$$

$$\omega = .000048 = \rho\frac{f_y}{f_c}$$

$$\rho = \frac{.000048(4)}{60} = .000003$$

$A_s = .000003(36)(84) = .009707$

Flexure $A_s = (200/f_y)bd = (200/60000)84(32.56) = 9.11$

Designed by: Checked by:

Stantec

SLIDING

Disturbing force (x-shear): 5.209^k

Factor of safety = 1.5

Resisting force ≥ 1.5(5.209) = 7.8135^k

$F = \left[.150 \frac{kip}{ft^3}(3b^2) + f_y\right]\mu$ ← coefficient of friction

(.150 kip/ft³ term ↑ self weight; f_y ↑ axial downward)

$7.835 = .5(.150)(3b^2) - .5(5.761)$

$\therefore b^2 = 47.5$

$b = 6.89 \rightarrow 7'$

Designed by: Checked by:

STAAD.foundation Output for Isolated Footings

Below illustrates and example of a calculation sheet that is produced through the automated design process within STAAD.foundation.

Isolated Footing Design(ACI 318-05)

Design For Isolated Footing 642

Design For Isolated Footing 643

Design For Isolated Footing 671

Design For Isolated Footing 672

Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
642	1	8.500ft	8.500ft	2.000ft

Footing No.	Footing Reinforcement				Pedestal Reinforcement	
-	Bottom Reinforcement(M_z)	Bottom Reinforcement(M_x)	Top Reinforcement(M_z)	Top Reinforcement(M_x)	Main Steel	Trans Steel
642	11 - #6	11 - #6	10 - #6	10 - #6	N/A	N/A

Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
643	2	8.500ft	8.500ft	2.000ft

Footing No.	Footing Reinforcement				Pedestal Reinforcement	
-	Bottom Reinforcement(M_z)	Bottom Reinforcement(M_x)	Top Reinforcement(M_z)	Top Reinforcement(M_x)	Main Steel	Trans Steel
643	11 - #6	11 - #6	10 - #6	10 - #6	N/A	N/A

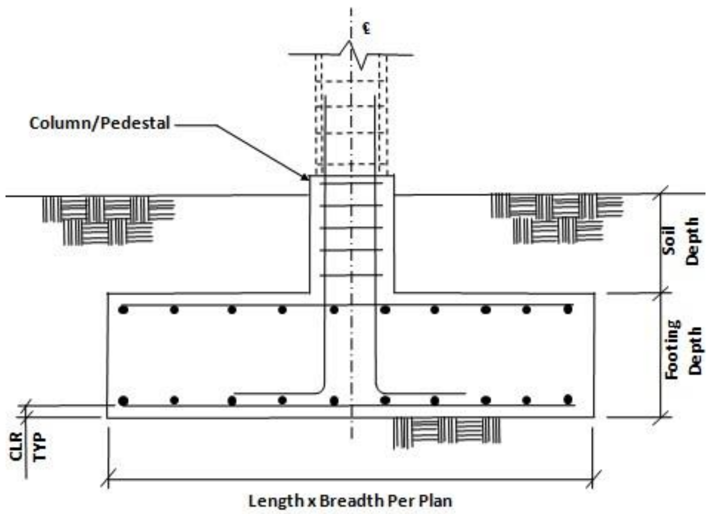
Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
671	3	8.500ft	8.500ft	2.000ft

Footing No.	Footing Reinforcement				Pedestal Reinforcement	
-	Bottom Reinforcement(M_z)	Bottom Reinforcement(M_x)	Top Reinforcement(M_z)	Top Reinforcement(M_x)	Main Steel	Trans Steel
671	11 - #6	11 - #6	10 - #6	10 - #6	N/A	N/A

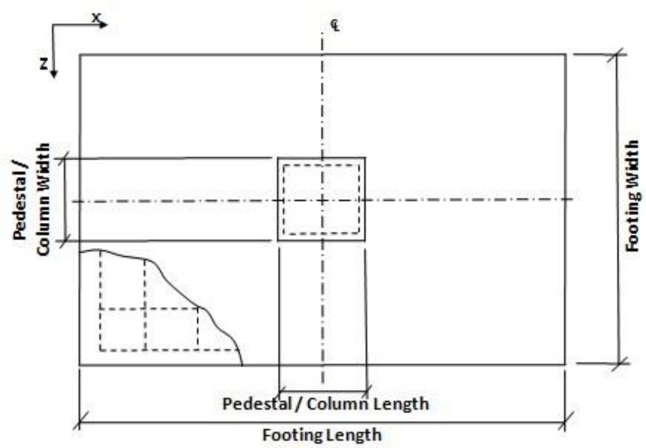
Footing No.	Group ID	Foundation Geometry		
-	-	Length	Width	Thickness
672	4	8.500ft	8.500ft	2.000ft

Footing No.	Footing Reinforcement				Pedestal Reinforcement	
-	Bottom Reinforcement(M_z)	Bottom Reinforcement(M_x)	Top Reinforcement(M_z)	Top Reinforcement(M_x)	Main Steel	Trans Steel
672	11 - #6	11 - #6	10 - #6	10 - #6	N/A	N/A

Isolated Footing 642



ELEVATION



PLAN

Input Values

Footing Geomtery

Design Type : Calculate Dimension

Footing Thickness (Ft) : 24.000in

Footing Length - X (Fl) : 40.000in

Footing Width - Z (Fw) : 40.000in

Eccentricity along X (Oxd) : 0.000in

Eccentricity along Z (Ozd) : 0.000in

Column Dimensions

Column Shape : Rectangular

Column Length - X (D_{col}) : 0.532ft

Column Width - Z (B_{col}) : 0.507ft

Pedestal

Include Pedestal? No

Pedestal Shape : N/A

Pedestal Height (Ph) : N/A

Pedestal Length - X (Pl) : N/A

Pedestal Width - Z (Pw) : N/A

Design Parameters

Concrete and Rebar Properties

Unit Weight of Concrete : 150.000lb/ft3

Strength of Concrete : 4.000ksi

Yield Strength of Steel : 60.000ksi

Minimum Bar Size : #6

Maximum Bar Size : #18 Top Footing Minimum Bar Size : #6

Top Footing Maximum Bar Size : #18 Pedestal Minimum Bar Size : #6

Pedestal Maximum Bar Size : #18

Minimum Bar Spacing : 6.000in

Maximum Bar Spacing : 12.000in

Pedestal Clear Cover (P, CL) : 3.000in

Bottom Footing Clear Cover (F, CL) : 3.000in

Soil Properties

Soil Type : Cohesionless Soil

Unit Weight : 112.000lb/ft3

Soil Bearing Capacity : 4.000kip/ft2

Soil Bearing Capacity Type: Net Bearing Capacity

Soil Surcharge : 0.000kip/in2

Depth of Soil above Footing : 0.000in

Type of Depth : Fixed Top

Undrained Shear Strength : 0.000kip/in2

Bearing Capacity Input Method: Fixed Bearing Capacity

Sliding and Overturning

Coefficient of Friction : 0.500

Factor of Safety Against Sliding : 1.500

Factor of Safety Against Overturning : 1.500

Global Settings

Top Reinforcement Option : Always calculate based on self weight Concrete Design Option : Gross Pressure

Top Reinforcement Factor : 1.000 ---

Design Calculations

Footing Size

Initial Length (L_o) = 3.333ft

Initial Width (W_o) = 3.333ft

Load Combination/s- Service Stress Level				
Load Combination Number	**Load Combination Title**	**Load Combination Factor**	**Soil Bearing Factor**	**Self Weight Factor**
110	D + W N-S	1.00	1.00	1.00
111	D + W S-N	1.00	1.00	1.00
112	D + W E-W	1.00	1.00	1.00
113	D + W W-E	1.00	1.00	1.00
120	0.6 DL + W N-S	1.00	1.00	1.00
121	0.6 DL + W S-N	1.00	1.00	1.00
122	0.6 DL + W E-W	1.00	1.00	1.00
123	0.6 DL + W W-E	1.00	1.00	1.00
200	1.4 DL	1.00	1.00	1.00
210	1.2 DL + 1.6 W N-S	1.00	1.00	1.00
211	1.2 DL + 1.6 W S-N	1.00	1.00	1.00
212	1.2 DL + 1.6 W E-W	1.00	1.00	1.00
213	1.2 DL + 1.6 W W-E	1.00	1.00	1.00
220	0.9 DL + 1.6 W N-S	1.00	1.00	1.00
221	0.9 DL + 1.6 W S-N	1.00	1.00	1.00
222	0.9 DL + 1.6 W E-W	1.00	1.00	1.00
223	0.9 DL + 1.6 W W-E	1.00	1.00	1.00

Load Combination/s- Strength Level				
Load Combination Number	**Load Combination Title**	**Load Combination Factor**	**Soil Bearing Factor**	**Self Weight Factor**
110	D + W N-S	1.00	1.00	1.00
111	D + W S-N	1.00	1.00	1.00
112	D + W E-W	1.00	1.00	1.00
113	D + W W-E	1.00	1.00	1.00
120	0.6 DL + W N-S	1.00	1.00	1.00
121	0.6 DL + W S-N	1.00	1.00	1.00
122	0.6 DL + W E-W	1.00	1.00	1.00
123	0.6 DL + W W-E	1.00	1.00	1.00
200	1.4 DL	1.00	1.00	1.00
210	1.2 DL + 1.6 W N-S	1.00	1.00	1.00
211	1.2 DL + 1.6 W S-N	1.00	1.00	1.00
212	1.2 DL + 1.6 W E-W	1.00	1.00	1.00
213	1.2 DL + 1.6 W W-E	1.00	1.00	1.00
220	0.9 DL + 1.6 W N-S	1.00	1.00	1.00
221	0.9 DL + 1.6 W S-N	1.00	1.00	1.00
222	0.9 DL + 1.6 W E-W	1.00	1.00	1.00
223	0.9 DL + 1.6 W W-E	1.00	1.00	1.00

Applied Loads - Service Stress Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000
122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000

Applied Loads - Strength Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000
122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000

Reduction of force due to buoyancy = 0.000kip

Effect due to adhesion = 0.000kip

Area from initial length and width, $A_o = L_o \times W_o$ = 11.111ft^2 Min. area required from bearing pressure, $A_{min} = P / q_{max}$ = 6.445ft^2

Note: A_{min} is an initial estimation.

P = Critical Factored Axial Load(without self weight/buoyancy/soil). q_{max} = Respective Factored Bearing Capacity.

Final Footing Size

Length (L_2) =	8.500 ft	Governing Load # 223 Case :
Width (W_2) =	8.500 ft	Governing Load # 223 Case :
Depth (D_2) =	2.000 ft	Governing Load # 212 Case :

Depth is governed by Ultimate Load Case

(Service check is performed with footing thickness requirements from concrete check)

Area (A_2) =	72.250 ft^2
Final Soil Height =	0.000 ft
Footing Self Weight =	21.675 kip

Gross Soil Bearing Capacity 4.22kip/ft2

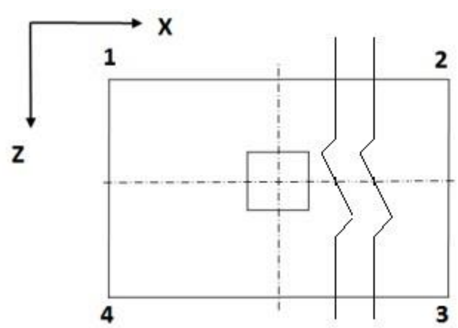
=

Soil Weight On Top Of

0.000 kip Footing =

Pressures at Four Corners

Please note that pressures values displayed in tables below are calculated after dividing by soil bearing factor



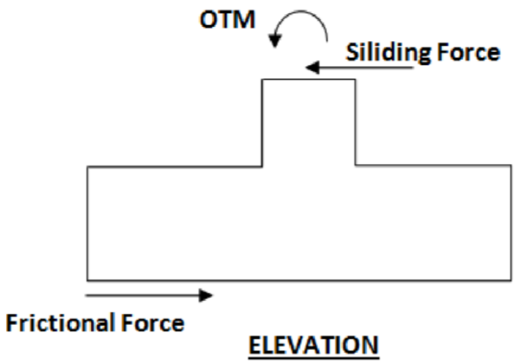
Load Case	Pressure at corner 1 (q_1) (kip/ft2)	Pressure at corner 2 (q_2) (kip/ft2)	Pressure at corner 3 (q_3) (kip/ft2)	Pressure at corner 4 (q_4) (kip/ft2)	Area of footing in uplift (A_u) (ft^2)
212	**0.7380**	0.5262	0.5232	0.7350	0.000
211	0.6204	**0.6133**	0.4909	0.4979	0.000
212	0.7380	0.5262	**0.5232**	0.7350	0.000
212	0.7380	0.5262	0.5232	**0.7350**	0.000

If A_U is zero, there is no uplift and no pressure adjustment is necessary. Otherwise, to account for uplift, areas of negative pressure will be set to zero and the pressure will be redistributed to remaining corners.

Summary of Adjusted Pressures at 4 corners Four Corners

Load Case	Pressure at corner 1 (q_1) (kip/ft2)	Pressure at corner 2 (q_2) (kip/ft2)	Pressure at corner 3 (q_3) (kip/ft2)	Pressure at corner 4 (q_4) (kip/ft2)
212	**0.7380**	0.5262	0.5232	0.7350
211	0.6204	**0.6133**	0.4909	0.4979
212	0.7380	0.5262	**0.5232**	0.7350
212	0.7380	0.5262	0.5232	**0.7350**

Check for stability against overturning and sliding



-	Factor of safety against sliding			Factor of safety against overturning	
Load Case No.	Along X-Direction	Along Z-Direction	Resultant	About X-Direction	About Z-Direction
110	200.897	6.654	6.650	28.278	853.812
111	127.962	8.990	8.968	38.206	543.837
112	5.679	341.470	5.678	1451.246	24.135
113	3.402	761.114	3.402	3234.734	14.457
120	481.893	5.701	5.700	24.228	2048.044
121	162.840	8.171	8.161	34.728	692.069
122	5.235	415.061	5.234	1764.010	22.248
123	2.829	69713.998	2.829	296284.492	12.022
200	119.945	339.092	113.079	1441.139	509.765
210	198.390	3.923	3.923	16.674	843.157
211	110.920	6.405	6.394	27.220	471.412
212	4.203	297.440	4.202	1264.119	17.862
213	1.786	1057.997	1.786	4496.486	7.592
220	353.961	3.486	3.486	14.818	1504.333
221	124.516	6.012	6.005	25.551	529.192
222	3.986	325.928	3.986	1385.194	16.941
223	1.527	4139.455	1.527	17592.683	6.492

Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - X Direction

Critical Load Case for Sliding along X-Direction : 223

Governing Disturbing Force : 5.209kip

Governing Restoring Force : 7.957kip

Minimum Sliding Ratio for the Critical Load Case : 1.527

Critical Load Case for Overturning about X-Direction : 220

Governing Overturning Moment : 6.119kip-ft

Governing Resisting Moment : 90.662kip-ft

Minimum Overturning Ratio for the Critical Load Case : 14.818

Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - Z Direction

Critical Load Case for Sliding along Z-Direction : 220

Governing Disturbing Force : 3.059kip

Governing Restoring Force : 10.666kip

Minimum Sliding Ratio for the Critical Load Case : 3.486

Critical Load Case for Overturning about Z-Direction : 223

Governing Overturning Moment : -10.418kip-ft

Governing Resisting Moment : 67.635kip-ft

Minimum Overturning Ratio for the Critical Load Case : 6.492

Critical Load Case And The Governing Factor Of Safety For Sliding Along Resultant Direction

Critical Load Case for Sliding along Resultant 223 Direction :

Governing Disturbing Force : 5.209kip

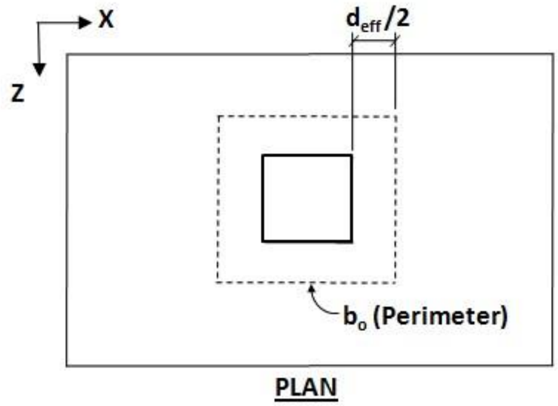
Governing Restoring Force : 7.957kip Minimum Sliding Ratio for the Critical Load Case : 1.527

Compression Development Length Check

Development length skipped as column reinforcement is not specified in input (Column Dimnesion Task Pane)

Shear Calculation

Punching Shear Check



Total Footing Depth, D = 2.000ft

Calculated Effective Depth, $d_{eff} = D - C_{cover} - 0.5 * d_b =$ 1.714ft

For rectangular column, $\beta_c = B_{col} / D_{col} =$ 1.049

Effective depth, d_{eff}, increased until $0.75XV_c \geq$ Punching Shear Force

Punching Shear Force, Vu = 42.418kip, Load Case # 212

From ACI Cl.11.12.2.1, b_o for column= 8.931ft $2 \times (B_{col} + D_{col} + 2 \times d_{eff}) =$

Equation 11-33, V_{c1} = 810.025kip $\left(2 + \frac{4}{\beta_c}\right) \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$

Equation 11-34, V_{c2} = 1348.397kip $\left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \lambda \times \sqrt{f_c} \times b_o \times d =$

Equation 11-35, V_{c3} = 557.493kip $4 \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$

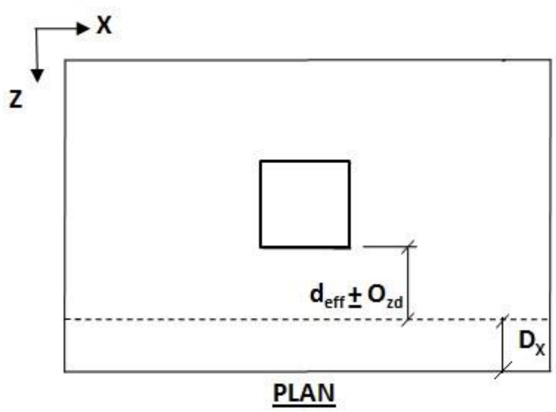
Punching shear strength, V_c = 0.75 X minimum of (V_{c1}, V_{c2}, V_{c3}) = 418.119kip

$0.75 X V_c > V_u$ hence, OK

One-Way Shear Check

Along X Direction

(Shear Plane Parallel to Global X Axis)



From ACI Cl.11.3.1.1, V_c = $2 \times L \times d_{eff} \times \sqrt{1000 \times F_c'}$ = 265.299kip

Distance along X to design for shear, $0.5 \times (W \pm D_{col}) - d_{eff} + O_{zd}$ =

2.283ft D_x =

Check that 0.75 X V_c > V_{ux} where V_{ux} is the shear force for the critical load cases at a distance d_{eff} from the face of the column caused by bending about the X axis.

From above calculations, 0.75 X V_c = 198.974 kip

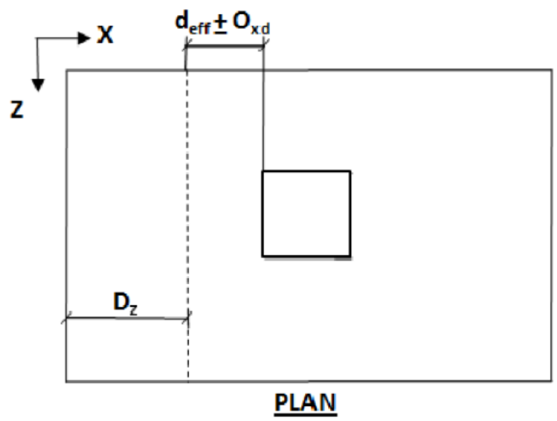
Critical load case for V_{ux} is # 212 $V_{ux} = V_{ux}|_{x=D_x}$ = 12.259 kip

0.75 X V_c > V_{ux} hence, OK

One-Way Shear Check

Along Z Direction

(Shear Plane Parallel to Global Z Axis)



From ACI Cl.11.3.1.1, V_c =

$2 \times W \times d_{eff} \times \sqrt{1000 \times F_c'}$ = 265.299 kip

Distance along X to design for shear, D_z = $0.5 \times (L \pm B_{col}) - d_{eff} + O_{xd}$ = 2.271 ft

Check that 0.75 X V_c > V_{uz} where V_{uz} is the shear force for the critical load cases at a distance d_{eff} from the face of the column caused by bending about the Z axis.

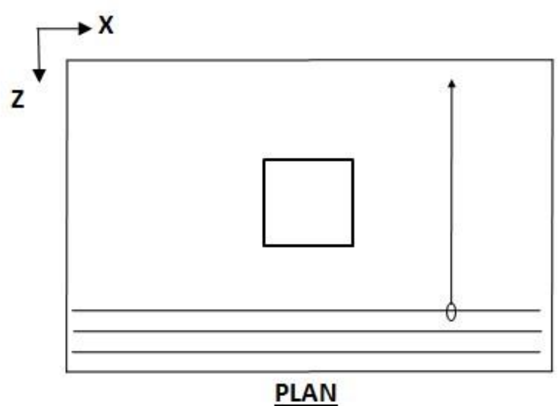
From above calculations, 0.75 X V_c = 198.974 kip

Critical load case for V_{uz} is # 212 $V_{uz} = V_{uz}|_{z=D_z}$ = 13.669 kip

0.75 X V_c > V_{uz} hence, OK

Design for Flexure about Z Axis

(For Reinforcement Parallel to X Axis)



Calculate the flexural reinforcement along the X direction of the footing. Find the area of steel required, A, as per Section 3.8

of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Bars parallel to X Direction are placed at bottom

Effective Depth d_{eff}= 1.719 ft

Factor β_1 from ACI Cl.10.2.7.3 = 0.850

From ACI Cl. 10.3.2, 0.02851 $\rho_{bal} = 0.85 \times \beta_1 \times F_c' \times \frac{87}{[f_y \times (87 + F_y)]} =$

From ACI Cl. 10.3.3, 0.02138 $\rho_{max} = 0.75 \times \rho_{bal} =$

From ACI Cl. 7.12.2, 0.00169 $\rho_{min} =$

From Ref. 1, Eq. 3.8.4a, constant m = $\frac{F_y}{(0.85 \times F_c')} =$ 17.647

Calculate reinforcement ratio ρ for critical load case

Design for flexure about Z axis is

performed at the face of the column at $0.5 \times L \pm 0.5 \times D_{col} + O_{xd} =$ 3.984 ft

a distance, D_x =

Ultimate moment, 47.454 kip-ft $M_u|_{z = D_z} =$

Nominal moment capacity, M_n = $\frac{M_u}{\Phi} =$ 52.726 kip-ft

(Based on effective depth) Required $\rho = \frac{1}{m} \times \left[1 - \sqrt{1 - 2 \times m \times \frac{M_n}{(F_y \times W \times d_{eff}^2)}}\right] =$

0.00025

Since $\rho \le \rho_{min}$ ρ_{min} Governs

(Based on gross depth) ρ x d_{eff} / Depth = 0.00021

Area of Steel Required, A_s = $\rho \times W \times d_{eff} =$ 4.141 in2

Selected bar Size = #6

Minimum spacing allowed (S_{min}) = = 6.000in

Selected spacing (S) = 10.583in

S_{min}<= S <= S_{max} and selected bar size < selected maximum bar size...

The reinforcement is accepted.

According to ACI 318 Clause No- 10.6.4 Max spacing for Cracking Consideration = 7.500in

Warning:Calculated spacing is more than maximum spacing cosidering cracking condition. Modify spacing manually if cracking consideration is necessary.

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 10.000in o.c.

Required development length for bars = $\frac{3 \times d_b \times f_y}{50 \times \lambda \times \sqrt{f_c}}$ = =2.372 ft

Available development length for bars, D_L = $0.5 \times (L - D_{col}) \cdot - C_{cover}$ = 3.734 ft

Try bar size # 6 Area of one bar = 0.440 in2

Number of bars required, N_{bar} = $\frac{A_s}{A_{bar}}$ = 10

Because the number of bars is rounded up, make sure new reinforcement ratio < ρ_{max}

Total reinforcement area, A_{s_total} = N_{bar} X (Area of one bar) = 4.400 in2

d_{eff} = D - C_{cover} - 0.5 X (dia. of one bar) = 1.719 ft

Reinforcement ratio, ρ = $\frac{A_{s\_total}}{(d_{eff} \times W)}$ = 0.00209

From ACI Cl.7.6.1, minimum req'd clear distance between bars

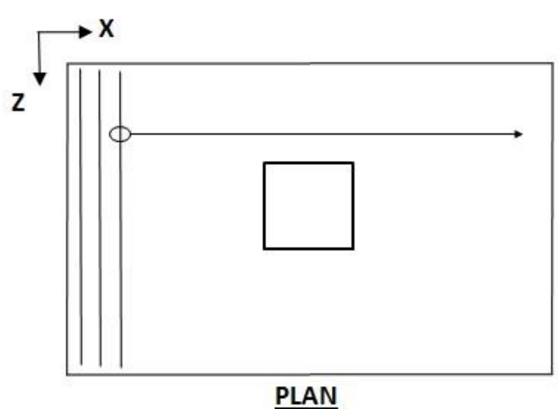
C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 6.000in

Provided Steel Area / Required Steel Area = 1.062

Check to see if width is sufficient to accomodate bars

Design for Flexure about X axis

(For Reinforcement Parallel to Z Axis)



Calculate the flexural reinforcement along the Z direction of the footing. Find the area of steel required, A, as per Section 3.8

of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Bars parallel to X Direction are placed at bottom

Effective Depth d_{eff}= 1.656 ft

Factor β_1 from ACI Cl.10.2.7.3 = 0.850

From ACI Cl. 10.3.2, 0.02851 $\rho_{bal} = 0.85 \times \beta_1 \times F_c' \times \frac{87}{[f_y \times (87 + F_y)]} =$

From ACI Cl. 10.3.3, 0.02138 $\rho_{max} = 0.75 \times \rho_{bal} =$

From ACI Cl.7.12.2, 0.00170 $\rho_{min} =$

From Ref. 1, Eq. 3.8.4a, constant m = $\frac{F_y}{(0.85 \times F_c')} =$ 17.647

Calculate reinforcement ratio ρ for critical load case

Design for flexure about X axis is

performed at the face of the column at $0.5 \times L \pm 0.5 \times B_{col} + O_{zd} =$ 3.997 ft

a distance, D_z =

Ultimate moment, $M_u|_{x=D_x}$ = 42.880 kip-ft

Nominal moment capacity, M_n = $\frac{M_u}{\Phi} =$ 47.645 kip-ft

(Based on effective depth) Required $\rho = \frac{1}{m} \times \left[1 - \sqrt{1 - 2 \times m \times \frac{M_n}{(F_y \times W \times d_{eff}^2)}}\right] =$ 0.00024

Since $\rho \leq \rho_{min}$ ρ_{min} Governs (Based on gross depth) ρ x d_{eff} / Depth = 0.00020

Area of Steel Required, A_s = $\rho \times W \times d_{eff} =$ 4.161 in2

Selected Bar Size = #6

Minimum spacing allowed (S_{min}) = 6.000in

Selected spacing (S) = 10.583in

S_{min}<= S <= S_{max} and selected bar size < selected maximum bar size...

The reinforcement is accepted.

According to ACI 318 Clause No- 10.6.4 Max spacing for Cracking Consideration = 7.500in

Warning:Calculated spacing is more than maximum spacing cosidering cracking condition. Modify spacing manually if cracking consideration is necessary.

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 10.000in o.c.

Required development length for bars = $\frac{d_b \times f_y}{25 \times \lambda \times \sqrt{f_c}} =$ =2.372 ft

Available development length for bars, D_L = $0.5 \times (L - D_{col}) \cdot -C_{cover} =$ 3.747 ft

Try bar size # 6 Area of one bar = 0.440 in2

Number of bars required, N_{bar} = $\frac{A_s}{A_{bar}} =$ 10

Because the number of bars is rounded up, make sure new reinforcement ratio < ρ_{max}

Total reinforcement area, A_{s_total} =	N_{bar} X (Area of one bar) =	4.400 in2
d_{eff} =	D - C_{cover} - 1.5 X (dia. of one bar) =	1.656 ft

Reinforcement ratio, $\rho = \frac{A_{s\_total}}{(d_{eff} \times W)} =$ 0.00217

From ACI Cl.7.6.1, minimum req'd clear distance between bars

C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 6.000in

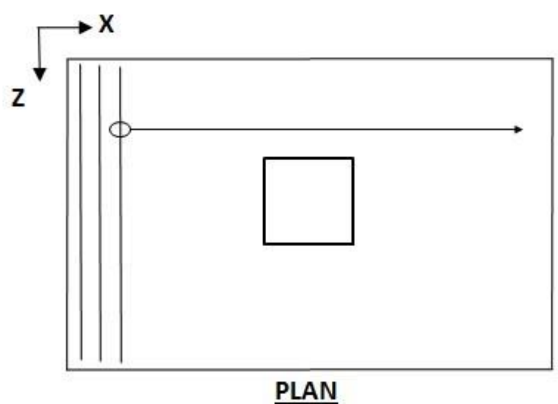
Provided Steel Area / Required Steel Area = 1.057

Check to see if width is sufficient to accomodate bars

Bending moment for uplift cases will be calculated based solely on selfweight, soil depth and surcharge loading.

As the footing size has already been determined based on all servicebility load cases, and design moment calculation is based on selfweight, soil depth and surcharge only, top reinforcement value for all pure uplift load cases will be the same.

Design For Top Reinforcement Parallel to Z Axis



Top reinforcement is calculated based on self weight of footing and soil

Calculate the flexural reinforcement for M_x. Find the area of steel required

The strength values of steel and concrete used in the formulae are in ksi

Bars parallel to X Direction are placed at bottom

Effective Depth d_{eff}= 1.656 ft

Factor β_1 from ACI Cl.10.2.7.3 = 0.850

From ACI Cl. 10.3.2, 0.02851 $\rho_{bal} = 0.85 \times \beta_1 \times F_c{}' \times \frac{87}{\left[f_y \times (87 + F_y)\right]} =$

From ACI Cl. 10.3.3, 0.02138 $\rho_{max} = 0.75 \times \rho_{bal} =$

$\rho_{min} =$

$$\frac{F_y}{(0.85 \times F_c{}')} =$$

From ACI Cl. 7.12.2, 0.00000

From Ref. 1, Eq. 3.8.4a, constant m = 17.647

Calculate reinforcement ratio ρ for critical load case

Design for flexure about X axis is

performed at the face of the column at a distance, D_x = $0.5 \times L \pm 0.5 \times D_{col} + O_{xd}$ = 3.997 ft

Ultimate moment, $M_u|_{z=D_z}$ = 20.366 kip-ft

Nominal moment capacity, M_n = $\frac{M_u}{\Phi}$ = 22.629 kip-ft

(Based on effective depth) ρ = $\frac{1}{m} \times \left[1 - \sqrt{1 - 2 \times m \times \frac{M_n}{\left(F_y \times W \times d_{eff}^{2}\right)}}\right]$ = 0.00011 Required =

(Based on gross depth) ρ x d_{eff} / Depth = 0.00009

Since $\rho_{min} \leq \rho \leq \rho_{max}$ OK

Area of Steel Required, A_s = $\rho \times W \times d_{eff}$ = 0.228 in2

Total reinforcement area, A_{s_total} = N_{bar} X (Area of one bar) = 0.884 in2

Provided Steel Area / Required Steel Area = 3.876

Selected bar Size = #6

Minimum spacing allowed (S_{min}) = 6.000in

Selected spacing (S) = 12.000in

S_{min}<= S <= S_{max} and selected bar size < selected maximum bar size...

The reinforcement is accepted.

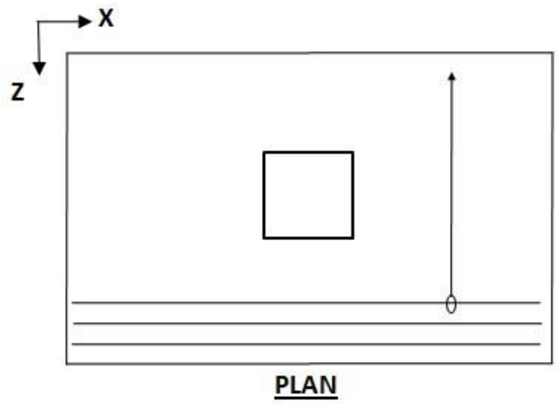
According to ACI 318 Clause No- 10.6.4 Max spacing for Cracking Consideration = 7.500in

Warning:Calculated spacing is more than maximum spacing cosidering cracking condition. Modify spacing manually if cracking consideration is necessary.

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 12.000in o.c.

Design For Top Reinforcement Parallel to X Axis



Top reinforcement is calculated based on self weight of footing and soil

Calculate the flexural reinforcement for M_z. Find the area of steel required

The strength values of steel and concrete used in the formulae are in ksi

Bars parallel to X Direction are placed at bottom

Effective Depth d_{eff}= 1.719 ft

Factor β_1 from ACI Cl.10.2.7.3 = 0.850

From ACI Cl. 10.3.2, $\rho_{bal} = 0.85 \times \beta_1 \times F_c' \times \frac{87}{\left[f_y \times (87 + F_y)\right]} =$ 0.02851

From ACI Cl. 10.3.3, $\rho_{max} = 0.75 \times \rho_{bal} =$ 0.02138

From ACI Cl.7.12.2, $\rho_{min} =$ 0.00000

From Ref. 1, Eq. 3.8.4a, constant $m = \frac{F_y}{(0.85 \times F_c')} =$ 17.647

Calculate reinforcement ratio ρ for critical load case

Design for flexure about Z axis is performed at the face of the column at a distance, $D_x = 0.5 \times L \pm 0.5 \times D_{col} + O_{xd} =$ 3.984 ft

Ultimate moment, $M_u|_{x=D_x} =$ 20.239 kip-ft

Nominal moment capacity, $M_n = \frac{M_u}{\Phi} =$ 22.488 kip-ft

Required $\rho = \frac{1}{m} \times \left[1 - \sqrt{1 - 2 \times m \times \frac{M_n}{\left(F_y \times W \times d_{eff}^2\right)}}\right] =$

(Based on effective depth) = 0.000104

(Based on gross depth) $\rho \times d_{eff}$ / Depth = 0.000089

Since $\rho_{min} \le \rho \le \rho_{max}$ OK

Area of Steel Required, $A_s = \rho \times W \times d_{eff} =$ 0.218 in2

Total reinforcement area, $A_{s\_total} = N_{bar} \times$ (Area of one bar) = 0.884 in2

Provided Steel Area / Required Steel Area = 4.048

Selected bar Size = #6

Minimum spacing allowed (S_{min}) = 6.000in

Selected spacing (S) = 12.000in

$S_{min} <= S <= S_{max}$ and selected bar size < selected maximum bar size...

The reinforcement is accepted.

According to ACI 318 Clause No- 10.6.4 Max spacing for Cracking Consideration = 7.500in

Warning:Calculated spacing is more than maximum spacing cosidering cracking condition. Modify spacing manually if cracking consideration is necessary.

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 12.000in o.c.

Isolated Footing Design Optimization

Through hand calculations, the design process and accuracy has been verified for the design of an isolated footing in STAAD.foundation. However, through testing the program, it has been found that the most effective design alternative is not automatically designed through the software analysis unless the design parameters are sufficiently constrained. For example, the program seems to almost always design to match the minimum selected thickness as highlighted to the right in Figure 1. Also noted in the figure are the length with ratio and the set as default option. The length with ratio was kept at 1 throughout our testing in order to assure the design of square footing. Additionally, when "No" is chosen for set to default, the program is supposed to optimize the design. Although this option helped in making the design more feasible, constraining other variables such as the reinforcement sizing and spacing was necessary in order to produce the most effective design.

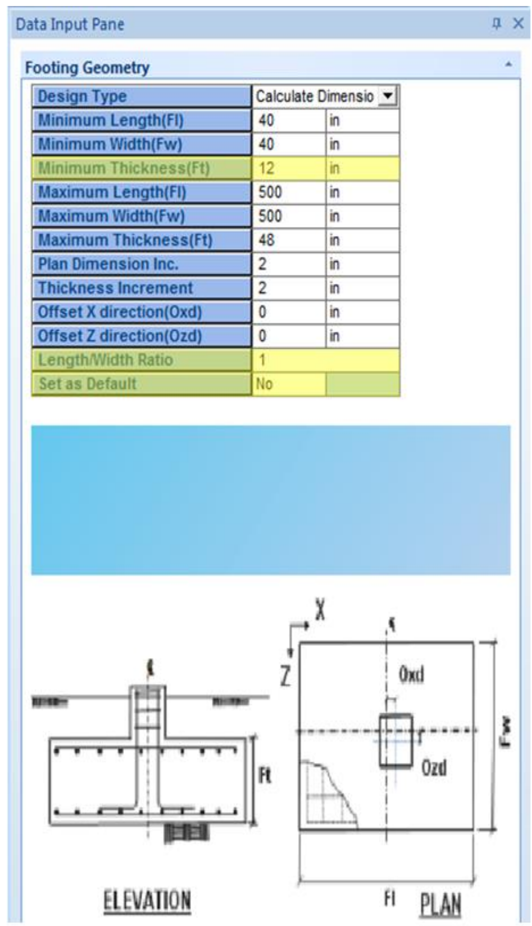


FIGURE 1: FOOTING GEOMETRY INPUT PANE IN STAAD.*FOUNDATION*

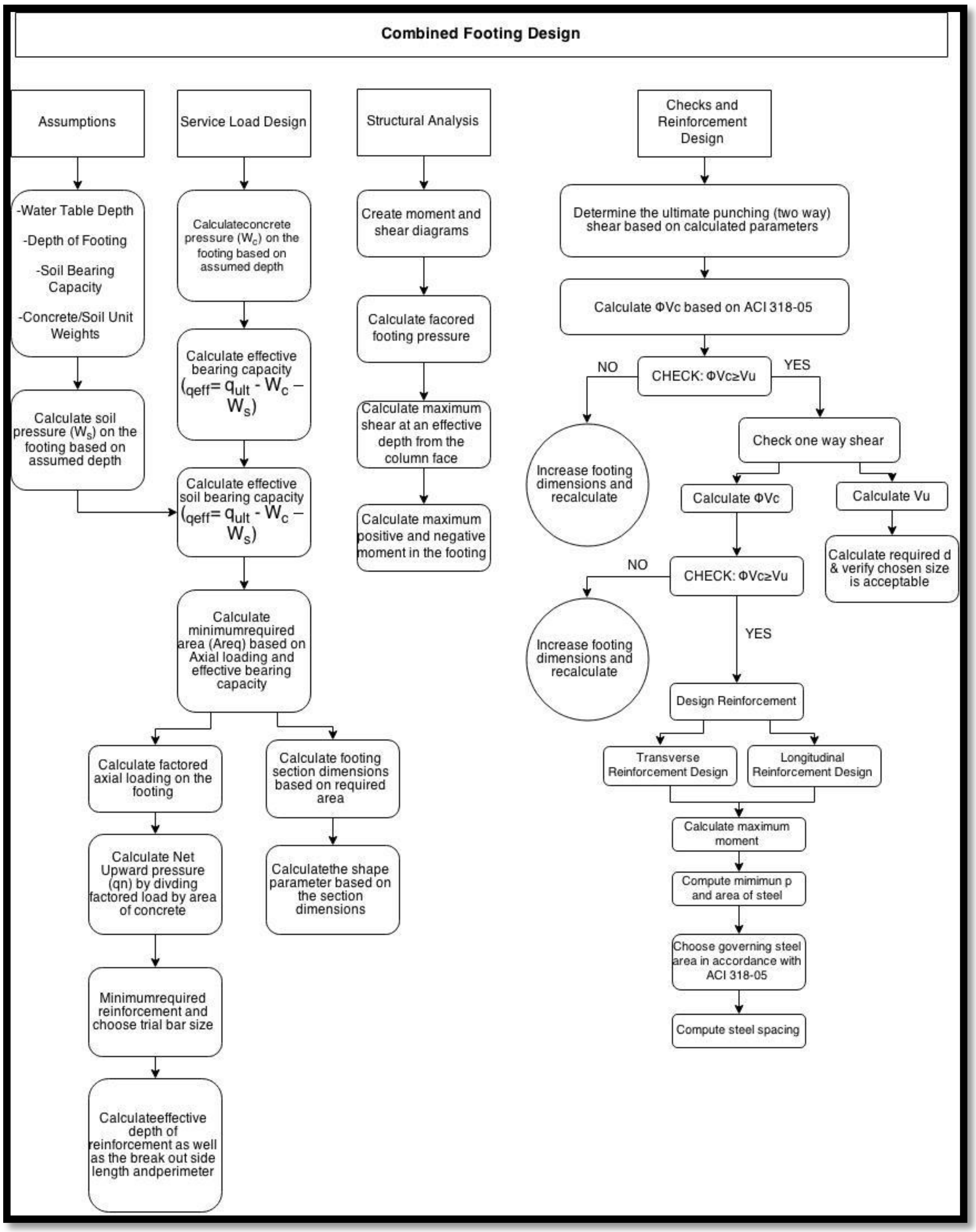
Another major issue within the automated analysis is the lack of consideration to negative forces when the governing loading is chosen. For example, when the design is analyzed, a 3.059 kip force will govern over a -3.134 kip force. Although this may be a negligible difference for this case, it may become an issue in which there is a more severe difference in the forces.

Overall, when using the design analysis for an isolated footing, it is up to the engineer to constrain the ranges to what he/she finds appropriate. For example, upon completion of an analysis, the designer may notice a large number of a small sized rebar is used, which may pose feasibility and constructability issues. For this reason, the designer may have to further constrain the design parameters in order to achieve a more economical result.

Appendix E...Combined Footing Design Verification

Several steps were taken in order to verify the automated calculations run within STAAD.foundation. This process was aided by the use of an excel spreadsheet in order to iterate several designs quickly. The functionality and accuracy of the spreadsheet was verified against hand calculations. When designing these footings, checks against sliding, overturning, and direct and punching shear were considered. Examples of this procedure can be seen below in the following sections.

Combined Footing Design Procedure



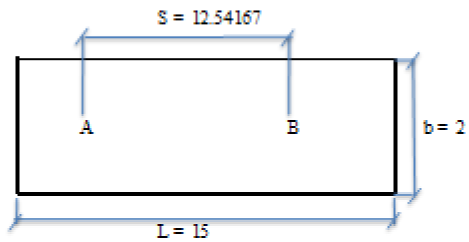
Excel Spreadsheet – Combined Footing

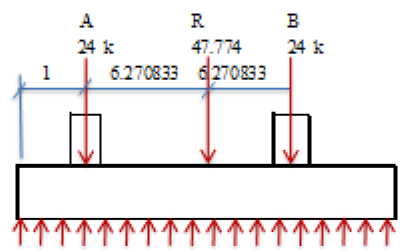
Design Checks			
Punching Shear Strength	φv_c	OK	
Punching Shear Strength	φv_c	OK	
Shear strength of concrete for footing section	φV_c	OK	
Bearing capacity of concrete at column base	P_c	Col A	OK
		Col B	OK

Combined Footings - Service Load Design

Column A: Node 642	Live Load	P_{1L}	0	Kips
	Dead Load	P_{1D}	23.887	Kips
	Total	P_{1T}	23.887	Kips
Column B: Node 643	Live Load	P_{2L}	0	Kips
	Dead Load	P_{2D}	23.887	Kips
	Total	P_{2T}	23.887	Kips
	Resultant	R	47.774	Kips
	Distance Between Columns	s	12.542	ft
	Allowable Soil Pressure	q_a	3000	psf
	Distance from column A to edge of footing	m	1	ft
	Depth of soil above footing		12	inches
	Unit weight of soil	γ_s	120	pcf
	Depth of footing		24	inches
	Unit weight of concrete	γ_c	150	pcf

Service Load Design			
Location of resultant from A	n	6	ft
Length of Footing	L	15	ft
Weight of Footing	q_f	300	psf
Weight of soil above footing	q_s	120	psf
Net soil bearing capacity	q_e	2580	psf
Required footing area	A_{req}	19	ft^2
Required width of footing	b_{req}	2	ft



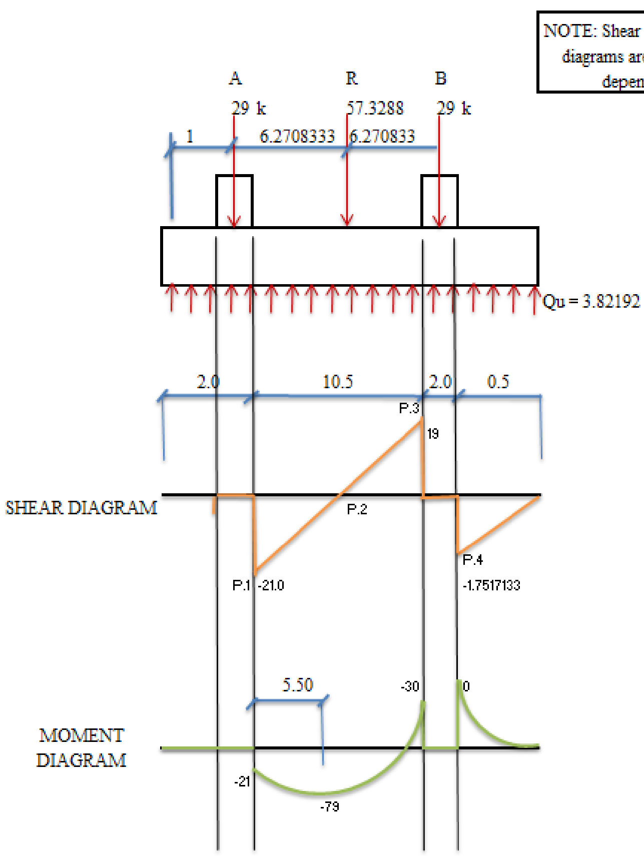


Combined Footings - Structural Analysis

Column Size	Depth	C_d	2	ft	Design Code
	Width	C_w	2	ft	ACI 318-05
	Area	A_c	4	ft^2	
Factored Column Loads	Column A	P_{ua}	28.66	kips	
	Column B	P_{ub}	28.66	kips	
Location of Resultant from column A		$R_{factored}$	7	ft	
Factored footing pressure per linear foot of footing		Q_u	3.8	k/ft	

Shear Diagram			
Point 1	V_{U1}	-21.0	kips
Point 3	V_{U3}	19.3	kips
Point 4	V_{U4}	-1.8	kips

Moment Diagram			
Distance from inside face of column A to peak moment	X	5.5	ft
Point 1	M_{U1}	-21	ft-kips
Point 2	M_{U2}	-78.8	ft-kips
Point 3	M_{U3}	-30.3	ft-kips
Point 4	M_{U4}	0.401	ft-kips



Combined Footings - Reinforcement Design

Compressive Strength of Concrete at 28 days	f'_c	4	ksi	
Yield Strength of rebar	f_y	60	ksi	
shear ratio	φ	0.75		

Check punching shear for column A				
Assume reinforcements are:	#	6	bars	
Bar Diameter	di	0.75	inches	
Cover	C	3	inches	
Effective depth	d	1.7	ft	
Factored footing pressure	q_{fact}	1.91	kips/ft^2	
Perimeter of punching shear	b_{oA}	112.5	inches	
Punching shear stress	V_{uA}	3.8	psi	
Punching Shear Strength	φv_c	189.7	psi	OK

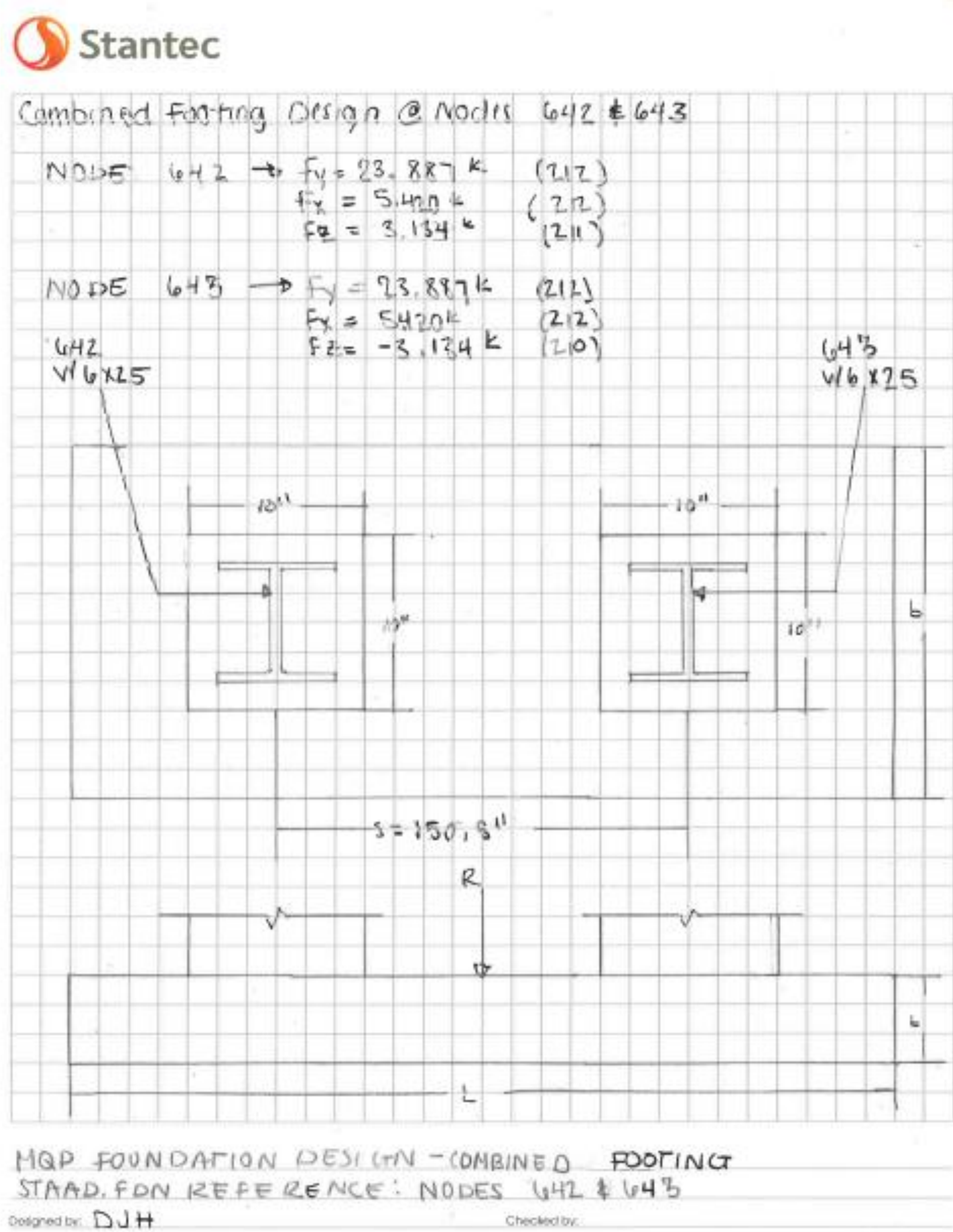
Check punching shear for column B				
Perimeter of punching shear	b_{oB}	177	inches	
Punching shear stress	V_{uB}	0.7	psi	
Punching Shear Strength	φv_c	189.7	psi	OK

Check Direct Shear				
Maximum Shear	V_{max}	19.3	kips	
Distance from zero shear to max shear	X	10.54167	ft	
Direct shear at the critical section	V_u	16.2	kips	
Shear strength of concrete for footing section	φV_c	115.265	kips	OK

Maximum Positive/Negative reinforcement in longitudinal direction				
Maximum Positive Moment	M_{max}	78.8	ft-kips	
Required width of footing	b_{req}	2	ft	
Moment ratio	φ_m	0.9		
Assume depth of Stress block	a	0.9	inches	
Iteration	T	53.1	kips	
	a	0.65	inches	
	T	52.7	kips	
	a	0.65	inches	
Converges	a	0.84	inches	
Area of steel	A_s	0.88	in^2	
Reinforcement ratio	ρ	0.00181		
Minimum Reinforcement Ratio	ρ_{min}	0.00241		
Adjusted Area of Steel	A_s	1.17	in^2	
Allowable Spacing	S	13.87	inches	
Choose Bar: Size	#	3		Manual Decision
Number		16		
Spacing		11.6	inches	OK

Determine reinforcement in transverse direction				
Distrance from face of column to footing edge	ℓ	0.5	ft	
For 1ft section		1	ft	
Factored moment at face of column	M_u	3.82	k-ft	
Assume "a"	a	0.1	inches	
Iteration	T	2.5	kips	
	a	0.06	inches	
	T	2.5	kips	
	a	0.06	inches	
Final "a"	a	0.06	inches	
Area steel for 1ft section	A_s	0.042006	in^2	
Reinforcement Ratio	ρ	0.00017		
Minimum Reinforcement Ratio	ρ_{min}	0.00023		
Adjusted Area of Steel	A_s	1.23		
Choose Bar: Size	#	5		Manual Decision
Number		5		
Spacing		4.50	inches	OK

Hand Calculations - Combined Footing



Stantec

TOTAL AXIAL LOAD:

$P_{ax} = P_{642} + P_{643} = 2(23.887) = 47.774^k$
$S = 150.5''$

→ assume allowable soil pressure: $4000\ lb/ft^2 = q_a$
→ assume soil unit weight: $120\ lb/ft^3 = \gamma_s$
→ assume unit weight of concrete: $150\ lb/ft^3 = \gamma_g$
→ assume distance from 642 to edge of ftng: 1 ft

→ Try: column thickness = 24"
depth of soil above footing = 12"

→ Length of footing: L = 184.5"

NET SOIL BEARING CAPACITY

$$W_L = 150 \frac{lb}{ft^3} (24\ in)\left(\frac{1\ ft}{12\ in}\right)\left(\frac{1^k}{1000}\right) = .3\ k/ft^2$$

$$W_S = 120 \frac{lb}{ft^3} (12\ in)\left(\frac{1\ ft}{12\ in}\right)\left(\frac{1^k}{1000}\right) = .12\ k/ft^2$$

$$q_{eff} = q_a - W_L - W_S = 4 - .3 - .12 = 3.58\ k/ft^2$$

REQUIRED FOOTING AREA

$$A_{req} = \frac{P_{ax}}{q_{eff}} = \frac{47.774}{3.58} = 13.34\ ft^2$$

$$b = \frac{A_{req}}{L} = \frac{13.34}{(14.54)} = .92\ ft \quad \therefore \text{use } 1\ ft = b$$

Designed by: Checked by:

Stantec

SHEAR & MOMENT CALCULATIONS

footing pressure:

$q_n = \frac{2(23.887)}{184.5} = .26$ k/in

Shear:

$+V_{P_1} = .26(17'') - 23.887$
$= -19.467^k$

$+V_{P_3} = .26(17 + 150.5) - 23.887$
$= 19.663^k$

$-V_{P_1} = 17(.26) = 4.42$

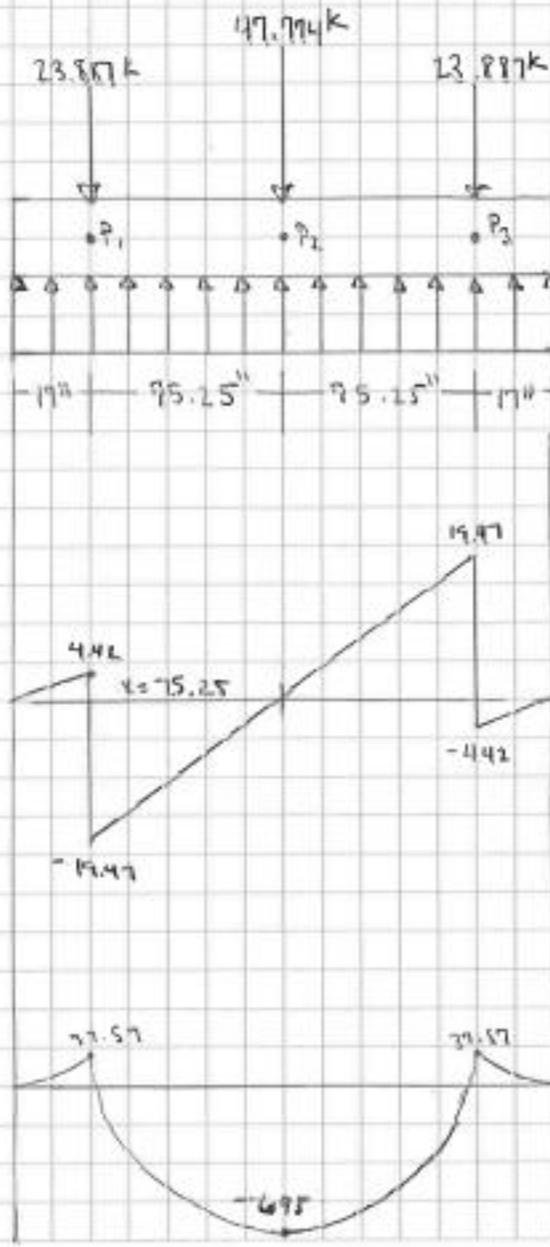
$-V_{P_3} = -17(.26) = -4.42$

moment:

$M_{P_1} = \frac{4.42(17)}{2} = 37.57$ k-in

$M_{P_2} = \frac{(-19.47)(75.25)}{2} = -732.56$ k-in
$+37.57 = -695$

$M_{P_3} = \frac{(-4.42)(-17)}{2} = 37.57$ k-in



Designed by:

Checked by:

Stantec

CHECK FOR FLEXURE:

$M_u = 645$ k-in, $b = L = 184.5"$, $d = 24"$

$R_n = \frac{M_u}{\phi b d^2} = \frac{645}{.9(184.5)(24^2)} = .0073$ k/in² (1000) = 7.3 lb/in²

$\rho = \frac{.85 f'c}{f_y}\left[1 - \sqrt{1 - \frac{2R_n}{.85 f'c}}\right] = \frac{.85(4000)}{60000}\left[1 - \sqrt{1 - \frac{2(7.3)}{.85(4000)}}\right] = .00013$

$\rho_b = .85\left[\frac{87000 \beta_1 f'c}{f_y(87000 + f_y)}\right] = .85\left[\frac{87000(.85)(4000)}{60000(87000 + 60000)}\right] = .0335$

$\rho_{max} = .75\rho_b = .0251 > \rho$, $\rho_{min} = .0018$ → use

$A_s = \rho b d = .0018(184.5)(24) = 7.79$ in², use 7 #10, $A_s = 8.89$ in²

CHECK FOR PUNCHING SHEAR: → column 642 = column 643

→ assume 3" cover

$d_{avg} = 24 - 3 - .5(1.278) = 20.36"$, $c = 10"$

punchout perimeter: $b_0 = 4(20.36 + 10) = 121.44"$

$V_u = P_c - q_n(c+d)^2 = 23.887 - .022(30.36)^2 = 3.61^k$

$\phi V_c = \left[\frac{\alpha d}{b_0} + 2\right]\sqrt{f'c}\, b_0 d = .75\left(\frac{20(20.36)}{121.44} + 2\right)\sqrt{4000}\,(121.44)(20.36)$

$\phi V_c = 627.82 > V_u$ ✓

Designed by: Checked by:

Stantec

CHECK FOR 1 WAY SHEAR:

$V_u = 19.47^k$

$\phi V_c = \phi 2 .75\sqrt{f'c}\, bd = .75(2)\sqrt{4000}\,(184.5)(12) = 210.04^k > V_u$ ✓

CHECK FOR SLIDING:

Disturbing force: 3.134^k (from STAAD.pro Analysis)

Resisting force: μ [Self weight + Axial force)

$.5[.150(2)(1)(14.54) + 23.887] = 14.125$

CHECK FACTOR OF SAFETY: $fs = \frac{14.125}{3.134} = 4.5 > 1.5$ ✓

REINFORCEMENT SPACING

$S = \frac{L - 2(\text{cover})}{n-1} = \frac{184.5 - 2(3)}{6} = 30''$ → max

Designed by: Checked by:

STAAD.Foundation Output for Combined Footing Design

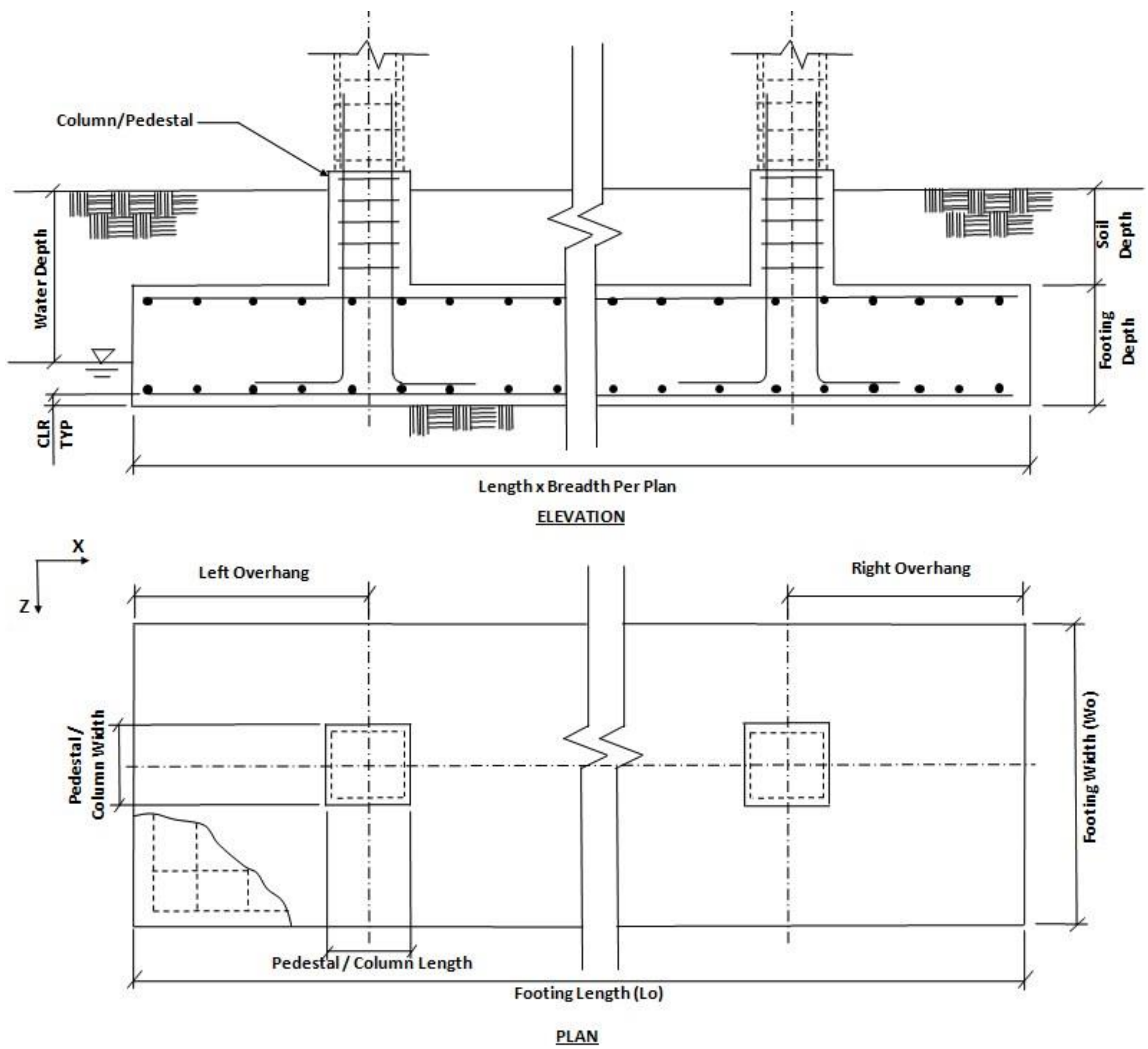
COMBINED FOUNDATION DESIGN (ACI 318-05)

Design For Combined Footing 1

Result Summary

Footing No.	Left Overhang (ft)	Right Overhang (ft)	Length (ft)	Width (ft)	Thickness (ft)
1	1.833	1.833	16.208	2.333	2.000

Footing No.	Footing Reinforcement			
-	Main Steel Top	Main Steel Bottom	Secondary Steel Top	Secondary Steel Bottom
1	4 - #6	4 - #7	22 - #6	16 - #7



Combined Footing 1

Input Data

Geometry of Footing

For Column 642

Column Dimensions

Column Shape : Rectangular

Column Length - X (D_{col}) : 0.532ft

Column Width - Z (B_{col}) : 0.507ft

Pedestal

Include Pedestal? No

Pedestal Shape : N/A

Pedestal Height (Ph) : N/A

Pedestal Length - X (Pl) : N/A

Pedestal Width - Z (Pw) : N/A

Eccentricity

Column Offset in Transverse Direction : 0.000ft

For Column 643

Column Dimensions

Column Shape : Rectangular

Column Length - X (D_{col}) : 0.532ft

Column Width - Z (B_{col}) : 0.507ft

Pedestal

Include Pedestal? No

Pedestal Shape : N/A

Pedestal Height (Ph) : N/A

Pedestal Length - X (Pl) : N/A

Pedestal Width - Z (Pw) : N/A

Eccentricity

Column Offset in Transverse Direction : 0.000ft

Length of left overhang : 1.000ft

Length of right overhang : 1.000ft

Is the length of left overhang fixed? No

Is the length of right overhang fixed? No

Minimum width of footing (Wo) : 1.000ft

Minimum Thickness of footing (Do) : 2.000ft

Maximum Width of Footing (Wo) : 10.000ft

Maximum Thickness of Footing (Do) : 5.000ft

Maximum Length of Footing (Lo) : 300.000ft

Length Increment : 2.000in

Depth Increment : 2.000in

Cover and Soil Properties

Pedestal Clear Cover : 2.000in

Footing Clear Cover : 3.000in

Unit Weight of soil : 120.000lb/ft3

Soil Bearing Capacity : 4.000kip/ft2

Soil Bearing Capacity Type: Net Bearing Capacity

Soil Surcharge : 0.000kip/in2

Depth of Soil above Footing : 12.000in

Type of Depth : Fixed Top

Depth of Water Table : 120.000ft

Concrete and Rebar Properties

Unit Weight of Concrete : 0.610kip/ft3

Compressive Strength of Concrete : 4.000ksi

Yield Strength of Steel : 60.000ksi

Minimum Bar Size : #7

Maximum Bar Size : #14 Minimum Pedestal Bar Size : #3

Maximum Pedestal Bar Size : #10

Minimum Bar Spacing : 2.000in

Maximum Bar Spacing : 18.000in

Design Calculations

Footing Size Calculations

Gross Soil Bearing Capacity = 4.36kip/ft^2

Reduction of force due to buoyancy = 0.000kip

Area from initial length and width, $A_o = L_o \times W_o$ = 14.542ft^2

Min. area required from bearing pressure, $A_{min} = P / q_{max}$ = 15.413ft^2

Note: A_{min} is an initial estimation.

P = Critical Factored Axial Load(without self weight/buoyancy/ q_{max} = Respective Factored Bearing Capacity.

Final footing dimensions are:

Length of footing, L : 16.208ft

Width of footing, W : 2.333ft

Depth of footing, Do : 2.000ft

Area, A : 37.820ft^2

Length of left overhang, $L_{left\_overhang}$: 1.833ft

Length of right overhang, $L_{right\_overhang}$: 1.833ft

Footing self weight : 46.140kip Soi weight on top of footing : 4.474kip

----

Load Combination Number	Load Combination Title	Load Combination Factor	Soil Bearing Factor	Self Weight Factor
110	D + W N-S	1.00	1.00	1.00
111	D + W S-N	1.00	1.00	1.00
112	D + W E-W	1.00	1.00	1.00
113	D + W W-E	1.00	1.00	1.00
120	0.6 DL + W N-S	1.00	1.00	1.00
121	0.6 DL + W S-N	1.00	1.00	1.00
122	0.6 DL + W E-W	1.00	1.00	1.00
123	0.6 DL + W W-E	1.00	1.00	1.00
200	1.4 DL	1.00	1.00	1.00
210	1.2 DL + 1.6 W N-S	1.00	1.00	1.00
211	1.2 DL + 1.6 W S-N	1.00	1.00	1.00
212	1.2 DL + 1.6 W E-W	1.00	1.00	1.00
213	1.2 DL + 1.6 W W-E	1.00	1.00	1.00
220	0.9 DL + 1.6 W N-S	1.00	1.00	1.00
221	0.9 DL + 1.6 W S-N	1.00	1.00	1.00
222	0.9 DL + 1.6 W E-W	1.00	1.00	1.00
223	0.9 DL + 1.6 W W-E	1.00	1.00	1.00

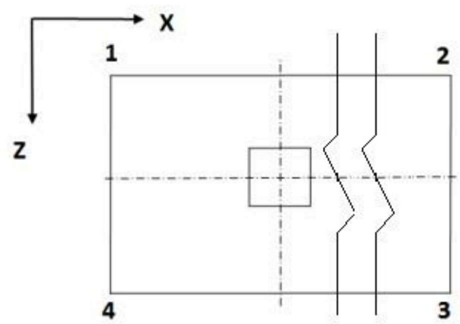
Load Combination Number	Load Combination Title	Load Combination Factor	Soil Bearing Factor	Self Weight Factor
110	D + W N-S	1.00	1.00	1.00
111	D + W S-N	1.00	1.00	1.00
112	D + W E-W	1.00	1.00	1.00
113	D + W W-E	1.00	1.00	1.00
120	0.6 DL + W N-S	1.00	1.00	1.00
121	0.6 DL + W S-N	1.00	1.00	1.00
122	0.6 DL + W E-W	1.00	1.00	1.00
123	0.6 DL + W W-E	1.00	1.00	1.00
200	1.4 DL	1.00	1.00	1.00
210	1.2 DL + 1.6 W N-S	1.00	1.00	1.00
211	1.2 DL + 1.6 W S-N	1.00	1.00	1.00
212	1.2 DL + 1.6 W E-W	1.00	1.00	1.00
213	1.2 DL + 1.6 W W-E	1.00	1.00	1.00
220	0.9 DL + 1.6 W N-S	1.00	1.00	1.00
221	0.9 DL + 1.6 W S-N	1.00	1.00	1.00
222	0.9 DL + 1.6 W E-W	1.00	1.00	1.00
223	0.9 DL + 1.6 W W-E	1.00	1.00	1.00

Applied Loads - Service Stress Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
-					
Column Number : 642					
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000
122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000
-					
Column Number : 643					
110	13.701	-0.138	1.968	0.000	0.000
111	3.562	-0.063	-1.897	0.000	0.000
112	17.087	-3.413	0.057	0.000	0.000
113	0.176	3.212	0.014	0.000	0.000
120	10.248	-0.098	1.953	0.000	0.000
121	0.109	-0.023	-1.911	0.000	0.000
122	13.635	-3.373	0.043	0.000	0.000
123	-3.277	3.252	0.000	0.000	0.000
200	12.084	-0.141	0.050	0.000	0.000
210	18.469	-0.181	3.134	0.000	0.000
211	2.247	-0.060	-3.049	0.000	0.000
212	23.887	-5.420	0.077	0.000	0.000
213	-3.172	5.179	0.009	0.000	0.000
220	15.879	-0.151	3.123	0.000	0.000
221	-0.343	-0.030	-3.059	0.000	0.000
222	21.298	-5.390	0.066	0.000	0.000
223	-5.761	5.209	-0.002	0.000	0.000

Applied Loads - Strength Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
-					
Column Number : 642					
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000

122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000
-					
Column Number : 643					
110	13.701	-0.138	1.968	0.000	0.000
111	3.562	-0.063	-1.897	0.000	0.000
112	17.087	-3.413	0.057	0.000	0.000
113	0.176	3.212	0.014	0.000	0.000
120	10.248	-0.098	1.953	0.000	0.000
121	0.109	-0.023	-1.911	0.000	0.000
122	13.635	-3.373	0.043	0.000	0.000
123	-3.277	3.252	0.000	0.000	0.000
200	12.084	-0.141	0.050	0.000	0.000
210	18.469	-0.181	3.134	0.000	0.000
211	2.247	-0.060	-3.049	0.000	0.000
212	23.887	-5.420	0.077	0.000	0.000
213	-3.172	5.179	0.009	0.000	0.000
220	15.879	-0.151	3.123	0.000	0.000
221	-0.343	-0.030	-3.059	0.000	0.000
222	21.298	-5.390	0.066	0.000	0.000
223	-5.761	5.209	-0.002	0.000	0.000

Calculated Pressures at Four Corners



Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)	Area of footing in uplift (A_u) (sq. ft)
211	**2.9700**	0.7365	0.8021	3.0356	0.000
210	0.7365	**2.9700**	3.0356	0.8021	0.000
212	1.1273	1.1273	**4.0757**	4.0757	0.000
212	1.1273	1.1273	4.0757	**4.0757**	0.000

If A_U is zero, there is no uplift and no pressure adjustment is necessary. Otherwise, to account for uplift, areas of negative pressure will be set to zero and the pressure will be redistributed to remaining corners.

Summary of Adjusted Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)
211	**2.9700**	0.7365	0.8021	3.0356
210	0.7365	**2.9700**	3.0356	0.8021
212	1.1273	1.1273	**4.0757**	4.0757
212	1.1273	1.1273	4.0757	**4.0757**

Check for stability against sliding

Load Case	Shear X (kip)	Shear Z (kip)	Resultant Shear (kip)	Resisting Sliding Force (kip)	Ratio X	Ratio Z	Resultant Ratio
110	-0.201	3.864	3.869	28.688	142.726	7.424	7.414
111	-0.201	-3.864	3.869	28.688	142.726	7.424	7.414
112	-6.826	-0.000	6.826	35.453	5.194	N/A	5.194
113	6.424	-0.000	6.424	21.924	3.413	N/A	3.413
120	-0.121	3.864	3.866	25.926	214.974	6.710	6.706
121	-0.121	-3.864	3.866	25.926	214.974	6.710	6.706
122	-6.745	0.000	6.745	32.691	4.847	N/A	4.847
123	6.504	-0.000	6.504	19.162	2.946	N/A	2.946
200	-0.281	-0.000	0.281	31.451	111.762	N/A	111.762
210	-0.241	6.183	6.187	30.070	124.664	4.864	4.860
211	-0.241	-6.183	6.187	30.070	124.664	4.864	4.860
212	-10.841	0.000	10.841	40.893	3.772	N/A	3.772
213	10.358	-0.000	10.358	19.246	1.858	187028.728	1.858
220	-0.181	6.183	6.185	27.998	154.767	4.529	4.527
221	-0.181	-6.183	6.185	27.998	154.767	4.529	4.527
222	-10.780	0.000	10.780	38.821	3.601	N/A	3.601
223	10.419	-0.000	10.419	17.175	1.648	N/A	1.648

Check for stability against overturning (Moments printed against Local axis)

Load Case	Moment X (kip-ft)	Moment Z (kip-ft)	Resisting Moment X (kip-ft)	Resisting Moment Z (kip-ft)	Ratio X	Ratio Z
110	0.436	-71.951	83.675	581.242	192.131	8.078
111	0.436	71.952	83.675	581.242	192.131	8.078
112	14.789	0.000	103.405	718.296	6.992	N/A
113	-13.918	0.001	63.945	444.188	4.594	426232.000
120	0.261	-71.951	75.619	525.282	289.388	7.301
121	0.261	71.952	75.619	525.282	289.388	7.300
122	14.615	-0.000	95.349	662.336	6.524	3236169.967
123	-14.092	0.001	55.889	388.227	3.966	466048.754
200	0.610	0.001	91.731	637.202	150.449	875162.136
210	0.523	-115.122	87.703	609.222	167.816	5.292
211	0.523	115.123	87.703	609.222	167.816	5.292
212	23.488	-0.000	119.271	828.509	5.078	4180125.941
213	-22.443	0.001	56.135	389.935	2.501	267463.273
220	0.392	-115.122	81.661	567.252	208.340	4.927
221	0.392	115.123	81.661	567.252	208.340	4.927
222	23.357	-0.000	113.229	786.539	4.848	2150476.606
223	-22.574	0.001	50.093	347.965	2.219	267190.760

Calculations of Footing Thickness

Footing thickness is calculated based on the ultimate load cases

Check for Punching Shear

For Column 642

Critical Load case for Punching Shear Check : 18

Total Footing Depth, D_o = 2.000ft

Calculated Effective Depth, d_{eff} = 1.714ft

For rectangular column, β_c = B_{col} / D_{col} : 1.049

Considering the particular column

as interior column, Slab Edge α_s : 40.0

Factor

Effective depth, d_{eff}, increased until 0.75*V_c $\geq$ Punching Shear Force

Punchng Shear Force, Vu = 17.599kip

From ACI Cl.11.12.2.1, b_o for column 8.931ft

Equation 11-33, V_{c1} $\left(2+\frac{4}{\beta_c}\right) \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$ 810.025kip

Equation 11-34, V_{c2} = $\left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \lambda \times \sqrt{f_c} \times b_o \times d =$ 1348.397kip

Equation 11-35, V_{c3} = $4 \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$ 557.493kip

Punching shear strength, V_c= 0.75 x minimum of (V_{c1}, V_{c2}, V_{c3}) = 418.119kip
0.75 * V_c > V_u hence, OK

For Column 643

Critical Load case for Punching Shear Check : 18

Total Footing Depth, D_o = 2.000ft

Calculated Effective Depth, d_{eff} = 1.714ft

For rectangular column, β_c = B_{col} / D_{col} : 1.049

Considering the particular column

as interior column, Slab Edge α_s : 40.0

Factor

Effective depth, d_{eff}, increased until 0.75*V_c $\geq$ Punching Shear Force

Punchng Shear Force, Vu = 17.599kip

From ACI Cl.11.12.2.1, b_o for column 8.931ft

Equation 11-33, V_{c1}810.025kip $\left(2+\frac{4}{\beta_c}\right) \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$

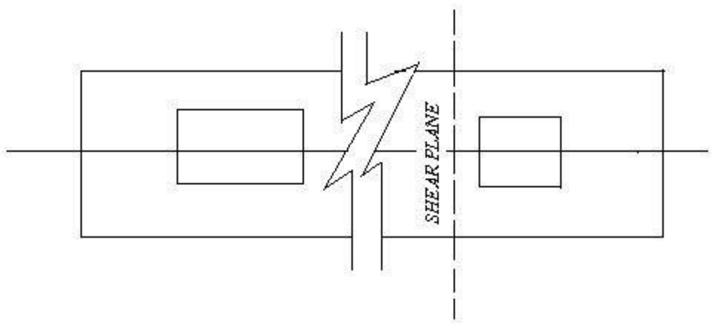
Equation 11-34, V_{c2} = 1348.397kip $\left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \lambda \times \sqrt{f_c} \times b_o \times d =$

Equation 11-35, V_{c3} = 557.493kip

Punching shear strength,V_c= 0.75 x minimum of $4 \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'} =$ (V_{c1},V_{c2},V_{c3}) = 418.119kip

0.75 * V_c > V_U hence, OK

Check for One-Way Shear



Shear Plane Parallel to Foundation Width

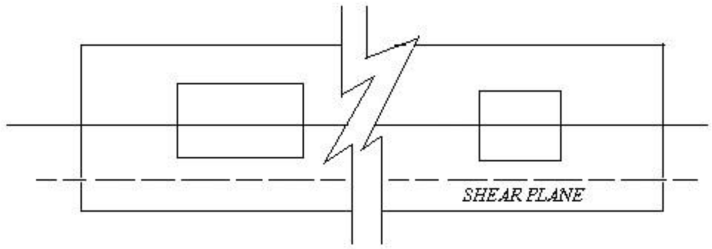
Critical load case for maximum shear force along the length of footing : 18

Critical Shear force,V_U	For the critical load case:	12.632kip
Point of occurance of V_U	Critical one-way shear position:	12.396ft

From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times F_c'} =$ 72.827kip

0.75 x V_c = 54.620kip

Since 0.75 * V_c > V_U hence, OK



Shear Plane Parallel to Foundation Length

Critical load case for maximum shear force along the width of footing :

Critical Shear force, V_u For the critical load case: 0.000kip
Point of occurance of V_u Critical one-way shear position: 3.134ft

From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times F_c'}$ = 0.000kip

0.75 x V_c = 0.000kip

Since 0.75 * V_c > V_u hence, OK

Design of flexure

Bottom Reinforcement

Critical load case : 23

Required Effective Depth : 1.641ft

β_1, from ACI Cl.10.2.7.3 = 0.8500

From ACI Cl. 10.3.2, ρ_{bal} 0.02851 $0.85 \times \beta_1 \times F_c' \times \frac{87}{[f_y \times (87 + F_y)]}$ =

From ACI Cl. 10.3.3, ρ_{max} 0.02138 $0.75 \times \rho_{bal}$ =

From ACI Cl. 7.12.2, ρ_{min} 0.00180 $\max\left(0.0018 \cdot \frac{60ksi}{F_y}, 0.0014\right)$ =

Modular Ratio,m17.6471 $\frac{F_y}{(0.85 \times F_c')}$ =

Ultimate Moment : 12.785kip-ft
Point of occurrence of the ultimate moment along the length of footing : 8.019ft

Nominal Moment Capacity : 14.205kip-ft
Required ρ (based on effective depth) : 0.0022 ρ x d_{eff} / Depth (based on gross depth) : 0.0018 Area of main steel required, A_s = ρ * W * 1.210in2 deff :

Top Reinforcement

Critical load case : 18

Required Effective Depth : 1.656ft

β_1, from ACI Cl.10.2.7.3 = 0.8500

From ACI Cl. 10.3.2, ρ_{bal} 0.02851 $0.85 \times \beta_1 \times F_c{}' \times \frac{87}{\left[f_y \times (87 + F_y)\right]} =$

From ACI Cl. 10.3.3, ρ_{max} 0.02138 $0.75 \times \rho_{bal} =$

From ACI Cl. 7.12.2, ρ_{min} 0.00180 $\max\left(0.0018 \cdot \frac{60ksi}{F_y}, 0.0014\right) =$

Modular Ratio,m17.6471 $\frac{F_y}{\left(0.85 \times F_c{}'\right)} =$

Ultimate Moment : 53.143kip-ft

Point of occurrence of the ultimate moment along the length of footing : 8.189ft

Nominal Moment Capacity : 59.048kip-ft

Required ρ (based on effective depth): 0.0022 ρ x d_{eff} / Depth (based on gross depth) : 0.0018

Area of main steel required, A_s = ρ * W * deff : 1.210in2

Distribution Reinforcement

Critical load case : 212

Critical Moment for distribution steel : 15.9307 kip-f

Nominal moment Capacity : 17.7008 kip-f

Point of occurance of the critical moment along length: 1.4200 ft

Required ρ (based on effective depth): 0.0022 ρ x d_{eff} / Depth (based on gross depth) : 0.0018

Area of distribution steel required, A_s = ρ * L * deff : 8.402 in2

Top surface disribution reinforcement

Moment at column face : 9.0473 kip-f

Provided Area for distribution steel along Z(Top reinforcement): 8.402 in2

Provided Reinforcement

Main bar no. for top Reinforcement: #6

Spacing of top reinforcement bar : 11.000 in

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 11in o.c.

in

Main bar no. for bottom Reinforcement: #7

Spacing of bottom reinforcement bar : 11.000

Based on spacing reinforcement increment; provided reinforcement is

#7 @ 11in o.c.

Distribution bar no. (Bottom):	#7	
Spacing of distribution bars (Bottom):	13.464	in

Based on spacing reinforcement increment; provided reinforcement is

#7 @ 13in o.c.

Distribution bar no.(Top):	#6	
Spacing of distribution bars(Top) :	9.921	in

Based on spacing reinforcement increment; provided reinforcement is

#6 @ 9in o.c.

Print Calculation Sheet

Combined Footing Design Optimization

When considering the optimization of a combined footing through design analysis in STAAD.foundation, several similarities in feasibility and reliability that were observed for and isolated footing are also noted for the isolated design. These parameters that generally need constraining include footing thickness, rebar spacing and sizing, and the width of the footing. More specific to a combined footing would be consideration to the minimum overhang, which is highlighted to the right in Figure 2. The default for this was five feet, which was far too larger for the testing case. In order to obtain a more reasonable result, the minimum was lowered to one foot and an over more feasible footing size was generated by the design analysis.

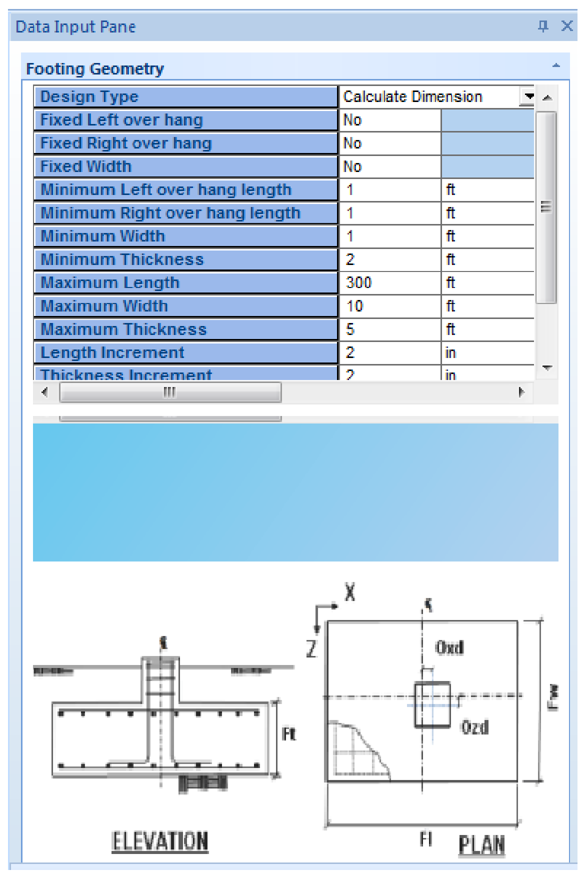


FIGURE 2: FOOTING GEOMETRY INPUT PANE

Another notable issue when reviewing the design sheet was the designation of an alpha value when calculating the factored allowable shear. The designated footing was designed for an exterior column and the designated value was chosen for an interior column. Although this was a negligible factor in this case, for more extreme shears in place, using a factor of 40 instead of 20 (in this case) could provide an adequate design where in reality the footing may fail.

Additionally, when verifying the designated governing loading cases for analysis there are some discrepancies between the hand calculations and STAAD.Foundation output. Although the calculated shears are similar to the program output, the calculation sheet references a critical load case that is not defined within the project. This is shown below in Figure 3, which in this case was load case 18. Although this is a technical issue opposed to a design concern, it complicates the designer's ability to address and pinpoint flaws within the program.

Top Reinforcement

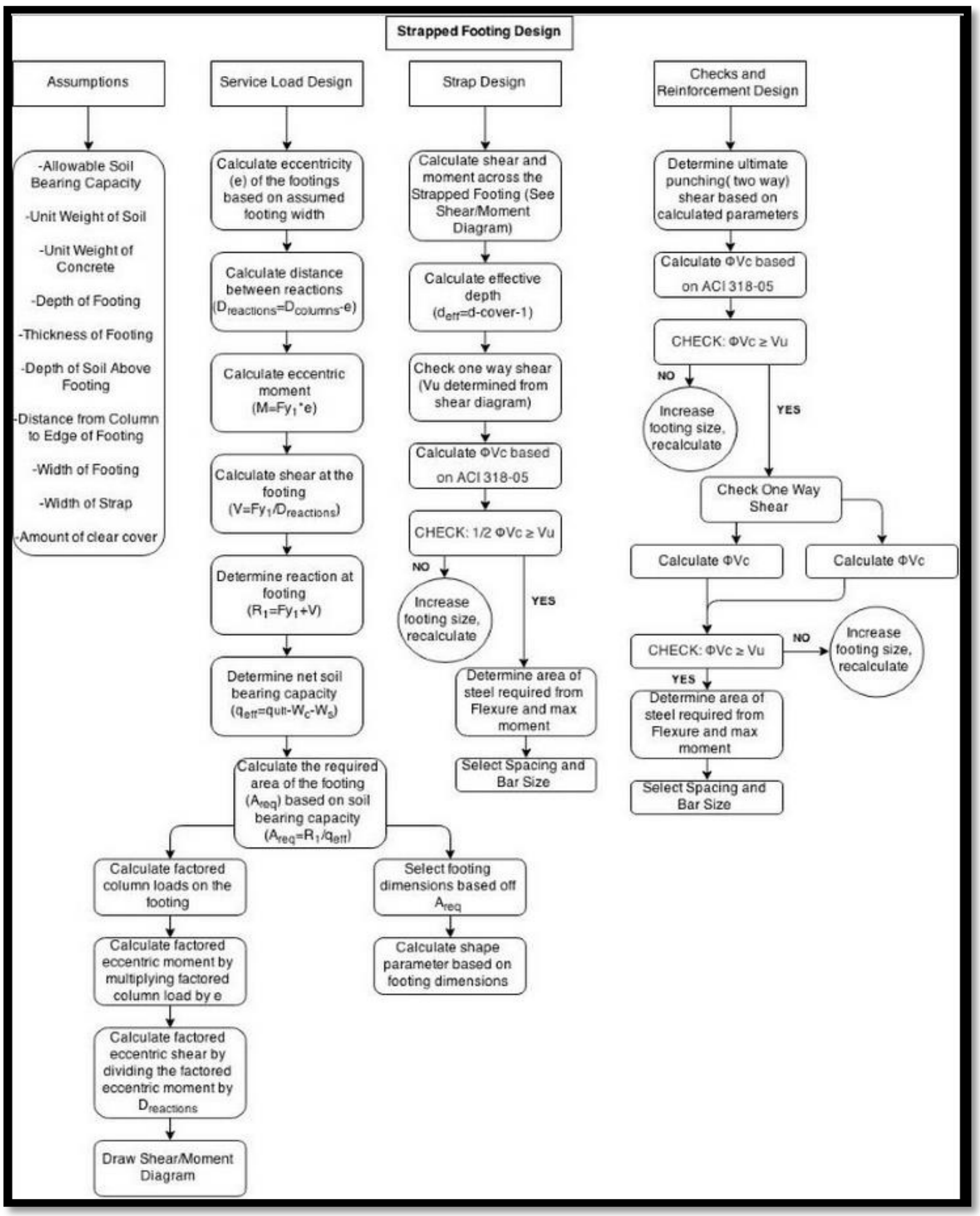
Critical load case :	18		
Required Effective Depth :	1.656ft		
β_1, from ACI Cl.10.2.7.3		=	0.8500
From ACI Cl. 10.3.2, ρ_{bal}	$0.85 \times \beta_1 \times F_c{}' \times \frac{87}{\left[f_y \times \left(87 + F_y\right)\right]}$	=	0.02851

FIGURE 3: COMBINED FOOTING CALCULATION SHEET

Appendix F…………………………………………………………………………Strap Footing Design Verification

Several steps were taken in order to verify the automated calculations run within STAAD.foundation. This process was aided by the use of an excel spreadsheet in order to iterate several designs quickly. The functionality and accuracy of the spreadsheet was verified against hand calculations. When designing these footings, checks against sliding, overturning, and direct and punching shear were considered. Examples of this procedure can be seen below in the following sections.

Strap Footing Design Procedure



Excel Spreadsheet – Strap Footing

Strap Footing Design			
DATE:	2/6/2015	DESIGN #:	1
PASS:	YES	CHECK:	DH

Footing	Node	642
Length		4 ft
Width		4 ft
Thickness		2 ft
Depth to base		3 ft
Size		# 7
Number		4
Spacing		12 in

Footing	Node	643
Length		3 ft
Width		3 ft
Thickness		2 ft
Depth to base		3 ft
Size		# 7
Number		4
Spacing		8 in

Strap Design	
Width	3 ft
Thickness	2 ft
Size	# 9
Number	3
Spacing	12 in

Strap Footing Design

DATE:	2/6/2015	**DESIGN #:**	1
PASS:	**YES**	**CHECK:**	DH

CHECKS:

1.0 Node 1

Check 1: **OKAY!**

1.1 Node 2

Check 1: **OKAY!**

1.2 Strap

Check 1: **OKAY!**
Check 2: **OKAY!**

1.3 Node 1 Reinforcement

Check 1: **OKAY!**
Check 2: **OKAY!**
Check 3: **OKAY!**

1.4 Node 2 Reinforcement

Check 1: **OKAY!**
Check 2: **OKAY!**
Check 3: **OKAY!**

Strap Footing Design

DATE:	2/6/2015	**DESIGN #:**	1
PASS:	**YES**	**CHECK:**	DH

Data

1.0 Loads

Nodes: 642 **&** 643

Load 1	23.887
Load 2	23.887

1.1 Material Properties

f'c	4000	psi	Concrete Compressive Strength
f_y	60	ksi	Steel Yield Strength
Wc	150	pcf	Density of Concrete
γ	120	pcf	Unit Weight of Soil
μ	0.5		Coefficient of Friction
q_{ult}	4000	psf	

1.2 Initial Assumptions & Structure Information

b	4	ft	Assumed Width of Footing
d	3	ft	Depth to Base of Footing
t	2	ft	Thickness of Footing
$D_{EdgeFooting}$	1	ft	Distance from Column to Footing Edge
D_{nodes}	150.5	in	Distance Between Nodes
$D_{Reactions}$	138.5	in	Distance Between Reactions
ColWidth	10	in	Width of Column
e	1	ft	Eccentricity

Strap Footing Design

DATE:	2/6/2015		**DESIGN #:**	1
PASS:	**YES**		**CHECK:**	DH

1.0 Node 1

M	23.887	ft-kip	Moment
V	2.07	kip	Shear
R_1	25.96	kip	Reaction at Node 1
q_{eff}	3580	lb	Net Soil Bearing Capacity
q_{eff}	3.58	kip	Net Soil Bearing Capacity
A_{Reqd}	7.25	ft^2	Required Area of Footing
Side 1	4	ft	Length of Side 1
Side 2	4	ft	Length of Side 2
A_{Ftng}	16	ft^2	Area of Footing
CHECK:	**OKAY!**		

2.0 Factored Node 1

Fy_1	28.66	kip
M	28.66	
V	2.48	

Strap Footing Design

DATE:	2/6/2015		**DESIGN #:**	1
PASS:	**YES**		**CHECK:**	DH

1.0 Node 2

M	23.887	ft-kip	Moment
V	2.07	kip	Shear
R_2	25.96	kip	Reaction at Node 1
q_{eff}	3580	lb	Net Soil Bearing Capacity
q_{eff}	3.58	kip	Net Soil Bearing Capacity
A_{Reqd}	7.25	ft^2	Required Area of Footing
Side 1	3	ft	Length of Side 1
Side 2	3	ft	Length of Side 2
A_{Ftng}	9	ft^2	Area of Footing
CHECK:	**OKAY!**		

2.0 Factored Node 2

Fy_2	28.66	kip
M	28.66	
V	2.48	

Strap Footing Design

DATE:	2/6/2015	**DESIGN #:**	1
PASS:	**YES**	**CHECK:**	DH

1.0 Factored Upward Pressures

qn1	7.79
qn2	8.73

1.2 Diagram & Shear Forces

+P1	14.28
-P1	-14.39
P2	2.48
P3	2.48
+P4	15.57
-P4	-13.09

1.3 X-Distances

X1	1.83	ft
X2	1.84	ft
X3	0.33	ft
X4	8.875	ft
X5	1.5	ft
X6	1.5	ft

1.4 Moments

Mu	13.062675
Mu	-26.176703
Mu	-25.766916
Mu	-3.7253372
Mu	9.8178157

Strap Footing Design

DATE:	2/6/2015	**DESIGN #**	1
PASS:	**YES**	**CHECK:**	DH

1.0 Initial Data

$Strap_{Width}$	3	ft	
$Strap_{Depth}$	2	ft	
$Strap_{Cover}$	3	in	Clear Cover
$D_{EffStrap}$	20.361	in	Effective Depth

1.1 One Way Shear

Vu	15.57		
ϕ	0.75		
ϕVc	34769.05	lb	
ϕVc	34.77	kip	
1/2 ϕVc	17.38	kip	
CHECK:	**OKAY!**		What is the check here?

1.2 Flexure

ϕ	0.9		
Mu	26.18		
a	2	in	Assumed
T	18.03	kip	
a	0.15	in	
a_{Used}	1	in	
T	17.57	kip	
As	0.29	in^2	
ρ	0.0004		
ρ_{min}	0.003333		
As_{min}	2.44332	in^2	
As	2.44332	in^2	
Size	# 9		Size of Steel Reinforcing
n	2.44		Number of Bars used to achieve Asmin
n_{used}	3		Number of Bars used
S_{max}	15	in	Maximum Allowable Spacing
Spacing	12	in	
Check:	**OKAY!**		Spacing<Smax

		Strap Footing Design		
DATE:	2/6/2015		DESIGN #:	1
PASS:	YES		CHECK:	DH

1.0 Node 642

Cover	3	in	
d_{eff}	20	in	
c+d	30	in	
b_o	120	in	
q_n	1.95	k/ft²	
F_y	28.66	kip	

1.1 Two Way Shear

α	20		Select Column Location
Vu	16.50	kip	
ϕVc	809543.08	lb	
ϕVc	809.54308	kip	
	CHECK:	OKAY!	

1.2 One Way Shear

Vu	14.39	kip
ϕ	0.75	
ϕVc	227683.99	lb
ϕVc	227.68	kip
	CHECK:	OKAY!

1.3 Flexure - Longtitudinal

ϕ	0.9	
Mu	26.18	kip-ft
Rn	0.018	k/in²
Rn	18.18	lb/in²

1.4 Reinforcement

β	1		Shape Paremeter
ρ	0.0003		
ρ_b	0.0335		
ρ_{max}	0.0251531		
ρ_{min}	0.0018		
ρ_{used}	0.0018		
As_{min}	1.728		
Size	#7		Size of Steel Reinforcing
n	2.88		Number of Bars used to achieve Asmin
n_{used}	4		Number of Bars used
A_{steel}	2.4	in²	Area of Steel
S_{max}	14.0	in	
Spacing	12	in	
	Check:	OKAY!	

		Strap Footing Design			
DATE:	2/6/2015			DESIGN #:	1
PASS:	YES			CHECK:	DH

1.0 Node 643

Cover	3	in	
d_{eff}	20	in	
c+d	30	in	
b_o	120	in	
q_n	2.91	k/ft^2	
F_y	28.66	kip	

1.1 Two Way Shear

α	20		Select Column Location
Vu	10.48	kip	
ϕVc	809543.08	kip	
ϕVc	809.54308	In	
CHECK:	OKAY!		

1.2 One Way Shear

Vu	15.57	kip
ϕ	0.75	
ϕVc	227683.99	lb
ϕVc	227.68	kip
CHECK:	OKAY!	

1.3 Flexure - Longtitudinal

ϕ	0.9	
Mu	26.18	kip-ft
Rn	0.018	k/in^2
Rn	18.18	lb/in^2

1.4 Reinforcement

β	1		Shape Paremeter
ρ	0.0003		
ρ_b	0.03		
ρ_{max}	0.0251531		
ρ_{min}	0.0018		
ρ_{used}	0.0018		
As_{min}	1.296		
Size	#7		Size of Steel Reinforcing
n	2.16		Number of Bars used to achieve Asmin
n_{used}	4		Number of Bars used
A_{steel}	2.4	in^2	Area of Steel
S_{max}	10	in	
Spacing	8	in	
Check:	OKAY!		

Hand Calculations – Strap Footing

Stantec

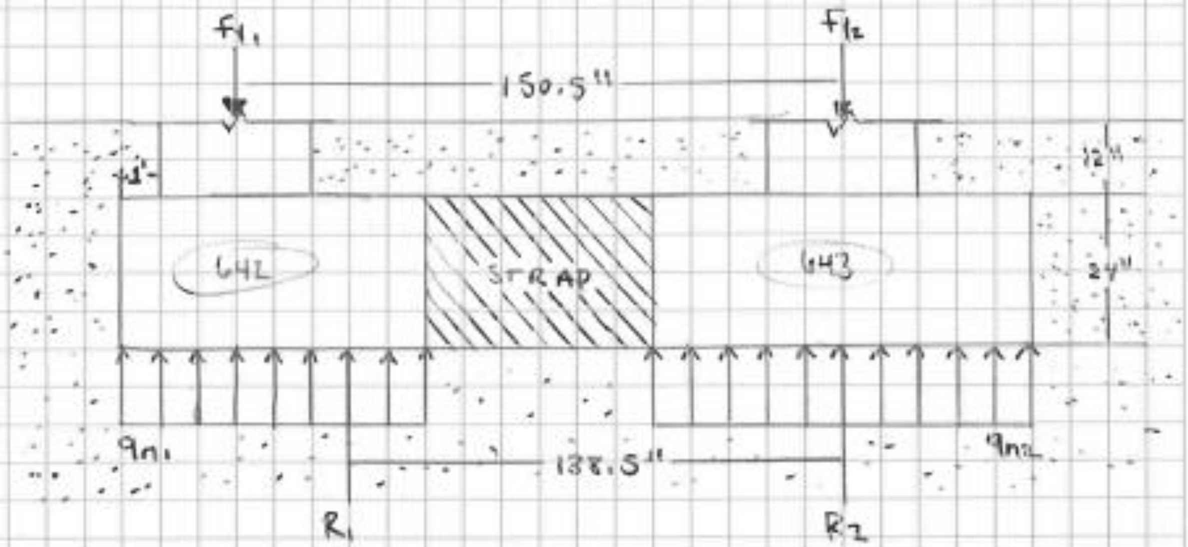
- STRAPPED FOOTING DESIGN FOR NODES 642 & 643

LOADING @ 642:

F_{y_1} = 23.897 k (case 212)
F_{x_1} = 5.42 k (case 212)
F_{z_1} = 3.134 k (case 211)

LOADING @ 643:

F_{y_2} = 23.897 k (case 212)
F_{x_2} = 5.41 k (case 212)
F_{z_2} = -3.134 k (case 210)



- ASSUME → Allowable soil bearing capacity q_a = 4000 lb/ft²
→ soil unit weight w_s = 120 lb/ft³
→ concrete unit weight w_c = 150 lb/ft³
→ depth of footing t = 24" = 2'
→ depth of soil above footing h_s = 12" = 1'
→ distance from column 642 edge to footing 1'

MBP FOUNDATION DESIGN - STRAPPED FOOTING
STAAD.fdn REFERENCE NODES
Designed by: DJH Checked by:

Stantec

- ASSUME FOOTING WIDTH, $b = 4'$ (642)

$c = 4/2 - 1 = 1' = 12''$

distance between R_1 & R_2 = 150.5'' - 12'' = 138.5''

- CALCULATE ECCENTRIC MOMENT:

$M = (23.887k)(1') = 23.887$ ft-kip

&

$V = \frac{23.887}{(138.5/12)} = 2.07^k$

- REACTION AT FOOTING 642:

$R_1 = 23.887 + 2.07 = 25.96$ k

- NET SOIL BEARING CAPACITY

$q_{eff} = q_a - w_c - w_s$

$= 4000 - 150\frac{lb}{ft^3}(2\ ft) - 120\frac{lb}{ft^3}(1\ ft) = 3580\ lb = 3.58^k$

- REQUIRED FOOTING AREA:

$A_{req} = \frac{R_1}{q_{eff}} = \frac{25.96}{3.58} = 7.25\ ft^2$

use 4' x 2' dimensions, $A = 8\ ft^2 > A_{req}$

- REACTION AT FOOTING 643:

$R_2 = 23.887 - 2.07 = 21.817$ K

Designed by: Checked by:

Stantec

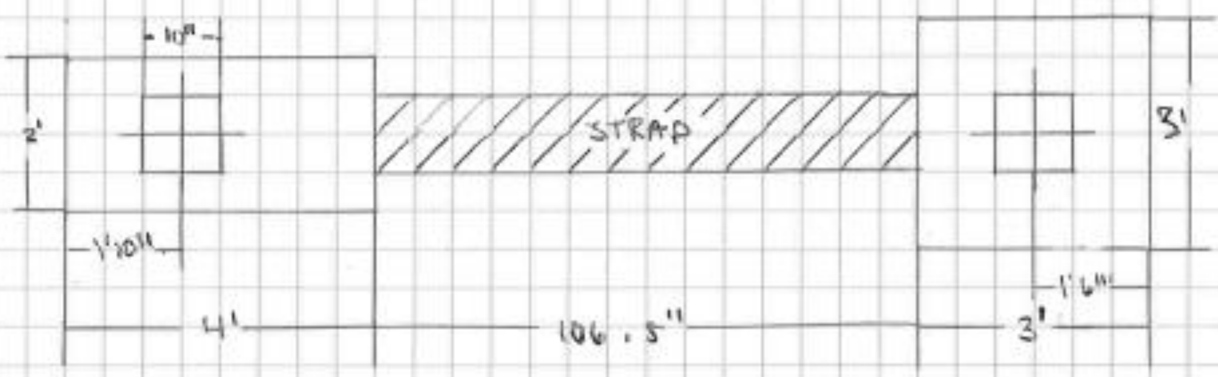
- REQUIRED FOOTING AREA

$A_{req} = \frac{21.817}{3.58} = 6.09\ ft^2$

(assume square footing) $bh = b^2$

* try $3' \times 3' \rightarrow A = 9\ ft^2 > A_{req}$

- MOMENT & SHEAR DIAGRAMS



- FACTORED COLUMN LOADS

$F_{y1} = 1.2(23.887) = 28.66^k$
$F_{y2} = 1.2(23.887) = 28.66^k$

- FACTORED ECCENTRIC MOMENT:

$M = 28.66\ k\ (1\ ft) = 28.66\ ft-k$

$V = 28.66/(138.5/12) = 2.5\ K$

Designed by: Checked by:

Stantec

- FACTORED UPWARD FOOTING PRESSURES

$q_{n1} = \frac{(28.66+2.5)}{4} = 7.79\ k/ft$

$q_{n2} = \frac{(28.66-2.5)}{3} = 8.72\ k/ft$

Shear:

$+P_1 = 7.79(1.83') = 14.26^k$

$-P_1 = 7.79(1.83) - 28.66 = -14.40$

$P_2 = 7.79(4') - 28.66 = 2.5$

$P_3 = 28.66 - 3(8.72) = 2.5$

$+P_4 = 7.79(1.83+2.17) - 28.66 + 8.72(1.5) = 15.58$

$-P_4 = 7.79(4) + 1.5(8.72) - 2(28.66) = -13.08$

Moment:

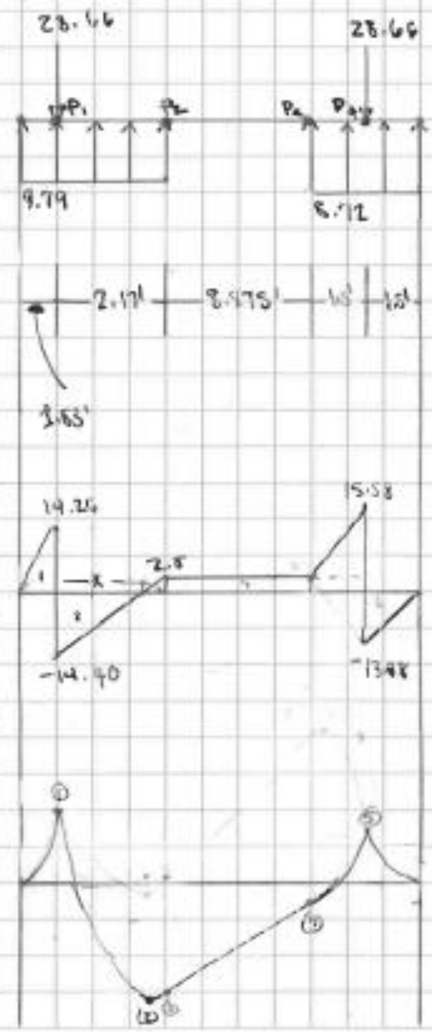
Moment 1 : 13.10

2 : -26.35 (MAX MOMENT)

3 : -25.9375

4 : -3.75

5 : 4.81



Designed by: Checked by:

Stantec

DESIGN STRAP:

b = 3'

d = 2' , w/ 3" clear cover

$d_{eff} = 24 - 3 - 1 = 20"$

CHECK ONE WAY SHEAR

$V_u = 15.58$ (from shear diagram)

$\phi V_c = \phi \sqrt{f'_c}\, bd = .75 \sqrt{4000}\,(20)(36) = 34.15^k$

$\frac{1}{2}\phi V_c = 17.07$ → no shear reinforcement needed in strap

CHECK FOR FLEXURE:

$M_u = 26.35$ k-ft , assume $a = 2$

$T = \frac{M_u}{\phi(d - a/2)} = \frac{26.35(12)}{.9(20 - 2/2)} = 18.49^k$

$a = \frac{T}{.85 f'_c b} = \frac{18.49}{.5(4)(36)} = .257"$ → use 1"

$T = \frac{26.35(12)}{.9(20 - 1/2)} = 18^k$

$A_s = \frac{T}{F_y} = \frac{18}{60} = .30$

$\rho = \frac{A_s}{bd} = \frac{.30}{20(36)} = .000417$

Designed by:

Checked by:

Stantec

$\rho_{min} = \frac{200}{F_y} = .0033 \rightarrow$ governs $\left[A_{s min} = \frac{200\ b_w d}{f_y},\ A_s = \rho b_w d \right]$

$A_s = \rho b d = .0033(20)(36) = 2.4\ in^2$, use 3#9, $A_1 = 3.0\ in^2$

DESIGN FOOTING 642 REINFORCEMENT: (4x4)

- 2' depth, $d_{eff} = 24 - 3 - 1 = 20''$

$b_o = 4(20+10) = 120''$, $c+d = 10 + 20 = 30''$

$q_n = \frac{7.79}{4} = 1.95\ k/ft^2$, $F_y = 28.66\ k$

TWO WAY SHEAR (PUNCHING)

$V_u = 28.66 - 1.95\left[(30/12)^2\right] = 16.47^k$

$\phi V_c = \left[\frac{\alpha d}{b_o} + 2\right]\sqrt{f'c}\ b_o d =$

ϕV_c

ONE WAY SHEAR (DIRECT)

$V_u = 14.40^k$

$\phi V_c = 2\phi\sqrt{f'c}\ b_o d = 2(.75)\sqrt{4000}(120)(20) = 228^k$ ✓

FLEXURE – longitudinal

$M_u = 26.35\ k\text{-}ft$

$R_n = \frac{M_u}{\phi b d^2} = \frac{26.35(12)}{.9(48)(20^2)} = .018\ k/in^2 = 18\ lb/in^2$

Designed by: Checked by:

Stantec

$\rho = \frac{.85 f'c}{fy}\left[1 - \sqrt{1 - \frac{2Rn}{.85 f'c}}\right] = \frac{.85\ 4000}{60000}\left[1 - \sqrt{1 - \frac{2(18)}{.85(4000)}}\right] = .0003$

$\rho_b = .85\left[\frac{87000 \beta_1 f'c}{fy(87000 + fy)}\right] = .033$

$\rho_{max} = .2138$

$\rho_{min} = .0018 \leftarrow$ use

$As = \rho bd = .0018(20)(48) = 1.728\ in^2 \Rightarrow$ use 4#7

$s = \frac{L - 2(cover)}{n - 1} = \frac{48 - 6}{4 - 1} = 14'' \Rightarrow$ MAX

Designed by: Checked by:

STAAD.Foundation Output for Strap Foundation Design

Strap Footing Design

Strap Footing Design(ACI 318-05)

Design For Strap Footing 1

Strap Footing 1

Input Parameters

Footing Geometry

Left Footing Geometry

Footing Thickness : 2.000ft
Footing Length : 4.000ft
Footing Width : 4.000ft
Max Footing Thickness : 120.000in
Max Footing Length : 240.000in
Max Footing Width : 240.000in
Eccentricity along X (Oxd) : 0.000in
Eccentricity along Z (Ozd) : 0.000in

Right Footing Geometry

Footing Thickness : 2.000ft
Footing Length : 3.000ft
Footing Width : 3.000ft
Max Footing Thickness : 120.000in
Max Footing Length : 240.000in
Max Footing Width : 240.000in
Eccentricity along X (Oxd) : 0.000in
Eccentricity along Z (Ozd) : 0.000in

Concrete and Rebar Properties

Unit Weight of Concrete : 0.150kip/ft3
Strength of Concrete : 4.000ksi
Yield Strength of Steel : 60.000ksi
Minimum Bar Size : #7
Maximum Bar Size : #14
Minimum Bar Spacing : 2.000in
Maximum Bar Spacing : 18.000in
Pedestal Clear Cover (P, CL) : 2.000in
Footing Clear Cover (F, CL) : 2.000in

Soil Properties

Unit Weight : 120.000lb/ft3
Soil Bearing Capacity : 4.000kip/ft2
Soil Bearing Capacity Type: Net Bearing Capacity
Soil Surcharge : 0.000kip/in2
Depth of Soil above Footing : 12.000in
Depth of Water Table : 120.000ft

Other Parameters

Footing Plan Increment : 1.000in
Footing Thickness Increment : 1.000in
Beam Depth : 24.000in
Beam Width : 36.000in
Coefficient of Friction : 0.500
Factor of Safety Against Sliding : 1.500
Factor of Safety Against Overturning : 1.500

Load Combination/s- Service Stress Level	
Load Combination Number	Load Combination Title
110	D + W N-S
111	D + W S-N
112	D + W E-W
113	D + W W-E
120	0.6 DL + W N-S
121	0.6 DL + W S-N
122	0.6 DL + W E-W
123	0.6 DL + W W-E
200	1.4 DL
210	1.2 DL + 1.6 W N-S
211	1.2 DL + 1.6 W S-N
212	1.2 DL + 1.6 W E-W
213	1.2 DL + 1.6 W W-E
220	0.9 DL + 1.6 W N-S
221	0.9 DL + 1.6 W S-N
222	0.9 DL + 1.6 W E-W
223	0.9 DL + 1.6 W W-E
Load Combination/s- Strength Level	
Load Combination Number	Load Combination Title
110	D + W N-S
111	D + W S-N
112	D + W E-W

113	D + W W-E
120	0.6 DL + W N-S
121	0.6 DL + W S-N
122	0.6 DL + W E-W
123	0.6 DL + W W-E
200	1.4 DL
210	1.2 DL + 1.6 W N-S
211	1.2 DL + 1.6 W S-N
212	1.2 DL + 1.6 W E-W
213	1.2 DL + 1.6 W W-E
220	0.9 DL + 1.6 W N-S
221	0.9 DL + 1.6 W S-N
222	0.9 DL + 1.6 W E-W
223	0.9 DL + 1.6 W W-E

Footing 642

Applied Loads - Service Stress Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000
122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000

Applied Loads - Strength Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	3.562	-0.063	1.896	0.000	0.000
111	13.701	-0.138	-1.968	0.000	0.000
112	17.087	-3.413	-0.057	0.000	0.000
113	0.176	3.212	-0.014	0.000	0.000
120	0.109	-0.023	1.911	0.000	0.000
121	10.248	-0.098	-1.953	0.000	0.000

122	13.635	-3.373	-0.043	0.000	0.000
123	-3.277	3.252	-0.000	0.000	0.000
200	12.084	-0.141	-0.050	0.000	0.000
210	2.247	-0.060	3.049	0.000	0.000
211	18.469	-0.181	-3.134	0.000	0.000
212	23.887	-5.420	-0.077	0.000	0.000
213	-3.171	5.179	-0.009	0.000	0.000
220	-0.343	-0.030	3.059	0.000	0.000
221	15.879	-0.151	-3.123	0.000	0.000
222	21.298	-5.390	-0.066	0.000	0.000
223	-5.761	5.209	0.002	0.000	0.000

Footing 643

Applied Loads - Service Stress Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	13.701	-0.138	1.968	0.000	0.000
111	3.562	-0.063	-1.897	0.000	0.000
112	17.087	-3.413	0.057	0.000	0.000
113	0.176	3.212	0.014	0.000	0.000
120	10.248	-0.098	1.953	0.000	0.000
121	0.109	-0.023	-1.911	0.000	0.000
122	13.635	-3.373	0.043	0.000	0.000
123	-3.277	3.252	0.000	0.000	0.000
200	12.084	-0.141	0.050	0.000	0.000
210	18.469	-0.181	3.134	0.000	0.000
211	2.247	-0.060	-3.049	0.000	0.000
212	23.887	-5.420	0.077	0.000	0.000
213	-3.172	5.179	0.009	0.000	0.000
220	15.879	-0.151	3.123	0.000	0.000
221	-0.343	-0.030	-3.059	0.000	0.000
222	21.298	-5.390	0.066	0.000	0.000
223	-5.761	5.209	-0.002	0.000	0.000

Applied Loads - Strength Level					
LC	Axial (kip)	Shear X (kip)	Shear Z (kip)	Moment X (kip-ft)	Moment Z (kip-ft)
110	13.701	-0.138	1.968	0.000	0.000
111	3.562	-0.063	-1.897	0.000	0.000
112	17.087	-3.413	0.057	0.000	0.000
113	0.176	3.212	0.014	0.000	0.000
120	10.248	-0.098	1.953	0.000	0.000
121	0.109	-0.023	-1.911	0.000	0.000
122	13.635	-3.373	0.043	0.000	0.000
123	-3.277	3.252	0.000	0.000	0.000
200	12.084	-0.141	0.050	0.000	0.000

210	18.469	-0.181	3.134	0.000	0.000
211	2.247	-0.060	-3.049	0.000	0.000
212	23.887	-5.420	0.077	0.000	0.000
213	-3.172	5.179	0.009	0.000	0.000
220	15.879	-0.151	3.123	0.000	0.000
221	-0.343	-0.030	-3.059	0.000	0.000
222	21.298	-5.390	0.066	0.000	0.000
223	-5.761	5.209	-0.002	0.000	0.000

Footing 642

Design Calculations

Footing Size

Initial Length (L_o) = 4.00ft

Initial Width (W_o) = 4.00ft

Gross Soil Bearing Capacity = 4.24kip/ft^2

Reduction of force due to buoyancy = -0.00kip

Effect due to adhesion = 0.00kip

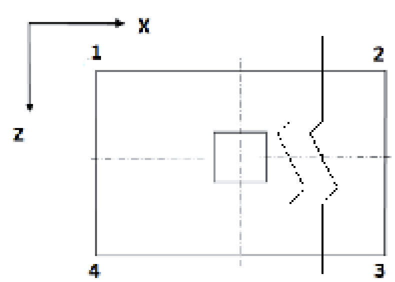
Min. area required from bearing pressure, A_{min} = P / q_{max} = 6.766ft^2

Area from initial length and width, A_o = $L_o * W_o$ = 16.00ft^2

Final Footing Size

Length (L_2) =	8.67	ft	Governing Load Case :	# 223
Width (W_2) =	8.33	ft	Governing Load Case :	# 223
Depth (D_2) =	2.00	ft	Governing Load Case :	# 223
Area (A_2) =	72.22	ft^2		

Pressures at Four Corners



Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)	Area of footing in uplift (A_u) (ft^2)

212	**0.7309**	0.5270	0.5239	0.7278	0.0000
211	0.6184	**0.6116**	0.4878	0.4946	0.0000
212	0.7309	0.5270	**0.5239**	0.7278	0.0000
212	0.7309	0.5270	0.5239	**0.7278**	0.0000

If A_u is zero, there is no uplift and no pressure adjustment is necessary.

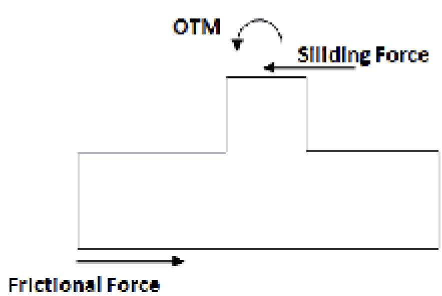
Otherwise, to account for uplift, areas of negative pressure will be set to zero and the pressure will be redistributed to remaining corners.

Summary of Adjusted Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)
212	**0.7309**	0.5270	0.5239	0.7278
211	0.6184	**0.6116**	0.4878	0.4946
212	0.7309	0.5270	**0.5239**	0.7278
212	0.7309	0.5270	0.5239	**0.7278**

Adjust footing size if necessary.

Check for stability against overturning and sliding



ELEVATION

-	Factor of safety against sliding			Factor of safety against overturning	
Load Case No.	Along X-Direction	Along Z-Direction	Resultant	About X-Direction	About Z-Direction
110	200.831	6.651	6.648	27.714	870.266
111	127.931	8.988	8.965	37.448	554.370
112	5.678	341.396	5.677	1422.484	24.603

113	3.400	760.824	3.400	3170.098	14.735
120	481.708	5.698	5.698	23.744	2087.403
121	162.797	8.169	8.159	34.038	705.455
122	5.233	414.963	5.233	1729.013	22.678
123	2.827	69682.422	2.827	290343.423	12.252
200	119.915	339.008	113.051	1412.533	519.632
210	198.321	3.922	3.921	16.342	859.390
211	110.897	6.403	6.393	26.681	480.556
212	4.202	297.385	4.202	1239.106	18.209
213	1.786	1057.520	1.786	4406.335	7.737
220	353.822	3.485	3.485	14.521	1533.230
221	124.488	6.011	6.004	25.045	539.448
222	3.985	325.865	3.985	1357.770	17.270
223	1.527	4137.287	1.527	17238.697	6.616

Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - X Direction

Critical Load Case for Sliding along X-Direction : 223
Governing Disturbing Force : 5.209kip
Governing Restoring Force : 7.953kip
Minimum Sliding Ratio for the Critical Load Case : 1.527
Critical Load Case for Overturning about X-Direction : 220
Governing Overturning Moment : 6.119kip-ft
Governing Resisting Moment : 88.849kip-ft
Minimum Overturning Ratio for the Critical Load Case : 14.521

Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - Z Direction

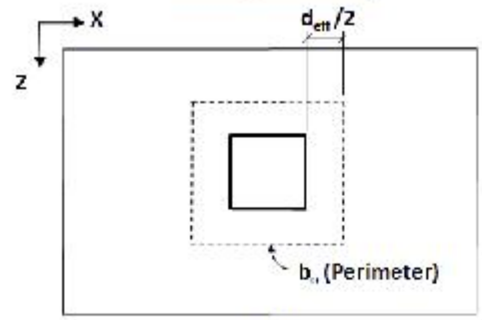
Critical Load Case for Sliding along Z-Direction : 220
Governing Disturbing Force : 3.059kip
Governing Restoring Force : 10.662kip
Minimum Sliding Ratio for the Critical Load Case : 3.485
Critical Load Case for Overturning about Z-Direction : 223
Governing Overturning Moment : -10.418kip-ft
Governing Resisting Moment : 68.925kip-ft
Minimum Overturning Ratio for the Critical Load Case : 6.616

Critical Load Case And The Governing Factor Of Safety For Sliding Along Resultant Direction

Critical Load Case for Sliding along Resultant Direction : 223
Governing Disturbing Force : 5.209kip
Governing Restoring Force : 7.953kip
Minimum Sliding Ratio for the Critical Load Case : 1.527

Shear Calculation

Punching Shear Check



PLAN

Total Footing Depth, D = 2.00ft

Calculated Effective Depth, d_{eff} = $D - C_{cover} - 1.0$ = 1.79ft

For rectangular pier, β_c = B_{col} / D_{col} = 1.00

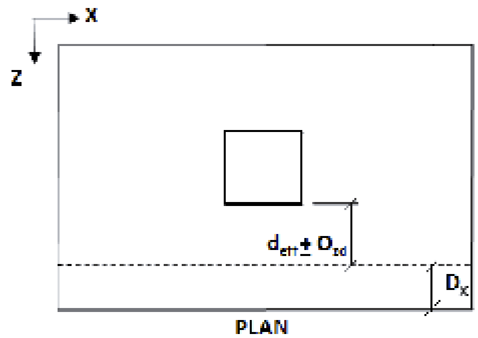
Effective depth, d_{eff} increased until $0.75*V_c \geq$ Punching Shear Force

Punching Shear Force, Vu = 19.18kip, Load Case # 212

From ACI Cl.11.12.2.1, b_o for pier=	$2 \times (B_{col} + D_{col} + 2 \times d_{eff})$ =	15.17ft
Equation 11-33, V_{c1} =	$\left(2 + \frac{4}{\beta_c}\right) \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'}$ =	1484.88kip
Equation 11-34, V_{c2} =	$\left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \lambda \times \sqrt{f'_c} \times b_o \times d$ =	1664.37kip
Equation 11-35, V_{c3} =	$4 \times b_o \times d_{eff} \times \sqrt{1000 \times F_c'}$ =	989.92kip
Punching shear strength, V_c =	0.75 * minimum of (V_{c1}, V_{c2}, V_{c3}) =	742.44kip

$0.75 * V_c > V_u$ hence, OK

One-Way Shear Check
Along X Direction



From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times f_c'} =$ 285.55kip

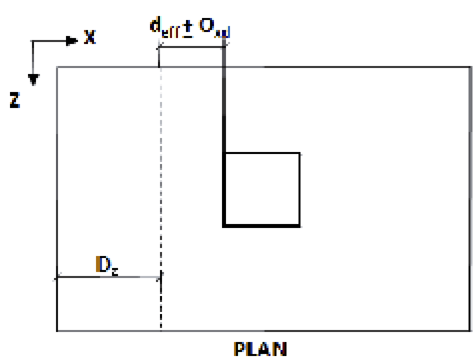
Distance along Z to design for shear, D_z = $0.5 \times (L - B_{col}) + d_{eff} + O_{zd} =$ 1.58ft

Check that $0.75 * V_c > V_{ux}$ where V_{ux} is the shear force for the critical load cases at a distance d_{eff} from the face of the pier caused by bending about the X axis.

From above calculations,	$0.75 * V_c$ =	214.17	kip
Critical load case for V_{ux} is # 212		$V_{ux} = V_{ux}\|_{x=D_z} =$	3.96 kip

$0.75 * V_c > V_{ux}$ hence, OK

Along Z Direction



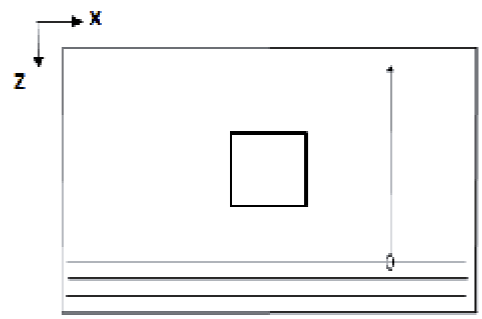
From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times f_c'} =$ 285.55 kip

Distance along X to design for shear, D_x = $0.5 \times (L \pm B_{col}) + d_{eff} + O_{xd} =$ 1.38 ft

Check that **$0.75 * V_c > V_{uz}$** where V_{uz} is the shear force for the critical load cases at a distance d_{eff} from the face of the pier caused by bending about the Z axis.

From above calculations,	$0.75 * V_c =$	203.97	kip
Critical load case for V_{uz} is # 212	$V_{uz} = V_{uz}\|_{z=D_z} =$	5.42	kip
		$0.75 * V_c > V_{uz}$ hence, OK	

Design for Flexure about Z axis



PLAN

Calculate the flexural reinforcement along the X direction of the footing. Find the area of steel required, A, as per Section 3.8 of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Factor β_1 from ACI Cl.10.2.7.3	for $F_c' \le 4$ ksi,	0.85	
From ACI Cl. 10.3.2, $\rho_{bal} =$	$0.85 \times \beta_1 \times F_c' \times \frac{87}{F_y \times (87 + F_y)} =$	0.02851	
From ACI Cl. 10.3.3, $\rho_{max} =$	$0.75 \times \rho_{bal} =$	0.02138	
From ACI Cl. 7.12.2, $\rho_{min} =$		0.00174	
From Ref. 1, Eq. 3.8.4a, constant m =	$\frac{F_y}{(0.85 \times F_c')} =$	17.65	

Calculate reinforcement ratio ρ for critical load case

Design for flexure about Z axis is performed at the face of the pier at a distance, D_x =	$0.5 \times L - 0.5 \times D_{c1} - C_{x1} =$	3.38	ft
Ultimate moment,	$M_{u\,x=D_x} =$	19.14	kip-ft
Nominal moment capacity, M_n =	$\frac{M_u}{\phi} =$	21.27	kip-ft
Required ρ =	$\frac{1}{m} \times \left[1 - \sqrt{1 - \frac{2 \times m \times M_n}{(F_y \times W \times d_{eff}^2)}}\right] =$	0.00009	

Since	$\rho_{min} \leq \rho \leq \rho_{max}$	OK	
Area of Steel Required, A_s =	$\rho \times W \times d_{eff}$	4.18	in2

Find suitable bar arrangement between minimum and maximum rebar sizes

Available development length for bars, D_L =	$0.5 \times (L - D_{col}) - C_{cover}$ =	38.50	in
Try bar size	Area of one bar =	0.60	in2
Number of bars required, N_{bar} =	$\frac{A_s}{A_{bar}}$ =	7	

Because the number of bars is rounded up, make sure new reinforcement ratio < $_{max}$

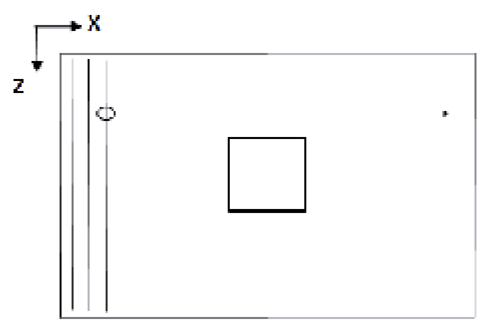
Total reinforcement area, A_{s_total} =	N_{bar} * (Area of one bar) =	4.20	in2
d_{eff} =	D - C_{cover} - 0.5 * (dia. of one bar) =	1.80	ft
Reinforcement ratio, ρ =	$\frac{A_{s\_total}}{(d_{eff} \times W)}$ =	0.00195	

From ACI Cl.7.6.1, minimum req'd clear distance between bars

C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 2.000in

Check to see if width is sufficient to accomodate bars

Design for Flexure about X axis



PLAN

Calculate the flexural reinforcement along the Z direction of the footing. Find the area of steel required, A, as per Section 3.8 of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Factor β_1 from ACI Cl.10.2.7.3	for F_c' $\leq$ 4 ksi,	0.85

From ACI Cl. 10.3.2, ρ_{bal} = $0.85 \cdot \beta_1 \times f_c' \times \frac{87}{[f_y \cdot (87 - f_y)]}$ = 0.02851

From ACI Cl. 10.3.3, ρ_{max} = $0.75 \times \rho_{bal}$ = 0.02138

From ACI Cl.7.12.2, ρ_{min} = 0.00173

From Ref. 1, Eq. 3.8.4a, constant m = $\frac{f_y}{(0.85 \times f_c')}$ = 17.65

Calculate reinforcement ratio ρ for critical load case

Design for flexure about X axis is performed at the face of the pier at a distance, D_z = $0.5 \times L \pm 0.5 \times B_{col}$ C_{col} = 3.17 ft

Ultimate moment, M_u ... D_z = 14.42 kip-ft

Nominal moment capacity, M_n = $\frac{M_u}{\phi}$ = 16.02 kip-ft

Required ρ = $\frac{1}{m} \times \left[1 - \sqrt{1 - 2 \cdot m \cdot \frac{M_n}{(f_y \times W \times d_{eff}^2)}}\right]$ = 0.00007

Since $\rho_{min} \le \rho \le \rho_{max}$ OK

Area of Steel Required, A_s = $\rho \times W \times d_{eff}$ = 4.37 in2

Find suitable bar arrangement between minimum and maximum rebar sizes

Available development length for bars, D_L = $0.5 \times (L - B_{col})$ C_{cover} = 36.00 in

Try bar size   Area of one bar = 0.79 in2

Number of bars required, N_{bar} = $\frac{A_s}{A_{bar}}$ = 6

Because the number of bars is rounded up, make sure new reinforcement ratio < $_{max}$

Total reinforcement area, A_{s_total} = N_{bar} * (Area of one bar) = 4.74 in2

d_{eff} = D - C_{cover} - 0.5 * (dia. of one bar) = 1.72 ft

Reinforcement ratio, ρ = $\frac{A_{s\_total}}{(d_{eff} \times W)}$ = 0.00219

From ACI Cl.7.6.1, minimum req'd clear distance between bars

C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 2.000in

Check to see if width is sufficient to accomodate bars

Footing 643

Design Calculations

Footing Size

Initial Length (L_o) = 3.00ft

Initial Width (W_o) = 3.00ft

Gross Soil Bearing Capacity = 4.24kip/ft^2

Reduction of force due to buoyancy = -0.00kip

Effect due to adhesion = 0.00kip

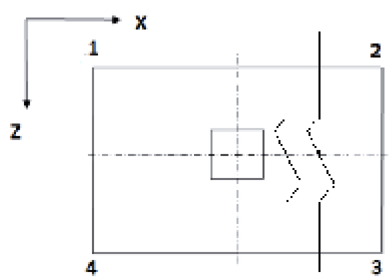
Min. area required from bearing pressure, A_{min} = P / q_{max} = 6.271ft^2

Area from initial length and width, A_o = $L_o * W_o$ = 9.00ft^2

Final Footing Size

Length (L_2) =	8.58	ft	Governing Load Case :	# 223
Width (W_2) =	8.33	ft	Governing Load Case :	# 223
Depth (D_2) =	2.00	ft	Governing Load Case :	# 223
Area (A_2) =	71.53	ft^2		

Pressures at Four Corners



Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)	Area of footing in uplift (A_u) (ft^2)
212	**0.7278**	0.5239	0.5270	0.7309	0.0000
212	0.7278	**0.5239**	0.5270	0.7309	0.0000
210	0.4946	0.4878	**0.6116**	0.6184	0.0000
212	0.7278	0.5239	0.5270	**0.7309**	0.0000

If A_u is zero, there is no uplift and no pressure adjustment is necessary.

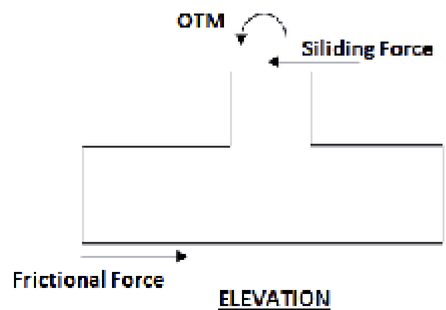
Otherwise, to account for uplift, areas of negative pressure will be set to zero and the pressure will be redistributed to remaining corners.

Summary of Adjusted Pressures at Four Corners

Load Case	Pressure at corner 1 (q_1) (kip/ft^2)	Pressure at corner 2 (q_2) (kip/ft^2)	Pressure at corner 3 (q_3) (kip/ft^2)	Pressure at corner 4 (q_4) (kip/ft^2)
212	**0.7278**	0.5239	0.5270	0.7309
212	0.7278	**0.5239**	0.5270	0.7309
210	0.4946	0.4878	**0.6116**	0.6184
212	0.7278	0.5239	0.5270	**0.7309**

Adjust footing size if necessary.

Check for stability against overturning and sliding



-	Factor of safety against sliding			Factor of safety against overturning	
Load Case No.	Along X-Direction	Along Z-Direction	Resultant	About X-Direction	About Z-Direction
110	127.210	8.935	8.913	37.227	545.942
111	199.282	6.596	6.593	27.484	855.252
112	5.647	339.563	5.646	1414.847	24.236
113	3.368	757.443	3.368	3156.013	14.454
120	161.769	8.116	8.106	33.816	694.258
121	477.541	5.644	5.643	23.516	2049.445
122	5.203	412.375	5.202	1718.229	22.328
123	2.795	N/A	2.795	517575.720	11.997
200	119.216	337.265	112.400	1405.271	511.634
210	110.347	6.370	6.360	26.542	473.573
211	196.729	3.888	3.887	16.199	844.294
212	4.183	295.971	4.182	1233.211	17.952

213	1.765	1058.048	1.765	4408.533	7.577
220	123.823	5.977	5.970	24.905	531.406
221	350.729	3.451	3.451	14.379	1505.214
222	3.966	324.161	3.966	1350.669	17.021
223	1.507	3896.915	1.507	16237.147	6.466

Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - X Direction

Critical Load Case for Sliding along X-Direction : 223
Governing Disturbing Force : 5.209kip
Governing Restoring Force : 7.849kip
Minimum Sliding Ratio for the Critical Load Case : 1.507
Critical Load Case for Overturning about X-Direction : 221
Governing Overturning Moment : -6.119kip-ft
Governing Resisting Moment : 87.981kip-ft
Minimum Overturning Ratio for the Critical Load Case : 14.379

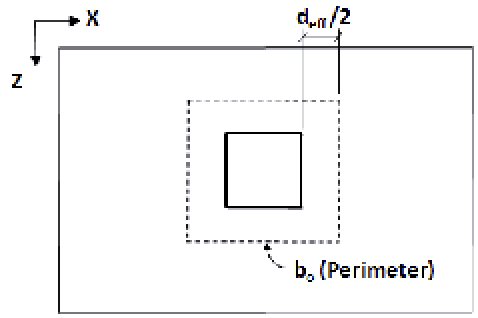
Critical Load Case And The Governing Factor Of Safety For Overturning And Sliding - Z Direction

Critical Load Case for Sliding along Z-Direction : 221
Governing Disturbing Force : -3.059kip
Governing Restoring Force : 10.558kip
Minimum Sliding Ratio for the Critical Load Case : 3.451
Critical Load Case for Overturning about Z-Direction : 223
Governing Overturning Moment : -10.419kip-ft
Governing Resisting Moment : 67.367kip-ft
Minimum Overturning Ratio for the Critical Load Case : 6.466

Critical Load Case And The Governing Factor Of Safety For Sliding Along Resultant Direction

Critical Load Case for Sliding along Resultant Direction : 223
Governing Disturbing Force : 5.209kip
Governing Restoring Force : 7.849kip
Minimum Sliding Ratio for the Critical Load Case : 1.507

Shear Calculation
Punching Shear Check



PLAN

Total Footing Depth, D = 2.00ft

Calculated Effective Depth, d_{eff} = D - C_{cover} - 1.0 = 1.79ft

For rectangular pier, β_c = B_{col} / D_{col} = 1.00

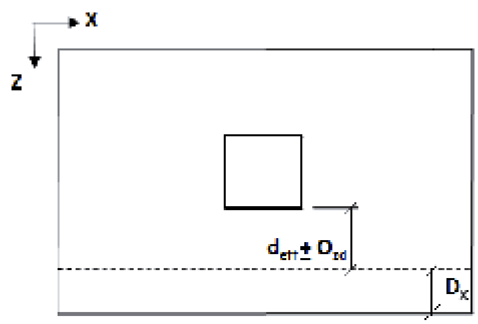
Effective depth, d_{eff} increased until 0.75*V_c ≥ Punching Shear Force

Punching Shear Force, Vu = 19.18kip, Load Case # 212

From ACI Cl.11.12.2.1, b_o for pier=	$2 \times (B_{col} + D_{col} + 2 \times d_{eff}) =$	15.17ft
Equation 11-33, V_{c1} =	$\left(2 + \frac{4}{\beta_c}\right) \times b_o \times d_{eff} \times \sqrt{1000 \times f_c'} =$	1484.88kip
Equation 11-34, V_{c2} =	$\left(\frac{\alpha_s \times d}{b_o} + 2\right) \times \lambda \times \sqrt{f_c} \times b_o \times d =$	1664.37kip
Equation 11-35, V_{c3} =	$4 \times b_o \times d_{eff} \times \sqrt{1000 \times f_c'} =$	989.92kip
Punching shear strength, V_c =	0.75 * minimum of (V_{c1}, V_{c2}, V_{c3}) =	742.44kip

0.75 * V_c > V_u hence, OK

One-Way Shear Check
Along X Direction



From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times f_c'}$ = 285.55kip

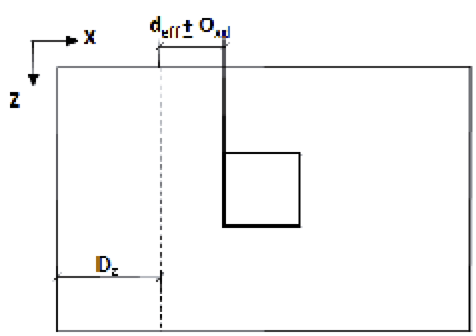
Distance along Z to design for shear, D_z = $0.5 \times (L - B_{col}) + d_{eff} + O_{zd}$ = 1.58ft

Check that $0.75 * V_c > V_{ux}$ where V_{ux} is the shear force for the critical load cases at a distance d_{eff} from the face of the pier caused by bending about the X axis.

From above calculations,	$0.75 * V_c$ =	214.17	kip
Critical load case for V_{ux} is # 212	$V_{ux} = V_{ux}\|_{x=D_z}$ =	3.96	kip

$0.75 * V_c > V_{ux}$ hence, OK

Along Z Direction



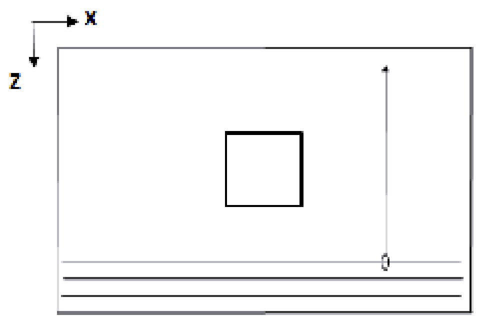
From ACI Cl.11.3.1.1, V_c = $2 \times W \times d_{eff} \times \sqrt{1000 \times f_c'}$ = 285.55 kip

Distance along X to design for shear, D_x = $1.5 \times (L \pm B_{col}) + d_{eff} + O_{xd}$ = 6.96 ft

Check that **$0.75 * V_c > V_{uz}$** where V_{uz} is the shear force for the critical load cases at a distance d_{eff} from the face of the pier caused by bending about the Z axis.

From above calculations,	$0.75 * V_c =$	203.97	kip
Critical load case for V_{uz} is # 212	$V_{uz} = V_{uz}\|_{x=D_x} =$	5.42	kip
		$0.75 * V_c > V_{uz}$ hence, OK	

Design for Flexure about Z axis



PLAN

Calculate the flexural reinforcement along the X direction of the footing. Find the area of steel required, A, as per Section 3.8 of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Factor β_1 from ACI Cl.10.2.7.3	for $F_c' \le 4$ ksi,	0.85
From ACI Cl. 10.3.2, $\rho_{bal} =$	$0.85 \times \beta_1 \times F_c' \times \frac{87}{[F_y \times (87 + F_y)]} =$	0.02851
From ACI Cl. 10.3.3, $\rho_{max} =$	$0.75 \times \rho_{bal} =$	0.02138
From ACI Cl. 7.12.2, $\rho_{min} =$		0.00174
From Ref. 1, Eq. 3.8.4a, constant m =	$\frac{F_y}{(0.85 \times F_c')} =$	17.65

Calculate reinforcement ratio ρ for critical load case

Design for flexure about Z axis is performed at the face of the pier at a distance, D_x =	$0.5 \times L - 0.5 \times D_{col} - C_{col} =$	3.38	ft
Ultimate moment,	$M_{u\,x=D_x} =$	19.14	kip-ft
Nominal moment capacity, M_n =	$\frac{M_u}{\phi} =$	21.27	kip-ft
Required ρ =	$\frac{1}{m} \times \left[1 - \sqrt{1 - 2 \times m \times \frac{M_n}{(F_y \times W \times d_{eff}^2)}}\right] =$	0.00009	

Since	$\rho_{min} \le \rho \le \rho_{max}$	OK	
Area of Steel Required, A_s =	$\rho \times W \times d_{eff}$	4.18	in2

Find suitable bar arrangement between minimum and maximum rebar sizes

Available development length for bars, D_L =	$0.5 \times (L - D_{col}) - C_{cover}$ =	38.50	in
Try bar size	Area of one bar =	0.60	in2
Number of bars required, N_{bar} =	$\frac{A_s}{A_{bar}}$ =	7	

Because the number of bars is rounded up, make sure new reinforcement ratio < $_{max}$

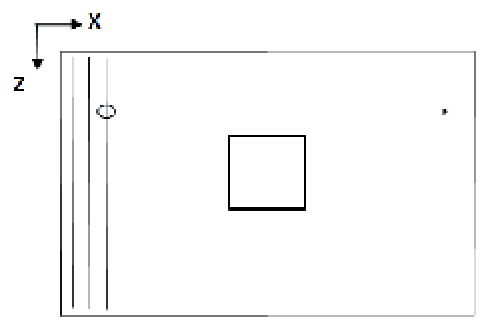
Total reinforcement area, A_{s_total} =	N_{bar} * (Area of one bar) =	4.20	in2
d_{eff} =	D - C_{cover} - 0.5 * (dia. of one bar) =	1.80	ft
Reinforcement ratio, ρ =	$\frac{A_{s\_total}}{(d_{eff} \times W)}$ =	0.00195	

From ACI Cl.7.6.1, minimum req'd clear distance between bars

C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 2.000in

Check to see if width is sufficient to accomodate bars

Design for Flexure about X axis



PLAN

Calculate the flexural reinforcement along the Z direction of the footing. Find the area of steel required, A, as per Section 3.8 of Reinforced Concrete Design (5th ed.) by Salmon and Wang (Ref. 1)

Critical Load Case # 212

The strength values of steel and concrete used in the formulae are in ksi

Factor β_1 from ACI Cl.10.2.7.3	for $F_c' \le$ 4 ksi,	0.85

From ACI Cl. 10.3.2, ρ_{bal} =	$0.85 \times \beta_1 \times f_c' \times \frac{87}{[f_y \times (87 + f_y)]}$ =	0.02851	
From ACI Cl. 10.3.3, ρ_{max} =	$0.75 \times \rho_{bal}$ =	0.02138	
From ACI Cl.7.12.2, ρ_{min} =		0.00173	
From Ref. 1, Eq. 3.8.4a, constant m =	$\frac{f_y}{(0.85 \times f_c')}$	17.65	

Calculate reinforcement ratio ρ for critical load case

Design for flexure about X axis is performed at the face of the pier at a distance, D_z =	$0.5 \times L \pm 0.5 \times B_{col} - C_{cl}$ =	3.17	ft
Ultimate moment,	M_u at D_z =	14.42	kip-ft
Nominal moment capacity, M_n =	$\frac{M_u}{\phi}$ =	16.02	kip-ft
Required ρ =	$\frac{1}{m} \times \left[1 - \sqrt{1 - \frac{2 \times m \times M_n}{(f_y \times W \times d_{eff}^2)}}\right]$ =	0.00007	
Since	$\rho_{min} \le \rho \le \rho_{max}$	OK	
Area of Steel Required, A_s =	$\rho \times W \times d_{eff}$ =	4.37	in2

Find suitable bar arrangement between minimum and maximum rebar sizes

Available development length for bars, D_L =	$0.5 \times (L - B_{col}) - C_{cover}$ =	36.00	in
Try bar size	Area of one bar =	0.79	in2
Number of bars required, N_{bar} =	$\frac{A_s}{A_{bar}}$ =	6	

Because the number of bars is rounded up, make sure new reinforcement ratio < $_{max}$

Total reinforcement area, A_{s_total} =	N_{bar} * (Area of one bar) =	4.74	in2
d_{eff} =	D - C_{cover} - 0.5 * (dia. of one bar) =	1.72	ft
Reinforcement ratio, ρ =	$\frac{A_{s\_total}}{(d_{eff} \times W)}$	0.00219	

From ACI Cl.7.6.1, minimum req'd clear distance between bars

C_d = max (Diameter of one bar, 1.0" (25.4mm), Min. User Spacing) = 2.000in

Check to see if width is sufficient to accomodate bars

Concrete Beam Design

CODE ACI 318-05

Analysis Results

Bending Moment Results

Load Case	Maximum Sagging Moment	Maximum Hogging Moment
211	0.00kip-ft	6.27kip-ft

Design Calculations

Optimization of Beam Size

Basic Design Data

β_1 (ACI 10.2.7.3)	$0.85, \max\left[0.85 - 0.05\cdot(f'_c - 4), 0.65\right]$	= 0.85
ρ_{min} (ACI 10.5.1)	$\max\left(\frac{0.2}{f_y}, 3\cdot\frac{\sqrt{f'_c}}{f_y}\right)$	= 0.0033
ρ_{bal} (ACI B8.4.3)	$0.85\cdot\beta_1\cdot f'_c\cdot\frac{87}{\left[f_y(87+f_y)\right]}$	= 0.0285
ρ_{max} (ACI B10.3.3)	$0.75\,\rho_{bal}$	= 0.0214
Modular ratio, m	$\frac{f_y}{0.85 f'_c}$	= 17.6471

Moment Strength Calculation

Moment reduction factor, ϕ = 0.9

Modulas of elasticity, E_s = 29000 ksi

Strain in concrete at extreme compression fiber, ε_c = 0.003

Yield strain of main reinforcement, ε_s	$\frac{F_{y\ main}}{E_s}$	= 0.0021
Effective depth, D_{eff}	$D - Cover_{bot} - 0.5\,Dia_{main} - Dia_{second}$	= 1.7179ft
Distance from extreme compression fiber to neutral axis at balanced condition, C_b	$D_{eff}\cdot\frac{\varepsilon_c}{\varepsilon_c + \varepsilon_s}$	= 1.0167ft
Depth of equivalent rectangular stress block at balanced condition, A_b	$\beta_1 C_b$	= 0.8642ft
Depth of equivalent rectangular stress block at maximum ratio of tension reinforcement, A_{max}	$0.75\,A_b$	= 0.6482ft
Moment strength at balanced		=

condition, M_n	$\phi \left[0.85 f_c' W a_{max} \left(D_{eff} - 0.5 a_{max} \right) \right]$	1194.27kip-ft

Checking of Beam Size

Beam size is optimized to withstand the maximum moment and shear.

Check For Sagging Moment

Maximum sagging moment, M_{max_sag}	Obtained from analysis	= 0.00kip-ft
Ultimate sagging moment, M_{u_sag} =	$\frac{M_{max\_sag}}{0.9}$	= 0.00kip-ft
Coefficient of resistance, R_u =	$\frac{M_u}{W \cdot D_{eff}^2}$	= 0.0000kip/ft^2
$1 - 2 \cdot m \cdot \frac{R_u}{f_y}$	= 1.0000	is greater than zero, it is o.k.

Check For Hogging Moment

Maximum hogging moment, M_{max_hog}	Obtained from analysis	= 6.27kip-ft
Ultimate hogging moment, M_{u_hog} =	$\frac{M_{max\_hog}}{0.9}$	= 6.96kip-ft
Coefficient of resistance, R_u =	$\frac{M_u}{W \cdot D_{eff}^2}$	= 0.7866kip/ft^2
$1 - 2 \cdot m \cdot \frac{R_u}{f_y}$	= 0.9968	is greater than zero, it is o.k.

Check For Shear

Maximum shear force, V_{max}	Obtained from analysis	= 0.00kip
Shear reduction factor	ϕ	= 0.75
Ultimate shear force, V_u	V_{max} / ϕ	= 0.00kip
Nominal shear strength of concrete, V_c	$2 \sqrt{f_c'} W D_{eff}$	97.33kip
Shear force to be resisted by stirrups, V_s	$\frac{V_u - \phi \cdot V_c}{\phi}$	0.00kip

Maximum shear force that can be resisted by stirrups, V_{s_max}	$8 \cdot \sqrt{f_c} \cdot W \cdot D_{eff}$	389.3396kip

Since V_s is less than V_{s_max}, it is o.k.

Since nominal shear strength of concrete is greater than maximum shear force, shear reinforcement is not required.

Final depth of beam, D	= 2.00ft
Final width of beam, W	= 3.00ft
Final moment capacity of the section, M_n	= 1194.27kip-ft

If M_n is less than M_{max}, the beam is to be designed as a doubly reinforced beam.

It is a singly reinforced beam.

Reinforcement Design

This is the primary design of reinforcements and it is performed considering the maximum values of hogging and sagging moments and the maximum shear force.

Design For Bottom Reinforcement

% of steel required, ρ_{req}	$\max\left[\rho_{min}, \frac{1}{m}\left(1 - \sqrt{1 - 2 \cdot m \cdot \frac{R_u}{f_y}}\right)\right]$	0.0033
Area of steel required, A_{st_bot}	$\rho_{req} \cdot W \cdot D_{eff}$	2.47in2
Area of steel used, A_{st_b}	no. of bars used x area of 1 bar	2.60in2
Moment capacity	$\phi\left[0.85 \cdot f_c \cdot A_{st\_bot} \cdot m \cdot \left(D_{eff} - 0.5 \cdot A_{st\_bot} \cdot \frac{m}{W}\right)\right]$	242.63kip-ft

Bar no. used = 4

Number of bars required = 13

Number of reinforcement layers = 1

Design For Top Reinforcement

% of steel required, ρ_{req}	$\max\left[\rho_{min}, \frac{1}{m}\left(1 - \sqrt{1 - 2 \cdot m \cdot \frac{R_u}{f_y}}\right)\right]$	0.0033
Area of steel required, A_{st_top}	$\rho_{req} \cdot W \cdot D_{eff}$	2.47in2
Area of steel used, A_{st_t}	no. of bars used x area of 1 bar	2.40in2
Moment capacity	$\phi\left[0.85 \cdot f_c \cdot A_{st\_top} \cdot m \cdot \left(D_{eff} - 0.5 \cdot A_{st\_top} \cdot \frac{m}{W}\right)\right]$	247.83kip-ft

Bar no. used = 4

Number of bars required = 12

Number of reinforcement layers = 1

Beam depth is less than 36 inches. Hence side reinforcement is not necessary.

Design For Shear Reinforcement

If design shear force > 2 V_c, spacing calculated from boundary condition is reduced by 50%.

Spacing calculated from boundary condition, Sp	$(0.5 \cdot D_{eff}, 24)$	10.69in
Minimum stirrup spacing, Sp_{min}	$0.75 \cdot \frac{\sqrt{f_c} \cdot W}{f_y}$	7.73in
Required stirrup spacing (cannot be zero)	$\min\left(Sp_{min}, \frac{V_s}{f_y \cdot D_{eff}}\right)$	7.73in

Bar no. used = 3

Print Calculation Sheet

Strap Footing Design Optimization

Unlike previous foundation models, the design analysis for strap footing does not seem to design in accordance with the minimum defined design constraints. Although some dimensions of the design seem reasonable, the width of the footings within the design were too large, regardless of constraining the parameters. After analyzing and the calculation sheet produced within STAAD.foundation, there has been no conclusion as to why the designated width is far larger than necessary. For this reason, it is inadvisable to rely heavily on this design analysis for a strap design.