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The Computer Aided Analysis Design and Detailing for Column Base Plate Steel Connections

by

Marthin Dody Sumajouw

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of the requirements
for the degree of

MASTER OF ENGINEERING*

***The Master of Engineering in the Civil and Environmental Engineering
Program is a joint program with the University of Ottawa, administered
by the Ottawa-Carleton Institute for Civil Engineering.**

**DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
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**"The Computer Aided Analysis Design and Detailing for
Column Base Plate Steel Connections"**

submitted by
Marthin Dody Sumajouw

in partial fulfillment of the requirements for
the degree of Master of Engineering

Professor J. L. Humar, Chair
Department of Civil and Environmental Engineering

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Ottawa, Ontario, Canada
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Abstract

An interactive computer-aided program, Steel Connection Analysis Design and Detailing (SCADD version 2.0) analyses, designs and details column base plates according to CAN/CSA-S16.1-M89 and CAN/CSA-A23.3-M84. The input to SCADD consists of material properties, cross-section geometry of the column, service and factored axial load, shear forces, and moments about one or both axes. The output consists of base plate dimensions, minimum plan dimensions of the footing, anchor bolts (length, diameter), size of angles and plates, and the size and location of welds and bolts in an engineering report, along with a 3D scaled rendition of the design. Control of SCADD is entirely through graphical activation of command menus, pull down menus and dialogue boxes displayed on the screen, some of which employ icons to group options into a logical order. For clarity and ease of use, only the relevant commands for that stage of the process are displayed. Designs have been developed for unstiffened welded base plate connections, angle web and flange connections, stiffened single web or flange plate connections, stiffened double plate and built-up stiffened connections. Uplift is considered when applicable. Detailed comparisons are made with solved examples in recognized steel structure texts and with many designs produced by CANRON Eastern Division and by CANAM, two of the largest steel fabrications in Eastern Canada.

The computer graphic system developed here for steel connection and in particular for base plates offer significant benefits with respect to productivity in the overall design process. In interacting with a computer for design, the use of graphics to visually build, manipulate and assign design constraints to a model is invaluable. The ease of use in which the analysis and design can be reviewed and evaluated allows the engineer to quickly understand the implication of the design, as well as to investigate design alternatives.

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List of Symbols

A_1	Area of base plate.
A_2	Area of concrete footing.
A_m	Weld size multiplied by the length of weld (for fillet welds).
A_n	Area of anchor bolt.
A_w	Size of the throat of the weld ($\frac{D}{\sqrt{2}}$) multiplied by the length of weld.
b	Width of column.
B	Width of base plate.
B_r	Factored bearing resistance as defined by CAN/CSA-S16.1-M89.
C	Length of base plate.
C_f	Factored compressive axial load.
d	Depth of column, Diameter of high strength bolts.
D	Diameter of anchor bolts.
e	Eccentricity, Minimum edge distance as defined in Clause 22.6 of CAN/CSA-S16.1-M89.
f'_c	Specified compressive strength of concrete.
F	Force acting on one anchor bolt.
F_u	Specified minimum tensile strength.
F_y	Specified minimum yield stress.
g	Width of stress block.
k	Distance from the outer face of flange to the toe of fillet on the web.
K_c	Actual bearing stress of concrete.
L	Length of angle.
L_n	Length of angle less number of bolt holes plus 2 mm.
m	Distance from the outer dimension of the column to the edge of the base plate.
M_f	Bending moment at column under factored load.

M_r	Moment resistance.
n	Distance from the outer dimension of the column to the edge of the base plate, Number of bolts.
p	Pitch.
P	Pitch of thread.
P_r	Factored pull-out resistance of concrete.
t_p	Thickness of base plate.
T_f	Factored tensile force in one anchor bolt.
T_r	Factored tensile resistance.
V_f	Factored shear force.
V_r	Factored shear resistance.
X_u	Ultimate strength as given by electrode classification number.
ϕ	Resistance factor = 0.90.
ϕ_b	Resistance factor for bolt = 0.67.
ϕ_c	Resistance factor for concrete = 0.60.
ϕ_w	Resistance factor for weld = 0.67.
λ	Factor to allow for low density concrete as defined in Clause 11.2.3 of CAN/CSA-A23.3-M84

Chapter 1

Introduction

1.1 Background

Modern software engineering concepts demand program development in a modular fashion, Krishnamoorthy and Rajeev (1991). Tasks are divided into subtasks, and the modules for these are developed and tested separately, before integrating them to form the complete design software module. Subprogramming allows the procedures and functions to be defined independently. Communication occurs via a data structure, global variables or parameters defined within and invoked by the program.

The first version of Steel Connection Analysis Design and Detailing (SCADD) module, Devitt (1992), was developed to analyse, design and detail beam-to-column-web, beam-to-column-flange and beam-to-beam simple connections that are orthogonally framed and composed of various bolted and welded combinations using single or double angles as connectors. All designs are rendered to scale in three dimensions on the screen, and may be viewed from any direction. Also shown are the corresponding engineering and material reports. The interactive screens are designed to provide user friendly, simple well defined input, instructive and informative output (design notes, resistances and 3D renderings of the design). The original version of SCADD was developed for three connection types and does not have the capacity to easily incorporate additional connection designs (subtasks).

1.2 Objectives

The objectives of this thesis are:

1. To modify the existing interface of SCADD to incorporate second generation windows; main, pop-up and pull-down menu's; scrolling tables and dialogue boxes.
2. To develop a library screen which will allow other applications for the design of other standard connections to be added readily.
3. To develop an application for the design of base plate connections for W and WWF shapes to resist axial load, shear, and bending moments about one or both principal axes according to CAN/CSA-S16.1-M89, CSA (1989) and CAN/CSA-A23.3-M84, CSA (1984).
4. To develop the corresponding design interfaces and 3D renderings.
5. To verify the base plate design module against known solutions and designs by major steel Canadian fabricators.

1.3 Base Plate Design Module and Program Attributes

The base plate design module will design the connecting parts and connections from the column to the base plate, the base plate, the anchor bolts and will provide the minimum size of footing (based on the bearing resistance of the concrete not on soil conditions) for W and WWF shapes for axial load, shear and bending moment about one or both principal axes according to CAN/CSA-S16.1-M89, CSA (1989) and CAN/CSA-A23.3-M84, CSA(1984). Simple or moment resistant connections can be specified with welded and/or bolted connections or welded built-up sections. Only the most common base plate connection arrangements are considered. The

designs are based on strength and geometric design (detailed and dimensioned) and are in accordance with the provisions given in CAN/CSA-S16.1-M89 and with current practice of steel fabricators in Canada. Uplift is considered if applicable.

Interactive graphic design modules must be informative, easy to use, flexible and efficient, Kostem and Shephard (1984). Design software with these basic attributes will allow practicing engineers to explore different design options and costs, and should increase their understanding about structural design.

The engineer must be in control of the system and must be comfortable to explore any available design option. The key is a well developed interactive graphic interface which provides continual feedback between the computer and the engineer during the connection design process. Design tasks must be performed in a logical order. Alternative connection designs (connection arrangements and weld or bolt sizes/strengths, base plate strengths) for a given set of loads should be provided to allow engineers to determine the most economical design. Design efficiency is achieved by taking advantage of the graphical facilities of the workstation to provide immediate visual feedback. Three dimensional scaled rendering of the connection allows the engineer to visualize the connection and to readily evaluate the design output. Interferences, incomplete or unrealistic connections are easily discernible. The graphic user interfaces was developed using a HOOPS, HOOPS (1991) and the program was written with C programming language, Kernighan (1978).

1.4 Overview

The modifications to the original version of SCADD and the development of a new connection library screen are presented in chapter two. The graphic interfaces for each screen are illustrated and the operation and limitation of the options provided (activated by buttons) are explained. Chapter three describes the design philosophy for common column base plate connections, the corresponding connectors and for the anchor bolts. The program architecture is also described. Chapter four gives detailed

traces (illustrates the design philosophy) for each possible base plate design that is available on SCADD. The results for each step of the design process are evaluated to ensure that the provisions in the standards and the geometric design are being calculated correctly. Design for column base plates subject to axial load, shear and bending moments is an interactive procedure that has been optimized to produce the best design configuration. Material and engineering reports, along with a scaled 3D rendering of the designed connection, are displayed on the screen. A large number of comparisons with designs published in textbooks and those produced by CANRON Eastern Division and CANAM (two of the largest steel fabricators in Eastern Canada) are presented. Note, the author is not aware of any other software that designs base plate connections. Conclusions, recommendations and future work are described in chapter five.

Chapter 2

Graphic User Interface Development

The graphic user interface for SCADD version 2.0 was developed from two existing interfaces, one called Steel Connection Analysis Design and Detailing (SCADD version 1.0), Devitt (1992), combined with a unique graphic tool interface called EMAP, Srna (1995). SCADD version 1.0 is directed by a main menu which has ten selectable buttons (**Files**, **Constraints**, **Connections**, **Design**, **Print Screen**, **Quit**, **Drawings**, **Print Result**, **Analysis and Evaluation**) as shown in Figure 2.1. The first six indicated by bold print are functional. The fabrication constraints, connection specification and design results are specified or displayed by invoking the appropriate button.

The fabrication constraint screen, Figure 2.2, sets the fabricators preferences for bolts, welds, angles and plates that compose the connection, and are used as default values within the program. These will be modified within the design process if required. The data presented on this screen represents the available options for Canadian fabricators. The connection screen shown in Figure 2.3 provides a limited library of three types of connections, a window indicating the selected connection, a member selection table and a window to specify the connection details. The design connection screen, shown in Figure 2.4, displays the engineers report, a description of the design loads and resistances; displays the materials report, sizes, strength and member of connectors; and a scaled 3D rendering of the designed connection.

Not shown is a primitive dialogue box for entering the load data that is invoked

Figure 2.1: The Main Menu, SCADD Version 1.0

Files	Drawings	Print Screen	Print Results	Quit
Constraints	Connection	Design	Analysis	Evaluation

Preferred Bolt

Hole Type

Punched
Drilled

Type

A307
A325M
A490M

pitch is 80 mm

gauge is 80 mm

gauge offset is 80 mm

read interception? YES

Size

M16	M20	M22
M24	M27	M30
M36		

CHANGE

CHANGE

CHANGE

CHANGE

Preferred Angle

Shape	Available Thicknesses									
L200X200	30	25	20	16	13	10				
L200X150	25	20	16	13						
L200X100	20	16	13	10						
L150X150	20	16	13	10						
L150X100	16	13	10	8						
L125X125	16	13	10	8						
L125X80	16	13	10	8						

Grade

230	260	300	350	400
-----	-----	-----	-----	-----

Preferred Bolt

Hole Type

Punched
Drilled

Type

A307
A325M
A490M

pitch is 80 mm

gauge is 80 mm

gauge offset is 80 mm

read interception? YES

Size

M16	M20	M22
M24	M27	M30
M36		

CHANGE

CHANGE

CHANGE

CHANGE

Preferred Angle

Shape	Available Thicknesses									
L200X200	30	25	20	16	13	10				
L200X150	25	20	16	13						
L200X100	20	16	13	10						
L150X150	20	16	13	10						
L150X100	16	13	10	8						
L125X125	16	13	10	8						
L125X80	16	13	10	8						

Grade

230	260	300	350	400
-----	-----	-----	-----	-----

Preferred Weld

Type

FILLET
BACK
BEVEL
FLARE BEVEL
FLARE J
SQUARE

Size

5	6	8
10	13	16
20	25	30

Preferred Plate

Edge Treatment

FLAME-CUT
SHEARED

Grade

230	260	300
350	400	450
700		

Thickness

5	6	8
10	12	14
16	18	20
22	25	28
30	35	40

Current File : default

Messages :

Figure 2.2: Fabrication Constraint Screen, SCADD Version 1.0

Files	Drawings	Print Screen	Print Results	Quit
Constraints	Connection	Design	Analysis	Evaluation

Connection Geometry

Beam to Column Web

Beam to Column Flange

Beam to Beam

step is 5 mm

gap is 10 mm

Member Selection

Shape	Available Thicknesses									
W690	125									
W610	241	217	195	174	155	140				
W610	125	113	101	91	84	92				
W610	82									
W530	219	196	182	165	150	138				
W530	123	109	101	92	82	72				
W530	85	74	66							

Grade

Selected Connection

Member 2:

W530X123

Member 1:

W610X82

Connection Details

<input type="button" value="SHEAR"/>	<input type="button" value="MOMENT"/>
<input type="button" value="SINGLE ANGLE"/>	<input type="button" value="DOUBLE ANGLE"/>
<input type="button" value="SINGLE PLATE"/>	<input type="button" value="DOUBLE PLATE"/>
<input type="button" value="END PLATE"/>	<input type="button" value="TEE"/>
<input type="button" value="UNSTIFF SEAT"/>	<input type="button" value="STIFF SEAT"/>

Member 1

Member 2

Bolt Design

Surface Preparation

Current File : default

Messages :

Figure 2.3: Connection Specification Screen, SCADD Version 1.0

Files	Drawings	Print Screen	Print Results	Quit
Constraints	Connection	Design	Analysis	Evaluation
<p>BUSINESS REPORT *****</p> <p>SERVICE AND PACKAGED LOADS 500 0 MM 450 0 MM</p> <p>CONNECTION TYPE IS FRICITION</p> <p>BEARING</p> <p>BE (BE/BE) : CORRECTING MEMBER 727 1 0 62 CORRECTING ANGLE 2457 1 0 17</p> <p>BLOCK/BEAR</p> <p>VZ (VZ/VZ) : CORRECTING ANGLE 980 0 0 46</p> <p>BEAR</p> <p>VZ (VZ/VZ) : CORRECTING MEMBER 1215 1 0 37 CORRECTING ANGLE 2456 5 0 18</p> <p>BOLTS</p> <p>VZ (VZ/VZ) ECCENTRIC BEAR 698 5 0 64</p> <p>WELDS</p> <p>ECCENTRIC CAPACITY VZ (VZ/VZ) : SUPPORTING MEMBER 710 9 0 65</p> <p>MATERIALS REPORT *****</p> <p>CORRECTING MEMBER M510 X 82 SUPPORTING MEMBER M510 X 123</p> <p>ANGLES</p> <p>NUMBER, SIZE 2 150 0 X 150 0 X 20 0 LENGTH, STRENGTH 402 0 MM 350 0 MPa 480 0 MPa</p> <p>FASTENERS FOR CORRECTING MEMBER</p> <p>BOLTS</p> <p>5 A490B M12 60 0 mm 1 washer per bolt</p> <p>FASTENERS FOR SUPPORTING MEMBER</p> <p>WELDS</p> <p>Straight line fillet weld 6 0 mm By 402 0 mm</p>				
<div> <div>5</div> <div>10</div> <div>15</div> <div>30</div> <div>45</div> <div>90</div> </div> <div> <div>Rotate Over</div> <div>Rotate Under</div> <div>Rotate Right</div> <div>Rotate Left</div> <div>Rotate CW</div> <div>Rotate CCW</div> <div>Zoom In</div> <div>Zoom Out</div> </div>				

Current File : default

Messages :

Figure 2.4: Designed Connection Screen, SCADD Version 1.0

at the start of the design process and databases for end distances, wrench clearances and bolt data which are utilized within the program.

It became apparent from the development of other applications for the design of structural steel members and further development of the concept for the over process for integrated analysis, design, fabrication and erection of steel structures, that these first attempts at a graphic user interfaces needed to be modified, and further developed to include more connection types and better system for integrating them with other applications.

2.1 SCADD, Version 2.0

The new version of SCADD has eight selectable main menu buttons related to connection design and ten optional system operation buttons adopted from EMAP without any modification as shown in Figure 2.5. These buttons are continuously shown on the top of screen during the connection definition and design process and are described more fully in section 2.2. Multiple connection and integrated design buttons have been added to the main menu to accommodate integration of this module with other applications. Although these are not developed, multiple connections will recall the building geometry and will allow the engineer to specify multiple connection types for each joint singly or in groups. Integrated design will retrieve the necessary loads, member geometry, design all connection types, redesign if necessary to limit the number of different variations and return updated member geometry back to the appropriate database for the next analysis or design iteration. The fabrication constraint screen has been adapted to the new format and is shown in Figure 2.6. The new connection library screen, shown in Figure 2.7, was created to allow the standard connection types to be readily added. The existing applications for beam-to-column-web, beam-to-column-flange and beam-to-beam have been added to the revised version along with the new application for base plate design. There are 14 empty icon spaces available for new applications for different standard connection designs. These can easily be added without modification to the existing connection

design module.

Due to the complexity and number of specific connection details, each type or group of types requires one specification screen. The appropriate screen is displayed for the selected connection. The modified specification screen for beam-to-column-web, beam-to-column-flange and beam-to-beam connections is shown in Figure 2.8. The new connection specification screen for base plate connections is shown in Figure 2.9. The types of connections (shear-angle-web, angle-flange, welded; moment-unstiffened, stiffened), base plate thicknesses, anchor bolt numbers, size and strength, concrete strengths and soil bearing capacities can readily be specified.

The group of buttons for controlling the 3D graphic image has been modified as shown in Figures 2.8 to 2.10. The symbolic buttons, for rotating the object, have been created to replace the command buttons which were confusing. These buttons make it easier to rotate, to zoom-in or out or to redisplay the object back to the original position. Several data files have been added: *aglbolts.dat* gives data on high strength bolts, *weld-bp.dat* gives data on weld sizes and *bpangles.dat* gives data on angle dimensions.

2.2 Main menu description

A brief description for each button for the main menu shown in Figure 2.5. follows :

1. JOB MANAGER

Existing data files from previously defined jobs will be listed on the screen in table when the Job Manager button is selected. New jobs (i.e. connection design definitions) can be saved to this database.

2. MULTIPLE CONNECTION

Currently, not active. It will consist of a number of screens that will allow the engineer to view the building geometry and to specify multiple connection types to individual joints or groups of joints.

Figure 2.5: The Main Menu, SCADD Version 2.0

3. INTEGRATED DESIGN

Currently, not active. It will provide specific input that will allow the engineer to control multiple connection designs. It will retrieve the necessary loads, member geometry, design all connection types, redesign if necessary to limit the number of different connection variations and return updated member geometry back to the appropriate database for the next analysis design iteration.

4. PRINT RESULT

Currently, not active. By activating this button the engineering and materials report will be printed.

5. CONSTRAINTS

This screen displays basic fabricator preferences in four windows, *Preferred Bolt*, *Preferred Angle*, *Preferred Weld* and *Preferred Plate*. The selected values become the default values in which the design is based.

6. CONNECTION TYPES

A library of connection types that are currently available in SCADD are displayed on the screen as icons. Currently, four types of connections have been installed and space for fourteen more are available for development of future applications.

7. CONNECTION DETAILS

The Connection Details button provides a tailored screen for specification of connection details for each connection type. For base plate design, refer to Figure 2.9, the type of column can be specified from the member selection group and the initial base plate thickness, anchor bolt diameter and strength, concrete strength and soil bearing capacity selected from predefined databases. The type of connection restraint represented by the SHEAR and MOMENT buttons differentiate between pinned and fixed base plates. Further definition of typical connection details can be made from the table provided. The graphical input which dictates the design can be completed very quickly.

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	MULTIPLE SCREEN	ADD TEXT	CONTINUE
<div style="display: flex; justify-content: space-between;"> Calc: Sep 27 1994 Time: 09:28 Approved by: user01 10 </div>								

Preferred Bolt

Hole Type

Punched

Drilled

Size

M16

M20

M22

M24

M27

M30

M36

pitch is 80 mm

gauge is 80 mm

gauge offset is 80 mm

thread interception? YES

Type

A307

A325M

A490M

Preferred Angle

Shape	Available Thicknesses									
L100X100	16	13	10	8	6					
L100X90	13	10	8	6						
L100X75	13	10	8	6						
L90X90	13	10	8	6						
L90X75	13	10	8	6	5					
L90X65	10	8	6	5						
L80X60	10	8	6	5						

Grade

230

260

300

350

400

Preferred Weld

Type

FILLET

BACK

BEVEL

FLARE-BEVEL

FLARE-J

SQUARE

Size

5

6

8

10

13

16

20

25

30

Preferred Plate

Edge Treatment

FLAME-CUT

SHEARED

Grade

230

260

300

350

400

450

700

Thickness

5	8
10	12
16	18
22	25
30	35
	40

Current File : default

Messages :

Figure 2.6: Fabrication Constraint Screen, SCADD version 2.0

EXIT SYSTEM INFO Date Sep 28 1994 Time 08:41		HELP FILES		JOB MANAGER CONSTRAINTS		MULTIPLE CONNECTIONS CONNECTION TYPES		INTEGRATED DESIGN CONNECTION DETAILS		PRINT RESULTS DESIGN OF A SINGLE CONN.		SELECTIVE PHOTO MULTIPLE SCREEN		SNAPSHOT ADD TEXT		QUIT CONTINUE			
Beam to Column Web				Beam to Column Flange				Beam to Beam
Column Base Plate

Current File : default Messages :

Figure 2.7: Connection Library Screen, SCADD Version 2.0

EDIT SYSTEM INFO 5:16 Sep 27 1994 Time 05:16	HELP FILES	JOB MANAGER CONSTRAINTS	MULTIPLE CONNECTIONS CONNECTION TYPES	INTEGRATED DESIGN CONNECTION DETAILS	PRINT RESULTS DESIGN OF A SINGLE CONN.	SELECTIVE PHOTO Pressing the arrow key MULTIPLE SCREEN ADD TEXT CONTINUE	SHAPING QUIT
--	---------------	----------------------------	--	---	---	--	-----------------

Connection Details

Connecting Member	W610X241	Boiled	Welded
Supporting Member	W690X240	Boiled	Welded

Shear ☐ **Moment** ☐

SINGLE ANGLE	DOUBLE ANGLE
SINGLE PLATE	DOUBLE PLATE
END PLATE	TEE
UPSTIFF SEAT	STIFF SEAT

Bolt Design

Friction

Bearing

Surface Preparation

Class A

Class B

Class C

step is 80 mm

gap is 79 mm

Orientation

CHANGE

CHANGE

CHANGE

Member Selection

Shape ☐ WRE ☐ W ☐ M ☐ S ☐ C ☐ EC ☐ HP

Available Weights

Shape	W760	W690	W690	W610	W610	W610	W530
Weight	161	265	125	241	125	82	219
W760	147	240	217	170	152	140	
W690				195	174	155	140
W610				101	91	84	92
W530				182	165	150	138

Grade

☐ 230 ☐ 280 ☐ 300 ☐ 350 ☐ 400

Current File : default

Messages :

Figure 2.8: Connection Specification Screen a Beam-to-Column Flange Connection, SCADD Version 2.0

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	CURT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Preview file selected job	MULTIPLE SCREEN	ADD TEXT
Date: Sep 20, 1994 Time: 11:28								

Connection Details for Base Plate

Column	W610X241	Soft	Welded				
Base Plate Thickness	20	25	30	35	40	Other	30 mm
Anchor Bolts	Number	Size	Type				

SHEAR	MOMENT
Angle_Web_Connection	Unstiffened
Angle_Flange_Connection	Stiffened
Welded_to_Base_Plate_Only	Plates
	Built Up

Concrete Strength (MPa)	20	25	30	35	Other	25 MPa
Soil Bearing Capacity (kPa)	400	450	500	550	Other	550 kPa

Member Selection

Shape	W	M	S	C	MC	HP
W760	161	147				
W690	265	240	217	170	152	140
W690	125					
W610	241	217	195	174	155	140
W610	125	113	101	91	84	92
W610	82					
W530	219	196	182	165	150	138

Grade	230	260	300	350	400
-------	-----	-----	-----	-----	-----

Current File : default Messages :

Figure 2.9: Connection Specification Screen for Base Plates, SCADD Version 2.0

8. DESIGN OF SINGLE CONNECTION

Selecting this button executes the program for base plate design. Eight additional buttons specific to reviewing data or for further processing, Engineers Report, Analysis, Drawings, Design, Materials Report, Evaluation, Rotation (moment rotation characteristic if applicable) and Load buttons are displayed. The design loads are defined through dialogue boxes that are displayed when the load button is activated. Control buttons for manipulating graphic image, a scaled 3D rendering of the designed connection, are located in the lower right hand corner of the screen. The material report or engineers report (summary of design loads and resistances) will be displayed in working window on the left side of the screen. The design button allows the engineer to redesign the connection for different load cases. The Analysis, Drawings, Evaluation and Rotation buttons are currently not active but will provide finite element modelling, production of shop drawings, cost evaluation based on the fabricators cost schedule and moment rotation characteristics (if applicable), respectively.

In addition to the eight main buttons, there are ten selectable buttons from EMAP that are tools for basic system management and operation, and are not part of the engineering process. These buttons are: EXIT, SYSTEM INFO, HELP, FILES, SELECTIVE PHOTO, SNAPSHOT, QUIT, MULTIPLE SCREEN, ADD TEXT and CONTINUE buttons. The functions of the most commonly used buttons is given below. For the others refer to Srna (1995).

- EXIT terminates the process.
- SYSTEM INFO gives an information about the name of segment.
- SNAPSHOT creates a post-script file.

EXIT SYSTEM INFO Date: Feb 14, 1998 Time: 12:24		HELP FILES		JOB MANAGER CONSTRAINTS		MULTIPLE CONNECTIONS CONNECTION TYPES		INTEGRATED DESIGN CONNECTION DETAILS		PRINT RESULTS DESIGN OF A SINGLE CONN.		SELECTIVE PHOTO Postscript file: design.ps MULTIPLE SCREEN ADD TEXT CONTINUE		SHAPESHOT QUIT	
---	--	---------------	--	----------------------------	--	--	--	---	--	---	--	--	--	-------------------	--

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS	2100.0 kN	2750.0 kN
SHEAR FORCES	X (kN)	Y (kN)
SERVICE	475.0	420.0
FACTORED	1400.0	1250.0
MOMENT	X (kN.m)	Y (kN.m)
SERVICE	445.0	545.0
FACTORED	1000.0	800.0

ANCHOR BOLTS

TENSION	192.0 kN
SHEAR	378.0 kN

WELDS AT COLUMN FLANGE

FILLET	Vr = 1628.3 N/mm
GROOVE	Vr = 2285.4 N/mm
PARTIAL PENETRATION	Vr = 2285.4 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

CONNECTORS

BOLT SHEAR STRENGTH	Vr = 354.1 kN/bolt
WELDING	Vr = 1792.9 N/mm
ANGLES - Shear	= 1251.8 kN
Bearing	= 1254.2 kN

Engineers Report

Analysis

Drawings

Design

Materials Report

Evaluation

Rotation

Loads

Current File : default

Messages :

Figure 2.10: Designed Connection Screen, SCADD Version 2.0

Chapter 3

Base Plate Design

3.1 General Behaviour

Base plates exist in all steel buildings and transfer the load of the structure to its foundation or footings. Generally they must transfer axial load, shear and bending moments about one or both principal axes from the column to the plate through welds, bolts, angles and/or plates and then to the foundation through anchor bolts and bearing on the concrete. Typical welded base plate connections for W and WWF shape columns and for HSS columns are shown in Figure 3.1 and Figure 3.2, respectively, Dowling et al. (1992). Figure 3.1.(a) with two anchor bolts aligned along the neutral axis for bending about the strong axis is considered to be pinned. This welded base plate is the most common and is generally associated with small to medium column sections with light axial loads. The remaining stiffened sections with four anchor bolts are considered to be fixed and are designed to transfer the column end moments about one or both principal axes to the foundation. Built-up sections may be used to transfer large bending moments.

The moment rotation characteristics of the column anchorage (column base plate connection and footing/foundation), the stress distribution under the base plate at ultimate and the bearing stress distribution between the column and the base plate are three aspects of the base plate behaviour that are relevant to design assumptions.

Figure 3.3 illustrates the influence of subsoil conditions on the moment rotation

Figure 3.1: Typical Base Plate Configurations for W and WWF Shapes, after Dowling et al. (1992)

Figure 3.2: Typical Base Plate Configurations for Hollow Structural Section, after Dowling et al. (1992)

Figure 3.3: Influence of Subsoil Conditions on Moment-Rotation Characteristics, after McGuire (1968)

characteristics of the column anchorage for a moment resisting frame with axial load only and with both lateral and axial loads, McGuire (1968). For axial load only, Figure 3.3.(a), the stress distribution under the footing will be uniform regardless of the compressibility of the subsoil. With lateral loads, the subsoil must be incompressible (rock) or the footing/foundation properly designed to transfer the moments to the subsoil for moment resisting base plate connection to be considered fixed and effective. Otherwise, the column anchorage will behave as though the base plate connection was designed as a pinned connection. For all base plate designs, it will be assumed that soil beneath the footing is incompressible or that the footing/foundation has the capacity of transmit the system of loads (axial, shear and moment) without any significant deformation. Apart from the subsoil characteristics, the most important variables that must be considered in determining the moment-rotation characteristics of any base plate connection are:

1. the dimensions and shape of the column, and
2. the plan dimensions and thickness of the base plate, and
3. the dimensions, locations and stress-strain characteristics of the anchor bolts, and
4. the connection between the column and base plate (welded, bolted, built-up), and
5. the dimensions and stress-strain characteristics of footing/foundation.

For cases where the ratio of the applied moment to axial load are small (the eccentricity of the axial load lies within the kern distance and the entire base plate interface is under compression), the nonlinear stress distribution resulting from that system of loads at ultimate is simply modelled as a statically equivalent rectangular distribution for design, refer to Figure 3.4, McGuire (1968). The variation in stress distribution for increasing moment and constant axial load is illustrated in Figure 3.5 for cases where uplift occurs.

Figure 3.4: Approximate Stress Distribution for Moment Resisting Base Plate Connection with Compression Across the Entire Base Plate, after McGuire (1968)

Stage 1 represents ratio of moment to axial load that are small and a stress distribution that is not dissimilar to the previous case. Stage 2 represents the point where there is zero compressive stress at the anchor bolts, and Stage 3 the ultimate load condition with uplift which is resisted by the anchor bolts in tension. Again the nonlinear interface stress distribution is replaced by a statically equivalent rectangular distribution for design.

Generally, saw cut ends for columns provide a uniform bearing surface on the base plate. For axially loaded columns, the bearing pressures are considered to be uniformly distributed over all contact surfaces as shown in Figure 3.6, Bresler (1960). The corresponding bending moment diagrams for the base plate, along its the principal axes are also shown. The general practice CISC (1992), is to assume that the load between the column and the base plate is uniformly distributed over an equivalent area measuring $0.8 b$ by $0.95 d$ as illustrated in Figure 3.7. The design moments for the base plate are indicated on the corresponding bending moment diagram. Note,

Figure 3.5: Approximate Stress Distributions for Moment Resisting Base Plates with Increasing Bending Moment and Constant Axial Load, after McGuire(1968).

the same equivalent area and critical sections are used for moment base plate connections.

3.2 Design Requirements

The three main components that are analyzed and designed geometrically and for strength in accordance with CAN/CSA-S16.1-M89 and CAN/CSA-A23.3-M84 are the base plate, the anchor bolts and the connection between the column and the plate (welded, bolted and welded angles). The design assumptions have been described in the previous section. The designs are limited to W and WWF shapes with base plate details that are used by Canadian fabricators.

3.2.1 Base Plate

In general the function of the base plate is to transmit the system of forces from the column to the footing/foundation without exceeding the bearing capacity of the concrete nor the bending resistance of the plate due to bearing pressure from the footing or from the tensile force from the anchor bolts about the appropriate critical section. Three functions *plateArea*, *initialPlateSize* and *actualPlateSize* are called within the main design program named *bp.c* (base plate) to calculate the base plate dimensions based on strength and geometric requirements.

3.2.1.1 Design for Strength - Plates with Axial Load

The design procedure for determining the plane plate dimensions, B and C , and the appropriate plate thickness, t_p , follows:

- Calculate the required base plate plan area

$$A = \frac{C_j}{b_r} \quad (mm^2) \quad (3.1)$$

Figure 3.6: The Pressures over Contact Surfaces, after Bresler (1960).

Figure 3.7: The Pressures over Equivalent Area

where, b_r is the factored bearing resistance per unit of bearing area, and can be expressed as:

$$b_r = 0.85\phi_c f'_c \sqrt{\frac{A_2}{A_1}} \quad (N/mm^2) \quad (3.2)$$

where,

$$\phi = 0.60.$$

$\sqrt{\frac{A_2}{A_1}}$ = a factor which represents the increase bearing capacity of the concrete which results from confinement provided by the surrounding footing. In all cases the maximum value of 2 is used

A_1 = bearing area, mm^2

A_2 = geometrically similar area of the surrounding concrete footing/foundation, mm^2

- Calculate B and C so that the dimensions m and n are approximately equal, refer to Figure 3.8. Select appropriate values of B and C (round up) and check the bearing capacity of the concrete, $B_r \geq C_f$ (according to Clause 10.15.1.1 of CAN/CSA-A23.3-M84)

where,

$$B_r = 0.85\phi_c f'_c A_1 \sqrt{\frac{A_2}{A_1}} \quad (kN) \quad (3.3)$$

- Calculate m and n

where,

$$m = (C - 0.95d)/2 \quad (mm) \quad (3.4)$$

$$n = (B - 0.80b)/2 \quad (mm) \quad (3.5)$$

Figure 3.8: Base Plate Plan Dimensions

- Calculate the plate thickness by equating the moment resistance and the factored moment along and about the critical section in both directions. Select the greater of:

$$t_p = \sqrt{\frac{2C_f m^2}{BC\phi F_y}} \quad (mm) \quad (3.6)$$

or

$$t_p = \sqrt{\frac{2C_f n^2}{BC\phi F_y}} \quad (mm) \quad (3.7)$$

- Select a plate thickness from a list of standard thickness produced by Canadian mills.

3.2.1.2 Design for Strength - Plates with Axial Load and Bending Moments

Calculate the equivalent eccentricity of the applied load with respect to the plate centroid, $e = M_f/C_f$, to establish whether or not uplift will occur. If e is small, less than $B/6$, compression will occur over the entire plate and the calculations for

Figure 3.9: The Base Plate with Axial Load and Moment

dimensioning the plate are the same as for axial load but with the statically equivalent stress distribution shown in Figure 3.9.(a). Otherwise, uplift will occur and the statically equivalent stress distribution in Figure 3.9.(b) must be used for subsequent calculations. Starting with the trial value of the plate length, B , the location and size of the anchor bolts, and assuming that the actual bearing stress of concrete K_c is equal to or less than the permissible stress defined by Clause 10.15.1.1 of CAN/CSA-A23.3-M84, the value of the length stress block, g , the tensile force on anchor bolts, T , and the width C , can be calculated from equations of equilibrium. The trial values must conform with the geometric design. From the summation of the vertical forces in Figure 3.9.(b),

$$C_f = 0.85K_c \sqrt{\left(\frac{A_2}{A_1}\right)} A_1 - T \quad (3.8)$$

or in the limit,

$$C_f = 1.70K_cA_1 - T \quad (3.9)$$

where, $\phi_c = 0.60$., and $K_c = \phi_c f'_c$; Select the larger value.

From moment equilibrium with moments taken about the center of the equivalent rectangular stress block,

$$M_f = T(d - g/2) + C f(B - g/2) \quad (3.10)$$

The base plate thickness can be calculated from equation 3.12 which is derived from the equation which equates the moment resistance,

$$M_r = \frac{(\phi F_y t^2) C}{4} \quad (3.11)$$

with the factored moment at the edge of the column due to the bearing pressure.

$$t = \sqrt{\left(\frac{4M_f}{\phi F_y C} \right)} \quad (3.12)$$

When the thickness of the plate is being calculated for moment about the transverse direction replace B with C , and C with B in Equations 3.10, 3.11 and 3.12 appropriately. Given the tensile force, the anchor bolt can now be designed in accordance with Clause 26 (CSA 1989). If the required anchor bolt is larger than the trial values, then the plate width, length and thickness will be recalculated. The procedure is repeated for the transverse moment if moments are applied about both principal axes. The governing sizes are selected.

3.2.1.3 Geometric Design

The minimum plan base plate area is based on fabrication and detailing limitations, and is determined by:

1. Calculating the minimum end distance from the column to the plate edge which is equal to 1.25 anchor bolt diameter plus the one half the nut size plus additional

clearance: for wrenches plus the weld size for the weld connecting the plate with the column.

2. Given the column depth, the minimum length of plate is calculated by adding two times the minimum end distance to the column depth. The minimum width of plate is calculated by adding two times the minimum end distance to the column width. The minimum plate area can be calculated.
3. Required plate thicknesses are based on strength and the actual thickness is selected from a data base of plate thicknesses produced by Canadian mills.
4. Based on the required base plate area and the maximum permissible bearing stress the minimum footing dimensions are calculated.

3.2.2 Anchor Bolts

Theoretically, anchor bolts are not required to transmit forces to the footing/foundation for base plates that are subjected to axial load only. However, in practice anchor bolts are provided by the fabricator/erector for aligning columns, levelling the column base on the footing and for construction loads that may occur during erection. Anchor bolts may be required to carry uplift and shear for base plates that are subjected to axial load and moments. Normally anchor bolts are fabricated from threaded round stock ASTM A36 steel with a yield strength of 248 MPa. The bolts are embedded in the concrete footing/foundation and are either anchored with sufficient bond length or more commonly with 90° hooks or with plates washers and nuts as indicated in Figure 3.10. Anchor bolt data is stored in a file called *bp-bolts.dat*.

Anchor bolts must be designed in accordance with Clause 25 and 26 of CAN/CSA-S16.1-M89. Clause 26.1 states that the anchor bolts shall be designed to resist the effect of uplift forces, bending moments, and shear forces with the resistances calculated for:

- Tension (Clause 26.2.1) as,

Figure 3.10: The Anchor Bolt

$$T_r = \phi_b A_n F_u \quad (3.13)$$

where,

$$\phi_b = 0.67$$

$$A_n = \frac{\pi}{4}(D - 0.938P)^2, \text{ net area of the anchor bolt at the root of the thread}$$

D = diameter of the anchor bolt

P = pitch of thread

- Shear (Clause 26.2.2) as,

$$V_r = 0.60\phi_b n A_b F_u \quad (3.14)$$

but not greater than $B_r = 1.4\phi_c n A f'_c$ as given by Clause 25.2.3.3

where,

$$A = \text{bearing area} = 5 d^2$$

d = anchor bolt diameter

n = number of bolts in shear

- Shear and Tension (Clause 26.2.3):

$$\left(\frac{V_f}{V_r}\right)^2 + \left(\frac{T_f}{T_r}\right)^2 \leq 1.0 \quad (3.15)$$

where V_f is the portion of the total shear per bolt transmitted by bearing of the anchor bolts on the concrete.

- Tension and Bending (Clause 26.2.4)

An anchor bolt that is required to develop resistance to both tension and bending shall be proportioned to meet the requirements of Clause 13.9(a):

$$\left(\frac{T_f}{T_r}\right) + \left(\frac{M_f}{M_r}\right) \leq 1.0 \quad (3.16)$$

where, $M_r = \phi S F_y$

- Resistance to pull-out as defined in Clause 25.2.2 which references Appendix H4.1 of CAN/CSA-A23.3-M84:

Full anchorage is obtained when the factored pull-out resistance, P_r , acting on the effective area is equal to or greater than the factored tensile resistance of the bolts, where P_r is defined as;

$$P_r = 0.3\lambda\phi_c\sqrt{f'_c} \quad (3.17)$$

The development length of standard hooks for the anchor bolts in both tension and compression must be calculated from equations given on Clauses 12.5.3.2 to 12.5.3.6 of CAN/CSA-A23.3-M84.

These calculations for resistances are performed by the functions *anchorBolts* and *pullOut*. If the resistances are insufficient the anchor bolt size is increased, the resistances re-calculated and the design requirements checked. Once a satisfactory

anchor bolt has been determined, then the information is passed back to the *basePlateDesign* function. Note, the diameter of anchor bolt holes in the base plate should provide for possible horizontal adjustments for alignment purposes.

3.2.3 Base Plate Column Connection

The column is connected to the base plate by a combination of fillet and partial or full penetration groove welds; or by angles bolted or welded to column flange or web and welded to the base plate. Geometric and strength designs for each component, for standard type base plate connections, are in accordance with CAN/CSA-S16.1-M89 and fabrication practices in Canada. The relevant clauses from the standard related to strength and detailing, as well as general detailing rules developed as part of this thesis, are listed for each component.

3.2.3.1 High Strength Bolts (ASTM A325, ASTM A490)

A minimum of two bolts are used for any connection. If the bolt group resistance is inadequate for the system of applied loads, then the number of bolts and number of lines of bolts will be increased upto a maximum of two lines with the number limited to the available space for the bolt group. If the resistance is still inadequate then the bolt group is replaced by welds. The appropriate resistances for bearing and shear are listed below:

- The factored bearing resistance, B_r , is given in Clause 13.10.1(c), as the lesser of

$$B_r = 3\phi t d n F_u \quad (3.18)$$

or

$$B_r = \phi t n e F_u \quad (3.19)$$

where, ϕ is taken as 0.67 and F_u is the tensile strength of the plate.

Figure 3.11: Load and Axes Definitions

- The shear capacity, V_r , of bolts is given in Clause 13.11.2(b) as

$$V_r = 0.60\phi_b n m A_b F_u \quad (3.20)$$

where,

m = number of shear plane

A_b = cross sectional area of bolt on its nominal diameter

3.2.3.2 Welds

Where required, fillet and partial or full penetration grooved welds are sized and detailed to give sufficient resistance for shear forces in either the x or y direction and for moments about one or both principal axes. The x and y axes are shown in Figure 3.11, along with the definition of loads.

The shear resistance of fillet welds is specified in clause 13.13.1 and given in Table 3(A) as the lesser of,

- Base metal:

$$V_r = 0.67\phi A_m F_y \quad (3.21)$$

• Weld metal:

$$V_r = 0.67\phi_w A_w X_u \quad (3.22)$$

where,

A_m = effective size $\times$ length of weld (for fillet welds), or

A_m = size of fusion face in base metal $\times$ length of weld
(for partial penetration groove welds)

A_w = size of effective throat of weld $\times$ length of weld

F_y = specified minimum yield stress

X_u = ultimate strength as given by electrode classification number

$\phi_w = 0.67$, resistance factor for welds

The resistance of partial and full penetration groove welds, Gagnon and Kennedy (1987), are given as,

$$T_{r1} = \phi_1 p A_p F_u \quad (3.23)$$

$$T_{r2} = \phi_2 (1.55p - 1.16p^2 + 0.61p^3) A_p F_u \quad (3.24)$$

where,

$$\phi_1 = 0.692$$

$$\phi_2 = 0.71$$

p = degree of weld penetration given as a fractile of plate thickness

A_p = area of the plate

F_u = ultimate strength of the base metal

Fillet weld sizes and lengths are calculated to resist each load and are combined and reconfigured subsequently into weld group combinations of equivalent resistances by the function *weldCombination* . For moment about the x -axis and for shear in either x and/or y direction the fillet weld size and length can be determined directly using the resistances specified in equations 3.21 and 3.22. For moment about the y -axis the following procedure was used,

1. the preferred weld size is retrieved from the *weld-bp.dat* file.
2. a 1.0 mm length of weld is located on both sides of the flange at each tip.
3. the moment resistance of this weld group about the *y*-axis is calculated
4. if the moment resistance is inadequate, then increase each weld length by 1.0 mm and recalculate the resistance. If the length exceeds half the column width, then increase the fillet weld size and repeat steps 2 to 4. If the moment resistance is adequate then execute *weldCombination* function.

The fillet welds for each load are combined into an equivalent fillet weld (provides the same total resistance) located full length of the flange or web on both sides. If the combined fillet weld is larger than 20 mm, then the weld is reconfigured into a combination fillet weld, with a minimum size of 12 mm, and a partial or full penetration groove weld. These simple guidelines will lead to the most cost effective weld group.

3.2.3.3 Angles

The angles are sized according to a combination of rules related to general fabricating, limitations in geometry (fit and clearance) and strength, after the number of bolts, *n*, required to transfer the force from the column to the angle has been determined. The design procedure follows:

1. Retrieve the minimum edge distance, *e*, from the *aglbolts.dat* file. This data file is as in Clause 22.6 and gives the end distance as a function of the bolt diameter and edge condition of section (flame-cut, sheared or rolled)
2. The minimum pitch, *p*, is calculated according to Clause 22.5 to be 3*d*.
3. The minimum edge length is calculated as,

$$L = 2e + (n - 1)p \quad (3.25)$$

4. The bearing capacity is calculated according to Von Mises yield criterion of $\frac{F_y}{\sqrt{3}}$ as given in equations 3.26 and 3.27.

- Shear on gross section:

$$V_r = 0.60\phi LtF_y \quad (3.26)$$

- Shear on net section:

$$V_r = 0.50\phi L_n t F_u \quad (3.27)$$

where, L_n is the angle length, L , less number of bolt holes plus 2 mm. The length or angle thickness are increased if required.

5. The minimum long leg and short leg lengths are calculated and are equal to the minimum edge distance plus the minimum clearance for one bolt line. The pitch is added to this length if two bolt lines exit.
6. The angle length must be less than either the column width or the depth-2k depending on its location. If the required length is greater the space available, then the number of bolt lines is increased from one to two, and the angle strength (bearing and shear capacity) is checked.

After calculating the required dimensions, the function *recomAngleBolt* is called and the appropriate angle is selected from a list of angles produced by Canadian mills.

3.2.4 Column Section

The size of column is specified by the engineer. The bearing capacity is checked according to Clause 13.10.1(c). If the capacity is inadequate then the bolt size is increased. Note, the engineer could select a column with a thicker web or flange as required. This is not done here as it is poor solution for a local failure such as bearing.

3.3 Program Description

Base plate design is one of four design modules in SCADD. The other three are; Beam-to-Column-Web, Beam-to-Column-Flange and Beam-to-Beam connections. The module, programmed in C language, is called from SCADD and performs all the geometric and strength calculations to properly size and detail the specified base plate connection. As indicated in Figure 3.12, SCADD provides the capacity to specify the design data and to display the results. The program structure, layout of its functions, is illustrated in Figure 3.13. The data are passed from any function to another using data files, type data structure and arguments.

A brief description of the five structured functions called in the main program are given below.

- INPUT DATA (*readInputData*)

This function reads the data specified through the interfaces provided (preferences, connection details, loads) and writes them to *bplate.in* file in DATA directory. This file along with all other files for section information, clearance, standard bolt and weld data found in the DATA directory can be accessed by other functions.

- BASE PLATE DESIGN (*basePlateDesign*)

This function calls three functions *plateThickness*, *actualPlateSize* and *pullOut* which calculate the dimensions of the base plate, the dimensions of footing, diameter and length of the anchor bolts, the weld size for connecting the column to the base plate, stiffeners when required, and the *h* and *b* sizes for connecting the column to the base plate (if angles are specified to connect column web or column flange to the base plate).

- SELECTION TYPE of CONNECTION (*TypeConnection*)

The type of connection is specified in the appropriate interface. The corresponding design procedure and generic 3D renderings are specified by the functions

Figure 3.12: The base plate design module

Figure 3.13: The Program Module `bp.c` Structure

within, as indicated in Figure 3.13. The design procedure for each type is illustrated through example traces in Chapter 4.

- **WRITE THE RESULT** (*writeResultData*)

This function writes the design data created from *basePlateDesign* and *select-TypeConnection* to the file caled *bplate.out*. These data is read by SCADD to generate the 3D rendering of the designed connection.

- **DISPLAY THE REPORTS** (*displayReport*)

This function retrieves information from *writeResultData* for the material and engineering reports that are displayed within SCADD.

Chapter 4

The Designed Connection

The design logic for each base plate connection type is detailed in section 4.1 and 4.2 for axially loaded columns and for columns subjected to axial load and moment about one or both principal axes, respectively. Complete traces of the program logic, calculations and output (engineering and material reports, 3D rendering of the design connection) are given. Calculated values retrieved by tracing through the program by use of the UPS debugger tool, are also given. These examples illustrate the versatility of the program. Section 4.3 gives comparisons with solutions provided by the Canadian Institute of Steel Construction, CISC (1992), McGuire (1968) and designs by CANRON Eastern Structural Division, Wells (1994) and The CANAM MANAC GROUP, Vincent (1995). The comparison verify the design produced by SCADD. Variations are given.

4.1 Axially Loaded Columns

4.1.1 Welded to Base Plate (most common)

Given:

Column W310 X 118, Grade 300 W

Anchor Bolts = 2 - 22 mm, ASTM A36 threaded round stock

Axially Loaded Columns	
Section	Description
4.1.1	welded to base plate only; 2 anchor bolts
4.1.2	angle web connection; angles bolted to column, welded to base plate; 4 anchor bolts
4.1.3	angle flange connection; angles welded to column and base plate; 4 anchor bolts
Axial Load and Bending Moment	
4.2.1	unstiffened moment welded connections; 4 anchor bolts
4.2.2	stiffened angle flange connection; bending moment about the major axis; angles bolted to column and welded to base plate; 4 anchor bolts
4.2.3	stiffened single web plate welded connection; bending moment about the major axis; 4 anchor bolts
4.2.4	stiffened flange plate welded connection; bending moment about the minor axis and major axis; 4 anchor bolts.
4.2.5	stiffened double plate welded connection; bending moment about the major axis; 4 anchor bolts
4.2.6	stiffened combination plate welded connection; biaxial bending moment; 4 anchor bolts
4.2.7	built-up 2 anchor bolt connection; bending moment about the major axis
4.2.8	built-up 4 anchor bolt connection; bending moment about the major axis

Table 4.1: Example Types of Base Plate Connections

Axial load, $C_f = 2500 \text{ kN}$

Factored shear in X direction = 475.0 kN

Factored shear in Y direction = 400.0 kN

Specified concrete strength = 20 MPa

Soil bearing capacity = 550 kPa

Preferred base plate thickness = 30 mm

Trace:

1. Read input data (readInputData), as per the given information.

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 446.0 mm ; width = 393.0 mm

- Plate thickness (plateThickness)

Extension of plate beyond the uniformly loaded area assumed under the column in the X and Y directions:

$n = (\text{plate width} - (0.8 \text{ column width}))/2.0 = 73.7 \text{ mm}$

$m = (\text{plate length} - (0.95 \text{ column depth}))/2.0 = 73.7 \text{ mm}$

$t_p = 23.96 \text{ mm}$ (calculated thickness)

thickness = 25 mm (recommended thickness)

- Anchor bolts (anchorBolts)

Preferred anchor bolt diameter = 22 mm .

$T_r = 103.53 \text{ kN}$; $V_r = 244.5 \text{ kN}$; $B_r = 203.2 \text{ kN}$; $T_f = -1094.1 \text{ kN}$. Negative values indicate that the base plate is under compression. As a result the minimum anchor bolt is used, which is 22 mm in this case.

- Pull out (pullOut)

the initial embedment length of the anchor bolt = 149.5 mm .

Development length required for standard hook = 230 mm .

Select the greater of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis (strong axis)

weld size = 0.0 mm (column flange to base plate $M_x = 0.0$)

Case II: Welds due to moment about the Y axis

weld size = 0.0 mm (column flange to base plate $M_y = 0.0$)

Case III: Weld due to shear in X direction (column flange to base plate)

$V_f = 475.0 \text{ kN}$; $A_m = 2625.76 \text{ mm}^2$; $A_w = 2204.46 \text{ mm}^2$;

weld size = 4.27 mm

Case IV: Weld due to shear in Y direction (column web to base plate)

$V_f = 400.0 \text{ kN}$; $A_m = 2211.17 \text{ mm}^2$; $A_w = 1856.39 \text{ mm}^2$;

weld size = 7.04 mm

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial and/or full penetration groove welds, or both.

Fillet weld size on flange = 5.0 mm; length = 307 mm; both sides.

Fillet weld size on web = 8.0 mm; length = 314 mm; both sides.

3. Results (writeResultData)

prefix W , shape $W310$, mass 118, grade 300 W

- column: $d = 314 \text{ mm}$; $b = 307 \text{ mm}$; $t = 18.7 \text{ mm}$; $w = 11.9 \text{ mm}$;

$k = 36.0 \text{ mm}$; $k_1 = 22.0 \text{ mm}$.

- base plate length = 446.0 mm; width = 393.0 mm; thickness = 25.0 mm

- anchor bolt number = 2; diameter = 22 mm; length = 230 mm.

- footing length = 2270.0 mm; footing width = 2000.0 mm.

connection type : WELDED TO BASE PLATE ONLY.

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Printout by: design job MULTIPLE SCREEN ADD TEXT CONTINUE		
Date: Mon 16, 1992 Time: 10:47								

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS	0.0 kN	2500.0 kN
SHEAR FORCES	X (kN)	Y (kN)
SERVICE	0.0	0.0
FACTORED	475.0	400.0
MOMENT	X (kN.m)	Y (kN.m)
SERVICE	0.0	0.0
FACTORED	0.0	0.0

ANCHOR BOLTS

TENSION	104.0 kN
SHEAR	102.0 kN

WELDS AT COLUMN FLANGE

FILLET GROOVE	Vr = 761.8 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

WELDS AT COLUMN WEB

FILLET GROOVE	Vr = 1216.9 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Analysis	Evaluation	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Drawings	Anchor Bolts Pattern	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Design	Loads	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Current File : default Messages :

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Printout by: design job MULTIPLE SCREEN ADD TEXT CONTINUE		
Date: Mon 16, 1992 Time: 10:47								

MATERIALS REPORT

COLUMN W310 X 118

BASE PLATE

THICKNESS	25.0 mm
WIDTH	350.0 mm
LENGTH	446.0 mm

ANCHOR BOLTS

TYPE	ASTM A36 round bar
SIZE	25.0 mm
LENGTH	227.0 mm
NUMBER	2

FOOTING

LENGTH	2270.0 mm
WIDTH	2000.0 mm

WELD STRENGTH 480 MPa

WELDS Column Web to Base Plate (mm) Column Flange to Base Plate (mm)

FILLET GROOVE	8.0	5.0
PARTIAL - PENETRATION	0.0	0.0
COMPLETE - PENETRATION	0.0	0.0
TOTAL LENGTH	628.0	614.0

Note: welds are full length on both sides of the flange and web

Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Analysis	Evaluation	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Drawings	Anchor Bolts Pattern	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Design	Loads	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Current File : default Messages :

Figure 4.1: Welded to Base Plate Only; 2 Anchor Bolts

4.1.2 Angle Web Connection

Given:

Column W460 X 177, Grade 300 W

Anchor Bolts: 4 - 22 mm diameter, ASTM A36 threaded round stock

Bolt preference = M16 ASTM A325M (connecting angle to the column web)

Axial load $C_f = 1750.0 \text{ kN}$

Factored shear in X direction $V_f = 600.0 \text{ kN}$

Factored shear in Y direction $V_f = 800.0 \text{ kN}$

Specified concrete strength = 20.0 MPa; Soil bearing capacity = 550.0 kPa

Trace:

1. Read input data (readInputData), as per the given information.

2. Base plate design (basePlateDesign)

- Plate Size (actualPlateSize)

length = 668.0 mm; width = 438.0 mm

- Plate thickness (plateThickness)

Extension of plate beyond the uniformly loaded area assumed under the column in the X and Y directions:

$n = (\text{plate width} - (0.8 \text{ column width}))/2.0 = 104.6 \text{ mm}$

$m = (\text{plate length} - (0.95 \text{ column depth}))/2.0 = 104.6 \text{ mm}$

$t_p = 22.03 \text{ mm}$ (calculated thickness)

thickness = 25 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22 mm

$T_r = 103.5 \text{ kN}$; $V_r = 244.5 \text{ kN}$; $B_r = 162.6 \text{ kN}$; $T_f = -420.3 \text{ kN}$. Negative values indicate that the base plate is under compression. As a result the minimum anchor bolt is used, which is 22 mm in this case.

- Pull out (pullOut)

the initial embedment length of the anchor bolt = 157.9 mm

Development length required for standard hook = 260 mm. Select the greater of these two values.

3. Design angle (angleWebShear)

Number of shear planes, $m = 2$;

Minimum number of bolts = 2

Initial angle thickness = 8.0 mm

Minimum number of bolt lines = 1

- Angle bearing capacity

Number of bolts required due to shear = 1 (use minimum number = 2).

Number of bolts required for bearing capacity of web = 4.

Minimum length of angle = 173.6 mm; thickness = 10.2 mm.

- Angle shear capacity

Length = 274.6 mm; $V_{r,gross} = 453.75 \text{ kN}$; $V_{r,net} = 401.95 \text{ kN}$;

thickness = 15 mm.

- Long and short leg size

Minimum long leg size = 66.0 mm; Short leg = long leg = 66.0 mm

- Welded part (angle to base plate)

$A_m = 4422.33 \text{ mm}^2$; $A_w = 3712.78 \text{ mm}^2$; weld size = 10.87 mm;

Welds are full length on angle size.

Thickness of angle required for this weld size = weld size/0.75 = 15.0 mm

Note: The length of angle must be less than $d - 2k$. Otherwise increase the number of bolt lines to two.

Available column depth = depth - (2 x k) = 394.0 mm

Angle length = 274.0 mm; Use only one line for bolts

Summary output of this function:

Bolt lines = 1; number of bolts = 4.0; pitch = 69.5 mm; diameter = 16 mm;
clearance = 25.0 mm; angle thickness = 15.0 mm; short leg = long leg =
66.0 mm.

4. Recommended size for angle and bolt (recomAnglesAndBolts)

A comparison is made between angle dimensions resulting from engineering calculations and the preferred angle dimensions specified by user.

Preferred angle long leg = 90.0 mm; short leg = 90.0 mm; thickness = 13.0 mm

Actual thickness = 15.0 mm

The required thickness is greater than the thickness specified, therefore another angle that meets all requirements must be found from the specified list of available angles.

The recommended angle:

Long leg = 100.0 mm; Short leg = 100.0 mm; Thickness = 16.0 mm

Summary output of this function:

Bolt lines = 1; number of bolts = 4; end distance = 33.0 mm; pitch = 69.5 mm;
gauge = 27.0 mm; clearance = 25 mm; washer = 1, length = 274.6 mm

5. Results (writeResultData)

prefix W, shape W460, mass 177, grade 300 W.

- column: d = 482.0 mm; b = 286.0 mm; t = 26.9 mm; w = 16.6 mm;
k = 44.0 mm; k1 = 24.0 mm.
- base plate: length = 668.0 mm; width = 438.0 mm; thickness = 25.0 mm.
- anchor bolt: number = 4; diameter = 22; length = 260 mm.
- footing: length = 2200 mm; width = 1440 mm.

connectors : BOLTED (from angles to the column web)

connection type : ANGLE WEB CONNECTION

4.1.3 Angle Flange Connection

Given:

Column W360 X 162, Grade 300 W

Anchor Bolts: 4 - 22 diameter, ASTM A36 threaded round stock

Bolt preference = M16 ASTM A325M (connecting angle to column flange)

Axial load, $C_f = 1750.0 \text{ kN}$

Factored shear in X direction $V_x = 270.0 \text{ kN}$

Factored shear in Y direction $V_y = 325.0 \text{ kN}$

Specified concrete strength = 20.0 MPa

Soil bearing capacity = 550.0 kPa

Trace:

1. Read input data (readInputData), as per the given information.

2. Base plate design (basePlateDesign)

- Plate Size (actualPlateSize)

length = 582.0 mm ; width = 533.0 mm .

- Plate thickness (plateThickness)

Extension of plate beyond the uniformly loaded area assumed under the column in the X and Y directions:

$n = (\text{plate width} - (0.8 \text{ column width}))/2.0 = 118.1 \text{ mm}$

$m = (\text{plate length} - (0.95 \text{ column depth}))/2.0 = 118.1 \text{ mm}$

$tp = 24.14 \text{ mm}$ (calculated thickness)

thickness = 25.0 mm (recommended thickness)

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Processed for design job		
Date: May 14, 1988 Time: 07:35						MULTIPLE SCREEN	ADD TEXT	CONTINUE

ENGINEERS REPORT SERVICE AND FACTORED LOADS AXIAL LOADS 0 0 kN 1750.0 kN SHEAR FORCES X (kN) Y (kN) SERVICE 0 0 0 0 FACTORED 600.0 800.0 MOMENTS X (kN.m) Y (kN.m) SERVICE 0 0 0 0 FACTORED 0 0 0 0 ANCHOR BOLTS TENSION 104.0 kN SHEAR 163.0 kN WELDS AT COLUMN FLANGE FILLET Vr = 761.8 N/mm GROOVE PARTIAL PENETRATION Vr = 0 0 N/mm COMPLETE PENETRATION Vr = 0 0 N/mm CONNECTORS BOLT SHEAR / TENSILE Vr = 134.3 kN/bolt WELDS Vr = 1657.1 N/mm ANGLES - Shear = 803.9 kN Bearing = 811.9 kN
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Engineers Report	Materials Report	ON/OFF	20	LOCAL
Analysis	Evaluation	50	50	100
Drawings	Anchor Bolts Pattern	100	100	100
Design	Loads	ON/OFF		
		PAN/CAM		

Current File: default Messages:

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Processed for design job		
Date: May 14, 1988 Time: 07:35						MULTIPLE SCREEN	ADD TEXT	CONTINUE

MATERIALS REPORT COLUMN: W460 X 177 BASE PLATE THICKNESS 25 0 mm WIDTH 438.0 mm LENGTH 668 0 mm ANCHOR BOLTS TYPE ASTM A36 round bar SIZE 22 mm LENGTH 240 0 mm NUMBER 4 FOOTING: LENGTH 2200 0 mm WIDTH 1440 0 mm WELD STRENGTH 480 MPa ANGLES NUMBER, SIZE 2, 100 0 X 1 1/2 X 16.0 LENGTH, STRENGTH 275 0 mm, 370 MPa FASTENERS FOR ANGLE TO COLUMN WEB BOLTS 1 X 4, A325, M16 1 washers per bolt FASTENERS FOR ANGLE TO BASE PLATE FILLET WELD 11.0 mm LENGTH 275 0 mm WELDS Column Flange to Base Plate (mm) FILLET 5 0 GROOVE PARTIAL PENETRATION 0 0 COMPLETE PENETRATION 0 0 TOTAL LENGTH 572 0 Note: welds are full length on both sides of the flange.
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Engineers Report	Materials Report	ON/OFF	20	LOCAL
Analysis	Evaluation	50	50	100
Drawings	Anchor Bolts Pattern	100	100	100
Design	Loads	ON/OFF		
		PAN/CAM		

Current File: default Messages:

Figure 4.2: Angle Web Connection

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22 mm

$$T_r = 103.5 \text{ kN}; V_r = 244.5 \text{ kN}; B_r = 162.6 \text{ kN}; T_f = -0.01 \text{ kN}$$

Negative values indicate that the base plate is under compression. As a result the minimum anchor bolt is used, which is 22 mm in this case.

- Pull out (pullOut)

the initial embedment length of the anchor bolt = 157.9 mm

Development length required for standard hook = 260 mm.

Select the greater of these two values.

3. Design angles (angleFlangeShear)

Number of shear planes, $m = 1$

Minimum number of bolts = 2

Initial angle thickness = 8.0 mm

Minimum number of bolt lines = 1

- Angle bearing capacity

Number of bolts required for bearing capacity of flange = 4

Minimum length of angle = 143.4 mm

Thickness = 8.0 mm

- Angle shear capacity

Length = 143.4 mm; $V_{r,gross} = 185.84 \text{ kN}$; $V_{r,net} = 135.10 \text{ kN}$;

Thickness = 8.0 mm

- Long and short leg size

Minimum long leg size = 55.0 mm; Short leg = long leg = 55.0 mm

- Welded part (angle to base plate)

$A_m = 746.27 \text{ mm}^2$; $A_w = 626.53 \text{ mm}^2$; weld size = 5.2 mm; welds are full length on both sides of the web.

Thickness of angle required for this weld size = weld size/0.75 = 7.0 mm

Note: The length of angle must be less than $b - 2k$, otherwise welds will be used instead of bolts.

Available column width = 370.0 mm

required angle length = 264.4 mm

Summary output for this function:

Bolt lines = 1; number of bolts = 4.0; pitch = 49.7 mm;

diameter = 16.0 mm; clearance = 25.0 mm; thickness = 8.0 mm;

short leg = long leg = 55.

4. Recommendation size for angle and bolt (recomAnglesAndBolts)

A comparison is made between angle dimensions resulting from engineering calculations and the preferred angle dimensions specified by user.

Preferred long leg = 90.0 mm; preferred short leg = 65.0 mm;

preferred thickness = 10.0 mm; actual thickness = 8.0 mm.

The required thickness is less than the thickness specified, otherwise another angle, that meets all requirements must be found from the list of available angles in *bpangles.dat* file. The recommended angle:

Long leg = 90.0 mm; Short leg = 65.0 mm; Thickness = 10.0 mm

Summary output for this function:

number of bolts = 8; End distance = 22.0 mm; pitch = 49.7 mm,

gauge = 27.0 mm; clearance = 25.0 mm; line = 1; Washer = 1;

angle length = 264.4 mm.

5. Results (writeResultData)

prefix W, shape W360, mass 122 , grade 300 W

- column: d = 364.0 mm; w = 370.0 mm; t = 21.8 mm; w = 13.3 mm;

k = 39.0 mm; k1 = 22.0 mm.

- base plate: length = 582.0 mm; width = 533.0 mm; thickness = 25.0 mm.
- Anchor bolts: number = 4; diameter = 22 mm; length = 260.0 mm.
- footing: length = 1860.0 mm; width = 1710.0 mm.

connectors : BOLTED (from angles to the column flange)

connection type : ANGLE FLANGE CONNECTION

4.2 Combination of Axial Load and Moment

4.2.1 Unstiffened Moment Connection

Given:

Column W360 X 147, Grade 300 W

Anchor Bolts = 4 - 22 mm diameter , ASTM A36 threaded round bar stock.

Axial load, $C_f = 2750.0 \text{ kN}$

Factored shear in X direction $V_x = 650.0 \text{ kN}$

Factored shear in Y direction $V_y = 750.0 \text{ kN}$

Factored moment about the X axis $M_x = 150.0 \text{ kNm}$

Factored moment about the Y axis $M_y = 175.0 \text{ kNm}$

Specified concrete strength = 25.0 MPa

Soil bearing capacity = 550.0 kPa

Trace:

1. Read input data (readInputData), as per the given information.
2. Base plate design (basePlateDesign)
 - Plate Size (actualPlateSize)

length = 556.0 mm; width = 566.0 mm

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Preview the design job	MULTIPLE SCREEN	ADD TEXT
Date: Mar 14, 1993 Time: 09:01							CONTINUE	

ENGINEERS REPORT SERVICE AND FACTORED LOADS AXIAL LOADS 0.0 kN 1750.0 kN SHEAR FORCES X (kN) Y (kN) SERVICE 0.0 0.0 FACTORED 270.0 320.0 MOMENTS X (kN.m) Y (kN.m) SERVICE 0.0 0.0 FACTORED 0.0 0.0 ANCHOR BOLTS TENSION 104.0 kN SHEAR 143.0 kN WELDS AT COLUMN WEB FILLET Vr = 761.8 N/mm GROOVE Vr = 0.0 N/mm PARTIAL PENETRATION Vr = 0.0 N/mm COMPLETE PENETRATION Vr = 0.0 N/mm CONNECTORS BOLT SHEAR STRENGTH Vr = 67.1 kN/bolt WELDS Vr = 792.9 N/mm ANGLES - Shear = 135.1 kN Bearing = 318.4 kN
Engineers Report Materials Report Analysis Evaluation Drawings Anchor Bolt Pattern Design Loads		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		

Current File : default Messages :

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Preview the design job	MULTIPLE SCREEN	ADD TEXT
Date: Mar 14, 1993 Time: 09:01							CONTINUE	

MATERIALS REPORT COLUMN: W360 X 162 BASE PLATE THICKNESS 25.0 mm WIDTH 533.0 mm LENGTH 582.0 mm ANCHOR BOLTS TYPE ASTM A36 round bar SIZE 22 mm LENGTH 260.0 mm NUMBER 4 FOOTING LENGTH 1860.0 mm WIDTH 1710.0 mm WFLD STRENGTH 480 MPa ANGLES NUMBER, SIZE 2, 90.0 X 65.0 X 10.0 LENGTH, STRENGTH 265.0 mm, 300 MPa FASTENERS FOR ANGLE TO COLUMN FLANGE BOLTS 1 X 4, A325M M6 1 washers per bolt FASTENERS FOR ANGLE TO BASE PLATE FILLET WELD 6.0 mm WELDS: Column Web to Base Plate (mm) FILLET 5.0 GROOVE 0.0 PARTIAL PENETRATION 0.0 COMPLETE PENETRATION 0.0 TOTAL LENGTH 286.0 Note: welds are full length on both sides of the web
Engineers Report Materials Report Analysis Evaluation Drawings Anchor Bolt Pattern Design Loads		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 END OF JOB PLOT ONLY		

Current File : default Messages :

Figure 4.3: Angle Flange Connection

- Plate thickness (plateThickness)

$t_p = 31.95 \text{ mm}$ (calculated thickness)

thickness = 35.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22 mm

$T_r = 103.5 \text{ kN}$; $V_r = 244.5 \text{ kN}$; $B_r = 203.28 \text{ kN}$;

$T_f = -445.189 \text{ kN}$ (base plate under compression); magnitude of the moments relatively small in comparison with the axial load.

Use the preferred anchor bolt = 22 mm.

- Pull out (pullOut)

the initial embedment length of the anchor bolt = 149.29 mm

Development length required for standard hook = 230.0 mm.

Select the greater of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis

$V_f = 416.67 \text{ kN}$; $A_m = 2303.3 \text{ mm}^2$; $A_w = 1933.74 \text{ mm}^2$

weld size = 3.11 mm (column flange to base plate)

Case II: Welds due to moment about the Y axis

V_f - required = 472.97 kN; V_f - calculated = 473.95 kN;

weld size = 5 mm (column flange to base plate).

Case III: Weld due to shear in X direction

$V_f = 650.0 \text{ kN}$; $A_m = 3593.15 \text{ mm}^2$; $A_w = 3016.63 \text{ mm}^2$;

weld size = 4.8 mm.

Case IV: Weld due to shear in Y direction

$V_f = 750.0 \text{ kN}$; $A_m = 4145.94 \text{ mm}^2$; $A_w = 3480.73 \text{ mm}^2$;

weld size = 5.7 mm.

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial and/or full penetration groove welds, or both.

Fillet weld size on flange = 5.0 mm.

Fillet weld size on web = 11.0 mm.

3. Results (writeResultData)

prefix *W*, shape *W360*, mass 147, grade 300 *W*

- column: $d = 360.0 \text{ mm}$; $b = 370.0 \text{ mm}$; $t = 19.8 \text{ mm}$; $w = 12.3 \text{ mm}$;
 $k = 37.0 \text{ mm}$; $k_1 = 21.0 \text{ mm}$.
- plate: length = 556.0 mm; width = 566.0 mm; thickness = 35.0 mm.
- anchor bolts: number = 4; diameter = 22 mm; length = 230 mm.
- footing: length = 3240 mm; width = 1700.0 mm.

connection type : UNSTIFFENED

4.2.2 Stiffened Angle Flange Connection

Given:

Column *W360 X 147* , Grade 300 *M*

Anchor Bolts = 4 - 22 mm diameter, ASTM A36 threaded round stock

Bolt preference = M16, ASTM A325M (connecting angle to the column flange)

Axial load, $C_f = 1560.0 \text{ kN}$

Factored shear in X direction $V_f = 175.0 \text{ kN}$

Factored moment about the X axis $M_x = 240.0 \text{ kNm}$

Specified concrete strength = 20.0 MPa

Soil bearing capacity = 550.0 kPa

Trace:

Figure 4.4: Unstiffened Moment Connection

1. Read input data (readInputData), as per the given information.

2. Base plate design (basePlateDesign)

- Plate Size (actualPlateSize)

length = 512.0 mm; width = 522.0 mm

- Plate thickness (plateThickness)

tp = 29.93 mm (calculated thickness)

thickness = 30.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22 mm

$T_r = 103.5 \text{ kN}$; $V_r = 244.5 \text{ kN}$; $B_r = 162.6 \text{ kN}$;

$T_f = 0.0 \text{ kN}$ (base plate is under compression).

Use the preferred anchor bolt size = 22 mm

- Pull out (pullOut)

the initial embedment length = 157.97 mm

Development length required for standard hook = 258.26 mm

3. Design angle (momentStiffAngleFlange)

Number of shear planes, $m = 1$

Minimum number of bolts = 2

Initial angle thickness = 8.0 mm (default thickness)

Minimum number of bolt line = 1

- Column flange bearing capacity

Bearing capacity = 260.49 kN; $V_f = 87.5 \text{ kN}$

- Angle bearing capacity

Number of bolts required for bearing capacity of flange = 2

Minimum length of angle = 44.0 mm

Thickness = 8.0 mm

- Angle shear capacity

Minimum length = 44.0 mm; V_r gross = 570.24 kN;

V_r net = 388.80 kN; Thickness = 8.0 mm

- Long and short leg size

Minimum long leg size = 55.0 mm; Short leg = long leg = 55.0 mm

- Welded part (angle to base plate)

$A_m = 483.69 \text{ mm}^2$; $A_w = 406.09 \text{ mm}^2$; weld size = 6.44 mm

Thickness of angle required for this weld size = weld size/0.75 = 9.0 mm

Note: The length of angle must be less than column width , otherwise welds will be used instead of bolts.

Available column width = 305.0 mm; Angle length = 190.5 mm

Summary output for this function:

Bolt lines = 1; number of bolts = 4.0; pitch = 43.2 mm; diameter = 16 mm; clearance = 25.0 mm; angle thickness = 9.0 mm; short leg = long leg = 55.0 mm

4. Recommended size for angle and bolt (recomAnglesAndBolts)

A comparison is made between angle dimensions resulting from engineering calculations and the preferred angle dimensions specified by user.

preferred long leg = 80.0 mm; preferred short leg = 60.0 mm;

preferred thickness = 10.0 mm.

Actual thickness = 10.0 mm.

The recommended angle:

Long leg = 80.0 mm, Short leg = 60.0 mm, Thickness = 10.0 mm

The recommended angle is the same as preferred angle

Summary output for this function:

number of bolts = 4; End distance = 22.0 mm; pitch = 43.2 mm;

gauge = 27.0 mm; clearance = 25.0 mm; Bolt lines line = 1; Washer = 1;
angle length = 190.5 mm.

5. Results (writeResultData)

prefix W, shape W360, mass 147 , grade 300 W

- column: d = 360.0 mm; w = 370.0 mm; t = 19.79 mm; w = 12.3 mm;
k = 37.0 mm; k1 = 21.0 mm.
- plate: length = 512.0 mm; width = 522.0 mm; thickness = 30.0 mm.
- Anchor bolts: number = 4; diameter = 22 mm; length = 260.0 mm.
- footing: length = 2480.0 mm; width = 1570.0 mm.

connectors : BOLTED (from angles to the column flange)

connection type : STIFFENED ANGLE FLANGE CONNECTION

4.2.3 Stiffened Single Plate Connection

Given:

Column W360 X 110 , Grade 300 W

Anchor Bolts = 4 - 22 mm diameter, ASTM A36 threaded round stock

Axial load, $C_f = 725.0 \text{ kN}$

Factored shear in the Y direction = 510.0 kN

Factored moment about the X axis = 320.0 kNm

Specified concrete strength = 25 MPa

Soil bearing capacity = 550.0 kPa

Preferred base plate thickness = 30.0 mm

Trace:

1. Read input data (readInputData), as per the given information.

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Preview the design on	MULTIPLE SCREEN	ADD TEXT
Date: Feb 05, 1992 Time: 10:07								

<p align="center">ENGINEERS REPORT</p> <p>SERVICE AND FACTORED LOADS</p> <p>AXIAL LOADS 0 0 kN 1560.0 kN</p> <p>SHEAR FORCES X (kN) Y (kN)</p> <p>SERVICE 0.0 0.0</p> <p>FACTORED 175.0 0.0</p> <p>MOMENTS X (kN.m) Y (kN.m)</p> <p>SERVICE 0.0 0.0</p> <p>FACTORED 240.0 0.0</p> <p>ANCHOR BOLTS</p> <p>TENSION 104.0 kN</p> <p>SHEAR 163.0 kN</p> <p>WELDS AT COLUMN WEB</p> <p>FILLET GROOVE Vr = 761.8 N/mm</p> <p>PARTIAL PENETRATION Vr = 0.0 N/mm</p> <p>COMPLETE PENETRATION Vr = 0.0 N/mm</p> <p>CONNECTORS</p> <p>BOLT SHEAR STRENGTH Vr = 47.1 kN/bolt</p> <p>WELDS Vr = 982.6 N/mm</p> <p>ANGLES - Shear = 89.1 kN</p> <p> Bearing = 106.1 kN</p> <p>COLUMN FLANGE BEARING CAPACITY Br = 286.5 kN</p>	<p align="center">Angle Flange</p>
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Engineers Report	Materials Report	ON/OFF	
Analysis	Evaluation	20	50
Drawings	Rotation	100	150
Design	Loads	200	250
		ON/OFF	
		20	50
		100	150
		200	250

Current File : default Messages :

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Preview the design on	MULTIPLE SCREEN	ADD TEXT
Date: Feb 05, 1992 Time: 10:07								

<p align="center">MATERIALS REPORT</p> <p>COLUMN: W360 X 147</p> <p>BASE PLATE</p> <p>THICKNESS 30.0 mm</p> <p>WIDTH 322.0 mm</p> <p>LENGTH 312.0 mm</p> <p>ANCHOR BOLTS</p> <p>TYPE ASTM A36 round bar</p> <p>SIZE 22 mm</p> <p>LENGTH 260.0 mm</p> <p>NUMBER 4</p> <p>FOOTING</p> <p>LENGTH 2480.0 mm</p> <p>WIDTH 1570.0 mm</p> <p>WELD STRENGTH 480 MPa</p> <p>ANGLES</p> <p>NUMBER, SIZE 2, 80.0 X 60.0 X 10.0</p> <p>LENGTH, STRENGTH 191.0 mm, 300 MPa</p> <p>FASTENERS FOR ANGLE TO COLUMN FLANGE</p> <p>BOLTS 1 x 2, A325H, M16</p> <p> 1 washers per bolt</p> <p>FASTENERS FOR ANGLE TO BASE PLATE</p> <p>FILLET WELD 7.0 mm</p> <p>WELDS</p> <p> Column Web to</p> <p> Base Plate (mm)</p> <p>FILLET 5.0</p> <p>GROOVE 0.0</p> <p>PARTIAL PENETRATION 0.0</p> <p>COMPLETE PENETRATION 0.0</p> <p>Note: welds are full length on both sides of the web</p>	<p align="center">Angle Flange</p>
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Engineers Report	Materials Report	ON/OFF	
Analysis	Evaluation	20	50
Drawings	Rotation	100	150
Design	Loads	200	250
		ON/OFF	
		20	50
		100	150
		200	250

Current File : default Messages :

Figure 4.5: Stiffened Angle Flange Connection

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 686.0 mm; width = 582.0 mm.

- Plate thickness (plateThickness)

tp = 54.57 mm (calculated thickness)

thickness = 55.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22 mm

$T_r = 278.7 \text{ kN}$; $V_r = 454.6 \text{ kN}$, $B_r = 378.0 \text{ kN}$; $T_f = 169.2 \text{ kN}$ Uplift.

The calculated anchor bolt diameter required = 36.0 mm.

- Pull out (pullOut)

the initial embedment length = 202.93 mm

Development length required for the standard hook = 540.0 mm

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis.

$V_f = 888.8 \text{ kN}$; $A_m = 4913.7 \text{ mm}^2$; $A_w = 4125.41 \text{ mm}^2$

weld size = 9.59 mm

Case II: Welds due to moment about the Y axis.

Not available because $M_y = 0.0$

Case III: Welds due to shear in X direction

Not available because $V_x = 0.0$.

Case IV: Welds due to shear in Y direction

$V_f = 510.0 \text{ kN}$; $A_m = 2819.24 \text{ mm}^2$; $A_w = 2366.9 \text{ mm}^2$;

weld size = 3.91 mm.

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 5.0 mm

Column flange to base plate, fillet weld size = 10.0 mm

3. Stiffeners (singlePlate)

length = 143 mm; height = 143 mm; thickness = 10.0 mm;

weld size = 5.0 mm.

4. Results (writeResultData)

prefix W, shape W360, mass 110, grade 300 W.

- column: d = 360 mm; b = 256 mm; t = 19.9 mm; w = 11.4 mm;

k = 39 mm; k1 = 24 mm

- base plate: length = 686.0 mm; width = 582.0 mm; thickness = 55.0 mm

- Anchor bolts: number = 4; diameter = 36 mm; length = 540.0 mm

- footing: length = 1840.0 mm; width = 1750.0 mm.

connection type : STIFFENED SINGLE PLATE

4.2.4 Stiffened Flange Plate Connection

Given:

Column W360 X 91 , Grade 300 W

Anchor Bolts = 4 - 22 mm diameter, ASTM A36 threaded round stock

Axial load, $C_f = 1150.0 \text{ kN}$

Factored shear in the X direction = 540.0 kN

Factored moment about the Y axis = 495.0 kNm

Factored moment about the X axis = 500.0 kNm

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Postscript file output on		
Date: Feb 28, 1999 Time: 09:38					MULTIPLE SCREEN ADD TEXT CONTINUE			

ENGINEERS REPORT SERVICE AND FACTORED LOADS AXIAL LOADS 0.0 kN 725.0 kN SHEAR FORCES X (kN) Y (kN) SERVICE 0.0 0.0 FACTORED 0.0 910.0 MOMENTS X (kN.m) / (kN.m) SERVICE 0.0 0.0 FACTORED 320.0 0.0 ANCHOR BOLTS TENSION 379.0 kN SHEAR 378.0 kN WELDS AT COLUMN FLANGE FILLET Vr = 1523.6 N/mm GROOVE Vc = 0.0 N/mm PARTIAL PENETRATION Vc = 0.0 N/mm COMPLETE PENETRATION Vc = 0.0 N/mm WELDS AT COLUMN WEB FILLET Vr = 761.8 N/mm GROOVE Vc = 0.0 N/mm PARTIAL PENETRATION Vc = 0.0 N/mm COMPLETE PENETRATION Vc = 0.0 N/mm WELDS FOR STIFFENER - Vr = 761.8 N/mm		Single Plate Flange Plate Double Plate Combination
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Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Analysis	Evaluation		50	60	100																		
Drawings	Rotation		120	150	220																		
Design	Loads		CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK		
			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM		

Current File: data.it Messages:

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Postscript file output on		
Date: Feb 28, 1999 Time: 09:38					MULTIPLE SCREEN ADD TEXT CONTINUE			

MATERIALS REPORT COLUMN W360 X 110 BASE PLATE THICKNESS 55.0 mm WIDTH 582.0 mm LENGTH 686.0 mm ANCHOR BOLTS TYPE ASTM A36 round bar SIZE 16 mm LENGTH 540.0 mm NUMBER 4 FOOTING LENGTH 1840.0 mm WIDTH 1750.0 mm WELD STRENGTH 480 N/mm WELDS Column Web to Column Flange Base Plate (mm) Base Plate (mm) FILLET 5.0 10.0 GROOVE 0.0 0.0 PARTIAL PENETRATION 0.0 0.0 COMPLETE PENETRATION 0.0 0.0 STIFFENER LENGTH 143.0 mm HEIGHT 143.0 mm THICKNESS 10.0 mm WELD SIZE 5.0 mm Note: welds are full length on both sides of the flange and web		Single Plate Flange Plate Double Plate Combination
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Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Analysis	Evaluation		50	60	100																		
Drawings	Rotation		120	150	220																		
Design	Loads		CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK			CHECK OK		
			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM			PAN CAM		

Current File: default Messages:

Figure 4.6: Stiffened Single Plate Connection

Specified concrete strength = 25.0 MPa

Soil bearing capacity = 550.0 kPa

Preferred base plate thickness = 30 mm

Trace:

1. Read input data (readInputData), as per given information.

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 759.0 mm; width = 660.0 mm.

- Plate thickness (plateThickeness)

tp = 68.01 mm (calculated thickness)

thickness = 70.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 22mm

$T_r = 382.5 \text{ kN}$; $V_r = 654.6 \text{ kN}$; $B_r = 544.3 \text{ kN}$; $T_f = 223.5 \text{ kN}$ Uplift.

The calculated anchor bolt diameter required = 42.0 mm.

- Pull out (pullOut)

the initial embedment length = 286.98 mm

Development length required for the standard hook = 630.0 mm

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis

$V_f = 1133.1 \text{ kN}$; $A_m = 6263.93 \text{ mm}^2$; $A_w = 5258.89 \text{ mm}^2$;

weld size = 12.33 mm

Case II: Welds due to moment about the Y axis

V_f required = 1948.82 kN; V_f calculated = 1953.72 kN;

weld size = 25.0 mm

Case III: Welds due to shear in X direction

$$V_f = 540.0 \text{ kN}; A_m = 2985.07 \text{ mm}^2; A_w = 2506.13 \text{ mm}^2;$$

$$\text{weld size} = 5.87 \text{ mm}$$

Case IV: Welds due to shear in Y direction

Not available because $V_y = 0.0$.

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 16.0 mm

Column flange to base plate, full penetration weld = 15.0 mm

3. Stiffeners (flangePlate)

$$\text{length} = 173.0 \text{ mm}; \text{height} = 173.0 \text{ mm}; \text{thickness} = 10.0 \text{ mm}$$

4. Results (writeResultData)

prefix W, shape W360, mass 91, grade 300 W

- column: $d = 353.0 \text{ mm}$; $b = 254.0 \text{ mm}$; $t = 16.4 \text{ mm}$; $w = 9.5 \text{ mm}$;

$$k = 36.0 \text{ mm}; k_1 = 23.0 \text{ mm}.$$

- base plate: length = 759.0 mm; width = 660.0 mm;

$$\text{thickness} = 70.0 \text{ mm}.$$

- Anchor bolts: number 4; diameter = 42 mm; length = 630.0 mm.

- footing length = 2270.0 mm; width = 1980.0 mm.

connection type : STIFFENED FLANGE PLATE

4.2.5 Stiffened Double Plate Connection

Given:

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	MULTIPLE SCREEN	ADD TEXT	CONTINUE

Date: Feb 05, 1995 Time: 10:05

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS	0.0 kN	1150.0 kN
SHEAR FORCES	X (kN)	Y (kN)
SERVICE	0.0	0.0
FACTORED	540.0	0.0
MOMENTS	X (kN.m)	Y (kN.m)
SERVICE	0.0	0.0
FACTORED	500.0	495.0

ANCHOR BOLTS

TENSION	383.0 kN
SHEAR	545.0 kN

WELDS AT COLUMN FLANGE

FILLET GROOVE	Vr = 0.0 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 3809.0 N/mm

WELDS AT COLUMN WEB

FILLET GROOVE	Vr = 2437.8 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

WELDS FOR STIFFENER - Vr = 761.8 N/mm

Single Plate
Flange Plate
Double Plate
Combination

Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12
Analysis	Evaluation	50	60	70	80	90	100	110	120	130	140	150	160	170
Drawings	Rotation	120	130	140	150	160	170	180	190	200	210	220	230	240
Design	Loads	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12
		PAN CAM	1	2	3	4	5	6	7	8	9	10	11	12

Current File : default Messages :

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	MULTIPLE SCREEN	ADD TEXT	CONTINUE

Date: Feb 05, 1995 Time: 10:05

MATERIALS REPORT

COLUMN W360 X 91

BASE PLATE

THICKNESS	7.0 mm
WIDTH	660.0 mm
LENGTH	759.0 mm

ANCHOR BOLTS

TYPE	ASTM A36 round bar
SIZE	42 mm
LENGTH	630.0 mm
NUMBER	4

FOOTING

LENGTH	2270.0 mm
WIDTH	1980.0 mm

WELD STRENGTH 480 MPa

WELDS

Column Web to Base Plate (mm)	16.0	Column Flange to Base Plate (mm)	0.0
FILLET GROOVE	0.0	0.0	0.0
PARTIAL PENETRATION	0.0	0.0	0.0
COMPLETE PENETRATION	0.0	15.0	0.0

STIFFENER

LENGTH	173.0 mm
WIDTH	173.0 mm
THICKNESS	10.0 mm
WELD SIZE	5.0 mm

Note: welds are full length on both sides of the flange and web

Single Plate
Flange Plate
Double Plate
Combination

Engineers Report	Materials Report	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12
Analysis	Evaluation	50	60	70	80	90	100	110	120	130	140	150	160	170
Drawings	Rotation	120	130	140	150	160	170	180	190	200	210	220	230	240
Design	Loads	ON/OFF	1	2	3	4	5	6	7	8	9	10	11	12
		PAN CAM	1	2	3	4	5	6	7	8	9	10	11	12

Current File : default Messages :

Figure 4.7: Stiffened Flange Plate Connection

Column W310 X 86 , Grade 300 W

Anchor Bolts: 4 - 24 mm diameter, ASTM A36 threaded round stock

Axial load, $C_f = 1640.0 \text{ kN}$

Factored shear in Y direction = 490.0 kN

Factored moment about the X axis = 440.0 kNm

Specified concrete strength = 25.0 MPa

Soil bearing capacity = 550.0 kPa

Preferred base thickness = 30.0 mm

Trace:

1. Read input data (readInputData), as per the given information.

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 648.0 mm; width = 592.0 mm

- Plate thickness (plateThickness)

tp = 68.55 mm (calculated thickness)

thickness = 70.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preference anchor bolt diameter = 24 mm

$T_r = 278.7 \text{ kN}$; $V_r = 454.65 \text{ kN}$; $B_r = 378 \text{ kN}$; $T_f = 166.39 \text{ kN}$ Uplift.

The calculated anchor bolt diameter required = 36.0 mm.

- Pull out (pullOut)

The initial embedment length = 244.96 mm

Development length required for the standard hook = 540.0 mm

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis

$$V_f = 1419.35 \text{ kN}; A_m = 7846.07 \text{ mm}^2; A_w = 6587.19 \text{ mm}^2;$$

weld size = 15.44 mm

Case II: Welds due to moment about the Y axis

Not available because $M_y = 0.0$

Case III: Welds due to shear in X direction

Not available because $V_x = 0.0$

Case IV: Welds due to shear in Y direction

$$V_f = 490.0 \text{ kN}; A_m = 2708.68 \text{ mm}^2; A_w = 22'4.08 \text{ mm}^2;$$

weld size = 4.36 mm.

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 5.0 mm

Column flange to base plate, fillet weld size = 16.0 mm

3. Stiffeners (doublePlate)

length = 588.0 mm; height = 139.0 mm; thickness = 10.0 mm;

weld size = 5.0 mm

4. Results (writeResultData)

prefix W, shape W310, mass 86, grade 300 W

- column: $d = 310.0 \text{ mm}$; $b = 254.0 \text{ mm}$; $t = 16.3 \text{ mm}$; $w = 9.1 \text{ mm}$;
 $k = 34.0 \text{ mm}$; $k1 = 20.0 \text{ mm}$.
- base plate: length = 648.0 mm; width = 592.0 mm; thickness = 70.0 mm.
- Anchor bolts: number 4; diameter = 36 mm; length = 540 mm.
- footing: length = 2690.0 mm; width = 1780.0 mm.

connection type : STIFFENED DOUBLE PLATE

Figure 4.8: Stiffened Double Plate Connection

4.2.6 Stiffened Combination Plate Connection

Given:

Column W310 X 143 , Grade 300 W

Anchor Bolts = 4 - 24 mm diameter, ASTM A36 threaded round stock

Axial load, $C_f = 1860.0 \text{ kN}$

Factored shear in X direction = 620.0 kN

Factored shear in Y direction = 530.0 kN

Factored moment the X axis = 580.0 kNm

Factored moment the Y axis = 520.0 kNm

Specified concrete strength = 25.0 MPa

Soil bearing capacity = 550.0 kPa

Preferred base plate thickness = 30.0 mm

Trace:

1. Read input data (readInputData), as per the given information.

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 663.0 mm; width = 649.0 mm

- Plate thickness (plateThickness)

tp = 70.69 mm (calculated thickness)

thickness = 70.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 24 mm.

$T_r = 278.70 \text{ kN}$; $V_r = 654.69 \text{ kN}$; $B_r = 544.32 \text{ kN}$; $T_f = 189.17 \text{ kN}$ Uplift.

The calculated anchor bolt diameter required = 36.0 mm.

- Pull out (pullOut)

The initial embedment length = 244.95 mm

Development length required for the standard hook = 540.0 mm

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment in X direction

$V_f = 1795.67 \text{ kN}$; $A_m = 9926.29 \text{ mm}^2$; $A_w = 8333.64 \text{ mm}^2$;

weld size = 16.06 mm

Case II: Welds due to moment in Y direction

V_f required = 1682.85 kN; V_f calculated = 1690.3 kN;

weld size = 16.0 mm

Case III: Weld due to shear in X direction

$V_f = 620.0 \text{ kN}$; $A_m = 3427.31 \text{ mm}^2$; $A_w = 2877.4 \text{ mm}^2$;

weld size = 5.54 mm

Case IV: Weld due to shear in Y direction

$V_f = 530.0 \text{ kN}$; $A_m = 2929.8 \text{ mm}^2$; $A_w = 2459.72 \text{ mm}^2$;

weld size = 4.5 mm

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 11.0 mm.

Column flange to base plate, fillet weld size = 17.0 mm.

3. Stiffeners (combinationPlate)

Stiffeners in parallel with the column web:

length = 603.0 mm; height = 140.0 mm; thickness = 10.0 mm

Stiffeners parallel with column flange:

length = 140.0 mm; height = 140.0 mm; thickness = 10.0 mm

4. Results (writeResultData)

prefix *W*, shape *W310*, mass 143, grade 300 *W*

- column: $d = 323.0 \text{ mm}$; $b = 309.0 \text{ mm}$; $t = 22.9 \text{ mm}$; $w = 14.0 \text{ mm}$;
 $k = 40.0 \text{ mm}$; $k_1 = 23.0 \text{ mm}$
- base plate: length = 663.0 *mm*; width = 649.0 *mm*; thickness = 70.0 *mm*
- anchor bolts: number = 4; diameter = 36 *mm*; length = 540 *mm*
- footing: length = 2870.0 *mm*; width = 1950.0 *mm*

connection type : STIFFENED COMBINATION PLATE

4.2.7 Built-Up Two Anchor Bolt Connection

Given:

Column *W360 X 91* , Grade 300 *W*

Anchor Bolts = 2 - 24 *mm* diameter, ASTM A36 threaded round stock

Axial load, $C_f = 1390.0 \text{ kN}$

Factored shear in *Y* direction = 545.0 *kN*

Factored moment about the *X* axis = 395.0 *kNm*

Specified concrete strength = 25.0 *MPa*

Soil bearing capacity = 550.0 *kPa*

Preferred base plate thickness = 30.0 *mm*

Trace:

1. Read input data (readInputData), as per the given information.
2. Base plate design. (basePlateDesign)
 - Plate size (actualPlateSize)
 length = 787.0 *mm*; width = 688.0 *mm*

QUIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Pathname for design job MULTIPLE SCREEN ADD TEXT CONTINUE		
Date: Feb 25, 1999 Time: 14:02								

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS 0.0 KN 1860.0 KN

SHEAR FORCES X (KN) Y (KN)

SERVICE 0.0 0.0

FACTORED 620.0 530.0

MOMENTS X (KN.M) Y (KN.M)

SERVICE 0.0 0.0

FACTORED 580.0 520.0

ANCHOR BOLTS

TENSION 278.0 KN

SHEAR 345.0 KN

WELDS AT COLUMN FLANGE

FILLET Vr = 2590.1 N/mm

GROOVE Vr = 0.0 N/mm

PARTIAL PENETRATION Vr = 0.0 N/mm

COMPLETE PENETRATION Vr = 0.0 N/mm

WELDS AT COLUMN WEB

FILLET Vr = 1676.0 N/mm

GROOVE Vr = 0.0 N/mm

PARTIAL PENETRATION Vr = 0.0 N/mm

COMPLETE PENETRATION Vr = 0.0 N/mm

WELDS FOR STIFFENERS

Parallel with Flange Vr = 761.8 N/mm

Parallel with Web Vr = 761.8 N/mm

Single Plate
 Flange Plate
 Double Plate
 Combination

Engineers Report

Analysis

Drawings

Design

Materials Report

Evaluation

Rotation

Loads

Current File : default Messages :

QUIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Pathname for design job MULTIPLE SCREEN ADD TEXT CONTINUE		
Date: Feb 25, 1999 Time: 14:02								

MATERIALS REPORT

COLUMN: W310 X 143

BASE PLATE:

THICKNESS 70.0 mm

WIDTH 649.0 mm

LENGTH 663.0 mm

ANCHOR BOLTS:

TYPE ASTM A36 Round bar

SIZE 36 mm

LENGTH 340.0 mm

NUMBER 4

FOOTING:

LENGTH 2870.0 mm

WIDTH 1950.0 mm

WELD STRENGTH 480 MPa

WELDS:

	Column Web to Base Plate (mm)	Column Flange to Base Plate (mm)
FILLET	11.0	17.0
GROOVE	0.0	0.0
PARTIAL PENETRATION	0.0	0.0
COMPLETE PENETRATION	0.0	0.0

STIFFENERS:

	Y-Y DIRECTION	X-X DIRECTION
LENGTH	503.0 mm	140.0 mm
WIDTH	140.0 mm	140.0 mm
THICKNESS	10.0 mm	10.0 mm
WELD SIZE	5.0 mm	5.0 mm

Note: welds are full length on both sides of the flange and web

Single Plate
 Flange Plate
 Double Plate
 Combination

Engineers Report

Analysis

Drawings

Design

Materials Report

Evaluation

Rotation

Loads

Current File : default Messages :

Figure 4.9: Stiffened Combination Plate Connection

- Plate thickness (plateThickness)

$t_p = 69.67 \text{ mm}$ (calculated thickness)

thickness = 70.0 mm (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 24mm

$T_r = 502.7 \text{ kN}$; $V_r = 445.58 \text{ kN}$; $B_r = 370.4 \text{ kN}$; $T_f = 215.68 \text{ kN}$ Uplift.

The calculated anchor bolt diameter required = 48 mm

- Pull out (pullOut)

The initial embedment length = 329.01 mm

Development length required for the standard hook = 720.0 mm

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis

$V_f = 1118.9 \text{ kN}$; $A_m = 6185.63 \text{ mm}^2$; $A_w = 5193.16 \text{ mm}^2$;

weld size = 12.17 mm

Case II: Welds due to moment about the Y axis

Not available because $M_y = 0.0$

Case III: Weld due to shear in X direction

Not available because $V_x = 0.0$

Case IV: Weld due to shear in Y direction

$V_f = 545.0 \text{ kN}$; $A_m = 3012.7 \text{ mm}^2$; $A_w = 2529.3 \text{ mm}^2$;

weld size = 4.26 mm

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 5.0 mm.

Column flange to base plate, fillet weld size = 13.0 mm.

3. Box stiffeners (designBuiltUpTwoBars)

- Horizontal stiffeners

length = 216.0 mm; height = 144.0 mm; thickness = 30.0 mm.

- Vertical stiffeners

length at top = 134.0 mm; length at bottom = 187.0 mm;

height = 234.0 mm; thickness = 14.0 mm.

4. Results (writeResultData)

prefix W, shape W36C, mass 91, grade 300 W

- column: $d = 353.0$ mm; $b = 254.0$ mm; $t = 16.4$ mm; $w = 9.5$ mm;

$k = 36.0$ mm; $k_1 = 23.0$ mm.

- base plate: length = 787.0 mm; width = 688.0 mm;

thickness = 70.0 mm.

- anchor bolts: number 2; diameter = 48 mm; length = 720 mm.

- footing: length = 2180.0 mm; width = 2060.0 mm.

connection type : STIFFENED BUILT-UP TWO BARS

4.2.8 Built-Up Four Anchor Bolt Connection

Given:

Column W360 X 196 , ASTM A36

Anchor Bolts = 4 - 24 mm, ASTM A36 threaded round stock

Axial load, $C_f = 355.0$ kN

Factored shear in Y direction = 485.0 kN

Factored moment about the X axis = 298.0 kNm

Specified concrete strength = 25.0 MPa

EXIT	HELP	JOB M'NAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Multiple Screen	ADD TEXT	CONTINUE
Date: Feb 05 1989 Time: 11:05								

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS	0.0 kN	1390.0 kN
SHEAR FORCES	X (kN)	Y (kN)
SERVICE	0.0	0.0
FACTORED	0.0	345.0
MOMENT	X (kN.m)	Y (kN.m)
SERVICE	0.0	0.0
FACTORED	395.0	0.0

ANCHOR BOLTS

TENSION	503.0 kN
SHEAR	371.0 kN

WELDS AT COLUMN FLANGE

FILLET	Vr = 1980.7 N/mm
GROOVE	Vr = 0.0 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

WELDS AT COLUMN WEB

FILLET	Vr = 761.8 N/mm
GROOVE	Vr = 0.0 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

Engineers Report	Materials Report
Analysis	Evaluation
Drawings	Rotation
Design	Loads

ON/OFF	1	5	20
	40	80	100
	120	160	200
ORBIT CAM			
PAN CAM			

Current File: default Messages:

EXIT	HELP	JOB M'NAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO	FILES	CONSTRAINTS	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Multiple Screen	ADD TEXT	CONTINUE
Date: Feb 05 1989 Time: 11:05								

MATERIALS REPORT

COLUMN W360 X 91

BASE PLATE

THICKNESS	70.0 mm
WIDTH	688.0 mm
LENGTH	787.0 mm

ANCHOR BOLTS

TYPE	ASTM A36 round bar
SIZE	48 mm
LENGTH	720.0 mm
NUMBER	2

FOOTING

LENGTH	2180.0 mm
WIDTH	2060.0 mm

WELD STRENGTH 480 MPa

WELDS

Column Web to Base Plate (mm)	5.0	Column Flange to Base Plate (mm)	13.0
FILLET	0.0	0.0	
GROOVE	0.0	0.0	
PARTIAL PENETRATION	0.0	0.0	
COMPLETE PENETRATION	0.0	0.0	

STIFFENERS

VERTICAL	LENGTH 187.0 mm (Bot), 134.0 mm (Top)	HORIZONTAL	LENGTH 216.0 mm
HEIGHT/WIDTH	238.0 mm	188.0 mm	
THICKNESS	14.0 mm	30.0 mm	

Not: welds are full length on both sides of the flange and web

Engineers Report	Materials Report
Analysis	Evaluation
Drawings	Rotation
Design	Loads

ON/OFF	1	5	20
	40	80	100
	120	160	200
ORBIT CAM			
PAN CAM			

Current File: default Messages:

Figure 4.10: Built-up Two Anchor Bolts Connection

2 of /de 2

PM-1 3½"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

Soil bearing capacity = 550.0 *kPa*

Preferred base plate thickness = 30.0 *mm*

Trace:

1. Read input data from *bplate.in* file. (readInputData), as per the given information.

2. Base plate design. (basePlateDesign)

- Plate size (actualPlateSize)

length = 690.0 *mm*; width = 692.0 *mm*

- Plate thickness (plateThickness)

tp = 44.09 *mm* (calculated thickness)

thickness = 45.0 *mm* (recommended thickness)

- Anchor bolts (anchorBolts)

preferred anchor bolt diameter = 24*mm*

$T_r = 278.7$ *kN*; $V_r = 654.46$ *kN*; $B_r = 544.32$ *kN*;

$T_f = 424.36$ *kN* Uplift.

The calculated anchor bolt diameter required = 36.0 *mm*

- Pull out (pullOut)

The initial embedment length = 244.95 *mm*

Development length required for the standard hook = 540.0 *mm*

Select the larger of these two values.

- Weld Size (weld-size)

Case I: Welds due to moment about the X axis

$V_f = 801.0$ *kN*; $A_m = 4428.28$ *mm*²; $A_w = 3717.77$ *mm*²;

weld size = 5.92 *mm*

Case II: Welds due to moment about the Y axis

Not available because $M_y = 0.0$

Case III: Weld due to shear in X direction

Not available because $V_x = 0.0$

Case IV: Weld due to shear in Y direction

$V_f = 485.0 \text{ kN}$; $A_m = 2681.04 \text{ mm}^2$; $A_w = 2250.87 \text{ mm}^2$;

weld size = 3.6 mm

- Combination of welds (weldCombination)

Based on the above cases, the weld size is combined into either fillet welds and/or partial or full penetration groove welds, or both.

Column web to base plate, fillet weld size = 5.0 mm.

Column flange to base plate, fillet weld size = 6.0 mm.

3. Box stiffeners (designBuiltUpFourBars)

- Horizontal stiffeners

length = 206.0 mm; height = 108.0 mm; thickness = 30.0 mm

- Vertical stiffeners

length at top = 98.0 mm; length at bottom = 129.0 mm;

height = 162.0 mm; thickness = 14.0 mm

4. Results (writeResultData)

prefix W, shape W360, mass 196, ASTM A36

- column: d = 372.0 mm; b = 374.0 mm; t = 26.2 mm; w = 16.4 mm;

k = 43.0 mm; k1 = 23.0 mm.

- base plate = 690.0 mm; width = 692.0 mm; thickness = 45.0 mm.

- Anchor bolt: number = 4; diameter = 36 mm; length = 540 mm.

- footing: length = 1420.0 mm; width = 2080.0 mm.

connection type : STIFFENED BUILT-UP FOUR BARS

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO		FILES	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Percentage for display on		
Date: Feb 25, 1995 Time: 10:54		CONSTRAINTS	MULTIPLE SCREEN ADD TEXT CONTINUE					

ENGINEERS REPORT

SERVICE AND FACTORED LOADS

AXIAL LOADS	0.0 kN	355.0 kN
SHEAR FORCES	X (kN)	Y (kN)
SERVICE	0.0	0.0
FACTORED	0.0	485.0
MOMENT	X (kN.m)	Y (kN.m)
SERVICE	0.0	0.0
FACTORED	298.0	0.0

ANCHOR BOLTS

TENSION	279.0 kN
SHEAR	545.0 kN

WELDS AT COL'N FLANGE

FILLET GROOVE	Vr = 914.2 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

WELDS AT COLUMN WEB

FILLET GROOVE	Vr = 761.8 N/mm
PARTIAL PENETRATION	Vr = 0.0 N/mm
COMPLETE PENETRATION	Vr = 0.0 N/mm

Engineers Report	Materials Report
Analysis	Evaluation
Drawings	Rotation
Design	Loads

ON/OFF	1	5	20	100	200	500	1000
SD	SD	SD	SD	SD	SD	SD	SD
120	180	200					
ORBIT CAM							
PAN CAM							

Current File: default Messages:

EXIT	HELP	JOB MANAGER	MULTIPLE CONNECTIONS	INTEGRATED DESIGN	PRINT RESULTS	SELECTIVE PHOTO	SNAPSHOT	QUIT
SYSTEM INFO		FILES	CONNECTION TYPES	CONNECTION DETAILS	DESIGN OF A SINGLE CONN.	Percentage for display on		
Date: Feb 25, 1995 Time: 10:54		CONSTRAINTS	MULTIPLE SCREEN ADD TEXT CONTINUE					

MATERIALS REPORT

COLUMN W350 X 196

BASE PLATE

THICKNESS	45.0 mm
WIDTH	492.0 mm
LENGTH	490.0 mm

ANCHOR BOLTS

TYPE	ASTM A36 round bar
SIZE	36 mm
LENGTH	540.0 mm
NUMBER	4

FOOTING

LENGTH	1420.0 mm
WIDTH	2080.0 mm

WELD STRENGTH 480 MPa

WELDS

Column Web to Base Plate (mm)	5.0	Column Flange to Base Plate (mm)	6.0
FILLET GROOVE			
PARTIAL PENETRATION	0.0	0.0	0.0
COMPLETE PENETRATION	0.0	0.0	0.0

STIFFENERS

LENGTH	129.0 mm (Bot)	99.0 mm (Top)	276.0 mm (Horizontal)
HEIGHT/WIDTH	142.0 mm		126.0 mm
THICKNESS	14.0 mm		30.0 mm

Note: welds are full length on both sides of the flange and web

Engineers Report	Materials Report
Analysis	Evaluation
Drawings	Rotation
Design	Loads

ON/OFF	1	5	20	100	200	500	1000
SD	SD	SD	SD	SD	SD	SD	SD
120	180	200					
ORBIT CAM							
PAN CAM							

Current File: default Messages:

Figure 4.11: Built-up Four Anchor Bolts Connection

4.3 Comparisons

Comparisons between design examples given in the Handbook of Steel Construction, CISC(1992), McGuire (1968), and for base plates designed by Canadian fabricators, Wells (1994) and Vincent (1995), and those produced from SCADD are described. Variations in the designed connections are discussed. Note, the designs by CAN-ROB, Wells (1994) are in accordance with AISC specification 9th edition, AISC (1986)(working stress design). Dimensions given in British units have been converted to SI units.

4.3.1 Base Plate for an Axially loaded Column

The base plate design given on page 4-155 of the Handbook of Steel Construction, CISC (1992) is for W310 X 118 column subjected to a factored axial load of 2500 kN. The specified 28-day strength of the concrete foundation is 20 MPa, and the steel is specified as G40.21-M81 grade 300 W. For this example, CISC (1992), the required base plate plan dimensions, 500 mm $\times$ 500 mm given in Table 4.2 are based on the bearing capacity of the concrete given in Clause 10.15.1.1 of A23.3-M84, without recognition of the maximum possible increase in capacity due to the surrounding concrete of $\sqrt{A_2/A_1}$ of 2.0. From which the extension of the plate in each direction beyond the assumed uniformly loaded area under the column are calculated appropriately as 101 mm and 127 mm, respectively. The plate thickness is then calculated to give the required plastic section modulus for bending of the plate about the critical section defining the bearing area. The plate thickness is then calculated against an empirical requirement of 1/5 the maximum plate extension to limit deformation. For this case the base plate becomes 35 mm $\times$ 500 mm $\times$ 500 mm.

Recognizing that most footings are such that the bearing capacity can be increased by a value of $\sqrt{A_2/A_1}$ equal to two and that the minimum base plate plan dimensions may be a function of geometry (minimum plan dimension in either direction is equal to the column dimension plus the fillet welds, plus the clearance and

	Handbook of Steel construction	SCADD
Plate area (mm^2)	245 000	223 244
n (mm)	127	73.7
m (mm)	101	73.7
Base plate size (mm)	500 X 500 X 35	446 X 393 X 25

Table 4.2: Comparison of Axially Loaded Base Plate Designs

end distance for the anchor bolt, if applicable). SCADD calculates the dimension to be $446 \text{ mm} \times 393 \text{ mm}$ as given in Table 4.2. From which all the other calculations follow as per the CISC example. SCADD also designs the anchor bolts and the welds between the column and the base plate, refer to section 4.1.1 for the complete engineering and material reports for the design and the corresponding 3D rendering of the designed connection.

4.3.2 Design Comparison of a Built-up Moment Base Plate Connection

A stiffened built-up four anchor bolts moment resisting base plate connection design given by McGuire (1968) is compared with the example given in section 4.2.8. The connection must resist an axial load of 355 kN and moment of 298 kNm. The 14 WF 142 (W360 X 196) column and base plate are constructed of A36 steel ($F_y = 248 \text{ MPa}$). The specified concrete strength of the footing is 3000 psi (20 MPa). McGuire's solution is based on working stress design where SCADD uses limit states design. Table 4.3 gives a summary of the design results for service or working loads and probable factored loads assuming a combined load factor of 1.3. The relevant designs are comparable with the limit states design yielding slightly smaller anchor bolts and larger plate thickness due to round up to thickness that are produced by

Load and Column Base Plate specification:	McGuire (1968)	SCADD service loads	SCADD factored loads
Column	14 WF 142	W360X196	W360X196
Axial Load	80 kip (355.8 kN)	355 kN	462 kN
Moment	220 kft (298.3 kN-m)	298 (kN-m)	387 (kN-m)
Bolt Size	2 in. (50.8 mm)	36 mm	42 mm
Bolt Numbers	4	4	4
Base Plate Size	28 in X 30 in (711 mm X 762 mm)	690 mm X 692 mm	746 mm X 744 mm
Thickness	2 in (50.8 mm)	45 mm	55 mm
Horizontal Stiffener (mm)	not given	206 X 108 X 30	240 X 126 X 35
Vertical Stiffeners (mm)	3 PLs 12" X 5" X 0.5" (304 X 127 X 12.7)	Top: 98 X 162 X 14 Bottom : 129 X 162 X 14	Top: 116 X 195 X 14 Bottom: 156 X 195 X 14

Table 4.3: Comparison of Built-up Moment Base Plate Connection

Canadian mills. Again, SCADD gives complete design details including the length of the anchor bolt to prevent pull-out, weld sizes to transfer the load from the column to the base plate, complete data for the built-up plates and a 3D rendering of the connection. Not shown, but illustrated is the geometric design.

4.3.3 Designed comparisons between CANRON and SCADD

The results of base plate designs produced by CANRON Eastern Structural Division, Wells (1994) and by SCADD for service and probable factored loads, assuming a combined for service load factor of 1.3, are summarized in Table 4.4. The loads given are service loads. CANRON's designs are in accordance with the AISC specification. A typical column base plate detail for CANRON's design is shown in Figure 4.12. The

No.	Loads (kN)	Column sections		Base plate dimension		
		AISC	CISC	CANRON Design	SCADD service load	SCADD factored load
1	889	W10 X 49	W250 X 73	355 X 355 X 25	348 X 386 X 20	348 X 386 X 25
2	1334	W10 X 60	W250 X 89	355 X 355 X 38	350 X 393 X 25	350 X 393 X 30
3	1779	W10 X 77	W250 X 115	355 X 355 X 38	353 X 402 X 30	353 X 402 X 30
4	2446	W14 X 211	W360 X 314	559 X 559 X 57	495 X 554 X 30	495 X 554 X 40
5	4225	W14 X 159	W360 X 237	508 X 508 X 51	489 X 534 X 35	489 X 534 X 40
6	6049	W12 X 210	W310 X 313	711 X 762 X 51	516 X 420 X 50	534 X 438 X 55
7	9785	W14 X 311	W360 X 463	711 X 660 X 64	591 X 507 X 55	658 X 574 X 70
8	14,082	W14 X 500	W360 X 744	762 X 762 X 127	713 X 585 X 70	804 X 676 X 100
9	16,017	W14 X 455	W360 X 677	660 X 762 X 89	633 X 750 X 90	846 X 729 X 110
10	19,517	W14 X 500	W360 X 744	787 X 852 X 140	699 X 827 X 110	934 X 806 X 130
11	23,543	W14 X 605	W360 X 900	965 X 965 X 177	914 X 763 X 120	1031 X 880 X 150
12	27,377	W14 X 730	W360 X 1086	889 X 889 X 152	994 X 816 X 130	1120 X 942 X 160

Table 4.4: Comparison of base plate designs produced by SCADD and CANRON

mean value of the ratio of plate area and thickness produced by SCADD and CANRON are 1.000 and 0.909, respectively. The increase lateral dimensions in SCADD are a function of the geometric design and the relative placing of the anchor bolts and may vary depending on the design criteria or constraints used by CANRON (these are unknown) and the variances in thicknesses are related to the calculation of moment resistance using WSD and LSD. In general the base plate designs are comparable. In all cases the anchor bolt size was dictated by the preference of the fabricator.

4.3.4 Designed comparisons between CANAM and SCADD

The design loads and the results of base plate designs by the CANAM MANAC Group, Vincent (1995), and SCADD are summarized in Tables 4.5, 4.6 and 4.7. A

Figure 4.12: A typical column base plate detail for CANRON

typical column base plate details for CANAM's design is shown in Figure 4.13.

Differences in the plan dimensions of base plate listed in Tables 4.6 and 4.7, are primarily due to the flexibility of determining the minimum and maximum edge distances as stated on Clause 22.6 and 22.7 of CAN/CSA-S16.1-M89, to the anchor bolt layout used and to constraints or preferences in fabrication (which are unknown). The minimum edge distance from the center of a bolt to any edge depends on the type of edge preparation of the steel given in Table 4.8 (sheared edge, rolled, sawn, or gas-cut edge), and the maximum edge distance from the center of any bolt to the nearest edge of the parts in contact (may be 12 times the thickness of outside connected part, but not greater than 150 mm). The mean value of the ratio of plate area and thickness produced by SCADD and CANAM are 1.096 and 0.852 respectively. The corresponding mean ratio of plate volume required is 0.94. SCADD produces comparable design that are marginally more economic but do not explicit recognize constraints of each particular job as these were not given. It is quite conceivable that these constraints would lead to more or less identical designs. Note, placement of the anchor bolts within the column profile leads to smaller base plate plane dimensions and more economical designs.

Figure 4.13: A typical column base plate details for CANAM

Columns ID	Gravity		Wind P wind-up [kN]	Earthquake				Crane Loads	
	P dead [kN]	P live [kN]		EQshear(E-W) [kN]	EQshear(N-S) [kN]	EQaxial(E-W) [kN]	EQaxial(N-S) [kN]	P dead [kN]	P live [kN]
C7	346	367	284	-	-	-	-	5	70
C8	346	367	284	-	88	-	158	5	70
C13	100	106	92	88	-	140	-	5	70
C18	73	78	68	88	-	140	-	5	70
C31	75	80	70	366	-	583	-	5	70
C36	503	671	356	-	-	-	-	5	70
C40	503	590	356	-	227	-	360	5	70
C46	361	774	165	324	-	50	-	3	18
C53	168	180	60	-	-	-	-	-	-
C59	215	431	76	-	-	-	-	3	18
C66	169	202	60	-	-	-	-	-	-
C70	270	720	151	-	-	-	-	-	-
C83	135	434	76	-	-	-	-	-	-
C90	80	145	30	-	-	-	-	-	-

Table 4.5: Service Loads on Foundations

Columns ID	Factored Loads [kN]	Column Sections	Base Plate Dimensions [mm]		Anchor Bolts [mm]
			CANAM's Design	SCADD	
C7	1094	W310 X 67	360 X 380 X 25	298 X 426 X 20	2 - 25
C8	1008	W310 X 67	360 X 380 X 25	254 X 382 X 20	4 - 20
C13	414	W250 X 89	330 X 350 X 25	306 X 349 X 20	4 - 20
C18	350	W250 X 58	280 X 330 X 20	253 X 330 X 20	4 - 20
C31	666	W250 X 58	280 X 480 X 30	297 X 374 X 20	8 - 25
C36	1746	W310 X 97	425 X 425 X 32	399 X 448 X 25	2 - 25
C40	1580	W310 X 97	425 X 425 X 32	412 X 363 X 25	4 - 25
C46	1321	W250 X 73	340 X 480 X 30	348 X 386 X 25	8 - 25
C53	480	W310 X 45	250 X 400 X 20	246 X 411 X 20	2 - 20
C59	946	W250 X 58	300 X 350 X 25	283 X 360 X 20	2 - 20
C66	514	W310 X 52	250 X 400 X 20	247 X 415 X 20	2 - 20
C70	1418	W250 X 73	250 X 350 X 25	334 X 372 X 25	2 - 20
C83	820	W200 X 52	250 X 300 X 25	384 X 317 X 20	2 - 20
C90	318	W200 X 36	250 X 300 X 25	245 X 304 X 20	2 - 20

Table 4.6: Comparison of base plate designs produced by CANAM and SCADD

Column ID	Column Sections	Vertical loads [kN]			Bracing			Factored Loads [kN]	Base plate dimensions [mm]		Anchor Bolts [mm]
		D.L	I.L	Wind +/-	V	H (E-W)	H (N-S)		CANAM	SCADD	
39	W310 X 86	320.25	289	-	-	-	31	834	521 X 356 X 20	396 X 304 X 20	4 - 20
50	W310 X 97	53.4	116	-138	187	80	-	474	356 X 330 X 25	412 X 363 X 20	4 - 25
64	W610 X 82	200	-	-	-	-	-	250	660 X 254 X 20	655 X 228 X 20	4 - 20
57	W360 X 101	205	67	-	-	-	-	357	508 X 305 X 20	471 X 335 X 20	3 - 20
58	W360 X 134	256	173	-	-	-	-	580	406 X 406 X 25	506 X 463 X 20	2 - 25
59	W360 X 134	200	231	-396	565	445	44.5	1303	406 X 406 X 25	470 X 427 X 25	4 - 25
A_14	W310 X 97	63	53	-29.4	-	22	24	174	350 X 330 X 30	448 X 399 X 20	2 - 25
B_1	W310 X 60	58	62	-34	-	30	-	166	360 X 270 X 20	423 X 297 X 20	2 - 25
C_14	W310 X 97	165	400	-221	-	-	30	806	350 X 330 X 30	448 X 399 X 20	2 - 25
D_14	W310 X 97	176	415	-313	-	30	74	843	350 X 330 X 30	424 X 375 X 20	4 - 30
F_1	W310 X 52	44	53	-327 +313	-	20	7.2	450	330 X 240 X 20	405 X 237 X 20	4 - 30
K_12	W310 X 79	101	242	-134	-	20	-	489	400 X 350 X 30	436 X 348 X 20	2 - 25

Table 4.7: Additional Comparisons

Bolt diameter (mm)	Minimum edge distance (mm)	
	At sheared edge	At rolled, sawn, or gas-cut edge
16	28	22
20	34	26
22	38	28
24	42	30
27	48	34
30	52	38
36	64	46
Over 36	1.75 x diameter	1.25 x diameter

Table 4.8: Minimum Edge Distance for Bolt Holes

Chapter 5

Summary, Conclusions, Recommendations and Future Work

5.1 Summary and Conclusion

A second generation graphics user interface has been developed for the computer aided analysis, design and detailing program for steel connections (SCADD) which allows for single and multiple connection designs. The interface provides an environment that is intended to encourage ease of use, flexibility and creativity in designing and detailing steel connections. Engineers and fabricators can specify their preference as to how and with what the connection will be constructed. This latest version of SCADD has been designed as an expandable module allowing other applications for the design of other connections to be easily added.

Four applications for the design of Beam-to-Column-Web, Beam-to-Column-Flange, Beam-to-Beam and Column Base Plate connections have been installed. Each analyses, designs, and details (geometric design) the corresponding connections according to CAN/CSA-S16.1-M89 and standard fabricating practices. A base plate connection design module has been developed for this thesis. To illustrate the design logic traces for each permutation is given. To verify the performance comparisons are made with solved published problems and with designs produced by two of the largest steel fabricators in eastern Canada, CANRON Eastern Structural Division and The

CANAM MANAC Group. The debugger tool can be used by engineer to review all calculations in detail.

A data file directory is created for each connection to store input data , output designs, and all intermediate calculations. The design data is summarized in an engineering and materials report and is represented on the same screen as a 3D rendering of the design connection. The design logic and results are visible. This eliminates the "black box" and helps to educate or re-educate engineers and fabricators about the design of steel connections.

5.2 Recommendations for Future Work

Based on the development of the graphics user interface for this second generation analysis and design module for structural steel connections and on the development of the application for base plate design, a number of recommendations for future work can be made which would enhance the versatility, make the program more comprehensive, increase its educational value, and to define the next step in the integration process. These are:

1. With respect to base plate design, simple additions that can be made include:

- the addition of automated finite element analysis for special cases where the connection may be subject to bending about one or more principal axes with uplift. The process could be coupled with the current procedures to develop designs quickly.
- to incorporate variable anchor bolt patterns to be specified by the engineer/fabricator.
- to incorporate base plate design for other column shapes such as HSS.
- to incorporate cost evaluations and cost comparative studies for different design options.
- to incorporate automatic shop drawing producing routines.

- to incorporate the design of footings and foundations. As part of this, the load deflection/rotation characteristics of the column, base plate, footing assembly could be analysed.
2. Redefine the system architecture for the design of arbitrary connections. The system must have memory capabilities to retain design procedures developed through the interface. These procedures would include the definition of connection geometry, fabrication constraints, construction constraints and the application of design rules for all possible failure modes (to be identified by the engineer). The system must have the capacity to design multiple combinations of connections and to update member geometry as a result of the design. The corresponding interface would need to be developed.

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