User Notes for
The Analysis & Design of Weld Groups
Subjected to Simultaneous Shear, Bending, Torsion and Axial Loading
WeldCalc

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Introduction

WeldCalc analyses any configuration of multi-linear weld lengths in an X-Y plane. The loads can be shear, moment, torsion and axial applied simultaneously.

WeldCalc calculates the induced stress at each node and identifies the node most highly stressed. It also calculates the magnitude of load resisted by each length of weld in the x, y and z direction.

In order to asses adequacy of the weld profiles subjected to stresses in 3 directions, WeldCalc offers 3 options for calculating the resultant equivalent stress. The 1st option calculates the equivalent stress in shear, the 2nd in axial tension or compression and the 3rd a vector sum SRSS.

A weld group can have up to 30 Nodes or 29 weld lengths. The line of weld lengths can be continuous or discontinuous. Each continuous series of weld lengths is termed as a Part and is given a reference number starting from 1 onwards. A weld group can have up to 15 parts connecting 30 nodes in any multi-linear pattern.

Loading the Template on to your Computer

WeldCalc is supplied as an Excel Template, having .XLT as its filename extension.

You can use WeldCalc by opening its file directly or copying it into the Microsoft Office folder for its Templates. Consult Microsoft Office documentation for the path to this folder.

When opening the WeldCalc file, Excel issues a routine Warning about running Macros and prompts whether or not to load them.

Answer YES to Load and Enable Macros. WeldCalc incorporates VB Macros and to allow your computer to use them is vital for its operation.

Codes of Practice

WeldCalc is a weld analysis program for International use. It is not dependent on the use of any specific code of practice.

However, to illustrate the use of WeldCalc and to discuss various weld details for design purposes ,reference has been to the British Standard Code of Practice BS 5950-1: 2000 Part 1, Structural Use of Steelwork in Building1.

Using WeldCalc

In addition to Job Information in the heading part, describe Applied Loads, Design Strength and details for each weld length. The applied loads can be factored or un-factored depending upon the specified design strength of welds. The weld details required are: part-number, coordinates x and y and throat thickness at each node.

WeldCalc also incorporates a data store facility. Information for up to and more than 10,000 weld groups is kept in the worksheet STORE. Clicking the "Store Existing Data" command button in the top row, saves the current weld group data. Clicking the "Get Stored Data" button retrieves the previously saved information.

In order to save or retrieve a weld group information, the Template uses a Datastore Number. This number starting from 1001 upwards must be specified to store and or retrieve a weld group data.

PLEASE NOTE that storing weld group data does not save the Excel File. To ensure saving data to your hard disk, you must use Excel File, Save Pull Down Menu Option in the usual Windows procedure.

Likewise, saving Excel file to hard disk does not store the existing screen data into the worksheet "STORE". To do so, you must use "Store Existing Data" button before saving the Excel file to hard disk.

Database of Weld Group Details and Applied Loading: Worksheet STORE

In each WeldCalc file, weld connection details and applied loads can be stored for well ove 10,000 weld groups if required. Starting from a minimum of 200 members, data rows are added and or deleted in multiples of 10 and up to 1000 rows at a time . The maximum limit is a storage of 10,000 weld groups in one file.

Each weld group is referenced by a number in a range starting from 1001 upwards. All information is kept in the worksheet STORE and is available to the user for use in the design process.

A casual Excel user generally does not need to tweak or amend the STORE worksheet. At the risk of upsetting this information, however, one can benefit by generating and using this information by Copy, Paste-Special-Values and Fill-Down commands of Excel.

It is strongly recommended that Cut Command of Excel is not used on this worksheet; using this command affects the worksheet layout and can disrupt the working of WeldCalc. Similarly the use of Paste command (as opposed to Paste-Special-Values command) can override the helpful cell formats.

An experienced Excel User can employ various Excel features to tweak or manage this information. For example, user reference, title, design strength values can be generated via Copy, Paste-Special-Values and Fill Down features of the spreadsheet.

Utilisation Ratio Limit and Values for Each Weld Profile

The data worksheet "Store" includes a column for displaying the utilisation ratio for each weld profile. The ratio values are calculated when a weld profile data is stored.

The check limit for this ratio is generally 1 but it can be changed to any desired numerical value. The cell specifying this ratio limit is in row 1 at head of the ratio column. When the utilisation ratio for any weld profile exceeds this limit, the weld profile title and its value cell utilisation ratio for any weld profile exceeds this limit, the weld profile title and its value cell changes to red. Hence all overstressed weld profiles become visible at a glance.

Auto Analysis of Weld Groups

Use this facility to analyse and or print all weld groups by a single click of ñAuto Analyse/Printò Button in the top right corner of the screen.

To use this facility, two columns coloured in yellow to the right of the ñStoreò worksheet are provided. One column is headed ñAnalyse Y?ò and the other as ñPrint ?ò. The ñAuto Analyse/Printò Button is located at the top of these two columns in the Worksheet ñStoreò.

Entering ñYò in these two columns, signifies that the respective weld group in a given row need to be analysed and or printed. Leaving the cells blank signifies that respective weld groups are not to be analysed or printed.

Auto Analysis facility is useful when all or a selected few weld groups are to be analysed and or printed after updating the weld group details and loading in the STORE worksheet.

Design of Fillet Welds

The vector sum of the design stresses due to all forces and moments transmitted by the weld should not exceed the design strength. When this design strength is shear, the valid option for the equivalent stress is Von Mises Shear",

When using BS 5950 the design strength pw under factored loads is 0.220 kN/mm2 for S275 Grade, 0.250 kN/mm2 for Grade S355 and 0.280 kN/mm2 for Grade S460 (Table 37, Cl 6.8.5). As these design values are about 0.6 times the applicable weld yield stresses, BS 5950 strength appear to represent the weld strengths in shear.

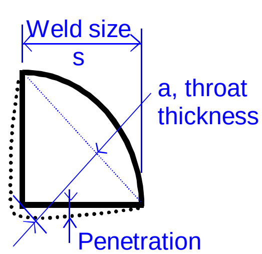
Throat Thickness

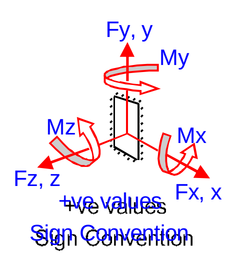
The size of the fillet is expressed by the length of the leg of the largest isosceles right angle triangle that can be inscribed on the outline of the weld. The weld usually has equal legs, but conditions may require the use of weld with unequal legs.

Thickness of the weld is measured by the perpendicular drawn from the intersection of the legs on to the hypotenuse, as shown in the figure. This is called the throat thickness or simply Throat of the fillet weld.

The strength of the fillet welds is related to the throat thickness and depends upon the angle between the fusion faces. This relationship between the leg length ***s*** and the throat thickness ***a*** for various angles between fusion faces is given as follows:

60^{o} to 90^{o}, a = 0.7 s
91^{o} to 100^{o}, a = 0.65 s
101^{o} to 106^{o}, a = 0.6 s
107^{o} to 113^{o}, a = 0.55 s
114^{o} to 120^{o}, a = 0.5 s





Sign Convention

The sign convention is shown on the screen and in the printed output via sketch as shown.

The applied point loads Fx, Fy and Fz are positive when acting in the direction of axes.

The applied moments Mx, My and Mz are positive Anti-clockwise when viewed looking into the origin.

Properties of Fillet Welds

The shape of fillet welds is usually triangular. As shown in the sketch, the outer surface of a weld is reinforced, i.e. made convex, but in strength calculations this reinforcement is ignored.

The failure of welds usually occurs in the throat section. This area is therefore used in strength calculations of welded joints. It is equal to the summation of the throat thickness multiplied by the weld length.

Other weld properties are also based on the throat area of welds. These properties are Ix, Iy and Ixy. The origin for these properties is at centroid of the welds and they are calculated by using x, y coordinates and the throat thickness defined by the user for each node.

Formulae for Stress Components

At each node, the components of stress in x, y and z direction are calculated by elastic analysis, given by:

$$f_x = \frac{F_x}{A} - \frac{M_z y}{I_p}$$

$$f_y = \frac{F_y}{A} + \frac{M_z x}{I_p}$$

$$f_z = \frac{F_z}{A} - \frac{M_y I_x + M_x I_{xy}}{I_x I_y - I_{xy}^2} x + \frac{M_x I_y + M_y I_{xy}}{I_x I_y - I_{xy}^2} y$$

Formulae for Induced Maximum Design Stress

At each node, the equivalent stress fe is calculated using component stresses fx and fy in shear and fz in axial tension or compression. The maximum of these fe values is then chosen and placed in the bottom cell.

The equation used for calculating fe depends upon the method selected by the user via a pull down menu. Three options are available described in the adjacent.

Option 1: Von Mises Shear

$$f_e = \sqrt{f_x^2 + f_y^2 + \frac{f_z^2}{3}} \geq f_z$$

Option 2: Von Mises Axial

$$f_e = \sqrt{3(f_x^2 + f_y^2) + f_z^2} \geq f_z$$

Option 3: SRSS

$$f_e = \sqrt{f_x^2 + f_y^2 + f_z^2} \geq f_z$$

Option 1 Von Mises Shear
is generally meant for comparing the design strength in shear. The calculated equivalent stress represents a stress value in shear. In general, the design strength relevant to this case roughly equal to py/sqrt(3). For example, a value of 0.55 Us in BS5950-1:2000, which implicitly assumes that the weld stress is in shear.
When designing fillet welds to BS5950, the design weld stresses happen to be:
0.800 py = 220 N/mm2 for S275,
0.704 py = 250 N/mm2 for S355 and
0.609 py = 280 N/mm2 for S460.

Option 2 Von Mises Axial
is generally meant for comparing the design strength in tension or compression. The calculated equivalent stress represents a stress value in tension or shear. In general, the design strength relevant to this case roughly equal to the yield stress py. Designing of fillet welds to Eurocode 3 involves the use of equation employed in this option.

Option 3 SRSS

Option 3 SRSS
represents square root of the sum of square values. This option simply calculates the resultant stress based on fx, fy and fz stress components.

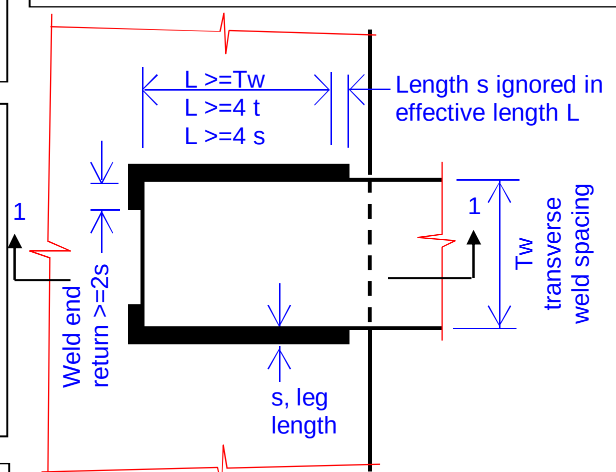
Detailing Requirements for the Design of Welds

The following requirements are based on recommendations contained in Cl 6.7.2 BS 5950-1: 20001. They are intended for guidance only. A user may employ another code of practice for such requirements.

End Connections
Where the ends of an element is connected only by a longitudinal fillet, the length of each weld should be, L >= T_w, the transverse spacing

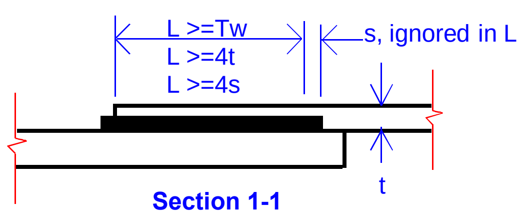
Effective Length
The effective length of a run of fillet weld should be taken as the over all length less one leg length, s, for each end which does not continue round the corner for a length of 2s, as shown in the sketch.
The effective length should be: L >= 4 s

End returns
Welds terminating at the ends or sides should be returned continuously around the corners for a distance >= 2 s (the weld leg length), wherever it is practicable. This detail is particularly important for welds in tension due to bending.



Welded end connection showing End Returns Lap & Effective Length Requirements

Lap Joints
Minimum lap should be: L >= 4t, where t is thickness of the thinner part.
Single fillet weld should only be used where parts are restrained to prevent opening of the joint.



Section 1-1

Maximum Fillet Weld Size

The maximum leg length for a fillet weld is to be limited to the plate thickness less 2 mm. Hence if the plate thickness is 12 mm, the maximum fillet weld size would be 10 mm. This limit helps ensure that edge of the plate being welded is not burned and provides a visual weld edge for checking its thickness.

Fillet Weld Size for Full Strength

Considering that the throat thickness controls the strength of fillet welds, the required size of two fillet welds is 0.707 * plate thickness. Hence if the plate size is 15 mm, the leg length of two fillet welds would be 0.707* 15 = 10.605 mm. This provides a total throat thickness of 2 *0.707*10.605 = 15 mm, which is equal to the plate thickness throat thickness of 2*0.707*10.605 = 15 mm, which is equal to the plate thickness.

Describing Weld Group Configuration

First estimate throat thickness for each length of weld in the joint and also select a convenient point as origin for defining coordinates. Weld group configuration is then defined by giving part-no, x-coordinate, y-coordinate and throat thickness at each node.

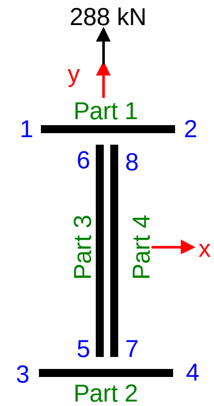
Start using part-no from 1 onwards at first node. When the line of welds becomes discontinuous or the throat thickness changes, increment the part-no by one for the node at next weld length.

Six examples are included in the worksheet STORE of this template. They can be viewed or recalled on the screen by giving their Datastore number from 1001 to 1006 after clicking ***Get Weld Group Data*** button. To illustrate data preparation, details of the first 4 examples are explained below via sketches.

Example 1

This example has 4 parts and 8 Nodes. It represents junction of a UB section welded at its top and bottom flanges and on either side of its web. To describe fillet weld legs of 8 and 6 mm, the throat thickness of the horizontal and vertical weld lengths are 5.6 and 4.2 mm respectively.

Weld Details:
Part, Node x,y Coordinates & Throat Thickness
Part1, Node 1: -86.6, 182.3, Throat 5.6
Part1, Node 2: +86.6, 182.3, Throat 5.6
Part2, Node 3: -86.6, -182.3, Throat 5.6
Part2, Node 4: +86.6, -182.3, Throat 5.6
Part3, Node 5: -5, +140, Throat 4.2
Part3, Node 6: -5, -140, Throat 4.2
Part4, Node 7: +5, +140, Throat 4.2
Part4, Node 8: +5, -140, Throat 4.2
Applied Loads:
F_y = 288 kN @ z_o = 250 mm

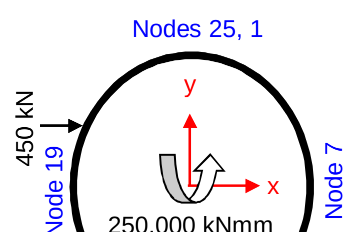


Example 2

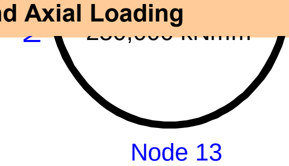
This example represents a circular weld of 400 mm diameter and 8 mm fillet weld. It has 1 Part and 25 Nodes. The first and the last node numbers 1 and 25 are physically coincident.

Only selected nodes and part data have been shown below for brevity.

Weld Details:
Part, Node x,y Coordinates & Throat Thickness
Part 1, Node 1: 0, 200, Throat 5.6
Part 1, Node 7: 200, 0, Throat 5.6
Part 1, Node 13: 0, -200, Throat 5.6
Part 1, Node 19: -200, 0, Throat 5.6
Part 1, Node 25: 0, 200, Throat 5.6
Applied Loads:



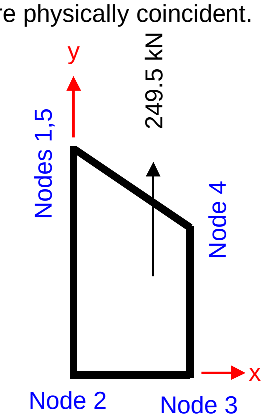
F_x = 450 kN @ y_o = 100 mm & z_o = 50 mm
M_z = 250,000 kNmm



Example 3

This example represents a closed trapezoidal weld of 5 mm fillet weld. It has 1 Part and 5 Nodes. The first and the last node numbers 1 and 5 are physically coincident.

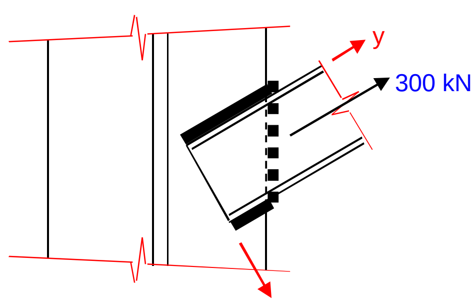
Weld Details:
Part, Node x,y Coordinates & Throat Thickness
Part 1, Node 1: 0, 170, Throat 3.5
Part 1, Node 2: 0, 0, Throat 3.5
Part 1, Node 3: 70, 0, Throat 3.5
Part 1, Node 4: 70, 100, Throat 3.5
Part 1, Node 5: 0, 170, Throat 3.5
Applied Loads:
Fy = 249.5 kN @ x_o = 49.9 mm



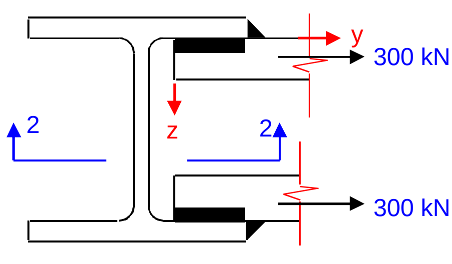
Example 4

This example is an open trapezoidal 8 mm fillet weld having a 5.6 mm Throat Thickness. It has therefore1 Part and 4 Nodes.

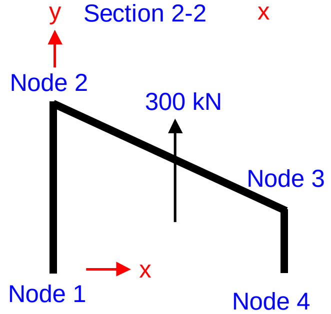
As shown in the sketch below, the weld group represents a 127x64 RSC (rolled steel channel) welded to the inside flange of a 305 x 205 UC (universal column) section at an angle. Acting at Centroid of the RSC, the applied axial load of Fy = 300 kN has an eccentricity of Xo = 62.5 mm and Zo = 19.4 mm. The weld group is therefore subjected to direct shear, bending and torsion simultaneously.



Section 2-2



Plan



Weld Details:
Part, Node x,y Coordinates & Throat Thickness
Part 1, Node 1: 0, 0, Throat 5.6
Part 1, Node 2: 0, 180, Throat 5.6
Part 1, Node 3: 127, 60, Throat 5.6
Part 1, Node 4: 127, 0, Throat 5.6
Applied Loads:
F_y = 300 kN @ x_o = 62.5 mm and z_o = 19.4 mm

References

1 BS 5950: Structural use of steelwork in building

BS 5950-1:2000: Code of practice for design - Rolled and welded sections, 2001
2 DD ENV 1993-1-1: 1992; Eurocode 3: Design of steel structures
Part 1.1 General rules and rules for buildings