

CADS SWMC FAQ

How to model column cap plate and beam flange connections in CADS SWMC



1.0 Introduction

The current version of CADS Steelwork Moment Connections Designer (SWMC) does not directly support column cap plate and beam/rafter flange connections of the types illustrated in figs 1.1, 1.2, 1.3 and 1.4. This is because at the time SWMC was first developed these connections were considered to be relatively uncommon and it was necessary to limit the scope of the product to achieve completion in reasonable time. In the intervening years industry developments have resulted in the increased use of moment connections with the end plate(s) applied to the column member(s) and bolted to the beam or rafter especially cap plate connections in mezzanine floor structures.

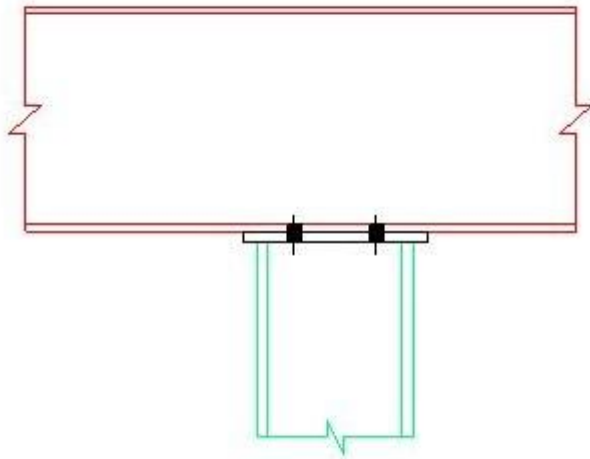


Fig 1.1: Typical column cap plate connection without stiffener plates.

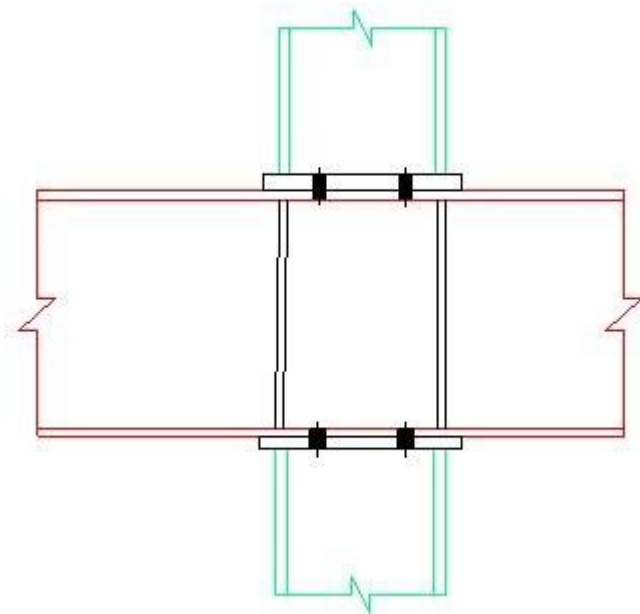


Fig 1.2: Typical beam flange connection with upper column and stiffener plates.

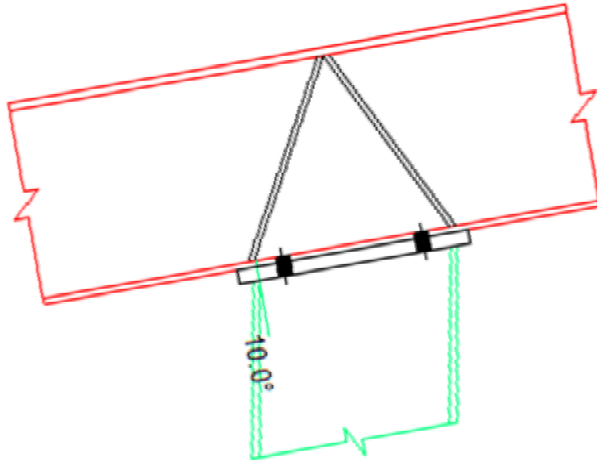


Fig 1.3: Oversailing rafter connection (unhaunched)

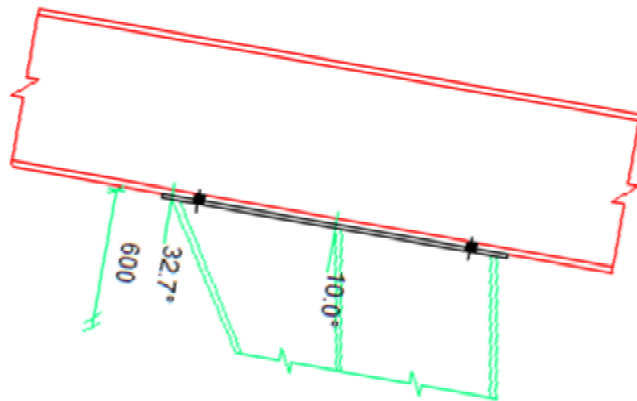


Fig 1.4: Oversailing rafter connection with haunched column.

It is planned to support these connection types directly in a forthcoming version of the software. In the meantime it is possible with care to use the existing column flange connection type to model beam flange connections as described in the following section.



Until the proposed upgrade is released it will not be possible to carry out a direct export to SWMC from Analyse 3D, A3D MAX or SMART Portal for column cap plate connections . It is necessary set up the model and input force effects manually as described below.

2 Setting up the connection model

This temporary procedure consists essentially of mapping the geometry of the intended beam flange connection so that it produces an equivalent quasi-column flange connection model in CADS SWMC. The connection is first viewed with the main beam/rafter on the left of the column. (Opposite to the normal view of a single sided connection.) This view is effectively rotated anticlockwise by $90^\circ +$ slope of the left beam/rafter member above the horizontal. The basics of the mapping are:-

- The lower column maps to the right/main connected member.
- If there is an upper column it maps to the left connected member.
- The main/sole portion of the beam/rafter maps to the lower column.
- The other portion of the beam/rafter (if present) maps to the upper column
- If the column is haunched the haunch must support the left beam/rafter which then maps to the lower column as illustrated in fig 1.4 above. This may require the beam/rafter to be reversed (viewed from the far side).
- The slope of the left beam/rafter above horizontal maps to the slope of the right quasi-beam above horizontal. In the unlikely event of a sloping column, its angle to the vertical should be added or subtracted as appropriate.

The following steps should be followed to create the quasi-column flange connection model:

- 1 Open CADS SWMC and open the *Connection preselector*.
- 2 Choose the Support condition *Column flange*. (Actually accept the default).
- 3 In the Members pane of the Connection preselector choose the model right member condition corresponding to the real column from the drop menu. Usually this will be *Uniform*. However if the real column is haunched to support the left beam or rafter span, select 2, 3 or 4 flange condition whatever is intended.
- 4 In the Members pane of the Connection preselector choose the model right member inclination corresponding to the slope of the real beam or rafter from the drop menu. If the beam/rafter is level or set at right angles to the column, select *Normal/level*. If the real beam/rafter slopes down to the left, select *Negative/downslope*. If the real beam/rafter slopes up to the left, select *Positive/upslope*.
- 5 If there is a real upper column select *Uniform* from the drop menu for the left member type. Haunches are unlikely to be required.
- 6 The inclination of the left member corresponding to the real upper column should normally be chosen to align with the inclination of the model right member. This means that if the model right member is not level the symmetry choice should be *Unsymmetrical* and the model left member inclination should be positive if the right member is negative and vice-versa.
- 7 If the real beam spans only to the left, the model column condition should be selected as *Discontinuous*. If the real beam has both left and right spans the model column condition should be selected as *Continuous*.

Fig 2.1 shows the Connection preselector inputs for a quasi-column flange model corresponding to a horizontal left beam spanning on to the cap plate of a vertical column. Note that the beam would be right/main member in the view of the real connection.

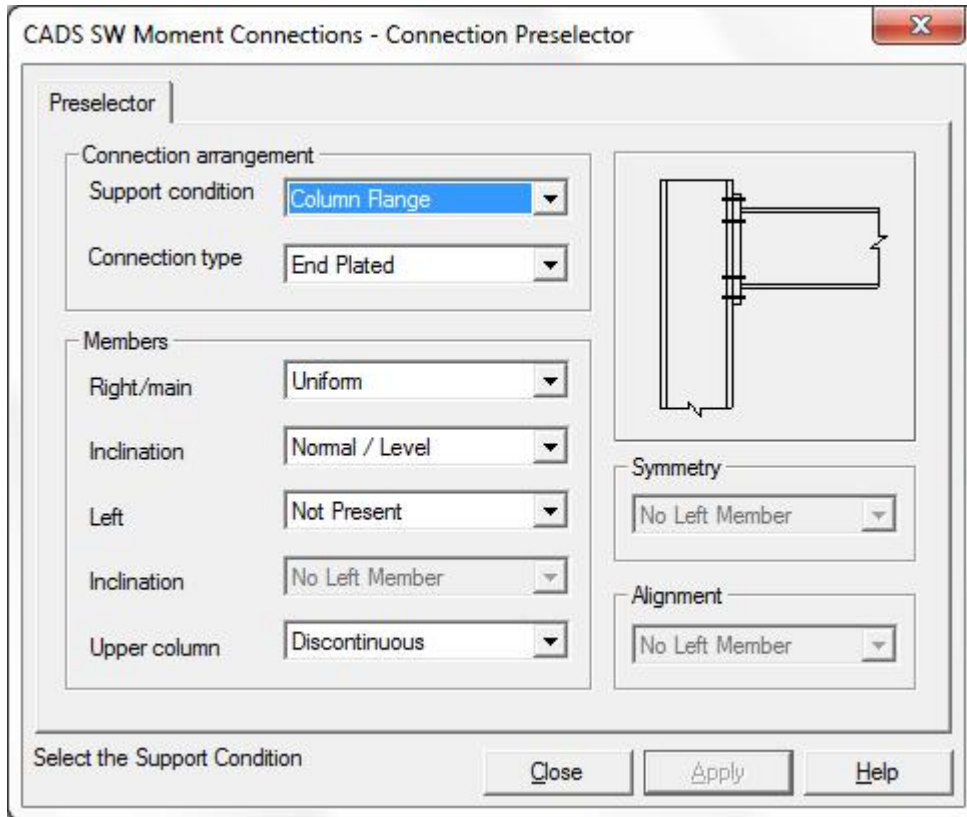


Fig 2.1 Connection preselector settings for quasi-column flange connection equivalent to left beam on lower column cap plate.

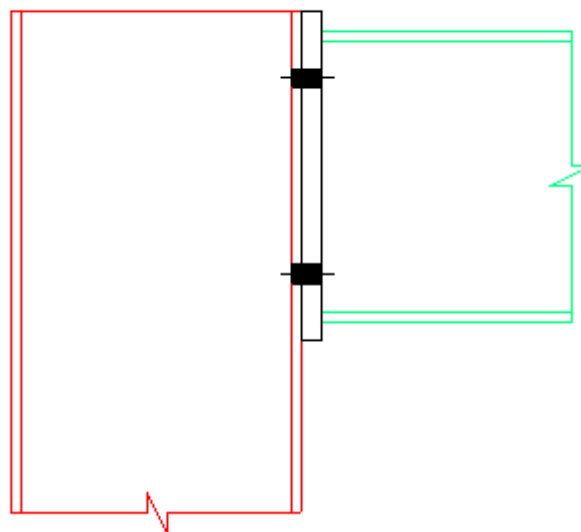


Fig 2.2 Default quasi-column flange connection equivalent to beam flange real connection shown in fig 2.3.

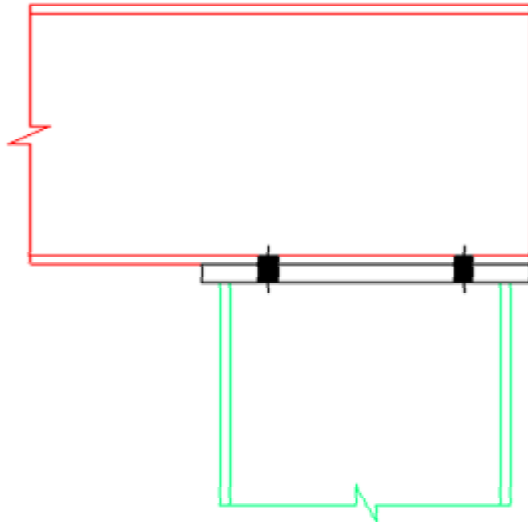


Fig 2.3 Real beam flange to column cap connection equivalent to fig 2.2.

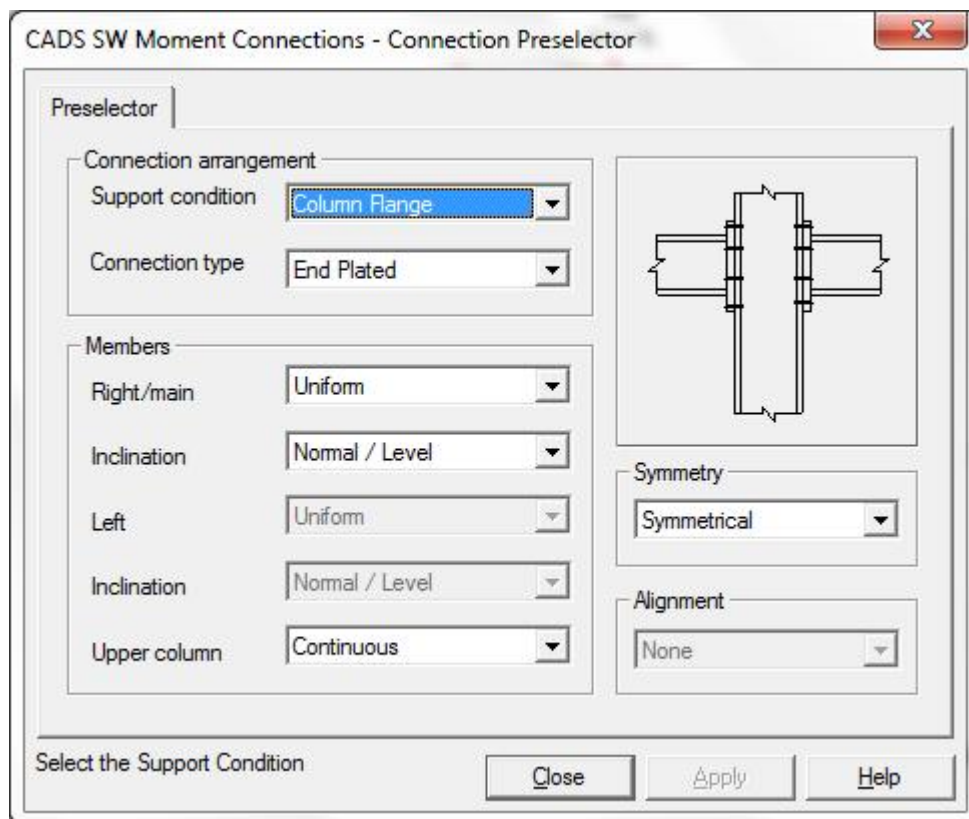


Fig 2.4 Preselector inputs for column flange model equivalent to continuous beam on column cap plate with upper column of same section as the lower column.

Fig 2.4 shows the Connection preselector inputs for a column flange model corresponding to a horizontal left and right beam spanning on to the cap plate of a vertical column with upper column of same section as the lower column. If the column sections are different select *Unsymmetrical*.

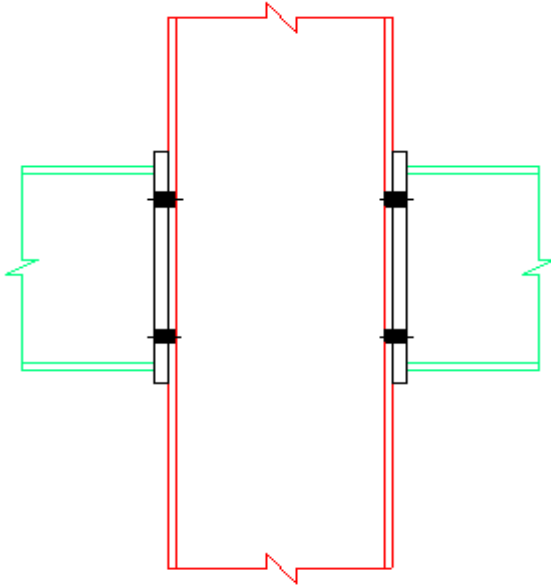


Fig 2.5 Default quasi-column flange connection equivalent to beam flange real connection shown in fig 2.6

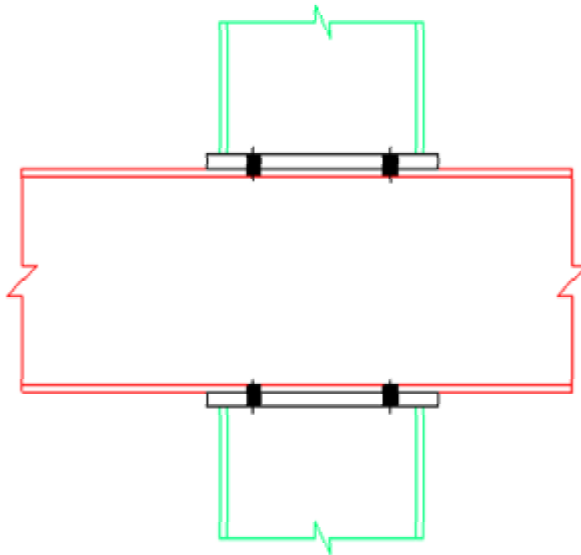


Fig 2.6 Real beam flange connection equivalent to the quasi-column flange model in fig 2.5.

Fig 2.7 shows the preselector inputs for a column flange connection model equivalent to an oversailing rafter on a haunched column.

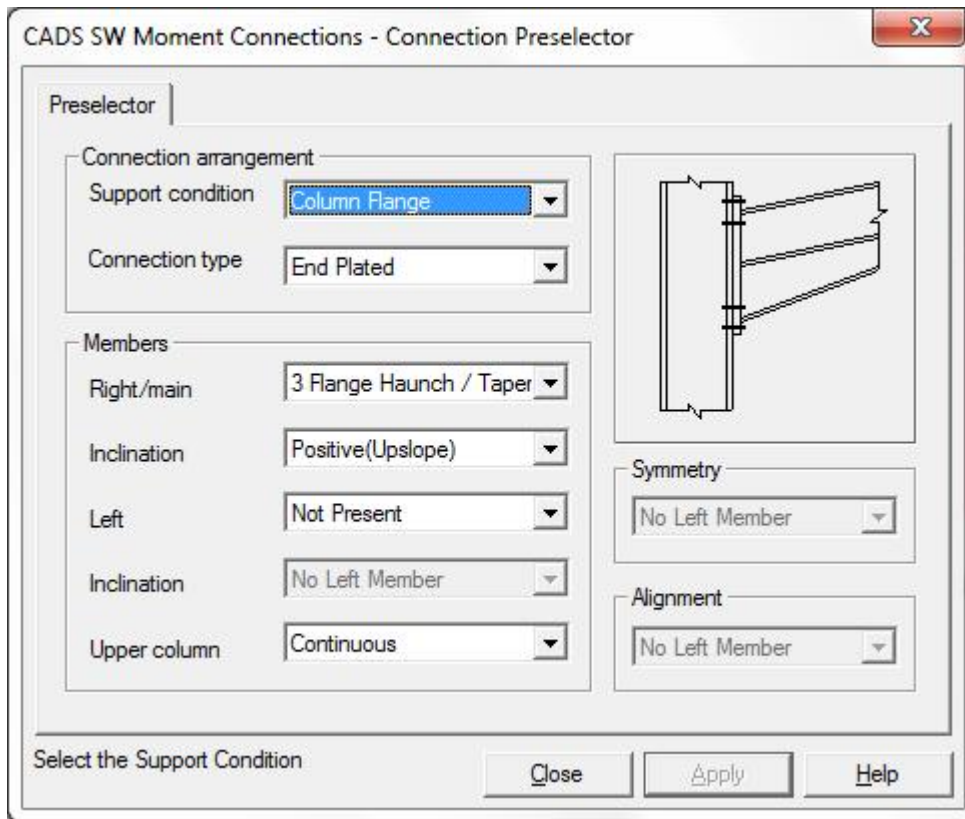


Fig 2.7 Preselector inputs for column flange connection model equivalent to real rafter oversail connection to haunched column

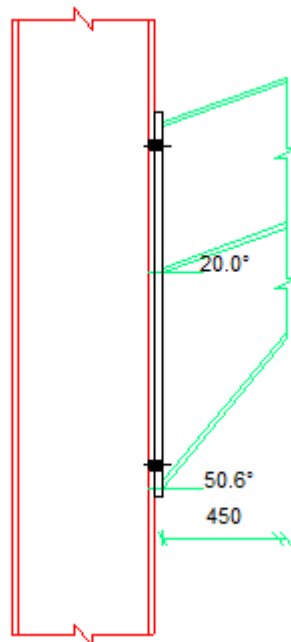


Fig 2.8 Default column flange connection equivalent to beam flange real connection shown in fig 2.9

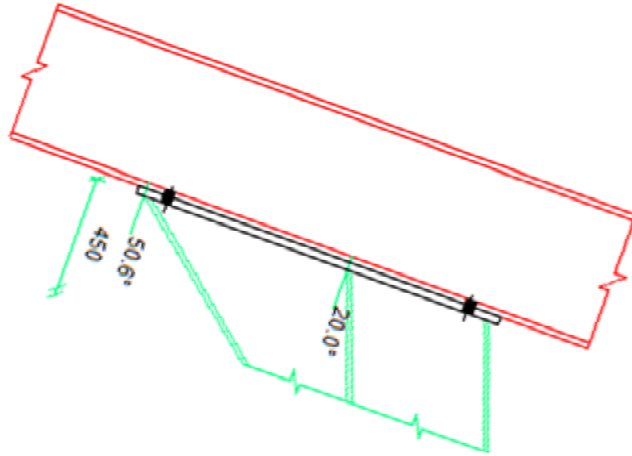


Fig 2.9 Real oversailing rafter connection to haunched column equivalent to quasi-column flange model shown in fig 2.8

3 Loading the connection model

As the current version of SWMC does not directly support beam flange / column cap plate connections, it is not possible to export load data directly from CADS Analyse 3D, A3D MAX or SMART Portal software for these connection types. The force effects acting on the connection must be input manually as described below. However an initial export as a column flange connection helps to tabulate the connection force effects conveniently and also allows the figures to be reviewed to determine which load combinations are critical and/or worth checking in the final model.

The force effects should be mapped as follows:

Real connection

Quasi column flange model

Lower column axial force	à	Right member axial force
Upper column axial force (if present)	à	Left member axial force
Left member axial force	à	Lower column axial force
Right member axial force(if present)	à	Upper column axial force
Lower column shear force x (-1.0)	à	Right member shear force
Upper col. shear force (if present) x (-1.0)	à	Left member shear force
Left member shear force	à	Lower column shear force



Right member shear force (if present)	à	Upper column shear force
Nearside member shear force	à	Add to lower column shear force or if upper present half each
Farside member shear force	à	Add to lower column shear force or if upper present half each
Lower column moment $\times (-1.0)$	à	Right member moment
Upper column moment (if present)	à	Left member moment
Left member moment	à	Lower column moment
Right member moment (if present) $\times (-1.0)$	à	Upper column moment

Note that beam hogging moments and downward shear forces are positive.

Note that if there is a beam only on one side of a column connection, CADS SWMC considers the beam to be the right hand member. Columns with beams only on the left side are therefore viewed from the far side. Note that in the case of columns with beams on both sides, if it is intended to haunch the column on the right hand side the quasi column flange connection model must be reversed (viewed from the far side) so that the haunch is applied to the underside of the quasi-beam modelling the actual column. This can be quite confusing so if in doubt sketch a diagram showing the forces and moments to see how they transpose to the quasi-column flange condition. If all the figures and signs are correctly input for right, left and upper quasi-members the software will display the correct lower column force effects to achieve equilibrium and these should be the same as the force effects in the left member of the original model.

4.0 Worked examples

4.1 Simple example – mezzanine floor beam to column connection.

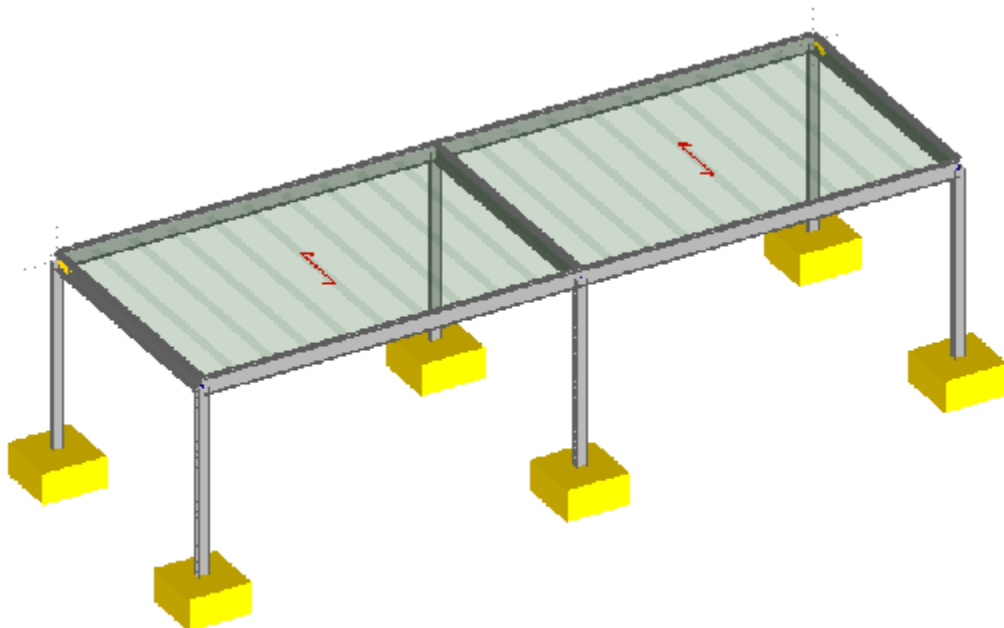


Fig 4.1 A3D MAX solid model of simple mezzanine floor structure.

The frame shown in fig 4.1 is required to have column cap plate connections under the main beams. The frame has been analysed for a single load combination containing dead and imposed floor loads and notional horizontal loads calculated as 2% of the vertical loads acting in the X direction. The frame is externally restrained in the Z direction. The main beams are 254x146UKB31 sections and columns 152x152UKC.

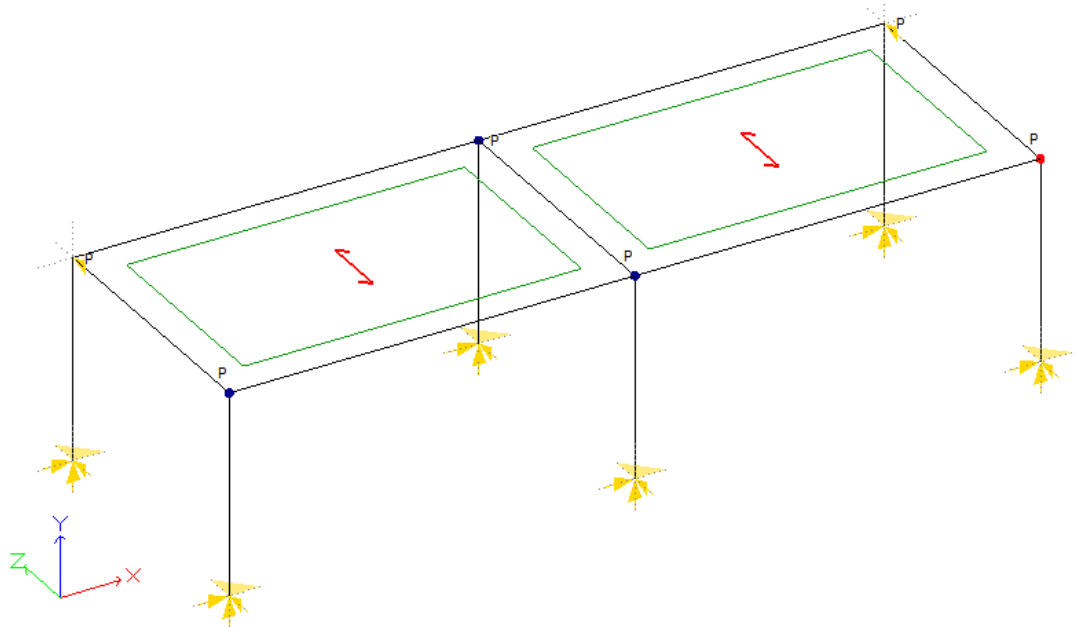


Fig 4.2 A3D MAX model in stick mode with joint selected for export to SWMC.

In this case SWMC offers no choice of connection types and opens with the connection assumed to be a column flange type as shown in fig 4.3. Note that according to CADS SWMC convention the sole beam is viewed from the far side so that it is on the right. For present purposes consider as viewed from the left.

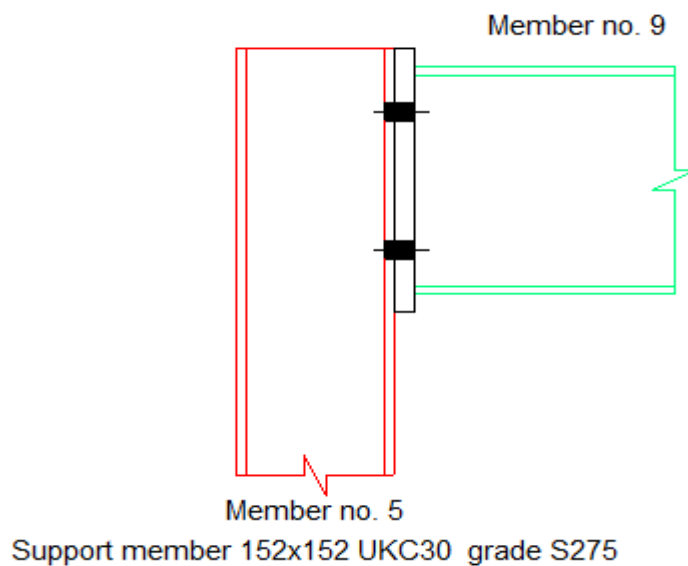


Fig 4.3 Default column flange connection

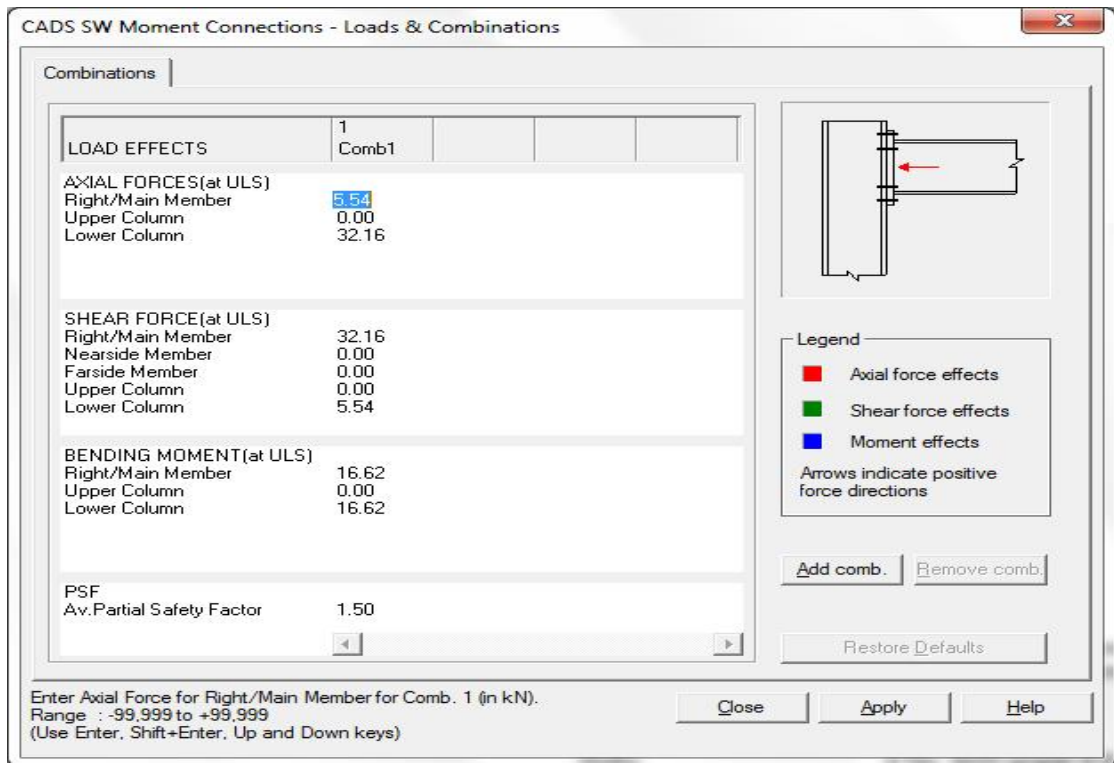


Fig 4.4 Load combination data for default column flange connection.

In order to model the required beam flange/column cap plate connection as a quasi-column flange connection proceed as follows:

1. Open CADS SWMC > Connection preselector and accept the default settings as shown in fig 4.5

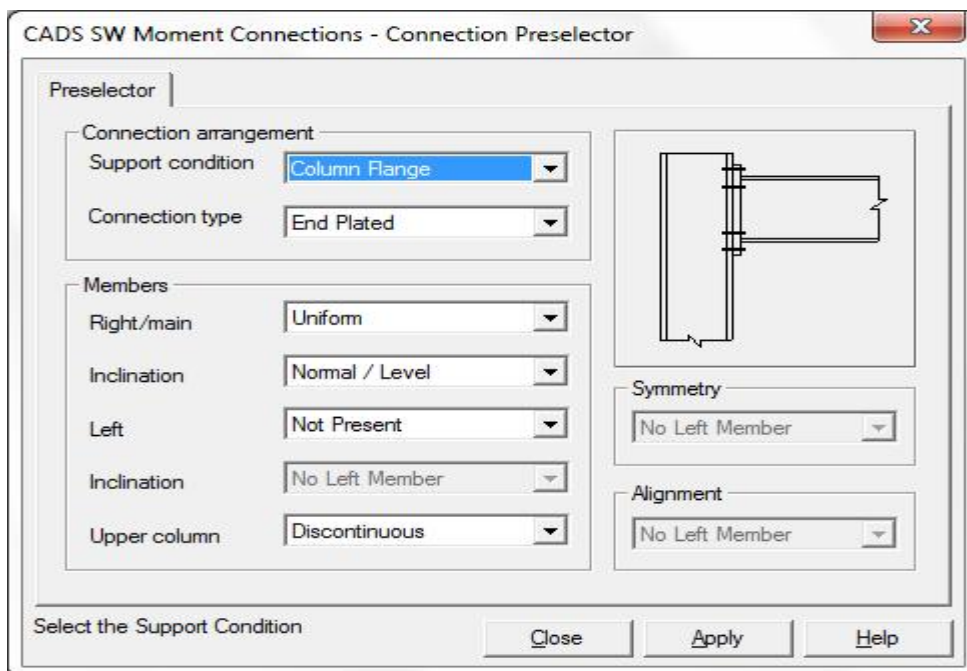


Fig 4.5 Connection preselector settings for example 1.

- The main view displays the selected connection arrangement with default 305x165UKB40 sections for both the members as shown in fig 4.6.

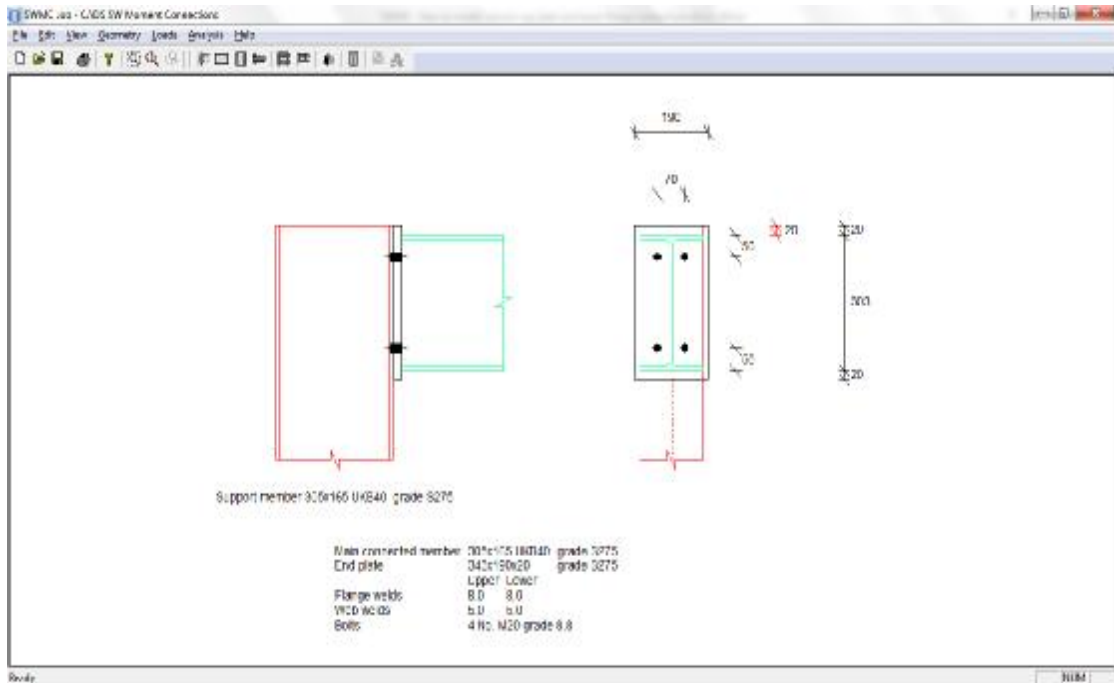


Fig 4.6: Default connection main view.

- Open the Connected members dialog to change the section to 152x152UKC30 as required for the column acting as quasi-beam. Anticipating the need to extend the column cap plate outside the flange, change the top face distance from 20 to 100 mm as shown in fig 4.7.

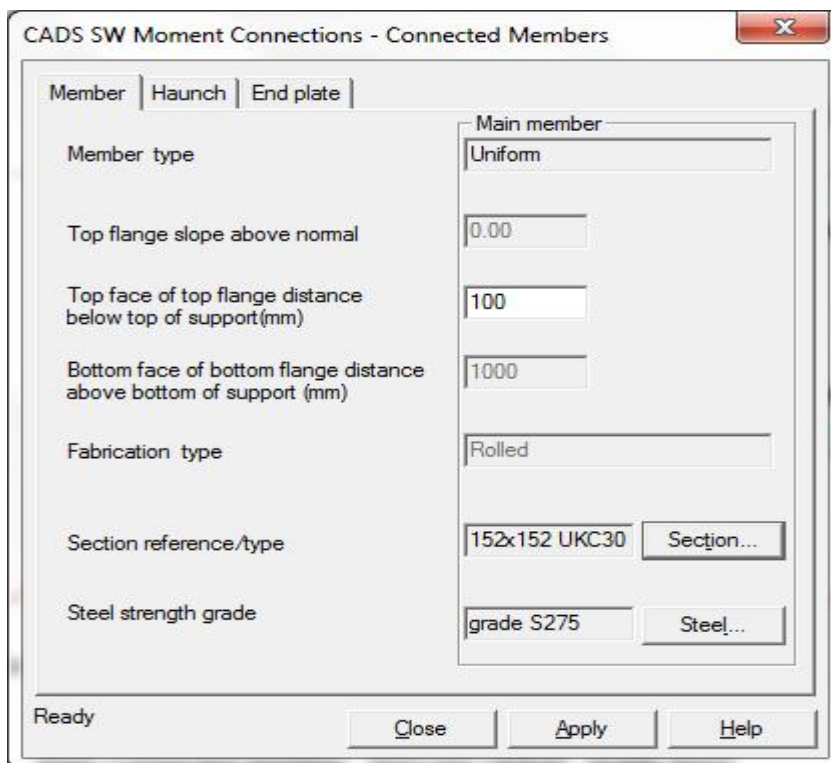


Fig 4.7

- Open the Support member dialog to change the default section to the required beam section 254x146UKB31 as shown in fig 4.8

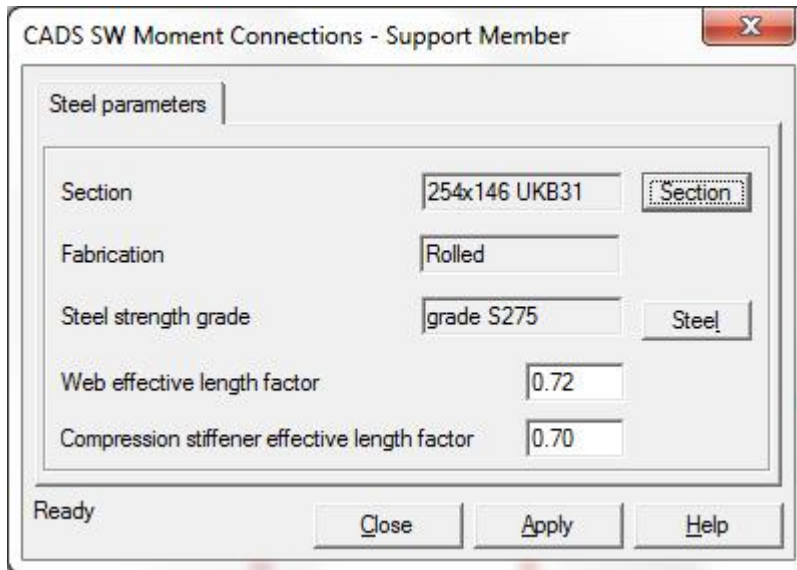


Fig 4.8

- The main view should now change to show the updated sections in their rotated position in the quasi-column flange arrangement as shown in fig 4.9.

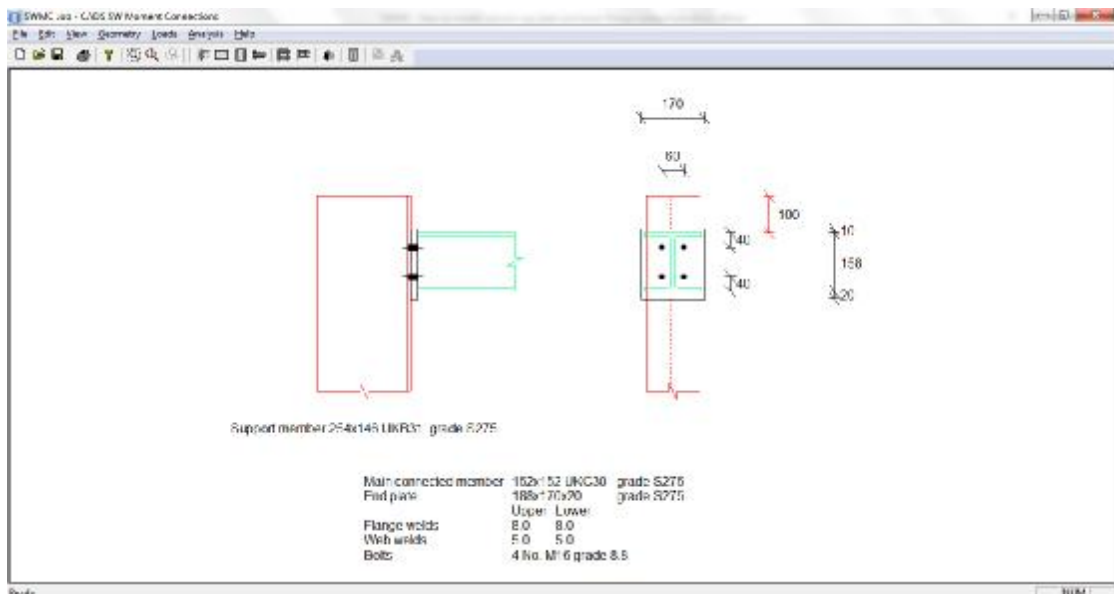


Fig 4.9 Quasi-column flange connection.

- Open the load combinations input page and enter the force effects from fig 4.4 'mapped' in accordance with the procedure given in section 3 above as illustrated in fig 4.10.

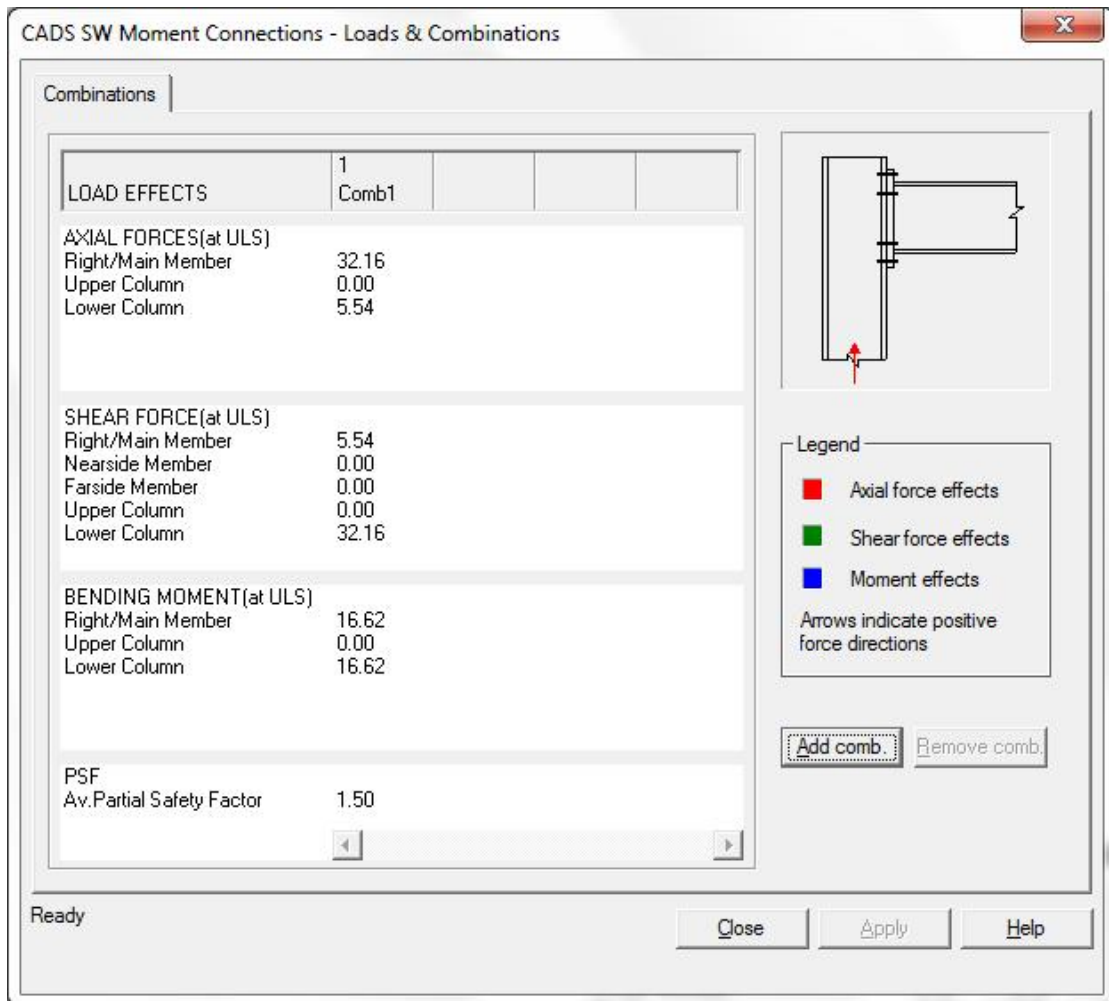


Fig 4.10 Load combinations input showing force effects for the quasi-column flange connection.

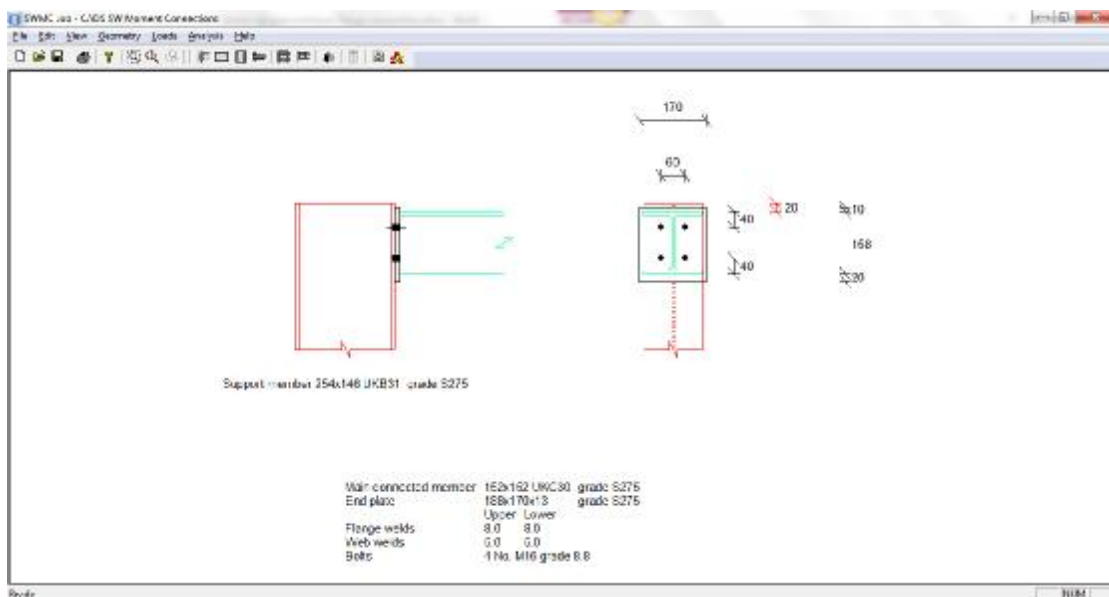


Fig 4.11 Final design with compact cap plate connection to the column.

On calculation the software reports pass results with the default flush end plate so the beam extension was not required in this instance. Fig 4.11 shows the final solution for this example. Where the moment to be transmitted is a significantly higher proportion of the section resistance moment an extended end/cap plate with bolts outside the flange would be necessary. In this example the moment is only a quarter of the column section capacity.

4.2 More complex example: portal frame with rafter oversailing column

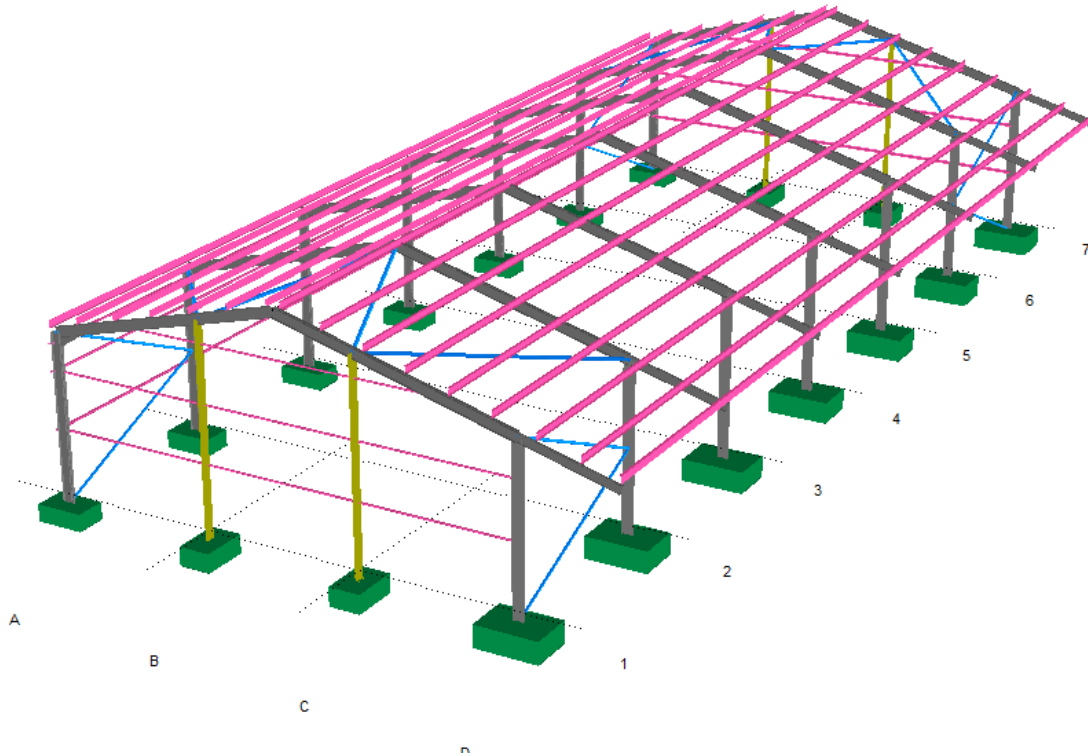


Fig 4.12 Solid model of portal frame with eaves cantilever.

This example was created in CADs SMART Portal 3D by a CADs customer. Fig 4.13 shows the stick diagram of a main frame with the right hand eaves connection selected for export to SWMC.

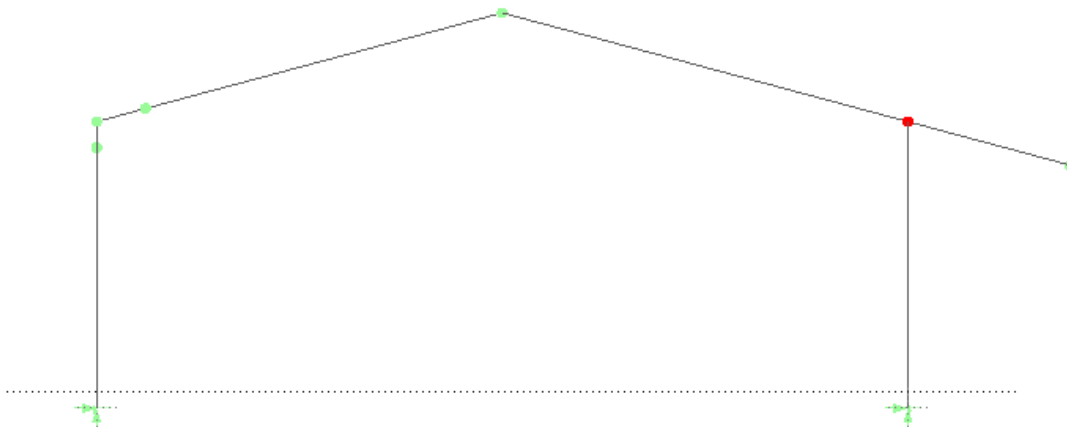


Fig 4.13 Stick model of main frame with right eaves connection selected.

After selecting *Export to SWMC*, the software produces a default column flange connection which after selecting *Top face alignment* appears as shown in fig 4.14

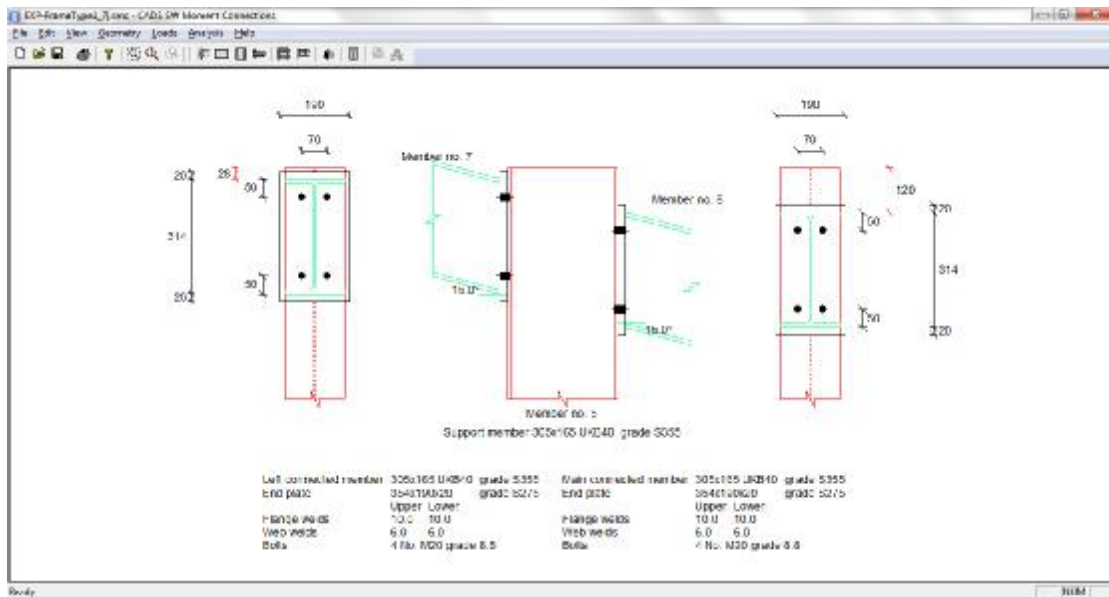


Fig 4.14 Column flange connection produced by export to SWMC

18 load combinations are generated by SP3D and imported and displayed in SWMC as shown in fig 4.15

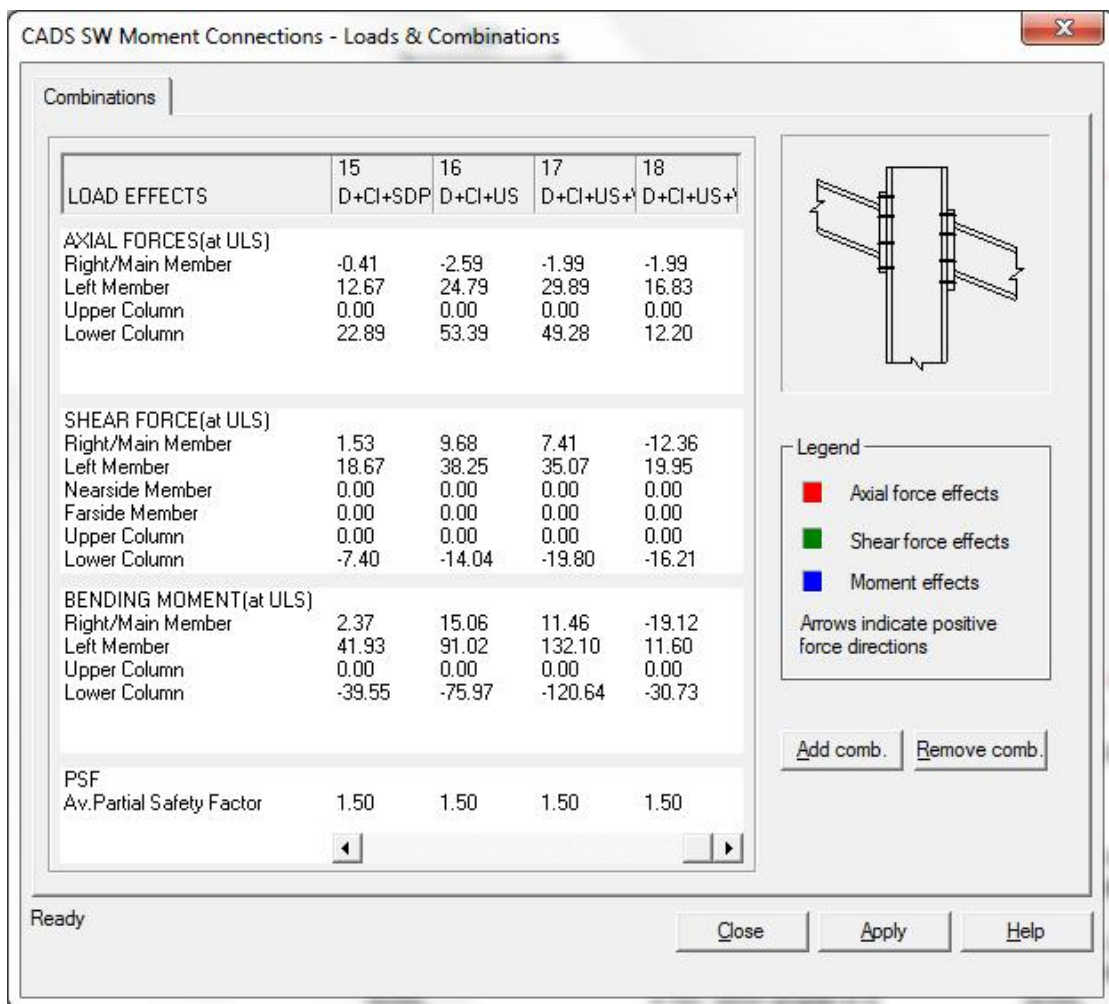


Fig 4.15 Load combinations page showing the last 4 of 18 imported combinations.



It would be very laborious to map all the load combinations data to a quasi-column flange connection set up by hand so we will extract the 2 load combinations which produce maximum + and – moments in the column. These are shown below in table 4.1:

Load comb. no.	11	17
Load comb. name	D+WRIP	D+CI+US+W LIS
Axial forces		
Right member	-0.34	-1.99
Left member	-23.85	29.89
Column	-51.50	49.28
Shear forces		
Right member	-21.79	7.41
Left member	-25.23	35.07
Column	10.54	-19.80
Moments		
Right member	-33.83	11.46
Left member	-91.26	132.10
Column	57.43	-120.64

Table 4.1 Extracted force effects for the actual connection for the two critical load combinations

These map to the quasi-column flange connection according to the procedure in section 3 above as shown in table 4.2:

Load comb. no.	1	2
Load comb. name	D+WRIP	D+CI+US+W LIS
Axial forces		
Right member	-51.50	49.28
Left member	n/a	n/a
Lower column	-23.85	29.89
Upper column	-0.34	-1.99
Shear forces		
Right member	-10.54	19.80
Left member	n/a	n/a
Lower column	-25.23	35.07
Upper column	-21.79	7.41
Moments		

Right member	57.43	120.64
Left member	n/a	n/a
Lower column	-91.26	132.10
Upper column	-33.83	-11.46

Table 4.2. Force effects for the quasi-column flange connection.

To create the quasi-column flange connection modelling the required beam flange connection proceed as follows:

1. Open SWMC. Open the *Connection preselector* input page and set up the geometry as shown in fig 4.16

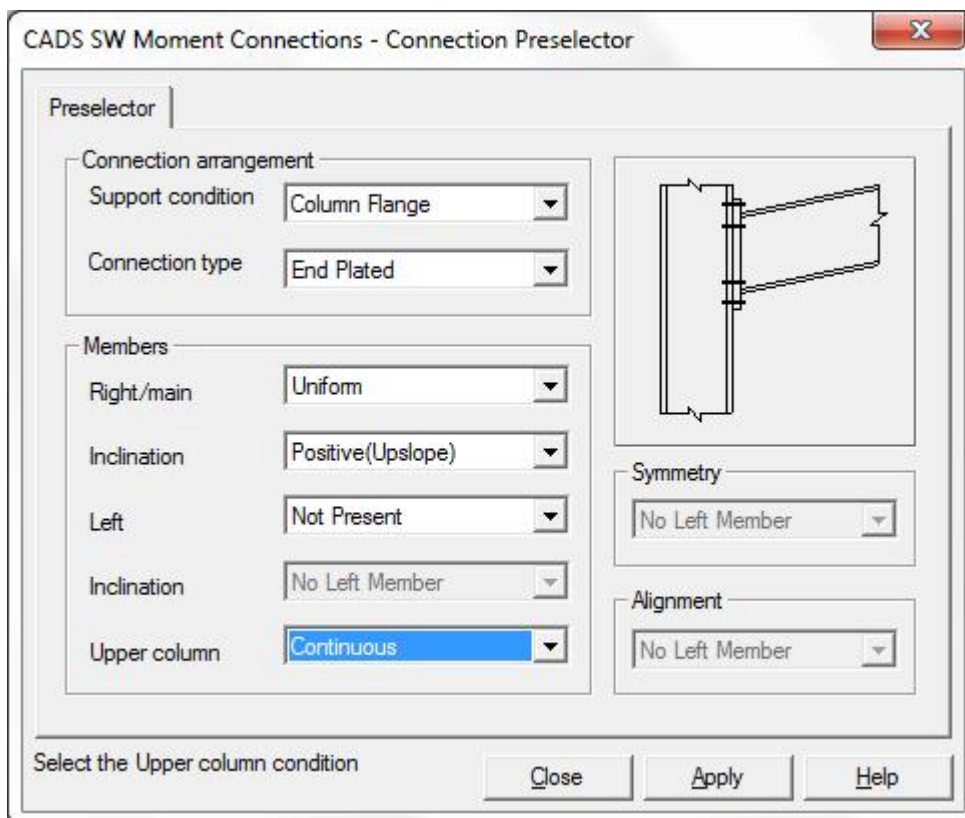


Fig 4.16 Connection preselector with inputs for quasi column flange connection.

2. Close the preselector and view the default arrangement in the main view as shown in fig 4.17
3. It so happens that the default sections are 305x165UKB 40 exactly as required for this example. In other circumstances the required sections would have to be selected in the *Connected member* and *support member* dialogs. However the default slope is 20° and we require 15° so open the *Connected member* dialog and edit accordingly as shown in fig 4.18. The steel grades are also edited from S275 to S355 in both dialogs.
4. Open the *Loads and combinations* dialog to enter the force effects tabulated above as shown in fig 4.19. Note that if the correct values are entered for the left and right quasi-rafters and upper column members, the software will calculate the the equilibrium values for the lower column which should be the same as in table 4.2.

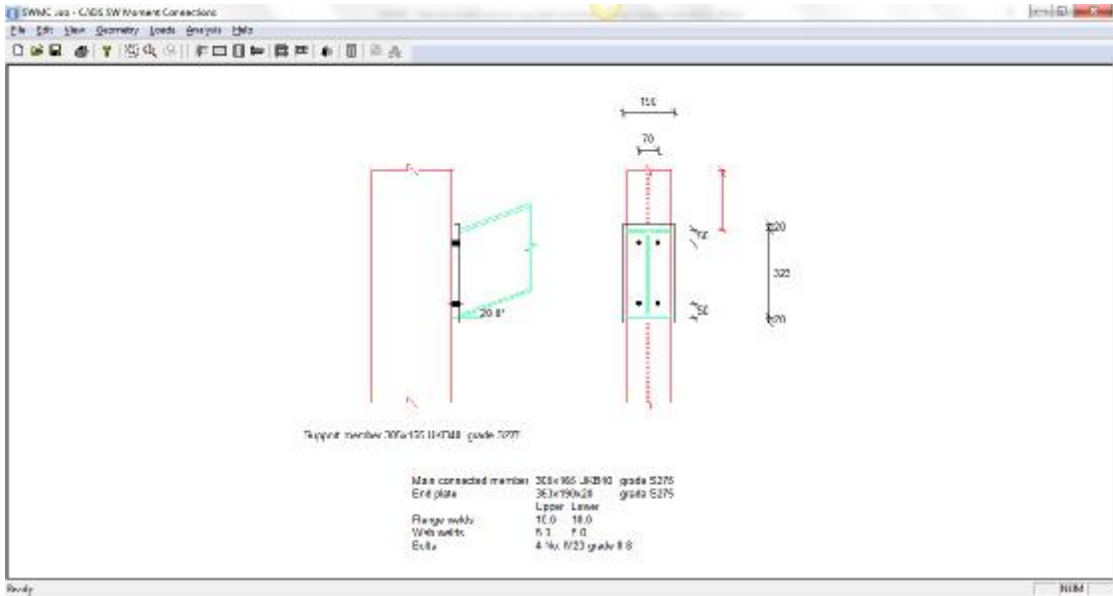


Fig 4.17 Main view showing default connection arrangement produced by the preselector settings in fig 4.16

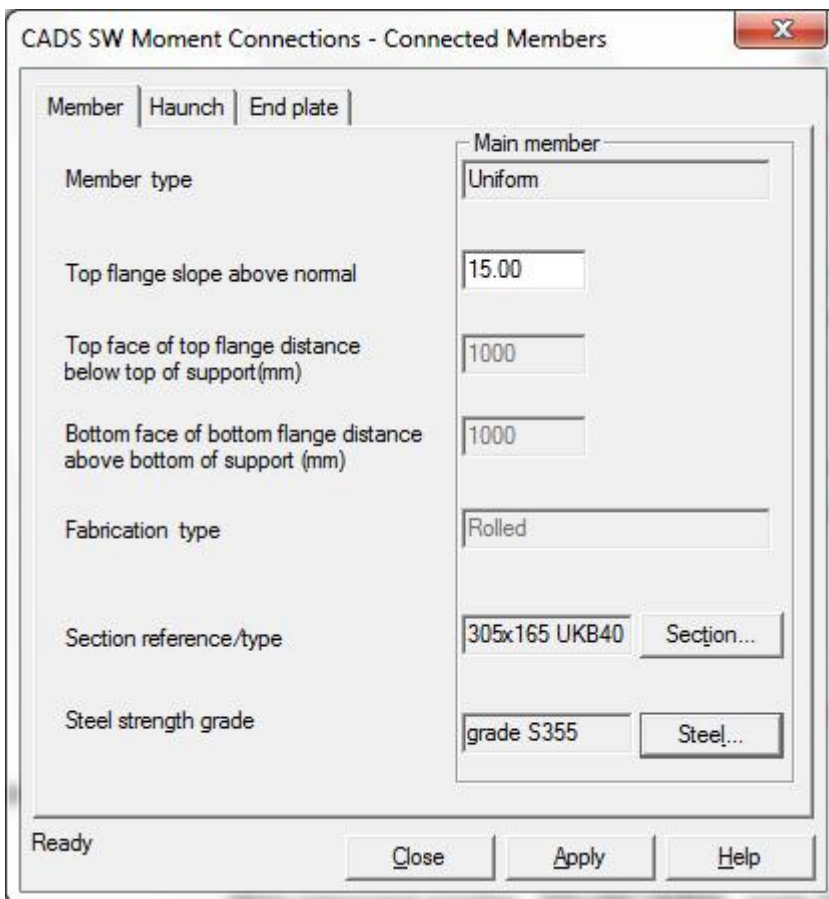


Fig 4.18 Connected members dialog with slope and steel grade edited.

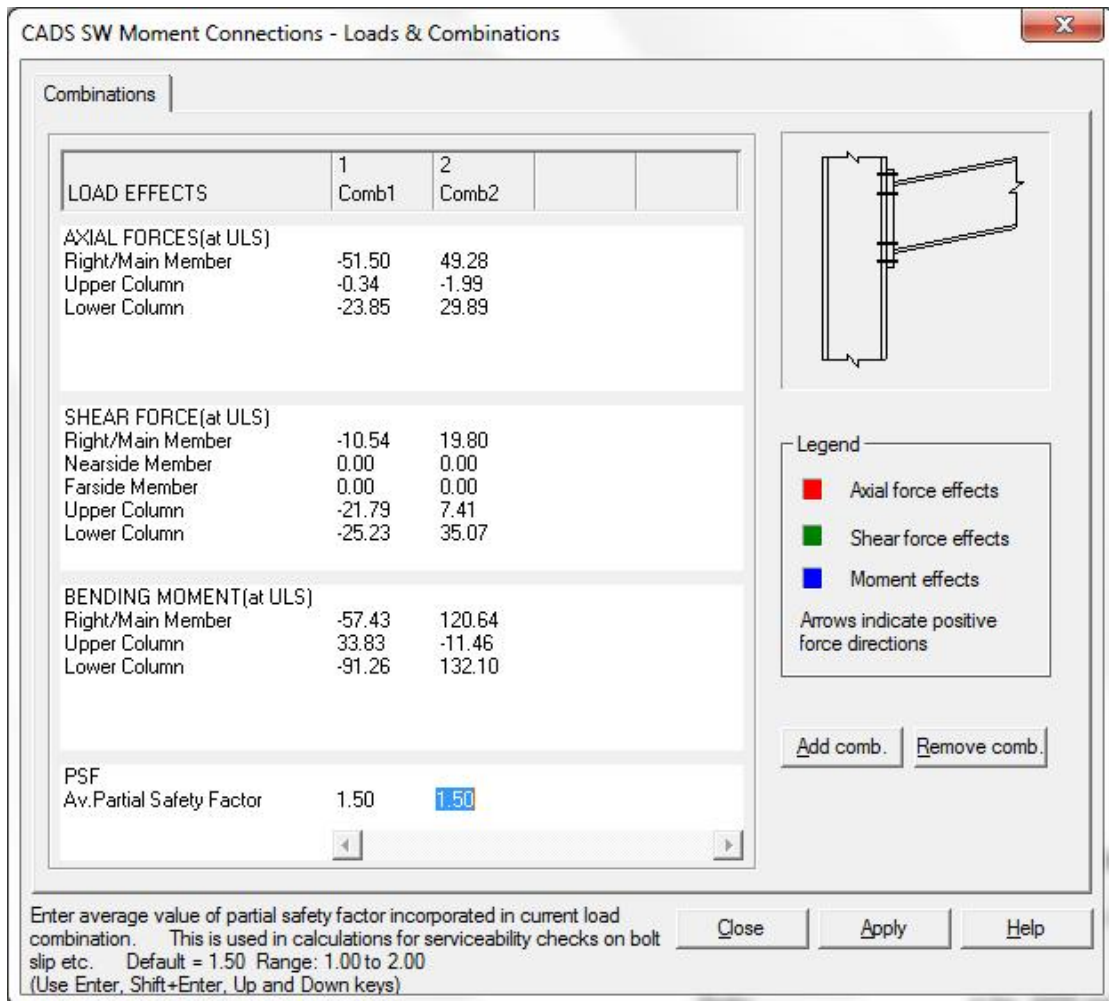


Fig 4.19 Loads and combinations page with force effects entered as per table 4.2.

- Having checked the loads and combinations data, select *Analysis calculations*. The summary results appear as shown in fig 4.20.

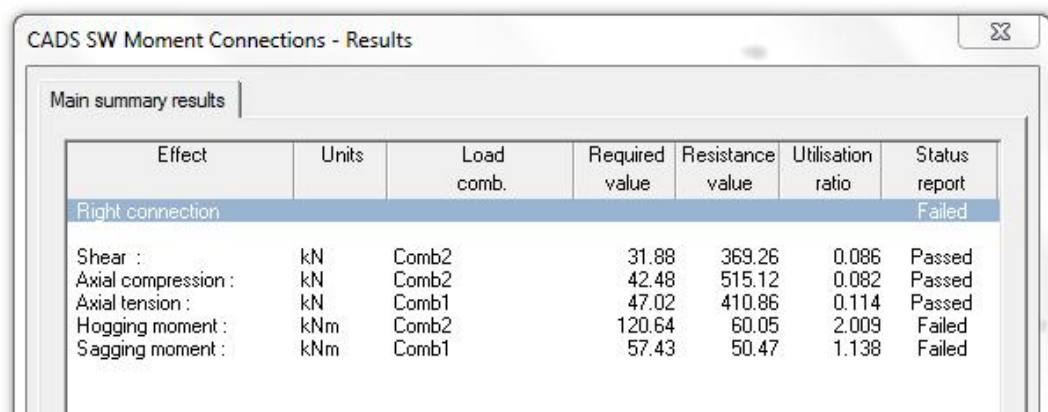


Fig 4.20 Summary results for unstiffened compact end plate connection.

As expected the results show that the connection is inadequate for both load combinations as currently detailed. In order to achieve pass results either add bolts and stiffener plates or add a haunch. Pursuing the first option we will add bolt rows outside the column (quasi-right member) flanges.

- Open the *Bolts>Bolt numbers* page and edit to provide bolt rows outside the flanges as shown in fig 4.21

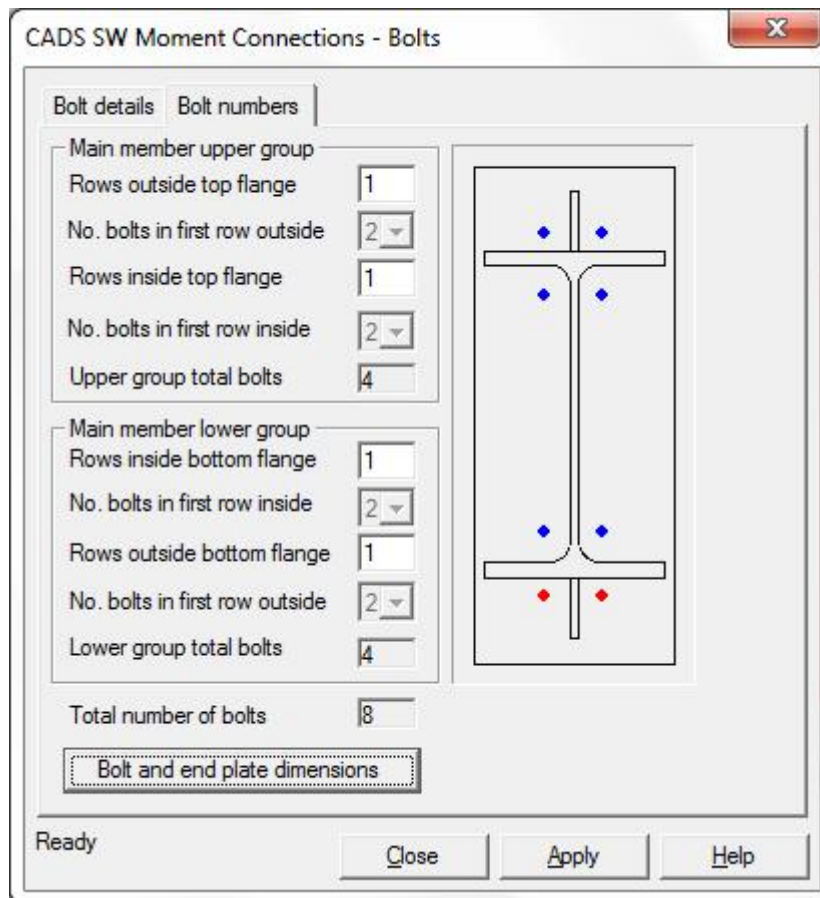


Fig 4.21 Bolt numbers page with outer bolt rows selected.

- Select *Analysis calculations* to obtain updated results as shown in fig 4.22.

Effect	Units	Load comb.	Required value	Resistance value	Utilisation ratio	Status report
Right connection						Failed
Shear :	kN	Comb2	31.88	401.42	0.079	Passed
Axial compression :	kN	Comb2	42.48	550.05	0.077	Passed
Axial tension :	kN	Comb1	47.02	738.97	0.064	Passed
Hogging moment :	kNm	Comb2	120.64	85.12	1.417	Failed
Sagging moment :	kNm	Comb1	57.43	94.70	0.606	Passed

Fig 4.22 Summary results after adding bolt rows outside the flanges.

The connection is now adequate for load combination 1 but inadequate for load combination 2.

- Open the *Connection resistance moments – Right* page for load combination 2 as shown in fig 4.24.

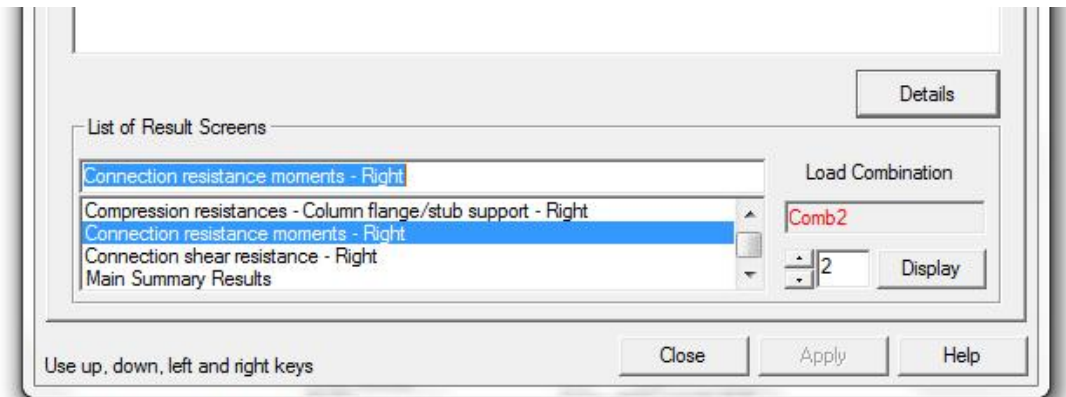


Fig 4.23 Selection of more detailed results for load combination 2.

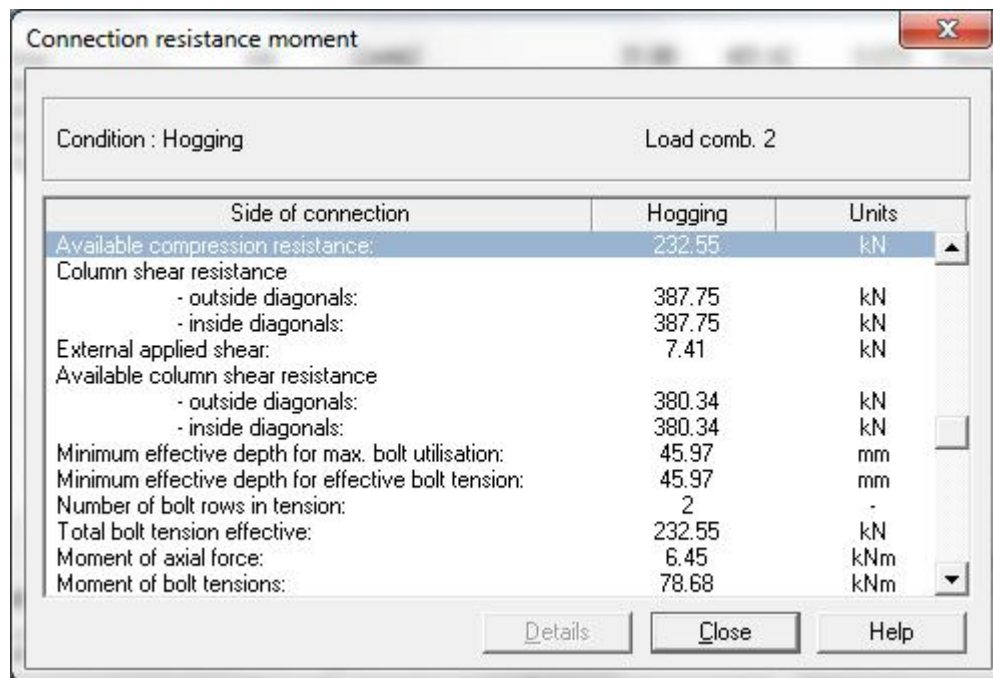


Fig 4.24 Part of Connection resistance moments results.

The *Connection resistance moments* results display shows that the bolt tension force is limited by the compression zone resistance. Therefore add compression stiffener plates using the *Support member stiffeners* dialog as shown in fig 4.25.

9. Select *Analysis calculations* to obtain updated results as shown in fig 4.26. The connection now passes the design criteria with one set of stiffeners. Therefore it may be concluded that the option of providing a column haunch is not worth pursuing.
10. Fig 4.27 shows the final quasi-column flange connection design. Fig 4.28 rotates the image to show the intended construction with rafter oversailing the column cap plate.

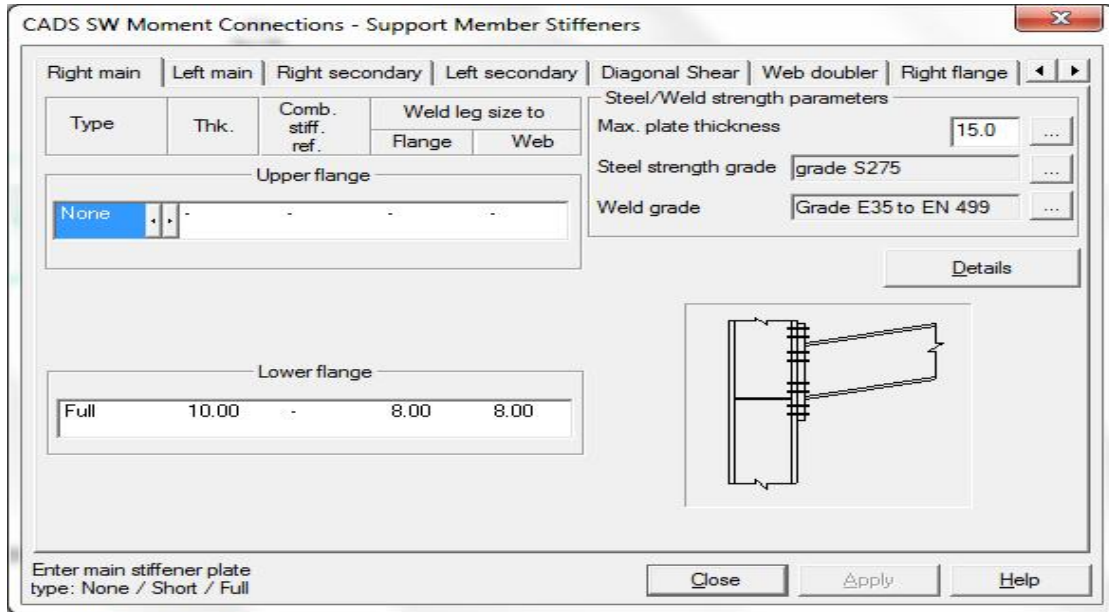


Fig 4.25 Support member stiffeners dialog with full stiffener selected.

Effect	Units	Load comb.	Required value	Resistance value	Utilisation ratio	Status report
Right connection						Passed
Shear :	kN	Comb2	31.88	401.42	0.079	Passed
Axial compression :	kN	Comb2	42.48	893.37	0.048	Passed
Axial tension :	kN	Comb1	47.02	780.34	0.060	Passed
Hogging moment :	kNm	Comb2	120.64	121.05	0.997	Passed
Sagging moment :	kNm	Comb1	57.43	94.70	0.606	Passed

Fig 4.26 Summary results updated after adding compression stiffener plates.

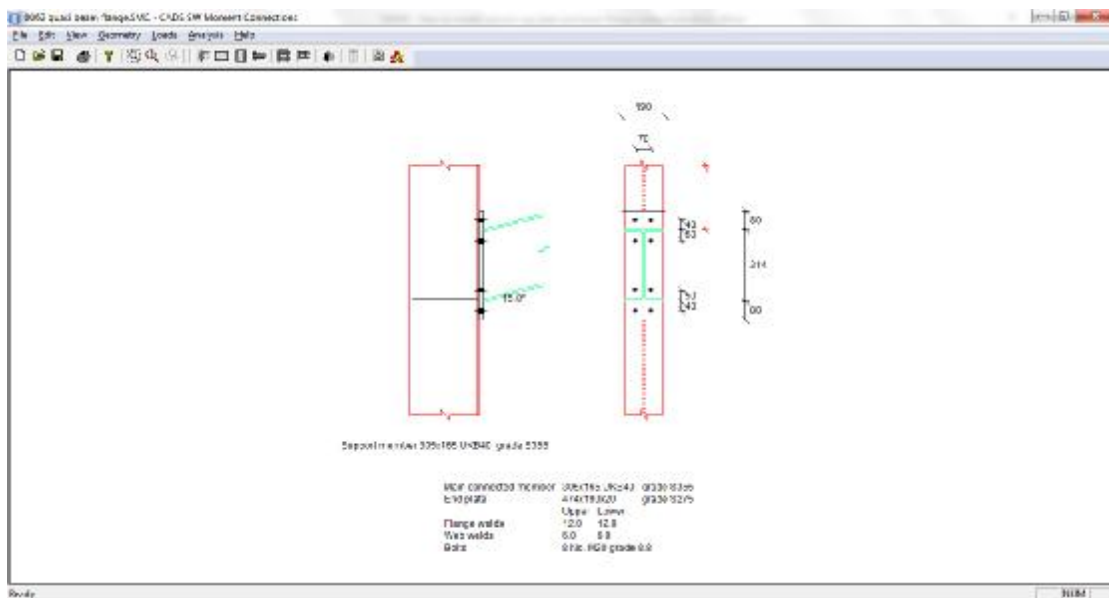


Fig 4.27 Final design of quasi-column flange connection.

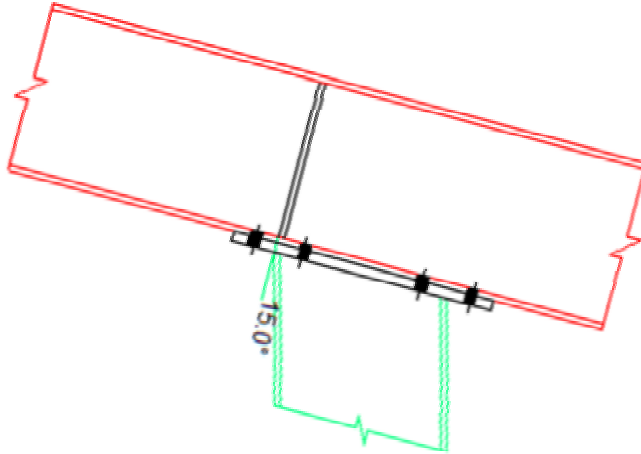


Fig 4.28 Final design column cap plate connection with oversailing rafter.

Please note that the graphics show only the details required for connection design. They do not show other components that may be required for stability/lateral restraint.

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