

A3D MAX FAQ

How can I model steel frames of 'simple design' using CADS A3D MAX.





1.0 Introduction

Steel frames of 'simple design' may be defined as those beam and column frames in which the connections have rotational fixity which is either negligible or ignored for the purposes of beam design. The design method seems to have emerged in the late nineteenth or early twentieth century to suit the types of connection then in use for which no reliable or significant moment resistance or rotational stiffness is or was calculable. Modern fin plate, part depth end plate, web angle cleats and seating angle connections also fit this description. However the method is also often applied to frames with unstiffened full depth end plate connections which could be classified as semi-rigid.

BS 5950-1:2000 recognises three types of frame design:

Simple design
Continuous design
Semi-continuous design

Although simple design remains the most common approach, the Code devotes much more space to continuous design and gives very little guidance for the third category: semi-continuous design, despite its attractions. The Eurocode EN 1993-1-1 adopts essentially the same categories and provides even less guidance for what it calls simple framing. Similarly, it must be admitted that most computer programs for structural analysis are best equipped for analysing continuous frames.

However with some careful extra effort it is quite feasible and practicable to make use of CADS A3D MAX for building frames of simple design and so benefit from a whole-building 3D model with its automatic load distribution, batch member design etc.

2.0 Beam design

BS 5950-1:2005 clause 2.1.2.2 states that for simple design:- "The distribution of forces may be determined assuming that the members intersecting at a joint are pin connected." This is usually interpreted to mean that the beams are designed to span between the axes of the supporting columns. Actually there is no reason why they should not be designed to span between the *faces* of the supporting columns provided this is taken into account in the design of the columns. However the resulting complication is not usually worthwhile. It will therefore be assumed in this note that the beams will be designed as simply supported between the column axes.

Clause 2.1.2.2 further states that "The structure should be laterally restrained, both in-plane and out-of-plane, to provide sway stability and resist horizontal forces." However, this statement should not be taken to preclude hybrid designs providing that adequate provision is made for lateral stability in all directions. For instance, it is reasonable and not uncommon to design for rigid frame action in one direction and braced simple frame action in the orthogonal direction.

3.0 Column design

BS 5950-1:2005 clause 4.7.7 has additional requirements for the design of columns in 'simple structures'. The principal requirement is that "the nominal moments applied to the column by simple beams or other simply supported members should be calculated from the eccentricity of their reactions." It then goes on to list three conditions of nominal eccentricity of which only the third need concern us here:- "In all other cases the reaction should be taken as acting 100 mm from the face of the steel column or at the centre of the length of stiff bearing, whichever gives the greater eccentricity." This is the essential guidance relevant to frame analysis by computer. Although not clearly stated, the remainder of clause 4.7.7 consists of simplifications of analysis (moment distribution) and design checking (effective length and interaction formula) to facilitate hand calculations by traditional methods. It is acceptable and convenient to ignore this part of clause 4.7.7 when using full frame analysis and to apply normal effective

length factors (usually $k = 1.0$) and the separate checking of capacity and buckling interaction formulae per clause 4.8 as applied to members in general.

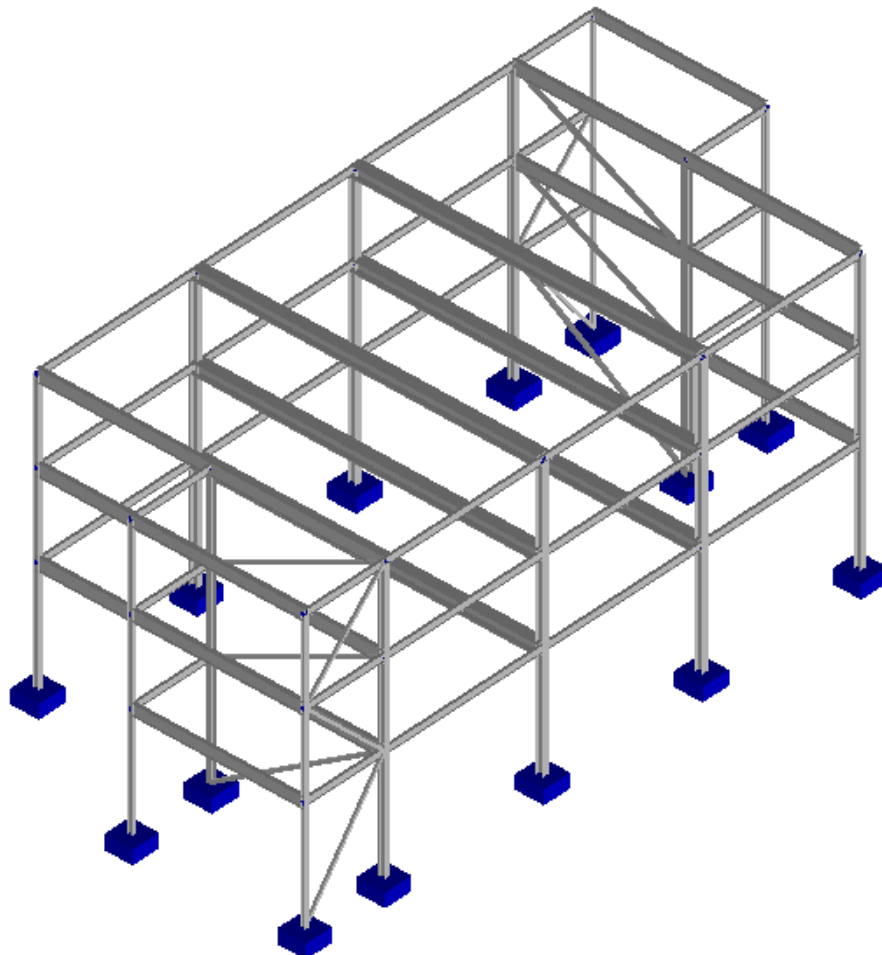
4.0 Implications for analysis by computer

It will be clear from the above, that the BS 5950 requirements for design of simple frames imply two different analysis models: one for beam design and one for column design. This is to reflect uncertainty in the behaviour of the connections. It is a departure from the usual and convenient practice of having one consistent analysis model of the structure as is possible with continuous or semi-continuous frames which have definable connection properties.

This duplication of models is not usually as onerous as it might first appear, although there is certainly more effort and care required from users of the existing software facilities.

In most simple frames the effect of beam reaction eccentricity moments on the columns is relatively small. This means that the design can be worked up to a near-final state using the model for beam design with beam members pinned to the column axes. A copy of the frame model is then made and modified to produce the eccentricity moments for the column design model. The procedure is described in more detail in the following paragraphs.

5.0 Simple frame worked example

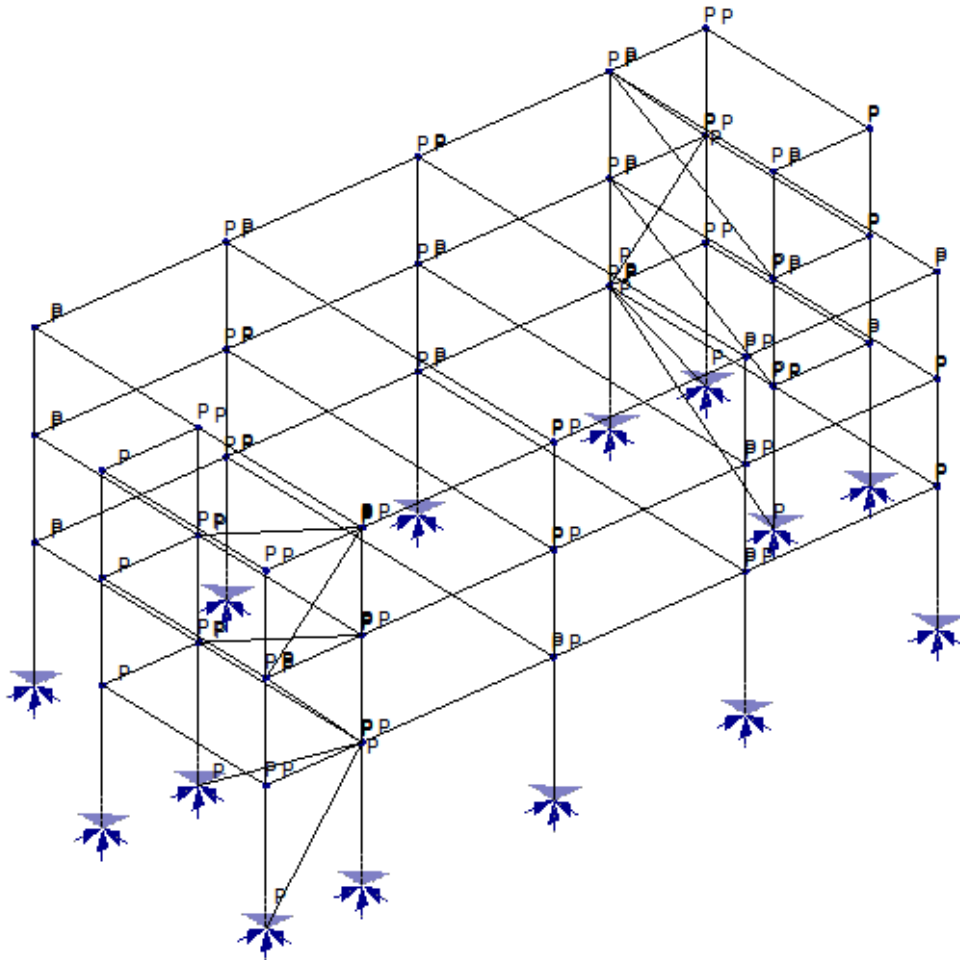


The illustration above shows a modest 3 storey frame with two sets of bracing in each orthogonal direction. The floor and roof loads are applied using the A3D MAX panel feature and with *rigid panel* action selected. Note that in the absence of rigid or semi rigid frame action, rigid panel action or equivalent floor/roof bracing is essential to transfer lateral loads to the vertical bracing systems and avoid mechanism failure due to multiple pins. Wind loads on

the building faces are also applied using the panel feature but with *non-rigid* panel action selected.

5.1 Simple frame example – beam design

The following illustration shows a ‘stick model’ representation of the frame with the beams pin-connected to the columns at joints on the column axes as required for the ‘beam design model’.



The members are allocated to a number of rational member types with preliminary ‘guestimated’ steel section sizes as shown in the illustration below. Note that the columns are assumed to be supplied as 3 storey lengths but this is not essential.

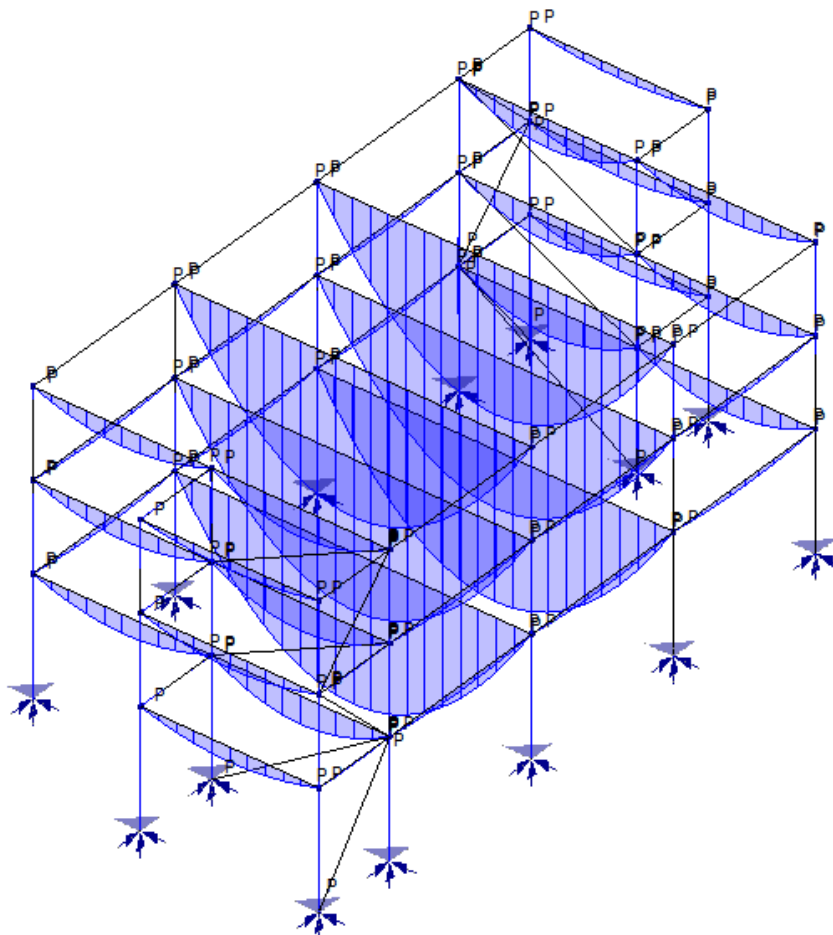


CADS A3D MAX - Member Type Editor

	Reference	Type	Section	Material	Used
1	x dir edge beams	SW Library	305x165 UKB40	UK-S275	30
2	z dir main beams	SW Library	356x368 UKC129	UK-S275	6
3	main columns	SW Library	203x203 UKC86	UK-S275	12
4	end columns	SW Library	203x203 UKC60	UK-S275	12
5	penult columns	SW Library	203x203 UKC60	UK-S275	18
6	end beams	SW Library	305x165 UKB40	UK-S275	6
7	penult beams	SW Library	406x178 UKB54	UK-S275	12
8	x dir bracing	SW Library	Celsius 355 100x1	UK-S355	6
9	z dir bracing	SW Library	Celsius 355 100x1	UK-S275	6

MemberType reference

The frame is analysed for several load combinations. The illustration below shows the moment diagram graphic for the 1.4 dead + 1.6 imposed ULS load combination:-



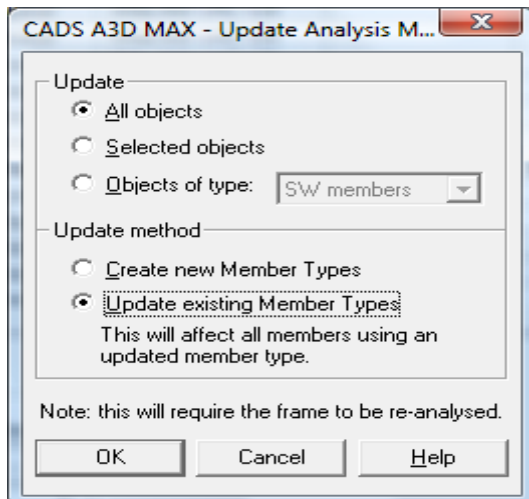
After inspecting the moment graphics, the *Design>Create SW Groups* wizard is used to set up member design groups which in this case conform with the member types. The groups are then batch processed using the *Design>Design results* dialog. The beam groups are assigned the SWMD template Tcontinuous which is suitable for beams with continuous top flange restraint by floor slabs. The column groups are assigned the *Defaults* template which



assumes no intermediate lateral restraints and effective length factors $k_x = k_y = 1.00$ corresponding to the sway-braced condition in each plane. Each design group is selected in turn and subjected to autodesign by pressing the *Design* button. The illustration below shows the upper part of the *Design results* dialog after autodesign.

Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac...										
Main beams	Passed		tcontinuous	356x368 UKC129	356x406 UK...	Least depth...	0.908	0.908	n / a	n / a
*1	Passed	136	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	n / a	n / a
*2	Passed	137	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	n / a	n / a
*3	Passed	138	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	n / a	n / a
*4	Passed	139	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	0.000	n / a
*5	Passed	140	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	n / a	n / a
*6	Passed	141	Tcontinuous	356x368 UKC129	356x406 UKC340		0.908	0.908	n / a	n / a
Gm span edg...	Passed		tcontinuous	305x165 UKB40	254x102 UK...	Least weight	0.796	0.796	n / a	n / a
*7	Passed	64	Tcontinuous	305x165 UKB40	254x102 UKB22		0.796	0.796	n / a	n / a
*8	Passed	66	Tcontinuous	305x165 UKB40	254x102 UKB22		0.796	0.796	n / a	n / a
*9	Passed	67	Tcontinuous	305x165 UKB40	254x102 UKB22		0.796	0.796	n / a	n / a
*10	Passed	69	Tcontinuous	305x165 UKB40	254x102 UKB22		0.796	0.796	n / a	n / a

The sections used for analysis are shown alongside the sections produced by autodesign. In some groups the design section is larger than the original section and in some groups smaller. Note that there are no results for deflection because autodesign currently only covers strength and stability. At this stage alternative sections can be substituted for the autodesigned sections by editing the *Member type* dialog and re-analysing eg: a 254 x146 UKB31 might be substituted for the 254 x102UB22. In any case re-analysis should be done. The *Update analysis model* button may be pressed and the dialog shown below appears giving options as to how the update should be managed.



In this case no member type is shared by more than one design group so the best option is to select *Update existing member types*.



Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac...										
Main beams	N/A		tcontinuous	356x406 UKC340		Least depth...	0.908	0.908	n/a	n/a
*1	N/A	136	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	n/a
*2	N/A	137	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	n/a
*3	N/A	138	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	n/a
*4	N/A	139	Tcontinuous	356x406 UKC340			0.908	0.908	0.000	n/a
*5	N/A	140	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	n/a
*6	N/A	141	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	n/a
6m span edg...	N/A		tcontinuous	254x146 UKB31		Least weight	0.796	0.796	n/a	n/a
*7	N/A	64	Tcontinuous	254x146 UKB31			0.796	0.796	n/a	n/a
*8	N/A	66	Tcontinuous	254x146 UKB31			0.796	0.796	n/a	n/a
*9	N/A	67	Tcontinuous	254x146 UKB31			0.796	0.796	n/a	n/a
*10	N/A	69	Tcontinuous	254x146 UKB31			0.796	0.796	n/a	n/a

Re-analysis required.
Results are based on Analysis 0011

The dialog colours now change to black and a message appears: *Re-analysis required.* Close the *Design results* dialog and select the *Calculate* toolbar icon or *Analysis > Calculate* to re-analyse the frame with the new sections. The *Design results* dialog and each design group is selected in turn for *Check* to verify the selected sections as shown below.

Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac...										
Main beams	Passed		tcontinuous	356x406 UKC340		Least depth...	0.908	0.908	n/a	0.537
*1	Passed	136	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
*2	Passed	137	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
*3	Passed	138	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
*4	Passed	139	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
*5	Passed	140	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
*6	Passed	141	Tcontinuous	356x406 UKC340			0.908	0.908	n/a	0.537
6m span edg...	Passed		tcontinuous	254x146 UKB31		Least weight	0.525	0.525	n/a	0.560
*7	Passed	64	Tcontinuous	254x146 UKB31			0.525	0.525	n/a	0.560
*8	Passed	66	Tcontinuous	254x146 UKB31			0.525	0.525	n/a	0.560
*9	Passed	67	Tcontinuous	254x146 UKB31			0.525	0.525	n/a	0.560
*10	Passed	69	Tcontinuous	254x146 UKB31			0.525	0.525	n/a	0.560

Current analysis number: 0012
Results are based on Analysis 0012

Because the frame is essentially statically determinate, the re-analysis is a formality for strength and stability but the deflection results are now available and in this case satisfactory. The beam design model is now verified so it is time to proceed to create the column design model as described below.

5.2 Simple frame example – column design model

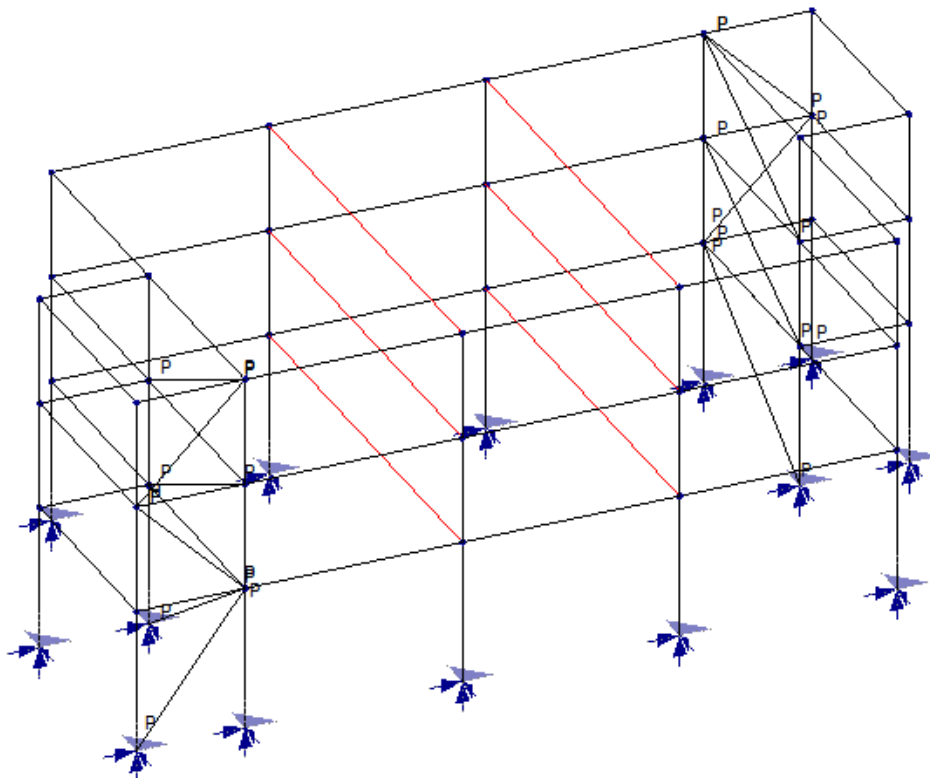
Using *Save as*, a copy is taken of the .a3m file, modifying the name to include “column design” or similar. Next step is to select all the beams. (This is most easily done by starting with an elevation view, then selecting each floor in turn using a ‘bounding window’. Use *Ctrl* to maintain the previous selection as each floor is selected. This will ensure that the beams are selected but not the columns or bracings. Revert to *Isometric view* to check the selection includes only the beams.)

A right mouse click on one of the selected members and selection of *Properties* from the drop menu opens the *Member attributes* dialog. (Ignore or close the *Joint properties* dialog which also displays). The member end fixity should display as *Pinned* at both ends and should be changed to *Fixed*.

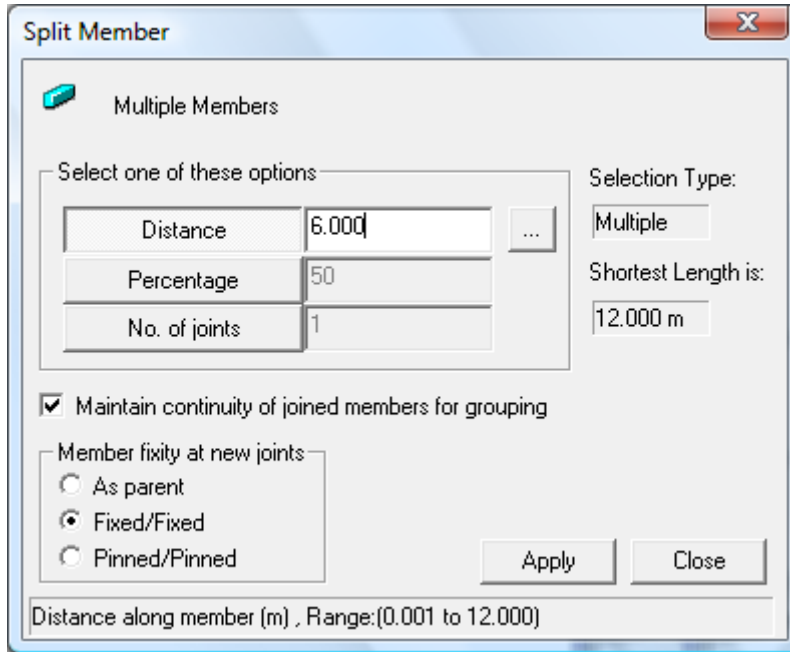
The next step is to insert pin joints in the beams to model the ‘offset pin’ model implied by BS 5950-1 clause 4.7.7.

Having preliminary sizes for the columns, it is easy to calculate the offsets for each beam framing into the column. Normally the flange connection offset will be $(0.5 \cdot D_c + 100) / 1000$ metres where D_c = column section depth in mm. Normally the web connection offset will be $(0.5 \cdot T_{wc} + 100) / 1000$ metres where T_{wc} = column web thickness in mm unless the connection is made to a flange toe plate. Usually the range of flange and web offsets is quite small, enabling some rationalisation and simplification.

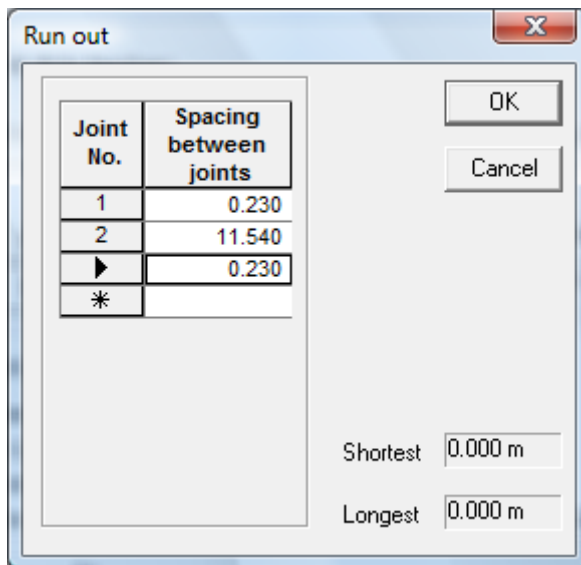
A group of beams is selected which have the same length and the same or similar column supports. The illustration below shows the main z direction beams selected.



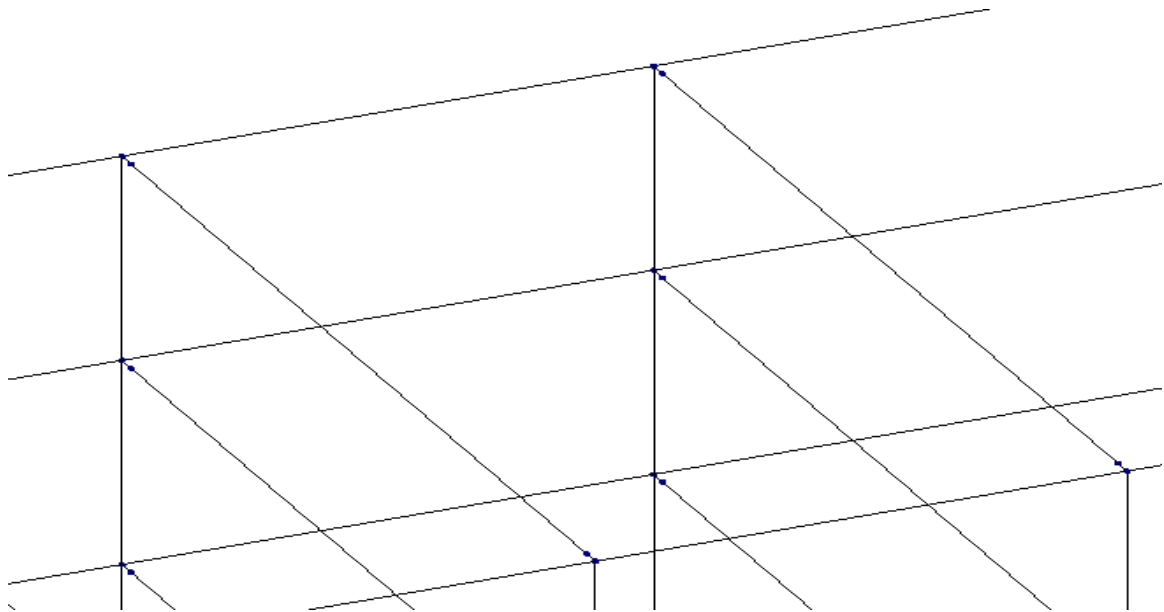
Selecting *Tools > Split selected members* opens the Split member dialog shown below.



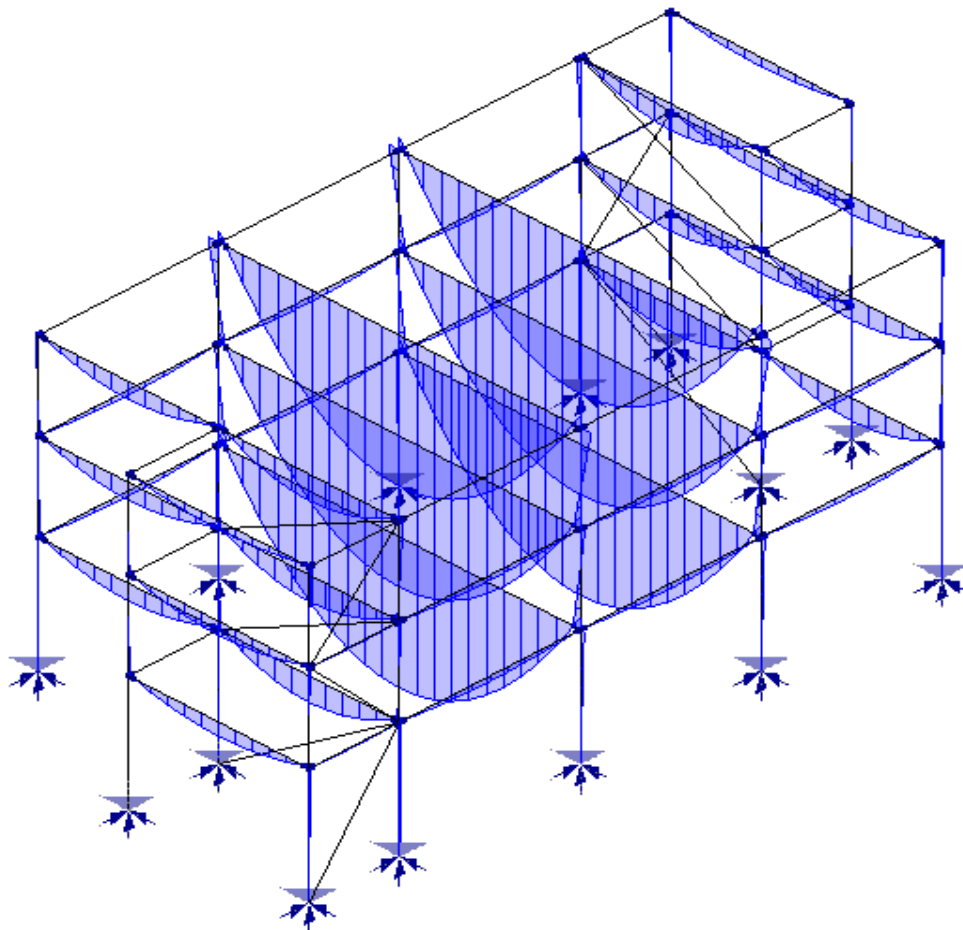
Pressing the ... browser button opens the *Run out* sub-dialog to input the positions along the member(s) where it is required to inset joints to model the offset pin connections. The inputs for the main beams are shown below.



Pressing OK and closing the main dialog inserts the additional joints which appear on the main view. This is illustrated below in a zoom view. This operation is repeated with all the groups of simple beams in the structure, inputting the relevant values for offsets. In this example there were four groups of beams in the Z direction and three groups of X direction beams.



Part zoom view showing offset joints inserted in the main beams.



Main view showing eccentricity moments induced in columns.

After inserting all the additional joints, all the main beam lengths between offsets are selected and using the *Member attributes* dialog, their end fixities changed from *Fixed* to *Pinned*. Each beam is now modelled as a pinned member spanning between short stub members fixed to the column joints.



The column design model can now be analysed. The illustration above shows the small eccentricity moments induced in the columns.

After completing the analysis, the *Design results* dialog is opened. All the beam design groups can be deleted. They now show 'Error' and will no longer calculate because of the internal pins that have been introduced. The remaining design groups are selected in turn then pressing *Check* to execute the BS 5950 design check. The main column members now fail in the ground storey by a small margin as shown below. All the other groups still pass the design checks.

Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac										
Main columns	Failed		defaults	254x254 UKC73		Least weight	0.692	1.075	n / a	0.034
*43	Failed	19	defaults	254x254 UKC73			0.692	1.075	n / a	0.031
*44	Failed	21	defaults	254x254 UKC73			0.692	1.065	n / a	0.028
*45	Passed	22	defaults	254x254 UKC73			0.451	0.680	n / a	0.020
*46	Passed	24	defaults	254x254 UKC73			0.451	0.687	n / a	0.022
*47	Passed	25	defaults	254x254 UKC73			0.441	0.455	n / a	0.034
*48	Passed	27	defaults	254x254 UKC73			0.441	0.456	n / a	0.034
*49	Failed	28	defaults	254x254 UKC73			0.692	1.067	n / a	0.029
*50	Failed	30	defaults	254x254 UKC73			0.692	1.072	n / a	0.031
*51	Passed	31	defaults	254x254 UKC73			0.451	0.685	n / a	0.022
*52	Passed	33	defaults	254x254 UKC73			0.451	0.682	n / a	0.020
*53	Passed	34	defaults	254x254 UKC73			0.441	0.456	n / a	0.034

The main column group is selected and *Design* button pressed. This produces the next weight section in the UKC list.

Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac...										
Main columns	Passed		defaults	254x254 UKC73	254x254 UK...	Least weight	0.591	0.900	n / a	n / a
*43	Passed	19	defaults	254x254 UKC73	254x254 UKC89		0.591	0.900	n / a	n / a
*44	Passed	21	defaults	254x254 UKC73	254x254 UKC89		0.591	0.892	n / a	n / a
*45	Passed	22	defaults	254x254 UKC73	254x254 UKC89		0.386	0.573	n / a	n / a
*46	Passed	24	defaults	254x254 UKC73	254x254 UKC89		0.386	0.579	n / a	n / a
*47	Passed	25	defaults	254x254 UKC73	254x254 UKC89		0.371	0.383	n / a	n / a
*48	Passed	27	defaults	254x254 UKC73	254x254 UKC89		0.371	0.383	n / a	n / a
*49	Passed	28	defaults	254x254 UKC73	254x254 UKC89		0.591	0.894	n / a	n / a
*50	Passed	30	defaults	254x254 UKC73	254x254 UKC89		0.591	0.898	n / a	n / a
*51	Passed	31	defaults	254x254 UKC73	254x254 UKC89		0.386	0.577	n / a	n / a
*52	Passed	33	defaults	254x254 UKC73	254x254 UKC89		0.386	0.575	n / a	n / a
*53	Passed	34	defaults	254x254 UKC73	254x254 UKC89		0.371	0.383	n / a	n / a

Finally *Update analysis model* is pressed followed by *Calculate* to re-analyse the structure. There is no need to change the offsets because the column dimension has barely changed. The illustration below shows the *Design results* dialog after re-analysis and *Check*.

CADS A3D MAX - Design & Check Results

Item	Status	Mbr. Ref.	Template Ref.	Analysis Sect.	Design Sect.	Design Option	Lcl C...	Lat B...	Tor B...	Def'n
Model - 3 storey brac...										
Main columns	Passed		defaults	254x254 UKC89		Least weight	0.591	0.903	n / a	0.027
*43	Passed	19	defaults	254x254 UKC89			0.591	0.903	n / a	0.026
*44	Passed	21	defaults	254x254 UKC89			0.591	0.892	n / a	0.024
*45	Passed	22	defaults	254x254 UKC89			0.386	0.573	n / a	0.016
*46	Passed	24	defaults	254x254 UKC89			0.386	0.581	n / a	0.018
*47	Passed	25	defaults	254x254 UKC89			0.371	0.383	n / a	0.027
*48	Passed	27	defaults	254x254 UKC89			0.371	0.384	n / a	0.027
*49	Passed	28	defaults	254x254 UKC89			0.591	0.896	n / a	0.024
*50	Passed	30	defaults	254x254 UKC89			0.591	0.899	n / a	0.024
*51	Passed	31	defaults	254x254 UKC89			0.386	0.578	n / a	0.017
*52	Passed	33	defaults	254x254 UKC89			0.386	0.576	n / a	0.016
*53	Passed	34	defaults	254x254 UKC89			0.371	0.383	n / a	0.027

Current analysis number: 0016
Warning - Results are based on Analysis numbers 0015 to 0016

Group editing tools: Merge..., Move to..., Break...
Selection: Properties..., Check, Design, Details...
Show: All objects / Report (including Errors) Current object type: SW members

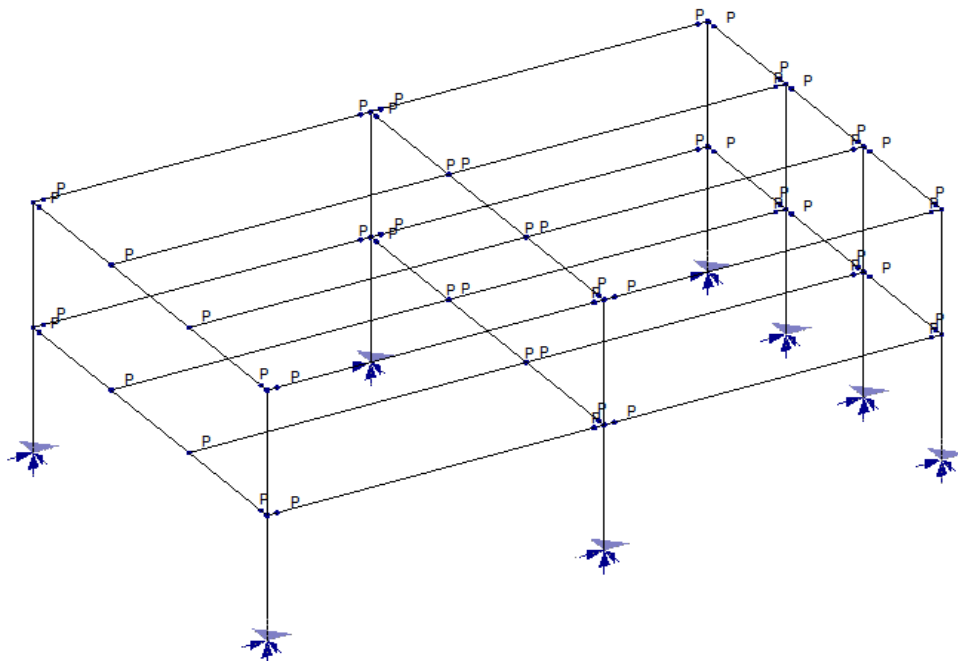
Settings...
Update Analysis Model...
Close Help

* * * - Objects with Common design feature

This completes the design process for this frame in terms of sizing the members.

6.0 Primary and secondary beams

Note that in the example discussed above, all the beams are directly supported by columns. In cases where there are secondary/primary beam grids, only the primary beam sub-member ends connecting to columns require to be modelled with offset pins.



The other ends should be fixed to maintain continuity of the sub-members making up the primary beam span. An example of the column design model for such a structure is shown above.

7.0 Hybrid frames

As stated earlier it may be advantageous to have some beams which are of 'simple construction' and some which with end connections which are rigid or semi-rigid. The

possibilities are endless but one common application is where the frames parallel to one global axis are of continuous construction and the frames in the other direction are simple. The stick model illustration below shows the 'column design' model for a version of the above worked example in which the Z direction beams are rigidly connected to the column flanges and the X direction beams are simply connected and modelled with offset pin connections. The Z direction bracing has been removed so that stability in this direction will rely on rigid moment frame action.

