ANALYSIS OF BRACING IN CYPE 3D

The fact that the bars in tension have a straight axis and only permit tension forces in line with their axis (pinned at both ends), implies that their representation on screen would only be strictly exact if a non-linear analysis of the structure was to be carried out for each loadcase combination, where all bracing bars whose axial forces are in compression are deleted.

Additionally, in order to evaluate the seismic behaviour of the structure, without allowing compression forces in the bracing bars, it would be necessary to carry out an analysis in the domain of time, entering the seismic loads by means of accelerograms.

As an approximation to the exact method, we propose an alternative method whose results, in those cases that comply with the following conditions, are sufficiently acceptable for current practice regarding bracing design, and allow for an integrated analysis of the complete structure.

The method has the following limitations, whose compliance is checked by the program:

- The diagonal forms part of a braced frame framing the four edges, or three, if the stiffening bars reach two exterior fixities. Additionally, each panel must form a rectangle (the four internal angles being right angles).

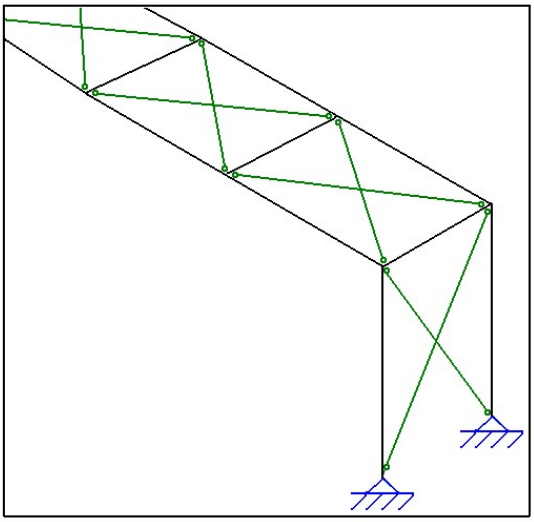


Figure 1

- The transverse area of the bracing is less than 20.0 % of the area of the rest of the elements (beams and columns) that complete the braced frame.
- The two diagonals (bars in tension) of the same braced frames should have the same transverse section, in other words, the same section and same type of steel.

Method application

The analysis method is linear and elastic with matrix formulations. Each bar in tension is entered in the stiffness matrix only with its axial stiffness (A·E/L), which is taken as half of the real stiffness of each tension bar. This way, the displacements obtained in the stiffness plane are similar to those that would be obtained if the bar in compression would have been erased from the matrix analysis and so taking into account the real area of the bar in tension.

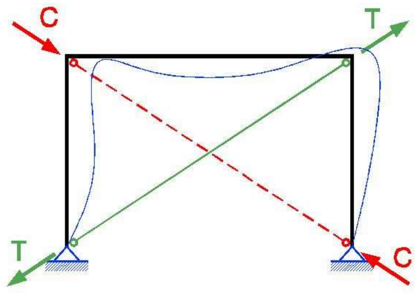
For each loadcase combination, the final forces in each tension bar are obtained and for those bars where the axial force results in compression, the following procedure is applied:

A. The axial force in the compressed bar is deleted.
B. The value of the force is added to the axial force of the other bar forming part of the braced frame.
C. With the new axial forces in bars configuration, the equilibrium in the nodes is restored.

Given that the method deals with force compatibility and not displacement compatibility, it is important to consider the axial stiffness restrictions of the sections forming the stiffened panel indicated in paragraph 2, as the method is more exact the smaller the relative differences in lengths are between the bars making up the frame. In all the cases analysed by CYPE Ingenieros, the discrepancies between the results obtained by this method and those obtained by linear analysis have been negligible.

The process described is detailed in the following figure:

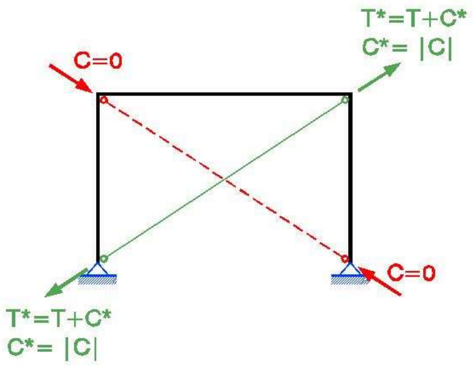
Forces resulting from each one of the studied combinations:



T: axial force in tension bar
C: axial force in compression bar

A. Deletion of the axial force of bar in compression. - Assignment of compression value to bar in tension.

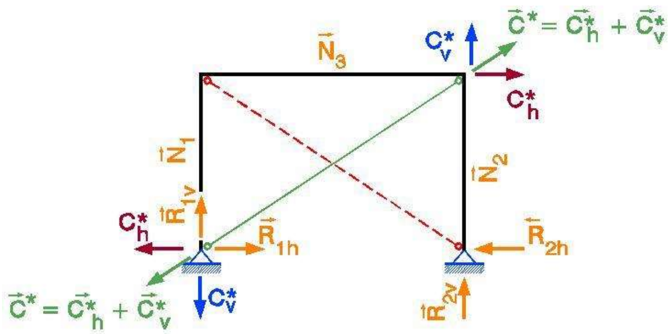
The axial force of the bar in compression (C=0) is deleted and this is added to the bar in tension (T*=T+|C|).



B. Distribution (by means of force decomposition) of the axial increment of the bar in tension (C*).

The axial increment (C*) in the tension bar is broken down in the direction of the bars (or fixity reactions) that join at the nodes.

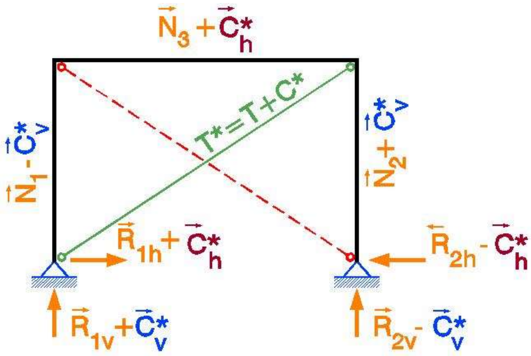
N_1, N_2, N_3, R_{1h}, R_{1v}, R_{2h}, R_{2v}: forces and reactions in the elements making up the stiffness frame without taking into account the tension of the tension bar.



C. Restoration of the equilibrium of the end nodes of the bars - Force equilibrium

A vector sum of the components of the tension increment (of the same absolute value as that of the eliminated compression force in the compression bar) is carried out for every bar and external fixity of the frame.

The final state of forces and reactions results as shown in the following figure:



These values can be consulted for every bar or node for loadcases and combinations. Each loadcase is treated as a unit combination.