

## Crossing Diagonal Unbraced Length Method in TOWER

### Introduction

Starting with TOWER version 7.32 you can specify a Crossing Diagonal Unbraced Length Method in the General Data dialog as shown at the right (yellow portion of the dialog). This check will automate the process of determining how much support against out-of-plane buckling is provided to a compressed member in a cross brace pair by the other member (the supporting member). Out-of-plane buckling is controlled by the value of the unbraced length ratio RLX (RLY for a member for which “Long Only” has been selected in the Connect Leg column of the Geometry/Angle Members table) or its alternate value RLOUT.

### Revisions

Version 7.36: Added AS3995 option

Version 7.54: Member end conditions can be modified by the check as described below.

Version 7.62: Added CSA S37-01 option

Version 10.67: *Geometry/Members/Capacities and Overrides* may now be used to enter “supported” and “unsupported” compression capacities for each member.

### Using the Check

To use the check you must place your cross braces in the *Crossing Diagonal* group type now available in *Geometry/Angle Groups* and supply some or all of the following information in *General/General Data*:

*Crossing Diagonal Unbraced Length Method* – choose from the following options

<b>Fixed</b>	Unbraced lengths will not be modified by TOWER (this is the default for all TOWER models prior to version 7.32).
<b>User Defined</b>	The user is responsible for determining the required percentage of compression force and the alternate unsupported RLOUT.
<b>ASCE 10</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per the guidelines in ASCE 10-97 example 7.
<b>AS 3995</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per appendix H3 (simple cross bracing only) of AS 3995-1994.
<b>CSA S37-01</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per 6.2.3.3.1 of CSA S37-01.
<b>TIA/EIA 222-G</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per section 4.5.2.1a of 222-G.
<b>CENELEC</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per annex J.6.3.3 of EN50341-1:2001.
<b>ECCS</b>	The ability of the support to resist out-of-plane buckling will be evaluated as per 7.3 of ECCS 39:1985.

*Required % of compression force in the tension (supporting) brace*

This is a limiting ratio ( $\%Ratio_{LIM}$ ) for the ratio ( $\%Ratio$ ) of the absolute value of the tension force in the supporting member (if any) divided by the force in the compressed member being checked. Note that for the User Defined method; you input whatever percentage you want used. For ASCE 10 and TIA/EIA 222-G this value is prescribed to be 20%. For AS3995 it is 60%. More complex provisions are used with CENELEC and ECCS.

*Alternate Unsupported RLOUT*

This alternate unbraced length ratio (RLOUT) may be used instead of the original unbraced length ratio (RLX or RLY) entered in the *Geometry/Angle Members* table for the most compressed member being checked.

The compression capacity of the compressed member ( $C_{Cap}$  in Eq. 3-3 of the TOWER manual) is based on the following assumptions:

**Fixed**

$C_{Cap}$  based on RLX, RLY and RLZ

Note for all of the following options: for the case of an unequal leg angle connected by the long leg or double angles for which the y-y axis is in the plane of the diagonals (the Connect Leg column in the Geometry/Angle Members table is set to "Long Only") then the roles of RLX and RLY are reversed.

### User Defined

$C_{Cap}$  based on RLX, RLY and RLZ if %Ratio  $\geq$  %Ratio<sub>LIM</sub>

$C_{Cap}$  based on RLOUT, RLY and RLZ if %Ratio < %Ratio<sub>LIM</sub>

### ASCE 10 or TIA/EIA 222-G

$C_{Cap}$  based on RLX, RLY and RLZ if %Ratio  $\geq$  20%

$C_{Cap}$  based on RLOUT, RLY and RLZ if %Ratio < 20%

### AS3995

$C_{Cap}$  based on RLX, RLY and RLZ if %Ratio  $\geq$  60%

$C_{Cap}$  based on RLOUT, RLY and RLZ if %Ratio < 60%

### CENELEC

$C_{Cap}$  based on RLY, RLZ and code specified formula for unbraced length ratio.

RLX and RLOUT have no effect on  $C_{Cap}$ .

RLZ must be input as L1/L2 to satisfy J.6.3.3 part 2 (case where tension and  $|S_d|/|N_d| > 2/3$ )

### ECCS

$C_{Cap}$  based on RLX, RLY and RLZ if %Ratio  $\geq$  50%

$C_{Cap}$  based on RLX=1 (modified as shown below), RLY and RLZ if %Ratio < 50%

The capacity based on RLX=1 is modified by the factor  $2(F_C/(F_C+F_T))$  where  $F_C$  is the compressive force in the compression member (counted positive) and  $F_T$  is the force in the other member (positive if compression and negative if in tension).

This implements the intent of ECCS 7.3 "The sum of the load carrying capacities of both bars in compression must be at least equal to the algebraic sum of the loads in the two bars" by rewriting it in a manner compatible with the way TOWER handles capacities.

### CSA S37-01

The user input value, RLOUT, has no effect on  $C_{Cap}$  (RLOUT is calculated as needed).

$C_{Cap}$  based on RLX, RLY and RLZ if %Ratio > 100%.

$C_{Cap}$  based on code specified formula when %Ratio  $\geq$  0% and < 100%.

When supporting member is in compression (both members in compression, %Ratio < 0) then ADL = DL1+DL2 (i.e. RLX = 1).

For all methods the calculated compression capacity shown in *Geometry/Member Capacities*

and Overrides is based on RLX, RLY and RLZ.

## The Crossing Diagonal Unbraced Length Check In Action

Once you have supplied the requisite input in *General/General Data* and specified a group type of *Crossing Diagonal* for all members you want checked in *Geometry/Angle Groups*, TOWER will do the following for you during each analysis:

- 1) Automatically find crossing diagonal pairs. To be considered a pair, both members must be in a group of type *Crossing Diagonal* and must intersect. Further, you must **not** model the intersection point (the members must be continuous).
- 2) For each load case determine the compression capacity  $C_{Cap}$  as described above.
- 3) Whenever the crossing diagonal check is triggered, change the member end conditions based on the strength checking code in effect for all codes except: CENELEC-Conservative, RTE-RESAL, PN-90/B-03200 and BS8100 which do not use conventional member end condition concepts. For all other codes, if the eccentricity code is 2 then promote it to 3. For all ASCE 10 compatible codes (ASCE10, AS3995, CSA S37, IS802, RTE-ASCE, TIA/EIA 222-F, ANSI/TIA 222-G) if the restraint code is 5 then promote it to 6. For all ECCS compatible codes (ECCS, CENELEC, RTE-ECCS, NGT-ECCS) if the restraint code is 5 promote it to 7 and if the restraint code is 6 promote it to 8.
- 4) For every load case and for all pairs where RLOUT controls the compression capacity instead of the input RLX, RLY and RLZ, output the following table in the *Analysis Results* report:

Crossing Diagonal Check for Load Case "WIND FACE" (RLOUT controls):

Comp. Member Label	Tens. Member Label	Connect Leg for Comp. Member	Force In Comp. Member (kips)	Force In Tens. Member (kips)	-----Original-----				L/R Curve No.	-----Alternate-----				
					-----Supported-----					-----Unsupported-----				
					L/R Cap. (kips)	RLX	RLY	RLZ		L/R Cap. (kips)	RLOUT	L/R Curve No.		
D8P	D8Y	Short only	-5.59	-5.59	22.08	0.550	0.550	0.550	107.86	2	21.09	1.000	109.56	3

Note that the "Alternate Unsupported L/r Cap" ( $C_{Cap}$  from above) is used when checking the compression member. If that load case and member happen to controls the group usage, the values from the "Alternate Unsupported" columns will be shown in the *Groups Summary* table. Please note that it is normal that these values not match those printed in *Geometry/ Member Capacities and Overrides* which assume that the compression member is supported ( $C_{Cap}$  based on RLX, RLY and RLZ). In the event that you find a lower than expected capacity for a compression member in the *Groups Summary* table you should check the *Crossing Diagonal Check for Load Case* output in the *Analysis Results* report to confirm that the *Crossing Diagonal Check* is responsible for the reduced capacity.

## Miscellaneous Notes

- 1) The Crossing Diagonal Check will use overridden compression capacities entered in *Geometry/Member Capacities and Overrides* so long as both the supported and the unsupported compression capacity are input.
- 2) You can batch apply the *Crossing Diagonal Check* settings you input in *General/General Data* to many other models using the *File/Batch Modify* command.
- 3) The *Crossing Diagonal Unbraced Length Method* is considered when optimizing a tower.
- 4) When using this check one should note that it is now possible that the member with greatest usage may not necessarily have the largest forces. Since the Groups Summary and Groups Summary Super Set tables report on the member that controlled the group (usage) they may no longer print the largest forces. If this is of concern you should make two runs: one with the check turned on and one with it turned off (set to Fixed).
- 5) Unequal leg angles with the short leg placed back to back (DAS) are a special case. These will normally have the short leg connected to the body (corner members) of the tower in order to have the strong axis resist out-of-plane buckling. From the introduction, if the leg connect code is "short only" then RLX is the candidate for replacement by RLOUT when the tension member does not adequately support the compression member. However, the AISC convention for double angles (which the default angle database supplied with TOWER follows) has RLY as the strong axis. The only way to resolve this incompatibility is to create a special angle property for DAS used as a crossing diagonal. This angle property will swap the radii of gyration Rx and Ry. Likewise the unbraced length ratios that are input, RLX and RLY must also be swapped. Once this is done, the crossing diagonal check may be used with a DAS member that is connected by the short leg.