Autodesk®
Robot™ Structural Analysis Professional

VERIFICATION MANUAL

FOR STEEL MEMBERS DESIGN

March 2014

American code ANSI/AISC 360-10

June 22, 2010

INTRODUCTION

This verification manual contains numerical examples for elements of steel structures prepared and originally calculated by **Autodesk Robot Structural Analysis Professional version 2015**.

All examples have been taken from **AISC Design Examples version 14.1**, handbooks that include benchmark tests covering fundamental types of behaviour encountered in structural analysis. Benchmark results (signed as “Handbook”) are recalled, and compared with results of Robot (signed further as “Robot”).

Each problem contains the following parts:

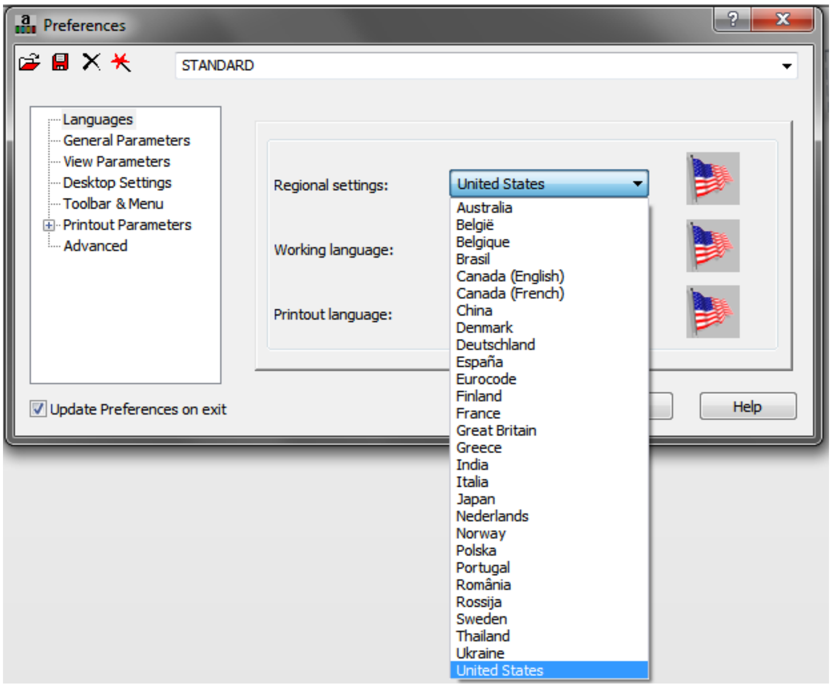
- title of the problem
- specification of the problem
- Robot solution of the problem
- outputs with calculation results and calculation notes
- comparison between Robot results and exact solution
- conclusions

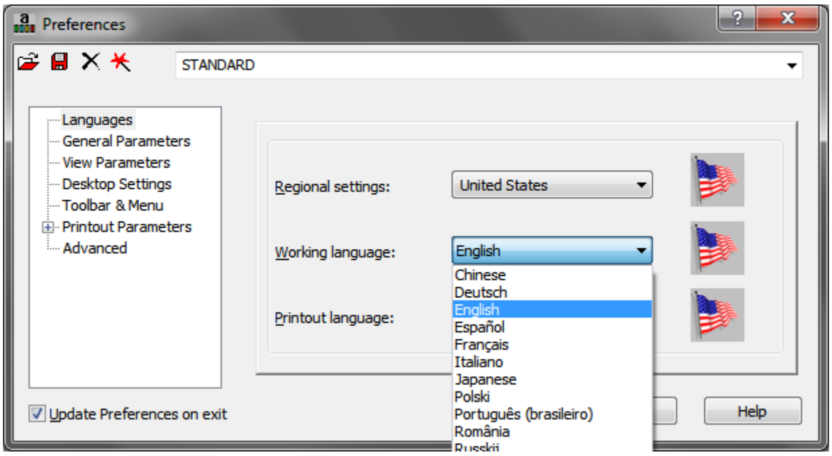
GENERAL REMARKS

If you make first step in Robot program you should select preferences corresponding to your example using "Preferences…" or "Job Preferences…" (click Tools).

A. Preferences

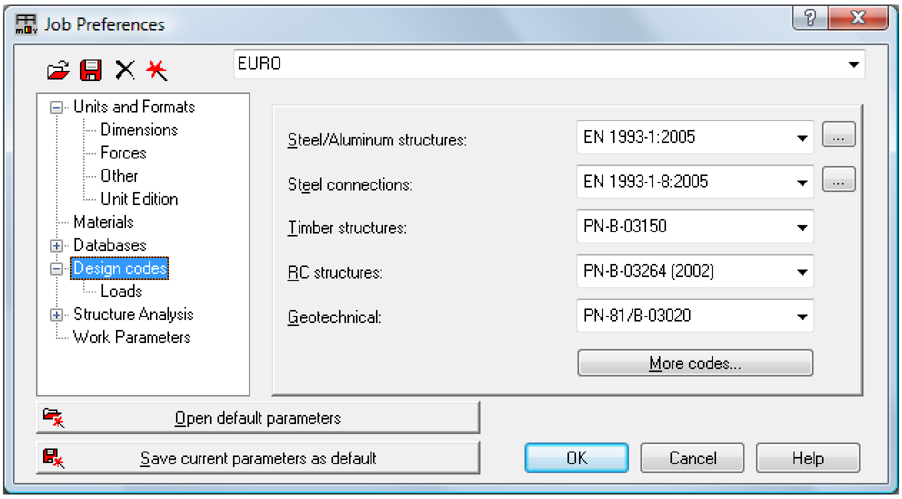
To specify your **regional preferences** click Tools / [Preferences...] and in default opened *Preferences* dialog box select in combo boxes a needed country (region) and working/printout language.



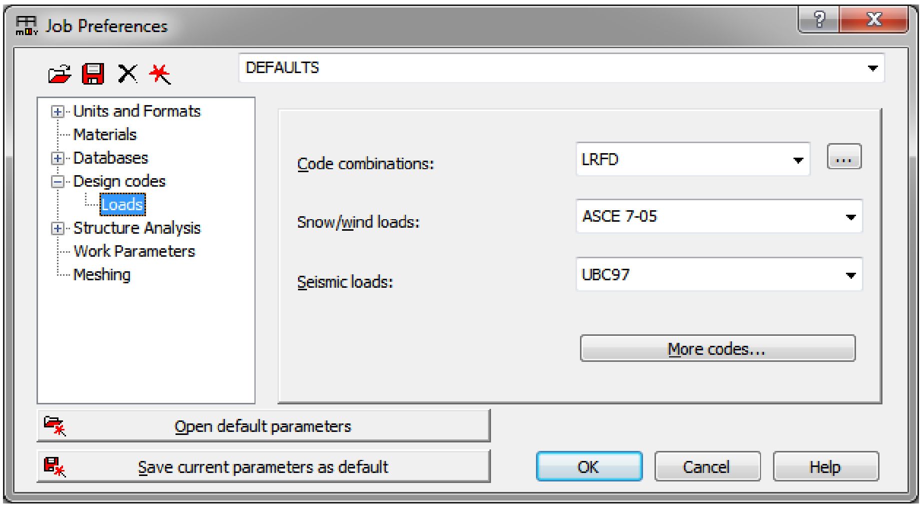


B. Job Preferences

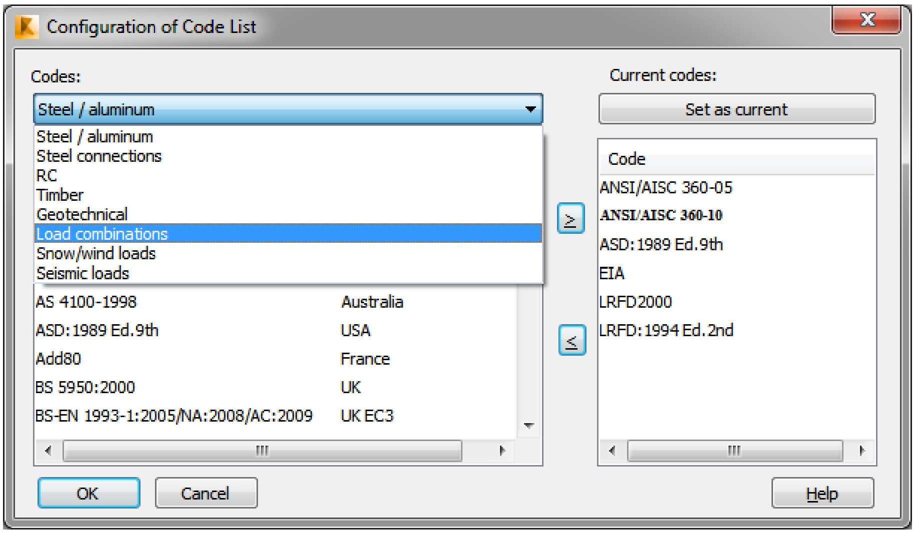
To specify your **job preferences** click Tools / [Job Preferences...] and in default opened *Job Preferences* dialog box select preferences corresponding to your example at the option of the left list and appropriate combo boxes. Below a screenshot shown for the selection [Design codes] :



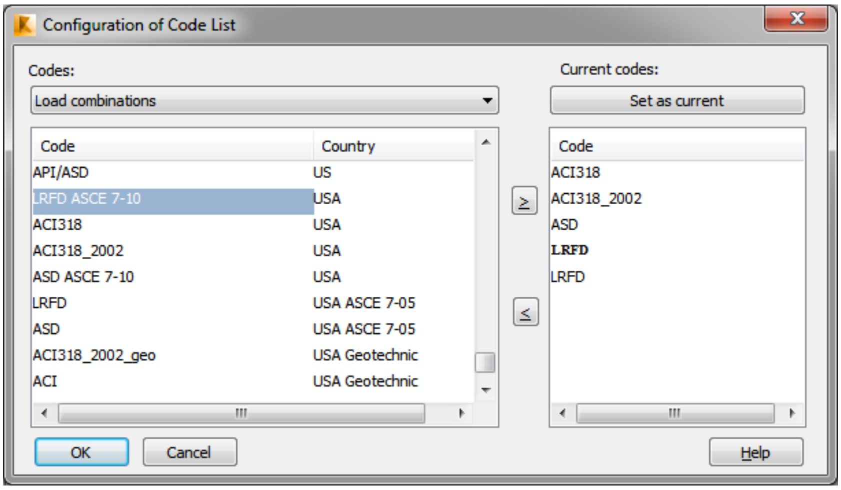
You can create a new Job Preferences with arbitrarily chosen options (standards, materials, databases, load codes etc.) under a new name to make it easier for future work, e.g. under the name LRFD or ASD for verification both ASD and LRFD requirements, respectively. In that case, first of all, make selection of all documents and parameters appropriate for USA condition choosing "United States" from regional setting in [Preferences…] dialog box. Than from [*Job Preferences*...] dialog box which looks like :



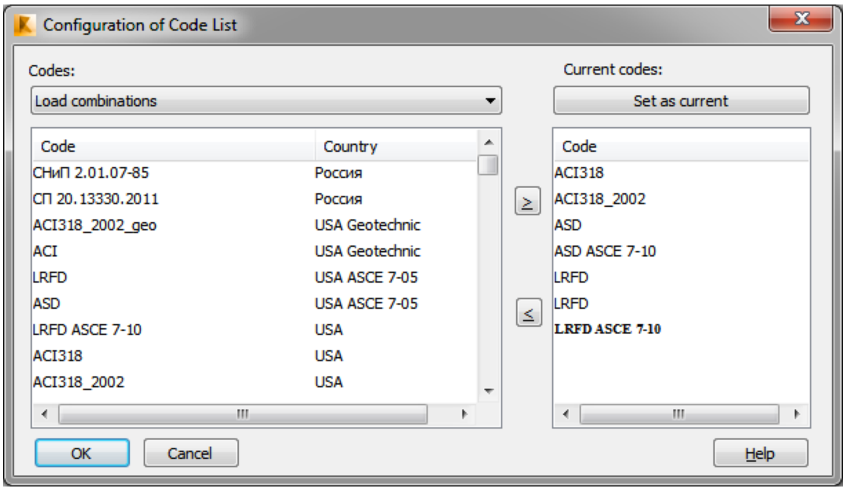
click *Loads* tab from the left list view and choose proper load codes from combo box or from [*Configuration of Code List]* dialog box which is opened after pressing [*More codes…]* button



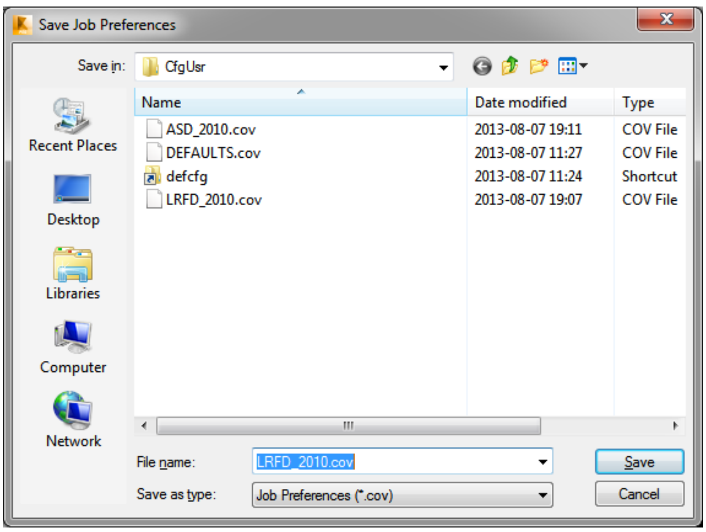
Pick *Load combinations* from *Codes* combo box . The new list view appears:



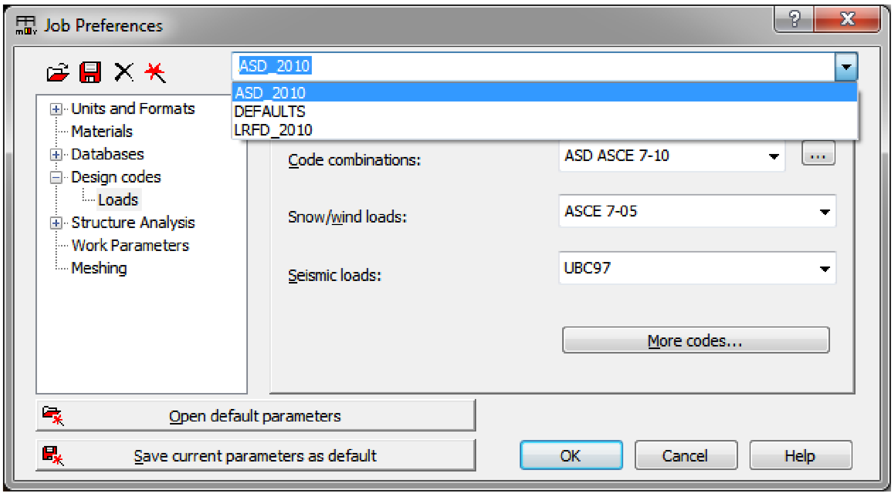
Set ASD ASCE 7-10 and LRFD ASCE 7-10 on the right list of the box using arrows than set LRFD ASCE 7-10 code as the *current* code .



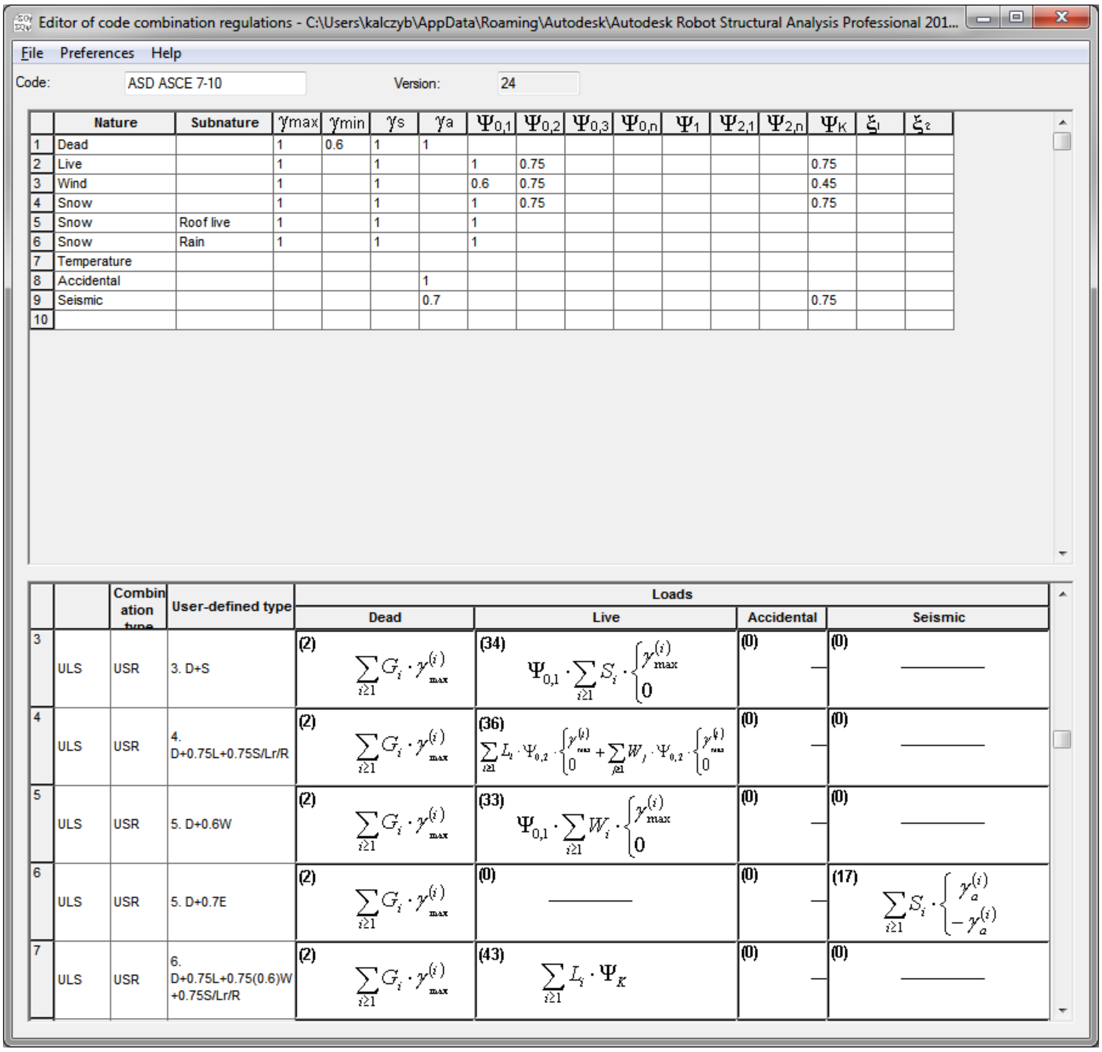
Press OK.
After the job preferences decisions are set, type a new name in combo box ,e.g. ***" LRFD_2010"*** and save it pressing *Save Job Preferences* icon placed on the top of *[Job Preferences]* dialog box . It opens *Save Job Preferences* dialog box



After saving the new name appears in [*Job Preferences*...] upper combo-box. Press OK button.
Do the same for ASD ASCE 7-10 code combination naming it ***" ASD_2010"***



You can check load combination regulations by pressing right button next to *Code combinations* combo-box in *Loads* tab *[Job Preference]* dialog box.
It opens proper *[Editor of code combination regulation]* dialog box.



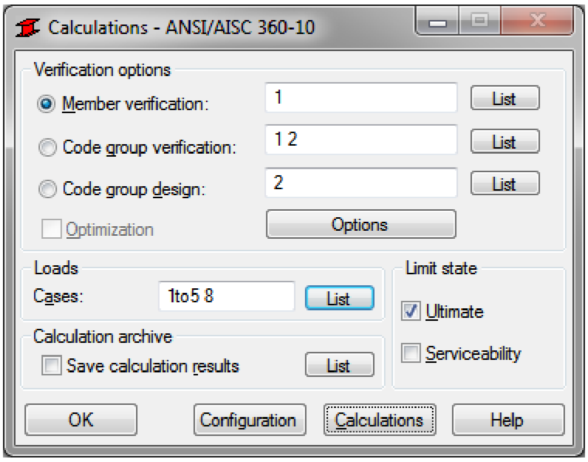
C. Calculation method

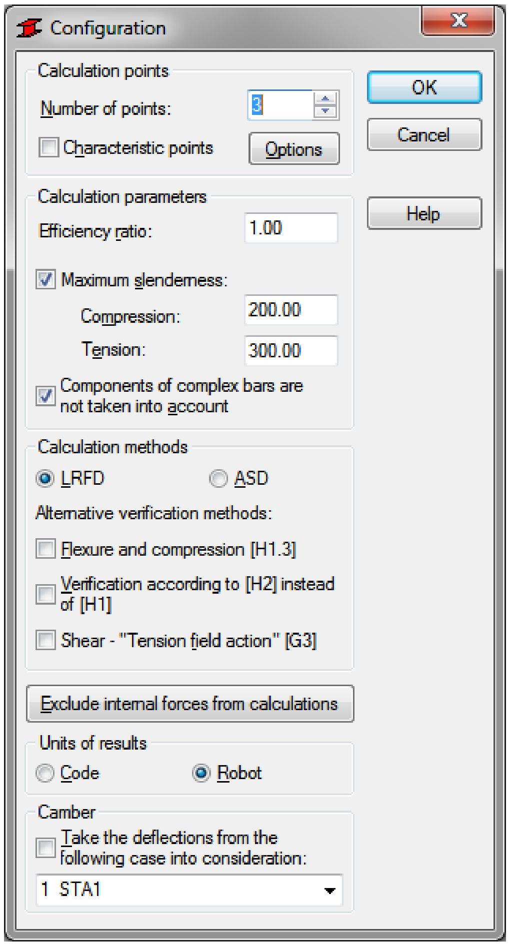
American code ANSI /AISC 360-10 gives two verification options: LRFD and ASD.
In Robot program you always have to manually adjust :

1. calculation method,
2. load code combination → appropriate for calculation method

ad.1 calculation method

Calculation method (LRFD or ASD) can be chosen on *Steel /Aluminum Design* layout.
Press the *Configuration* button in *[Calculations]* dialog box.



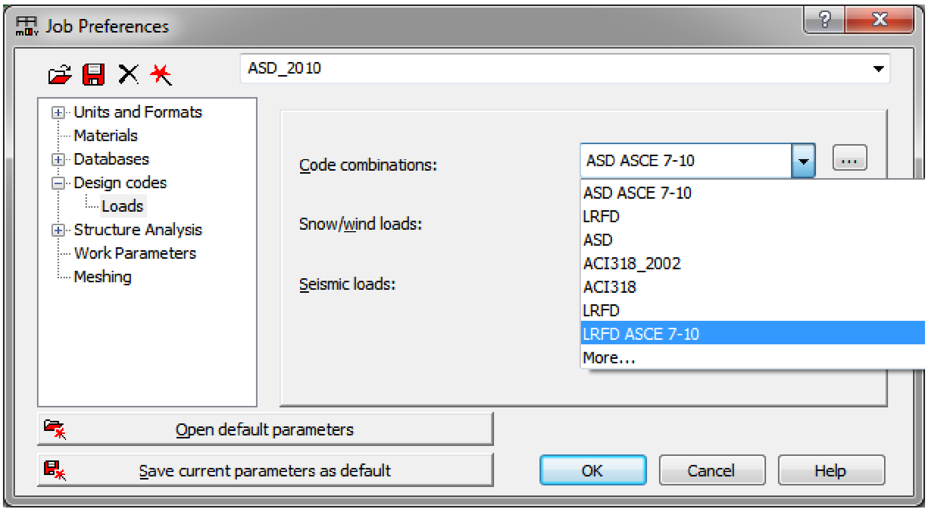


Here you can choose only calculation method, NOT load combination which is selected in *[Job Preferences]* .

ad.2a load code combinations – basic approach

To select load code combination (LRFD or ASD) appropriate for calculation method , click Menu / Tools / Job Preferences. *[Job Preferences]* dialog box opens. Now, you can proceed either of two ways as was described in Chapter B :

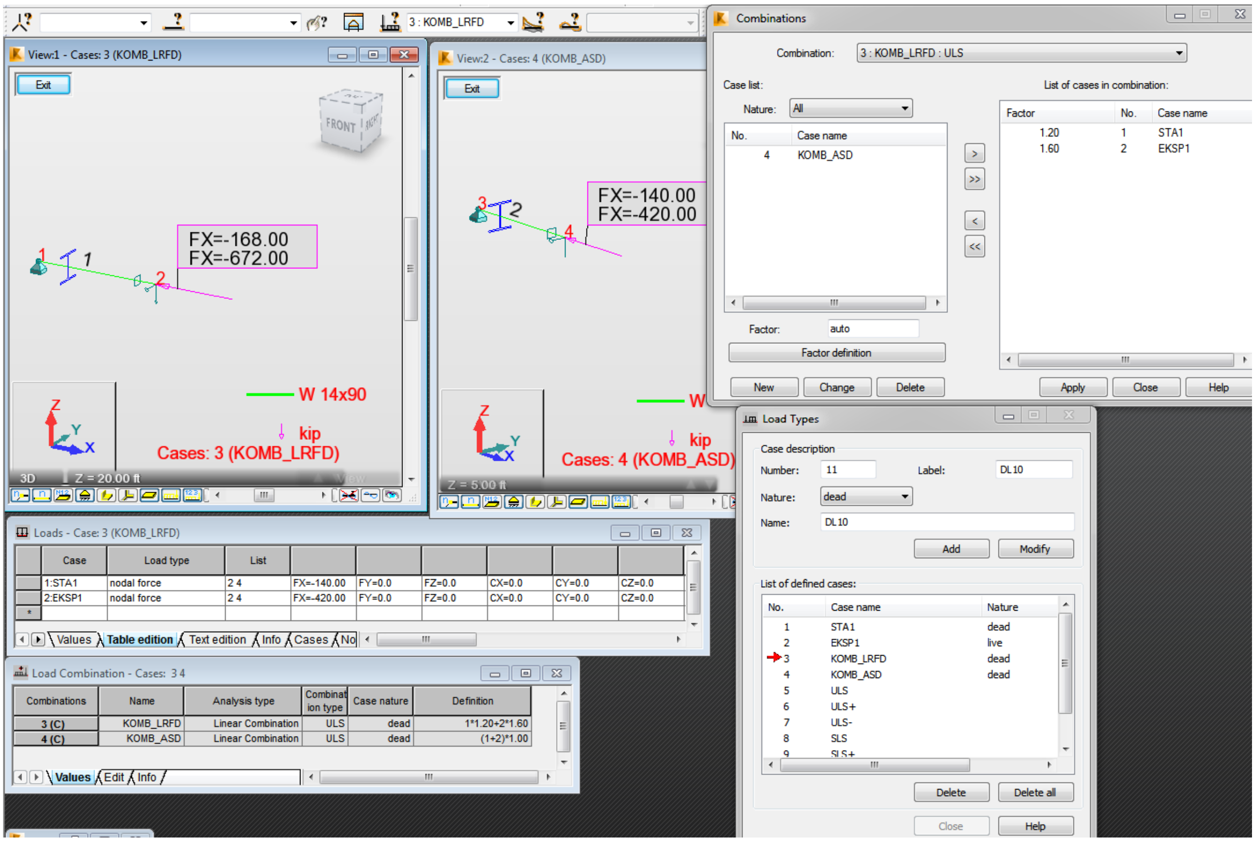
- 1st way – expand *Design codes* , click on *Loads* tab from the left list view and choose proper load codes from combo box or from *[Configuration of Code List]* dialog box which is opened after pressing *[More codes…]* button
- 2nd way -- select earlier prepared job preferences by clicking its name from combo-box . In following dialog box "***LRFD_2010*** " named job preferences is chosen from among several other possibilities previously defined.



By pressing OK button you accept chosen job preferences for a current task.

ad.2b load code combinations - alternative (tricky-easy) approach

Start in *Loads* layout. Here, you can prepare load combination for both calculation method for further using (for member verification) . Create manually LRFD load combinations and ASD load combinations in *[Load Types]* dialog box .



In this case, you can choose for LRFD and ASD verification respectively prepared load combinations corresponding to calculation method .

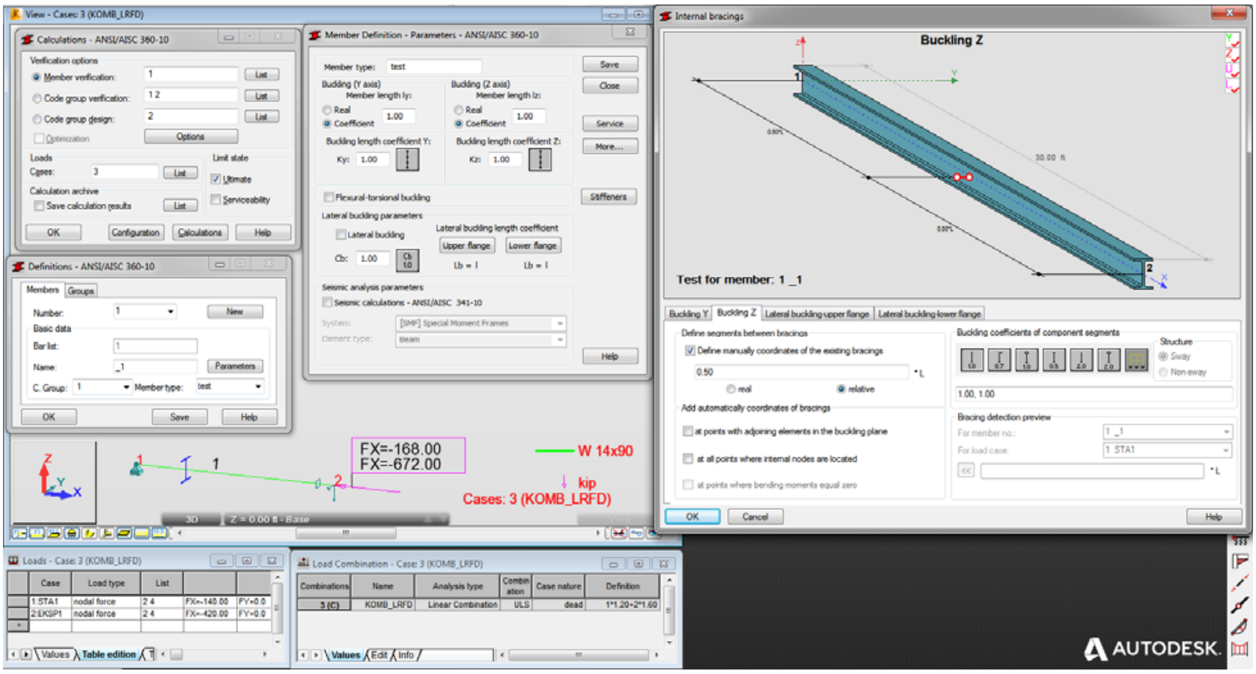
VERIFICATION PROBLEM 1
design of members for compression

Example taken from AISC Steel Construction Manual v14.0
AISC Design Examples
File: MAN_ex_E1d.rtd

TITLE:
Example E.1d – W-Shape Available Strength Calculation

SPECIFICATION:

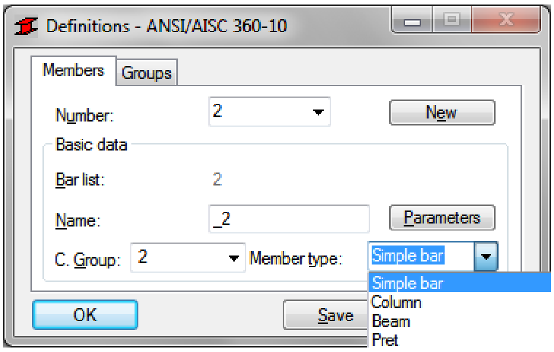
Select an ASTM A992 (*Fy* = 50 ksi) W14x90 bar to carry an axial dead load of 140 kips and live load of 420 kips. Assume the design member is 30 feet long, is pinned top and bottom in both axes and is laterally braced about the z-z axis at the midpoint.
Verify the strength of a defined compression member .
You can choose ASD or LFRD calculation method .



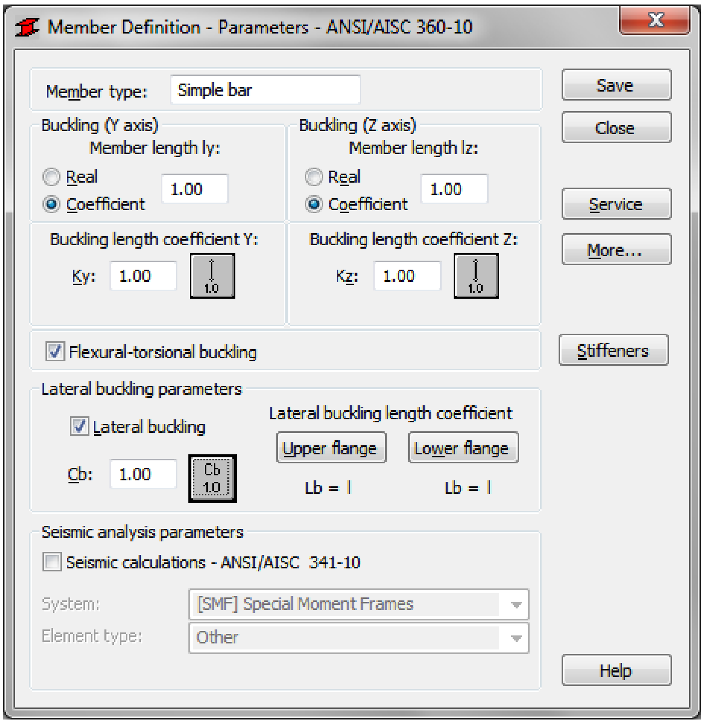
SOLUTION:

You must remember to specify appropriate (LRSD or ASD) load code combination in JOB PREFERENCES dialog box (click Menu/Tools/Job Preferences) for considered verification method in a current task or define it manually.

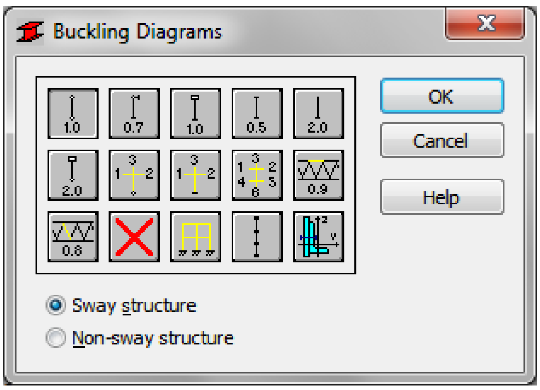
In DEFINITIONS dialog box define a new type of member, laterally braced about the *z-z* axis at the midpoint . It can be set in *Member type* combo-box.
Pre-defined type of member "*simple bar*" may be initially opened.



For a chosen member type (here "*simple bar*"), press the *Parameters* button on *Members* tab, which opens MEMBER DEFINITION–PARAMETERS dialog box.



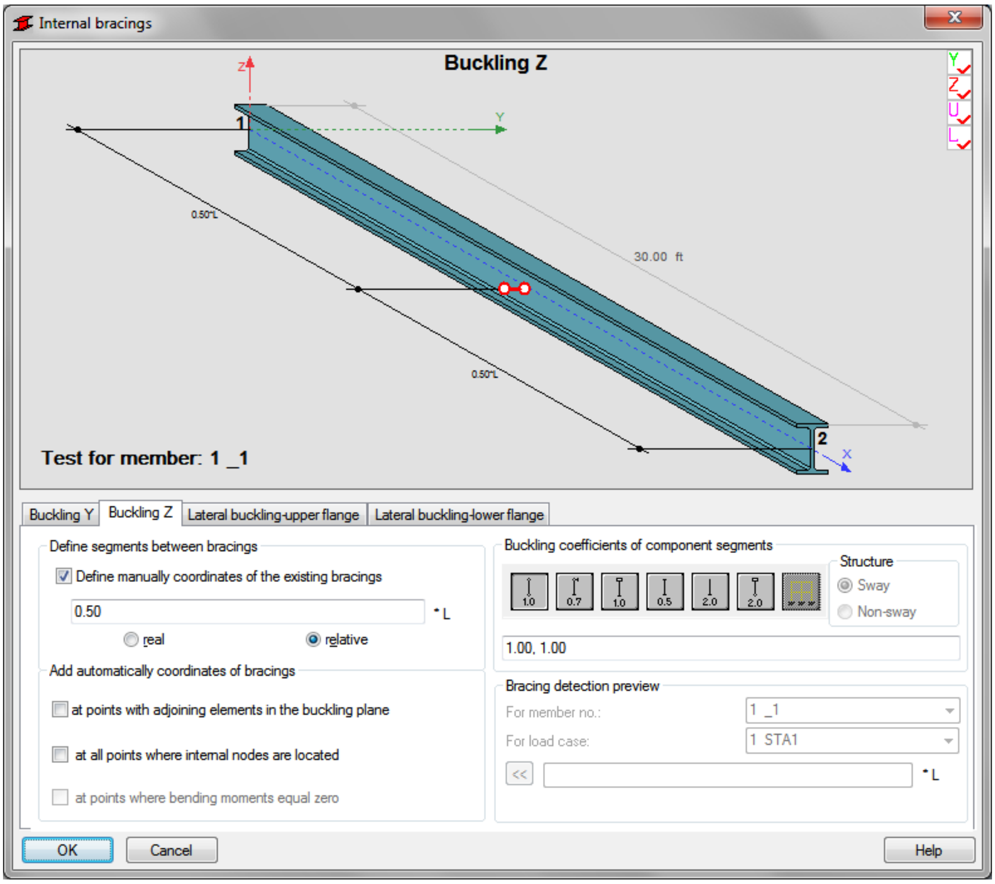
Type a new name in the *Member type* editable field. Change parameters to meet initial data requirements of the structure . In this particular compression case define buckling z-z parameters . Press *Buckling length coefficient Z* icon which opens BUCKLING DIAGRAMS dialog box.



Click second to last icon.

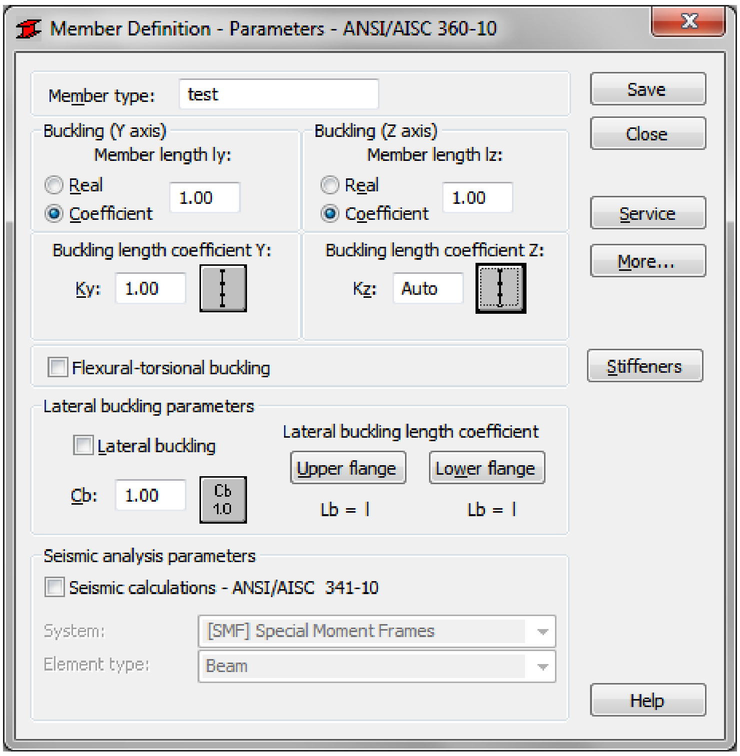
The new dialog box *INTERNAL BRACING* will appear with active *Buckling Z* tab.

In *Buckling Z* tab define internal support in the middle of the member by typing relative value 0.5 for marked *Define manually coordinates of the existing bracings* field.



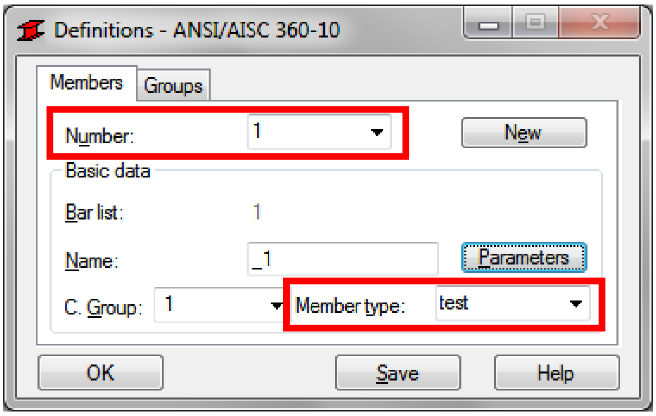
Press OK.

Save the newly-created member type , e.g. *"test"* :



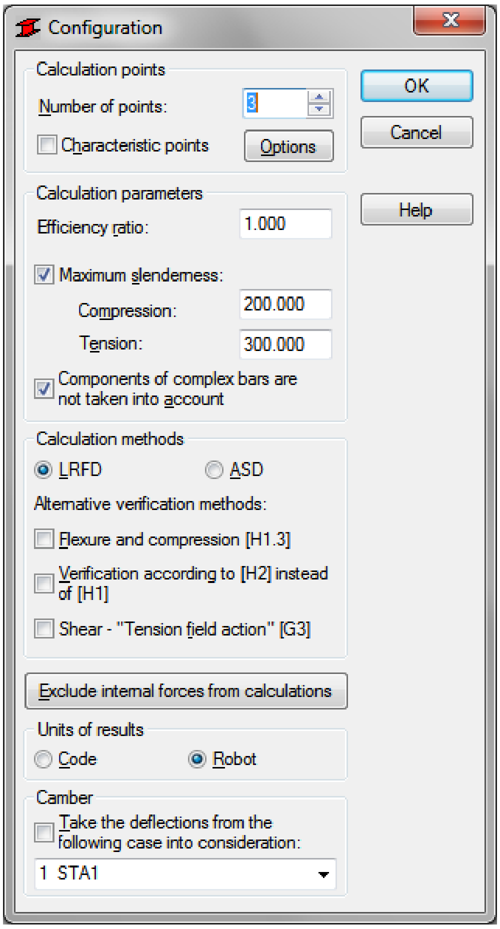
Number of the member must be assigned to appropriate name of *Member type.*

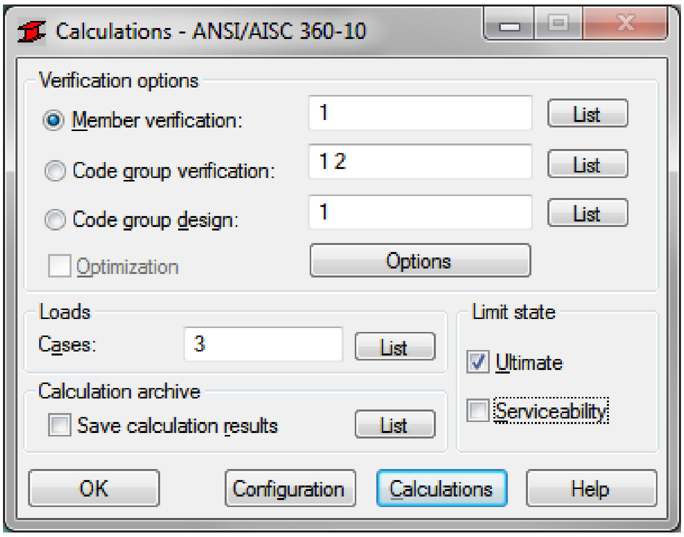
(It is very important when you verify different member types.)



In the CALCULATIONS dialog box set for this task:

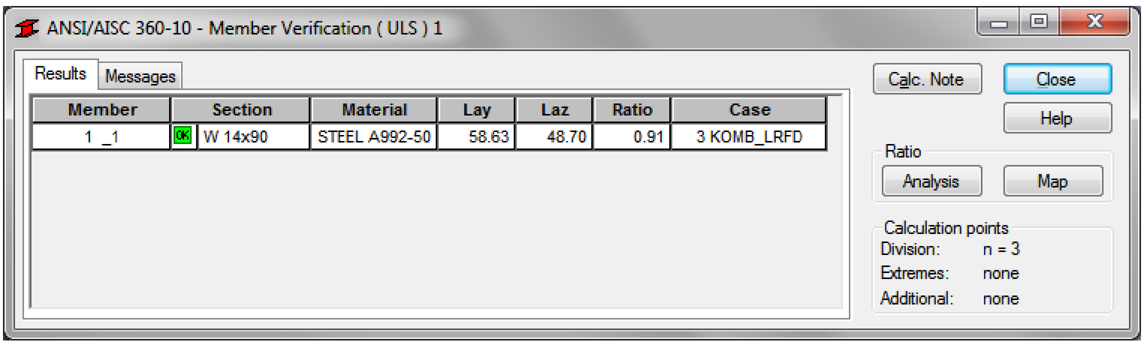
- *Verification option* → Member Verification
- *Loads cases* → for LRFD design (defined as n^o 3)
- *Limit state* → only Ultimate Limit state will be analyzed so switch off *Limit stat Serviceability*.
- *Calculation method* → *switch on LRFD radio button* in CONFIGURATION box, opened by [Configuration] button.





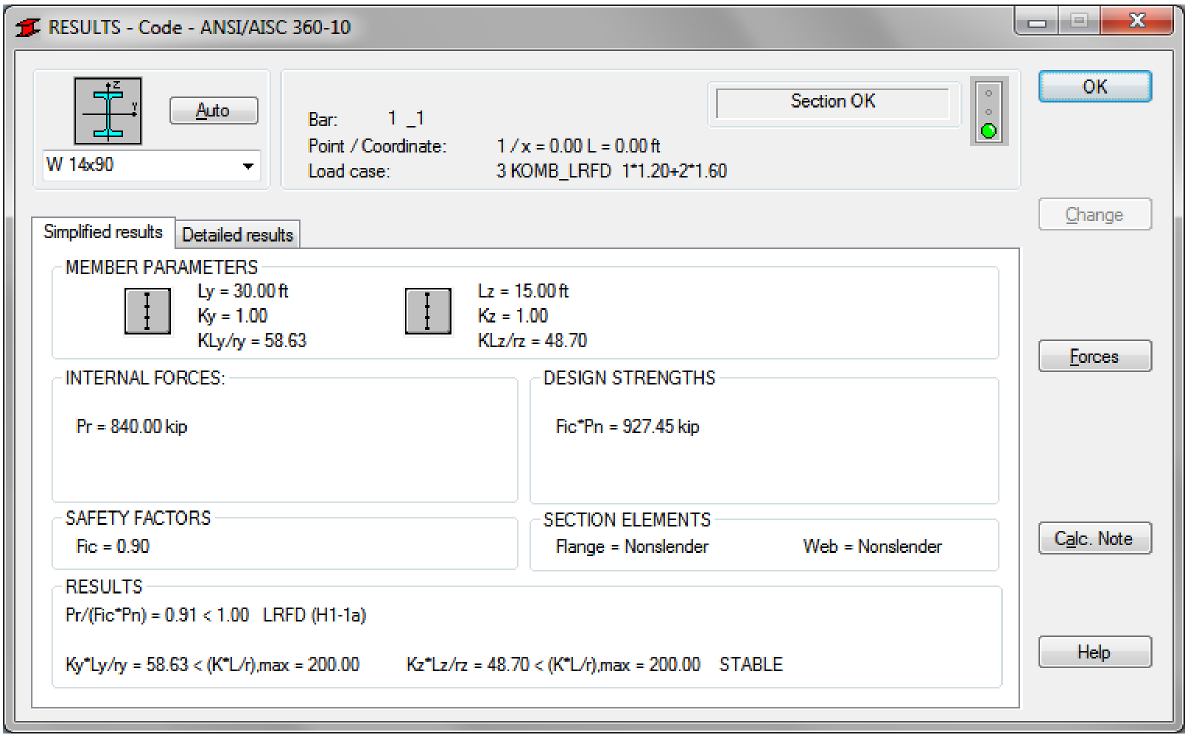
Now, start calculations by pressing *Calculations* button.

MEMBER VERIFICATION dialog box with most significant results data will appear on screen.

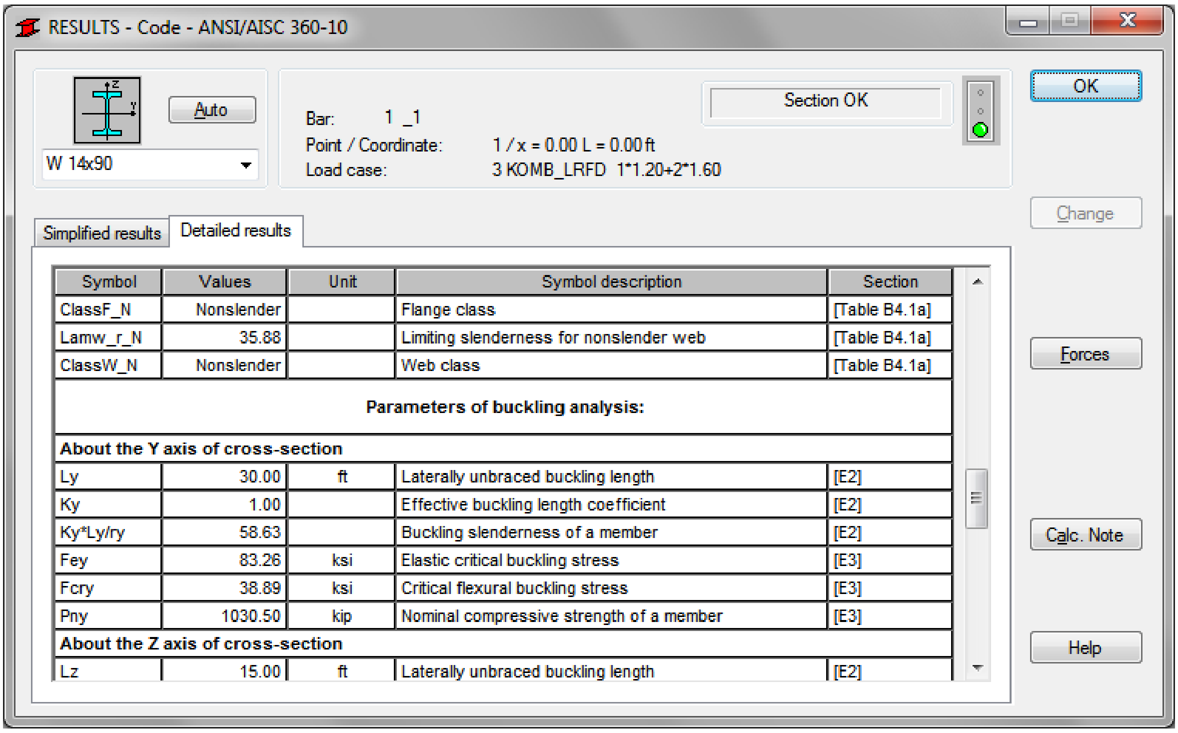


Pressing the line with results for the member 1 opens the RESULTS dialog box with detailed results for the analyzed member. The view of the RESULTS windows are presented below.

Simplified results tab



Detailed results tab



Pressing the [*Calc.Note]* button in “RESULTS –Code” dialog box opens the printout note for the analyzed member. You can obtain *Simplified results printout* or *Detailed results printout.* It depends on which tab is active .

The printout note view of Simplified *results* is presented below.

RESULTS for LRFD method:

a) In the first calculation step W14x90 section was considered. The results are presented below.

STEEL DESIGN

CODE: ANSI/AISC 360-10 An American National Standard, June 22, 2010
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 _1 **POINT:** 1 **COORDINATE:** x = 0.00 L = 0.00 ft

---

LOADS:
Governing Load Case: 3 KOMB_LRFD 1*1.20+2*1.60

MATERIAL:
STEEL A992-50 Fy = 50.00 ksi Fu = 65.00 ksi E = 29000.00 ksi

SECTION PARAMETERS: W 14x90

d=14.00 in	Ay=20.590 in2	Az=6.160 in2	Ax=26.500 in2
bf=14.50 in	Iy=999.000 in4	Iz=362.000 in4	J=4.060 in4
tw=0.44 in	Sy=142.714 in3	Sz=49.931 in3	
tf=0.71 in	Zy=157.000 in3	Zz=75.600 in3	

MEMBER PARAMETERS:

Ly = 30.00 ft	Lz = 15.00 ft
Ky = 1.00	Kz = 1.00
KLy/ry = 58.63	KLz/rz = 48.70

INTERNAL FORCES:
Pr = 840.00 kip

DESIGN STRENGTHS
Fic*Pn = 927.45 kip

SAFETY FACTORS
Fic = 0.90

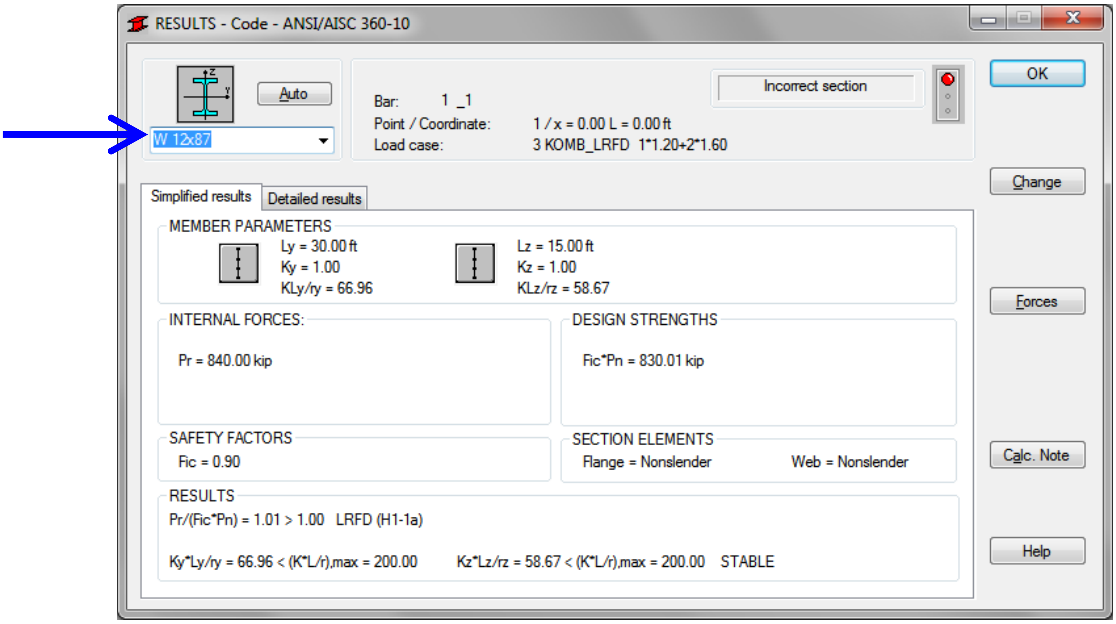
SECTION ELEMENTS:
Flange = Nonslender Web = Nonslender

VERIFICATION FORMULAS:
Pr/(Fic*Pn) = 0.91 < 1.00 LRFD (H1-1a) Verified
Ky*Ly/ry = 58.63 < (K*L/r),max = 200.00 Kz*Lz/rz = 48.70 < (K*L/r),max = 200.00 STABLE

Section OK !!!

b) From economical reason try to check a lighter W section.

Being still in *RESULTS- CODE* dialog box, type W 12x87 in the editable field below drawing of a section and press ENTER. Calculations (and results) are refreshed instantly.



The results (Calcul.Note) for the new selected section are presented below.

STEEL DESIGN

CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 _1 **POINT:** 1 **COORDINATE:** x = 0.00 L = 0.00 ft

LOADS:
Governing Load Case: 3 KOMB_LRFD 1*1.20+2*1.60

MATERIAL:
STEEL A992-50 Fy = 50.00 ksi Fu = 65.00 ksi E = 29000.00 ksi

SECTION PARAMETERS: W 12x87

d=12.50 in	Ay=19.602 in2	Az=6.438 in2	Ax=25.600 in2
bf=12.10 in	Iy=740.000 in4	Iz=241.000 in4	J=5.100 in4
tw=0.52 in	Sy=118.400 in3	Sz=39.835 in3	
tf=0.81 in	Zy=132.000 in3	Zz=60.400 in3	

MEMBER PARAMETERS:

Ly = 30.00 ft	Lz = 15.00 ft
Ky = 1.00	Kz = 1.00
KLy/ry = 66.96	KLz/rz = 58.67

INTERNAL FORCES:
Pr = 840.00 kip

DESIGN STRENGTHS
Fic*Pn = 830.01 kip

SAFETY FACTORS
Fic = 0.90

SECTION ELEMENTS:
Flange = Nonslender Web = Nonslender

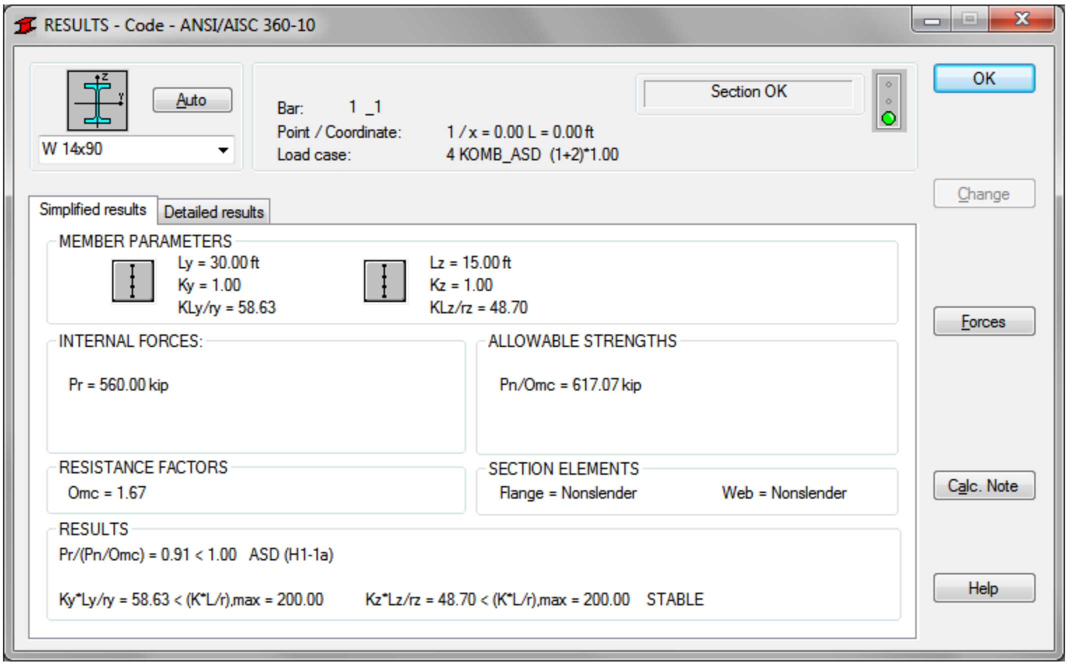
VERIFICATION FORMULAS:
Pr/(Fic*Pn) = 1.01 > 1.00 LRFD (H1-1a) Not verified
Ky*Ly/ry = 66.96 < (K*L/r),max = 200.00 Kz*Lz/rz = 58.67 < (K*L/r),max = 200.00 STABLE

Incorrect section !!!

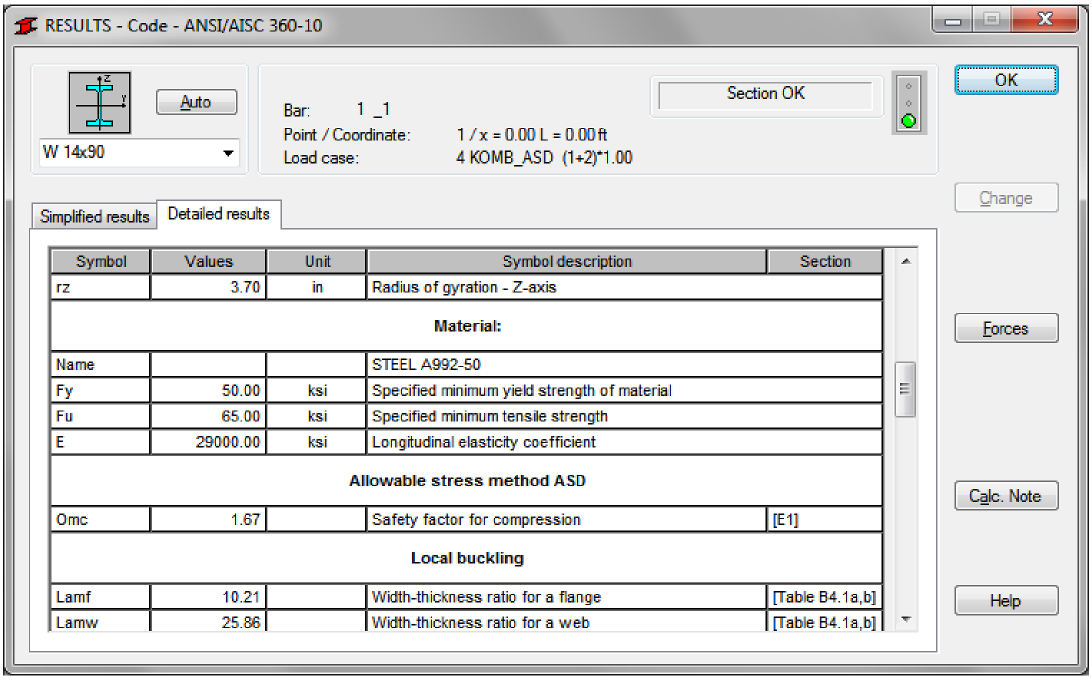
<u>RESULTS for ASD method</u> (selecting in CONFIGURATION dialog box):

A section W14x90 was considered. The results are presented below.

Simplified results tab



Detailed results tab



The printout note view of *Simplified results* for ASD is presented below.

STEEL DESIGN

CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 _1 **POINT:** 1 **COORDINATE:** x = 0.00 L = 0.00 ft

---

LOADS:
Governing Load Case: 4 KOMB_ASD (1+2)*1.00

MATERIAL:
STEEL A992-50 Fy = 50.00 ksi Fu = 65.00 ksi E = 29000.00 ksi

SECTION PARAMETERS: W 14x90

d=14.00 in	Ay=20.590 in2	Az=6.160 in2	Ax=26.500 in2
bf=14.50 in	Iy=999.000 in4	Iz=362.000 in4	J=4.060 in4
tw=0.44 in	Sy=142.714 in3	Sz=49.931 in3	
tf=0.71 in	Zy=157.000 in3	Zz=75.600 in3	

MEMBER PARAMETERS:

Ly = 30.00 ft	Lz = 15.00 ft
Ky = 1.00	Kz = 1.00
KLy/ry = 58.63	KLz/rz = 48.70

INTERNAL FORCES: Pr = 560.00 kip

ALLOWABLE STRENGTHS Pn/Omc = 617.07 kip

RESISTANCE FACTORS
Omc = 1.67

SECTION ELEMENTS:
Flange = Nonslender Web = Nonslender

VERIFICATION FORMULAS:
Pr/(Pn/Omc) = 0.91 < 1.00 ASD (H1-1a) Verified
Ky*Ly/ry = 58.63 < (K*L/r),max = 200.00 Kz*Lz/rz = 48.70 < (K*L/r),max = 200.00 STABLE

Section OK !!!

COMPARISON:

Resistance, interaction expression		Robot	Handbook
F_{cr} – Critical flexural buckling stress P_n - Nominal compressive strength	[ksi] [kips]	38,89 1030,5	38,9 1030
For W14x90 **, LRFD** Fic=0.90 1. P_r - Required compressive strength 2. Fic*P_n - Design compressive strength P_r < (Fic*P_n)	 [kips] [kips]	840,0 927,45 840 < 927,5	840 927 840< 927
For W14x90 , **ASD** Omc =1.67 1. P_r - Required compressive strength 2. P_n/Omc - Allowable compressive strength P_r < (P_n/Omc))	 [kips] [kips]	560,0 617,1 560 < 617,1	560 617 560 < 617

CONCLUSIONS:

Calculations compatibility are good.

The small differences are caused by different accuracy of parameters in calculations.

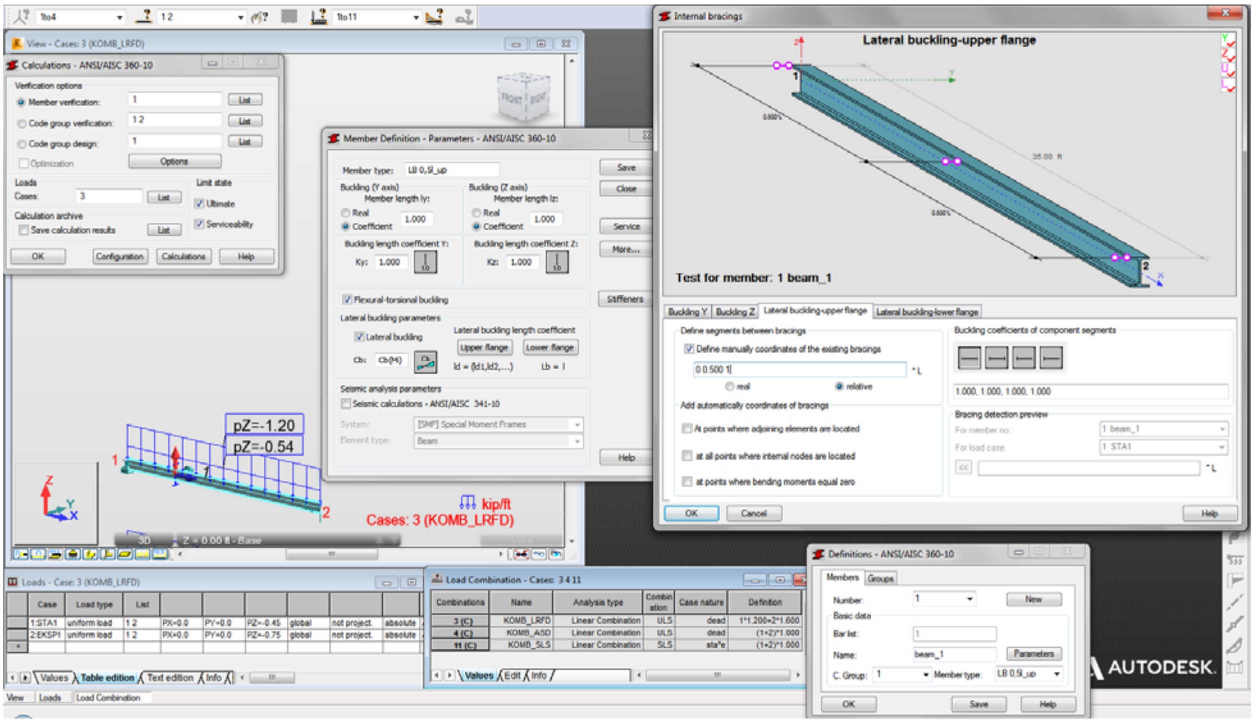
VERIFICATION PROBLEM 2
Lateral-torsional buckling of beams

Example taken from AISC Steel Construction Manual v.14.0
AISC Design Examples
File: MAN_EX_F1_3B.rtd

TITLE:
Example F.1-3b -- W-Shape Flexural Member Design in Strong-Axis Bending, Braced at Midspan

SPECIFICATION:

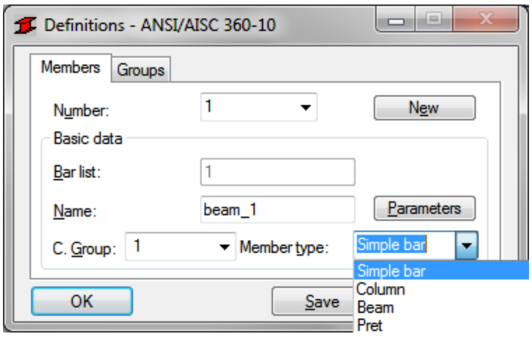
Verify the strength of the ASTM A992 W18×50 beam with a simple span of 35 feet. The beam is braced at the ends and center point. The nominal loads are a uniform dead load of 0.45 kip/ft and a uniform live load of 0.75 kip/ft.
You can choose ASD or LFRD calculation method.



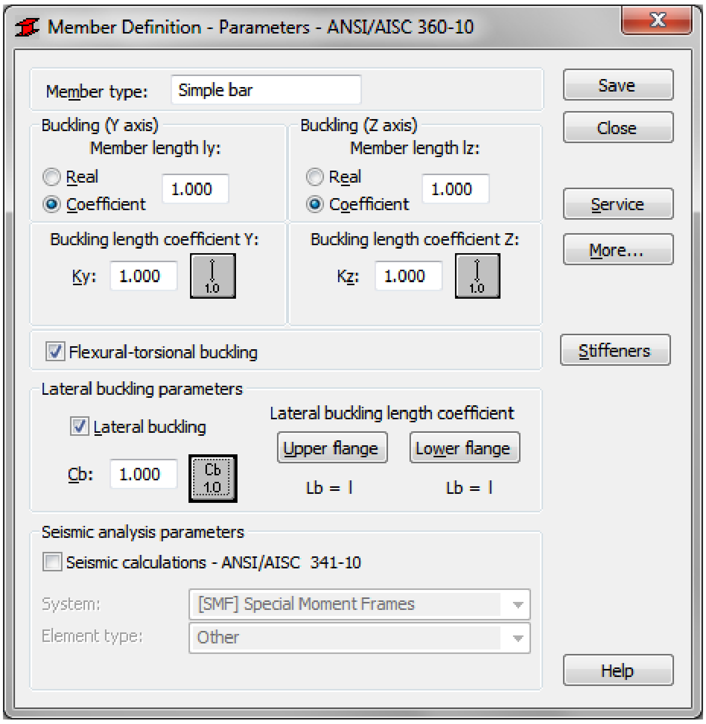
SOLUTION:

You must remember to specify appropriate (LRSD or ASD) load code combination in JOB PREFERENCES dialog box (click Menu/Tools/Job Preferences) for considered verification method in a current task or define it manually.

In DEFINITIONS dialog box define a new type of member, laterally braced upper flange about the *z-z* axis and torsional braced at the midpoint . It can be set in *Member type* combo-box. Pre-defined type of member "*simple bar*" may be initially opened.

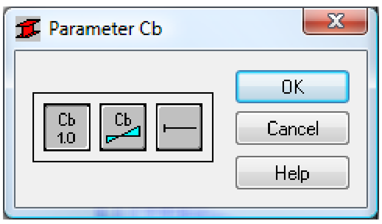


For chosen member type , press the *Parameters* button on *Members* tab.
It opens MEMBER DEFINITION – PARAMETERS dialog box.



Type a new name in the *Member type* editable field. Then, change parameters to meet initial data requirements of the structure. In this particular bending case set the following lateral-buckling parameters :

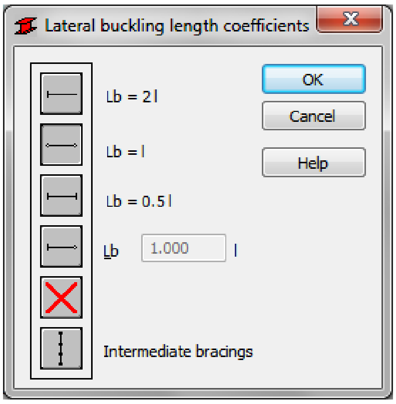
- switch on *Flexural-torsional buckling ;*
- switch on *Lateral buckling*
- define appropriate value of parameter Cb by manually entering in editable field or pressing Cb icon which opens PARAMETER Cb dialog box :



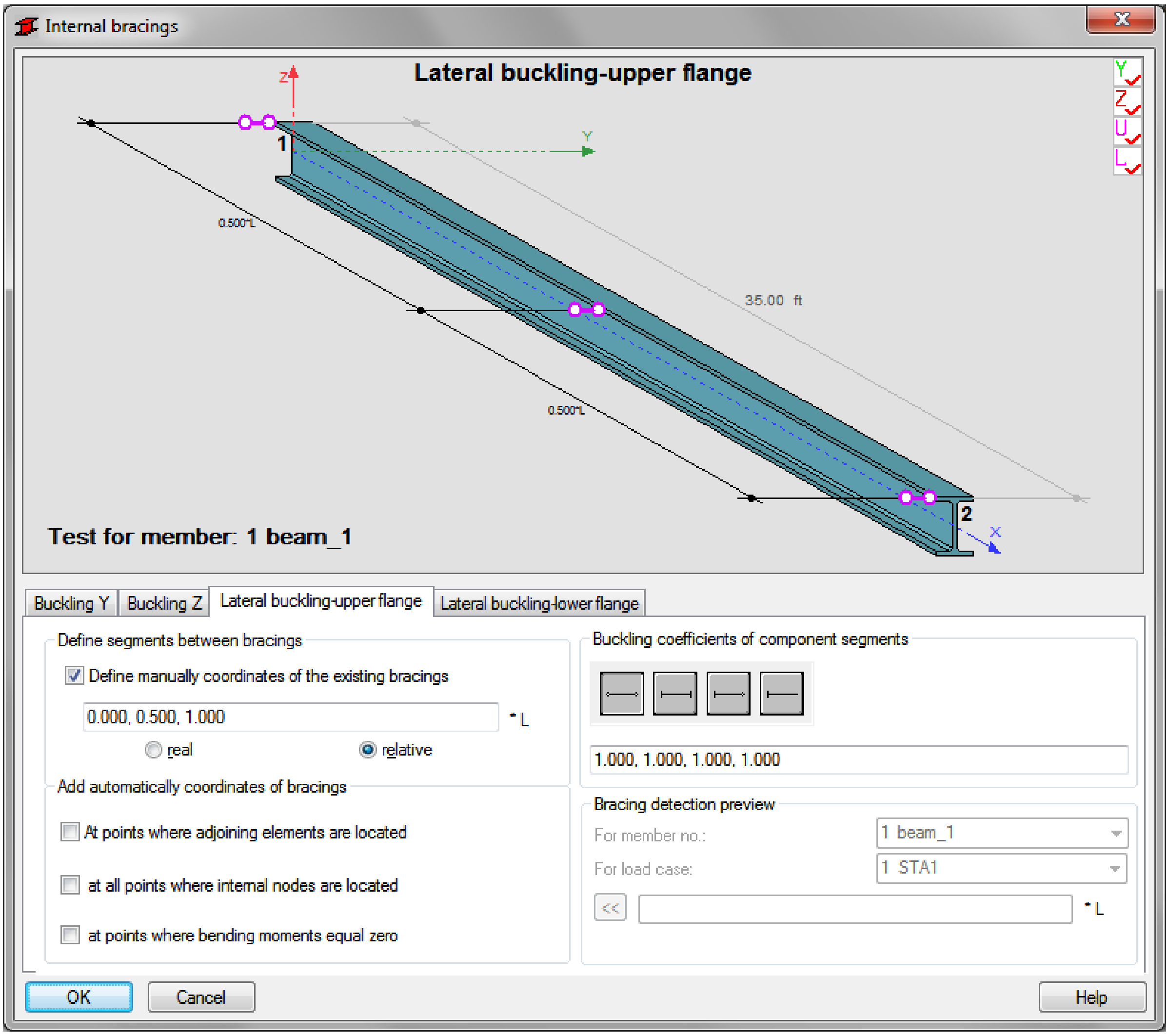
For this task the second icon Cb=f(Mi) was selected.

- define bracings for *Lateral buckling* and *Buckling Z .*

To define *Lateral buckling length coefficient* for this structure , press *Upper flange* button.
It opens LATERAL BUCKLING LENGTH COEFFICIENTS dialog box.

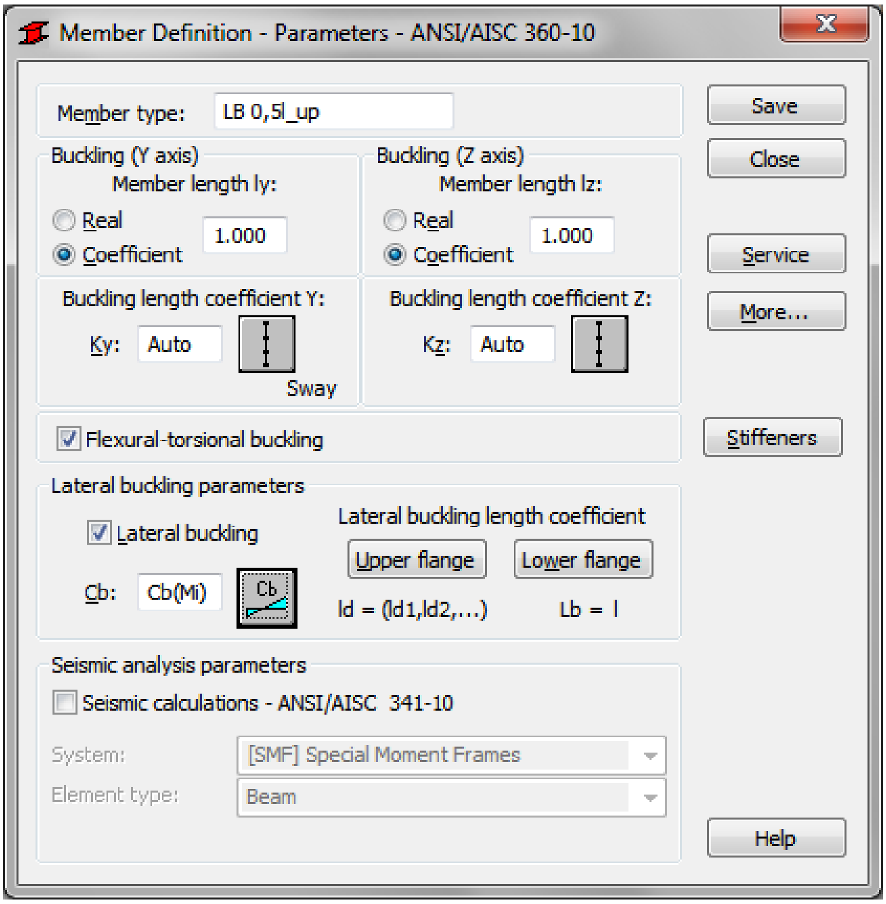


Click the last icon *Intermediate bracings*. The new dialog box *INTERNAL BRACINGS* will appear with automatically active *Lateral buckling - Upper flange* tab .
In *INTERNAL BRACINGS* dialog box there are possibilities of defining independent bracings for buckling and lateral buckling of the marked *member type*.
In *Lateral buckling-upper flange* tab define internal support in the middle of the member by typing typing relative value 0.5 for marked *Define manually coordinates of the existing bracings* field.



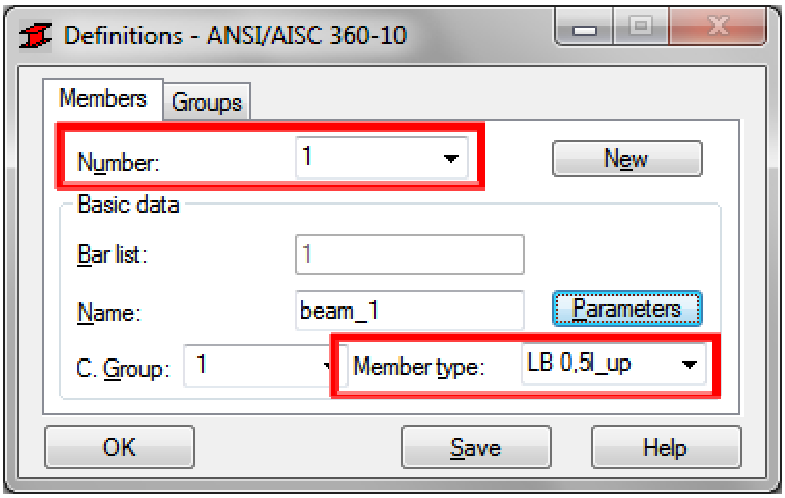
Press OK.

Save the newly-created member type,
e.g. as "LB 0,5l up"



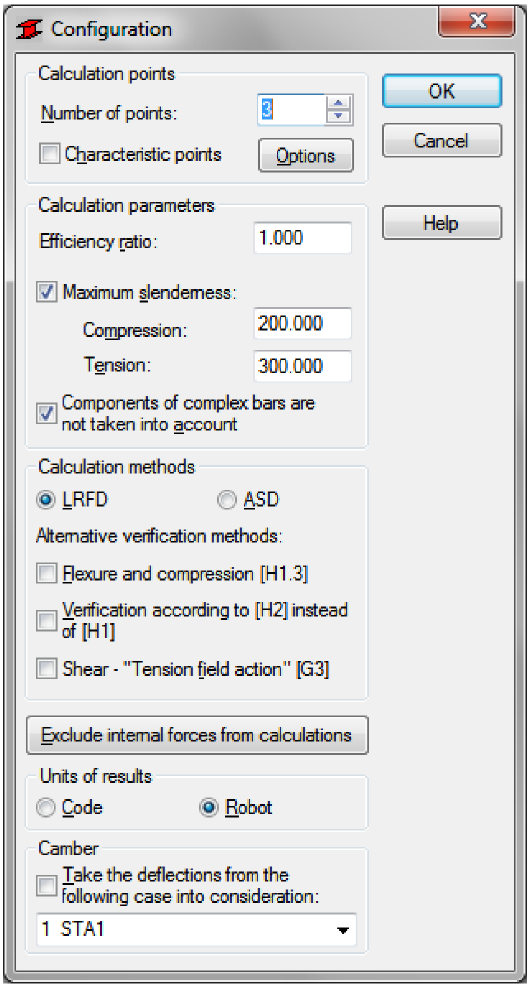
Number of the member must be assigned to the appropriate name of *Member type.*

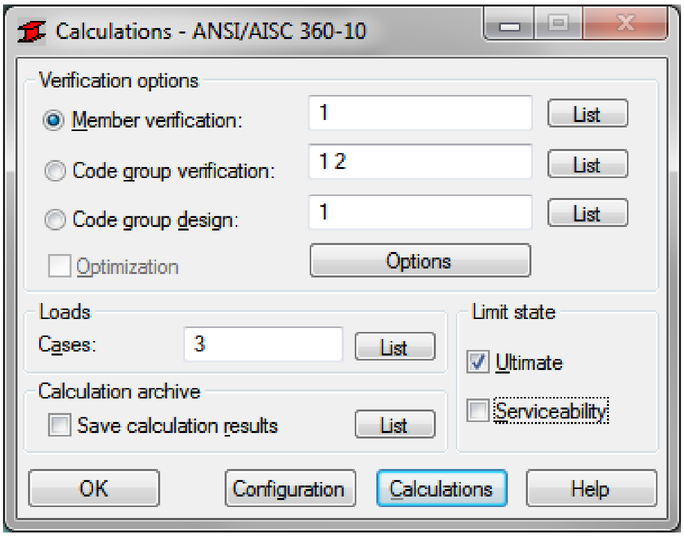
(It is very important when you verify
different member types.)



In the CALCULATIONS dialog box set for this task :

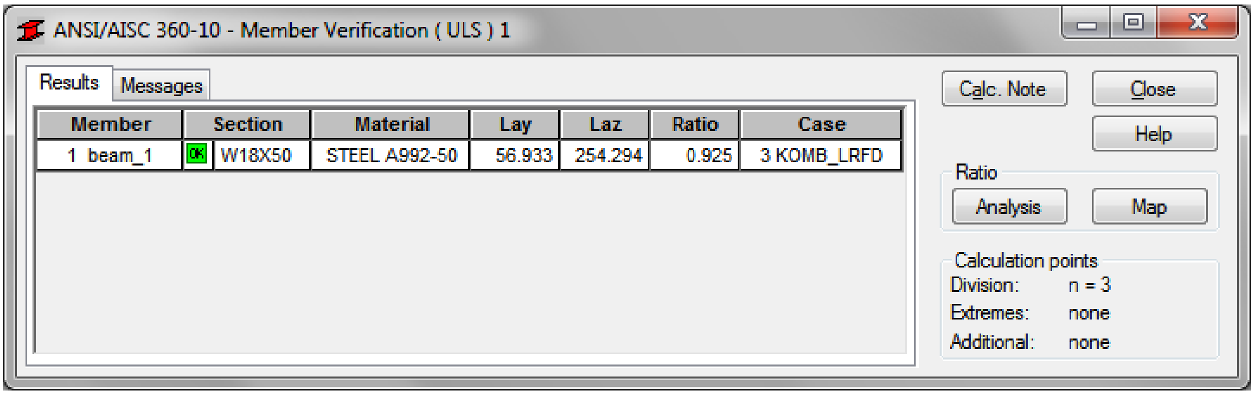
- *Verification option* → Member Verification
- *Loads cases* → for LRFD design (defined as n° 3)
- *Limit state* → only Ultimate Limit state will be analyzed so switch off *Limit stat Serviceability*.
- *Calculation method* → *switch on LRFD radio button* in CONFIGURATION dialog box, opened by [Configuration] button.





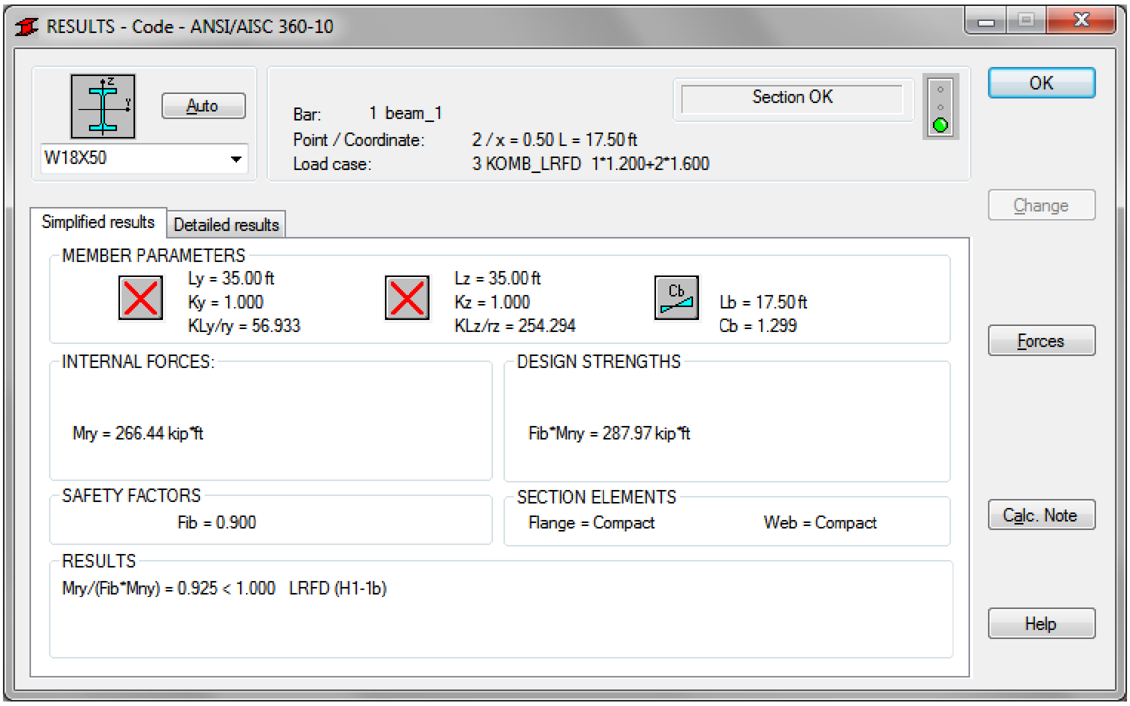
Now, start verifications by pressing *[Calculations]* button.

MEMBER VERIFICATION dialog box with most significant results data will appear on screen.

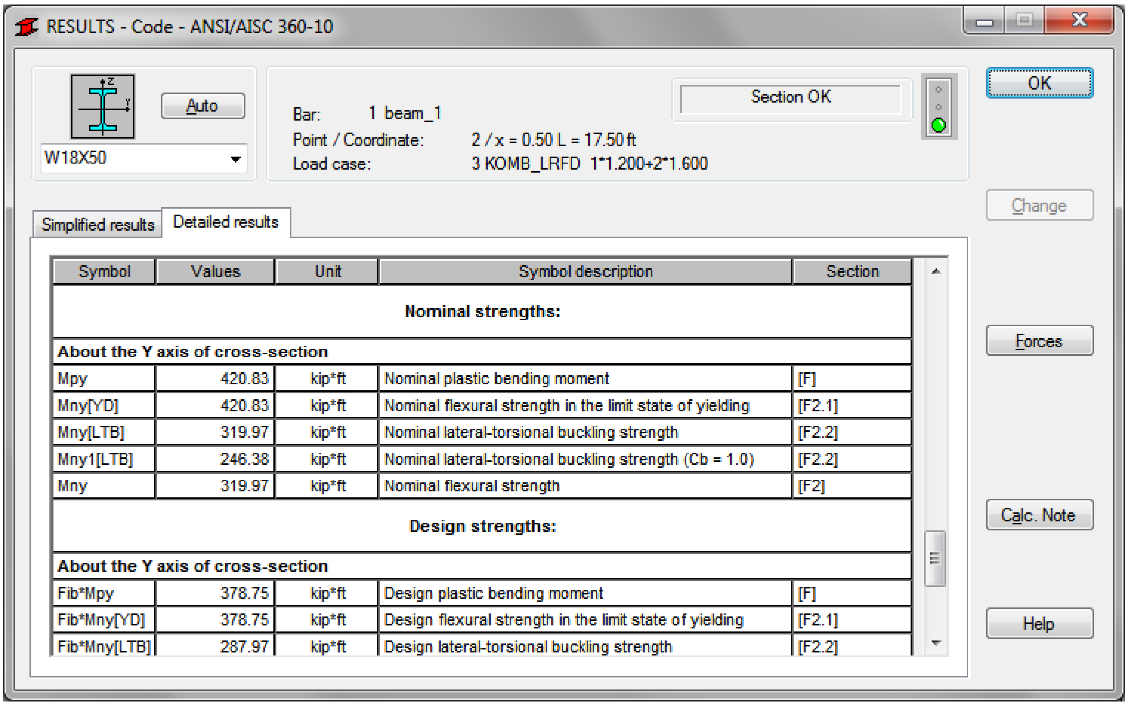


Pressing the line with general results for the member 1 opens the RESULTS dialog box with detailed results for the analyzed member. The view of the RESULTS windows are presented below.

Simplified results tab



Detailed results tab



Symbol	Values	Unit	Symbol description	Section
			Nominal strengths:	
About the Y axis of cross-section				
Mpy	420.83	kip*ft	Nominal plastic bending moment	[F]
Mny[YD]	420.83	kip*ft	Nominal flexural strength in the limit state of yielding	[F2.1]
Mny[LTB]	319.97	kip*ft	Nominal lateral-torsional buckling strength	[F2.2]
Mny1[LTB]	246.38	kip*ft	Nominal lateral-torsional buckling strength (Cb = 1.0)	[F2.2]
Mny	319.97	kip*ft	Nominal flexural strength	[F2]
			Design strengths:	
About the Y axis of cross-section				
Fib*Mpy	378.75	kip*ft	Design plastic bending moment	[F]
Fib*Mny[YD]	378.75	kip*ft	Design flexural strength in the limit state of yielding	[F2.1]
Fib*Mny[LTB]	287.97	kip*ft	Design lateral-torsional buckling strength	[F2.2]

Pressing the *[Calc.Note]* button in “RESULTS –Code” dialog box opens the printout note for the analyzed member. You can obtain *Simplified results printout* or *Detailed results printout* . It depends on which tab is active .

The printout note view of *Simplified results* is presented below.

RESULTS for LRFD method:

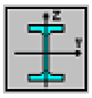
STEEL DESIGN

CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 beam_1 **POINT:** 2 **COORDINATE:** x = 0.50 L = 17.50 ft

LOADS:
Governing Load Case: 3 KOMB_LRFD 1*1.200+2*1.600

MATERIAL:
STEEL A992-50 Fy = 50.00 ksi Fu = 65.00 ksi E = 29000.00 ksi



SECTION PARAMETERS: W18X50

d=17.99 in	Ay=8.544 in2	Az=6.386 in2	Ax=14.700 in2
bf=7.50 in	Iy=800.000 in4	Iz=40.100 in4	J=1.240 in4
tw=0.35 in	Sy=88.938 in3	Sz=10.700 in3	
tf=0.57 in	Zy=101.000 in3	Zz=17.000 in3	

MEMBER PARAMETERS:

Ly = 35.00 ft	Lz = 35.00 ft	
Ky = 1.000	Kz = 1.000	Lb = 17.50 ft
KLy/ry = 56.933	KLz/rz = 254.294	Cb = 1.299

INTERNAL FORCES:
Mry = 266.44 kip*ft

DESIGN STRENGTHS
Fib*Mny = 287.97 kip*ft

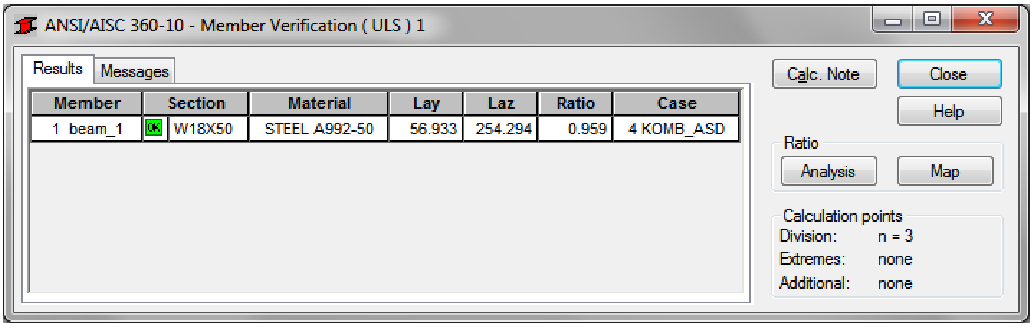
SAFETY FACTORS
Fib = 0.900

SECTION ELEMENTS:
Flange = Compact Web = Compact

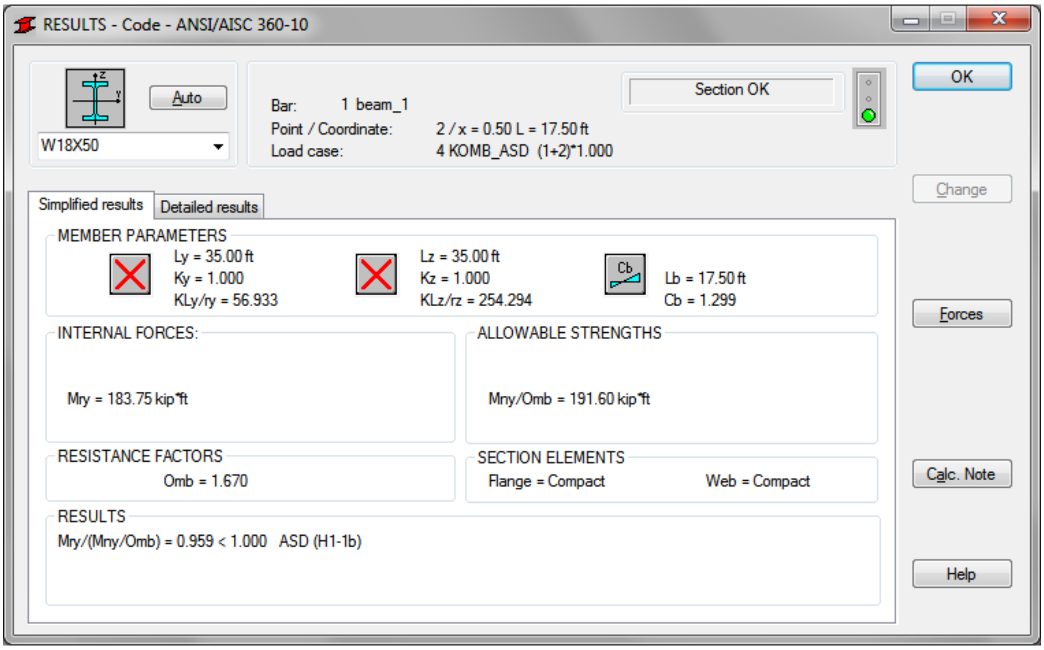
VERIFICATION FORMULAS:
Mry/(Fib*Mny) = 0.925 < 1.000 LRFD (H1-1b) Verified

Section OK !!!

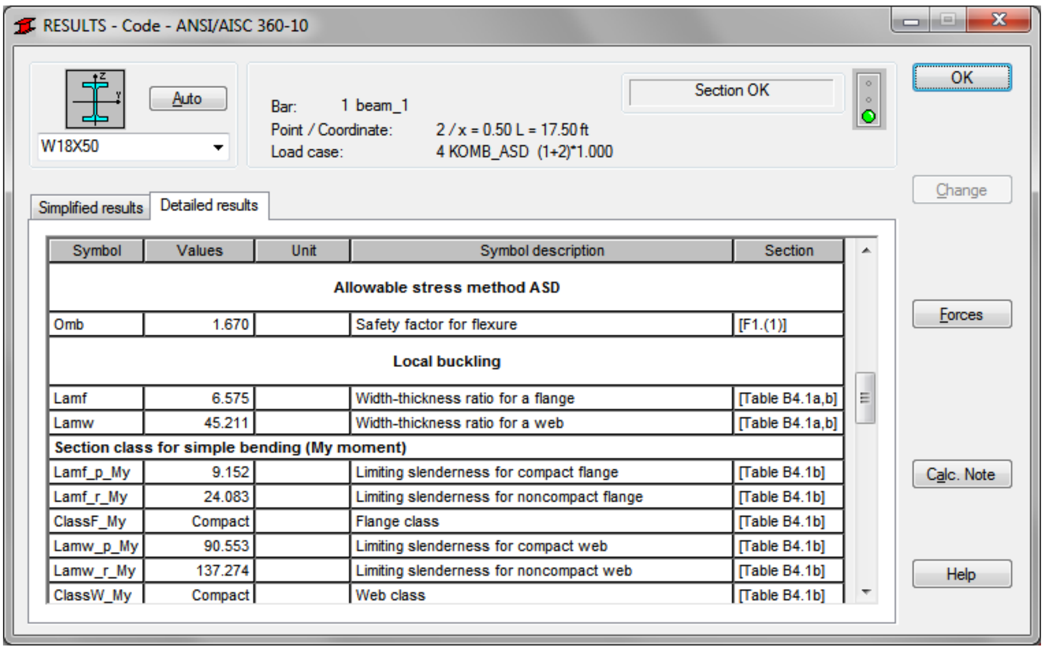
RESULTS for ASD method:



Simplified results tab



Detailed results tab



Pressing the *[Calc.Note]* button in "RESULTS –Code" dialog box opens the printout note for the analyzed member. You can obtain *Simplified results printout* or *Detailed results printout* . It depends on which tab is active.
The printout note view of *Simplified results* for ASD is presented below.

STEEL DESIGN

CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 beam_1 **POINT:** 2 **COORDINATE:** x = 0.50 L = 17.50 ft

---

LOADS:
Governing Load Case: 4 KOMB_ASD (1+2)*1.000

MATERIAL:
STEEL A992-50 Fy = 50.00 ksi Fu = 65.00 ksi E = 29000.00 ksi

SECTION PARAMETERS: W18X50

d=17.99 in	Ay=8.544 in2	Az=6.386 in2	Ax=14.700 in2
bf=7.50 in	Iy=800.000 in4	Iz=40.100 in4	J=1.240 in4
tw=0.35 in	Sy=88.938 in3	Sz=10.700 in3	
tf=0.57 in	Zy=101.000 in3	Zz=17.000 in3	

MEMBER PARAMETERS:

Ly = 35.00 ft	Lz = 35.00 ft	
Ky = 1.000	Kz = 1.000	Lb = 17.50 ft
KLy/ry = 56.933	KLz/rz = 254.294	Cb = 1.299

INTERNAL FORCES:
Mry = 183.75 kip*ft

ALLOWABLE STRENGTHS
Mny/Omb = 191.60 kip*ft

RESISTANCE FACTORS
Omb = 1.670

SECTION ELEMENTS:
Flange = Compact Web = Compact

VERIFICATION FORMULAS:
Mry/(Mny/Omb) = 0.959 < 1.000 ASD (H1-1b) Verified

Section OK !!!

COMPARISON:

verifications parameters, interaction expression	Robot	Handbook
Cb - Lateral-torsional buckling modification factor	1,3	1,3
Lpy - Limiting laterally unbraced length for the limit state of yielding [ft]	5,83	5,83
Lry - Literally unbraced length for the limit state of inelastic lateral- torsional buckling [ft]	16,96	17,0
FcrLtb - Critical stress (lateral-torsional buckling) [ksi]	43,17	43,2
M_{ny} - Nominal flexural strength [kip*ft]	319,97	320
LRFD , Fib=0.90		
1. M_{ry} - Required flexural strength [kip*ft]	266,44	266
2. Fib* M_{ny} - Design compressive strength [kip*ft]	287,97	288
M_{ry} < (Fib* M_{ny})	266,44< 287,97	266< 288
ASD , Omc =1.67		
1. M_{ry} - Required flexural strength [kip*ft]	183,75	184
2. M_{ny} /Omc - Allowable flexural strength [kip*ft]	191,6	192
M_{ry} < (M_{ny} /Omc))	183,75< 191,60	184<192

CONCLUSIONS:

Consistency of results.
The small differences are caused by different accuracy of parameters in calculations .

VERIFICATION PROBLEM 3
combined compression and bending about both axes

Example taken from AISC Steel Construction Manual v14.0
AISC Design Examples
File: MAN_ex_H1b.rtd

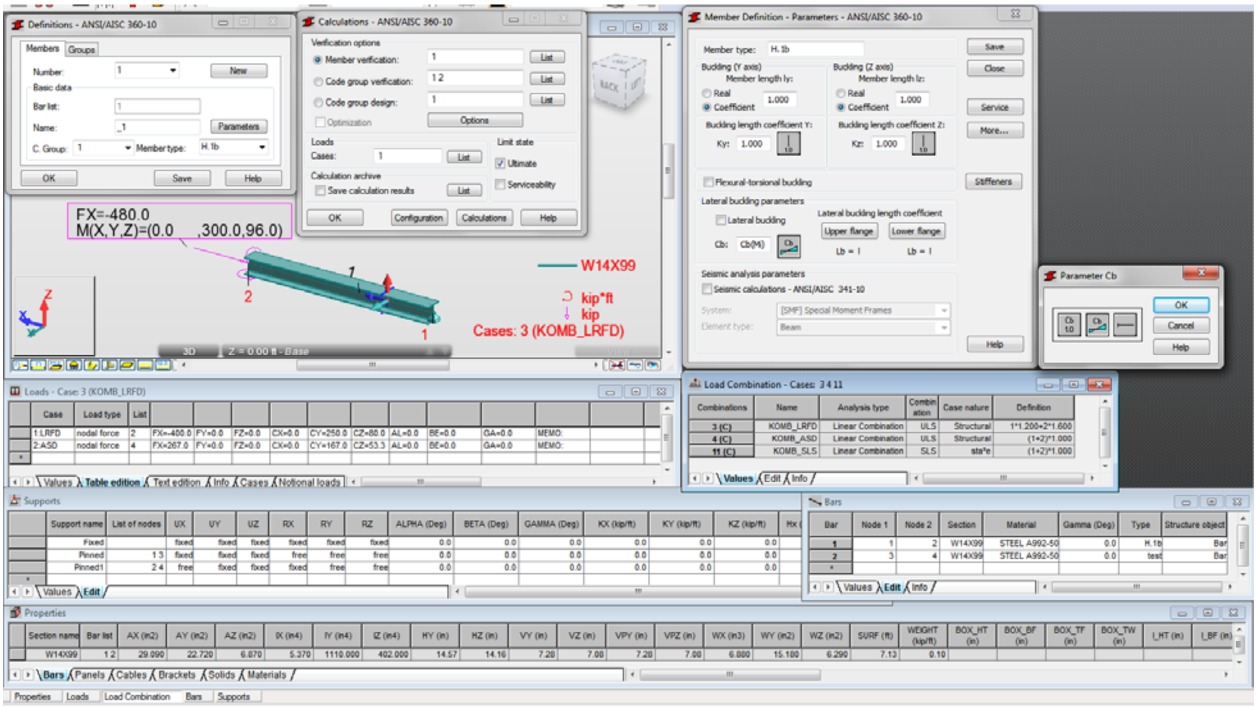
TITLE:
Example H.1 b -- W-shape Subjected to Combined Compression and Bending About Both Axes (braced frame).

SPECIFICATION:

Verify if an ASTM A992 W14×99 has sufficient available strength to support the axial forces and moments listed below, obtained from a second order analysis that includes second-order effects. The unbraced length is 14 ft and the member has pinned ends. $KLx = KLy = Lb$ = 14.0 ft

LRFD	ASD
Pu = 400 kips	Pa = 267 kips
Mux = 250 kip-ft	Max = 167 kip-ft
Muy = 80.0 kip-ft	May = 53.3 kip-ft

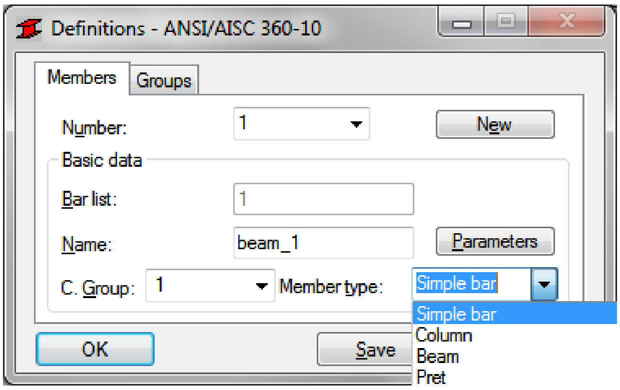
Material Properties:
ASTM A992 Fy = 50 ksi Fu = 65 ksi



SOLUTION:

You must remember to specify appropriate (LRSD or ASD) load code combination in JOB PREFERENCES dialog box (click Menu/Tools/Job Preferences) for considered verification method in a current task or define it manually.

In DEFINITIONS dialog box define a new type of member. It can be set in *Member type* combo-box. Pre-defined type of member “*simple bar*” may be initially opened.

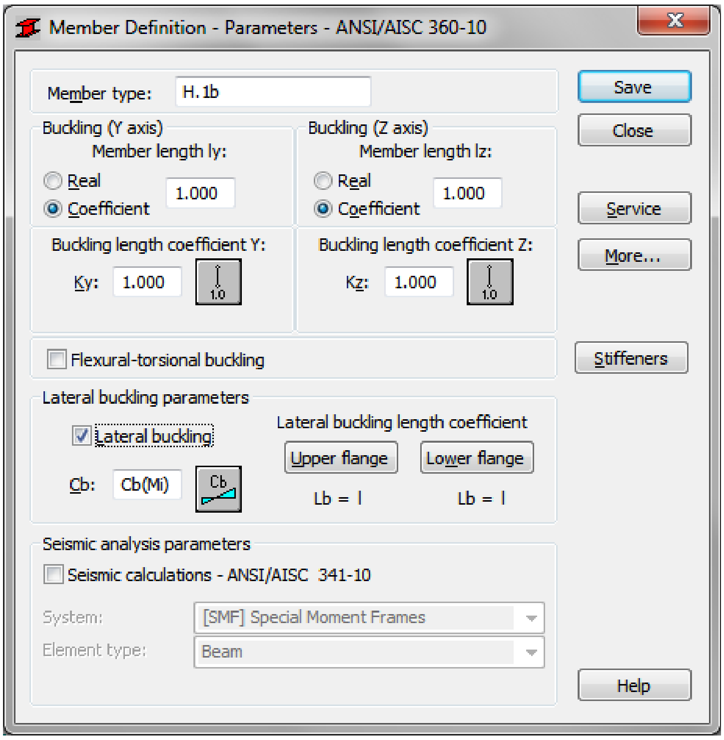


For chosen member type click the *[Parameters]* button on *Members* tab.
It opens MEMBER DEFINITION–PARAMETERS dialog box.

Type a new name in the *Member type* editable field. Then change parameters to meet initial data requirements of the structure. For this particular task switch off *Flexural-torsional buckling.*

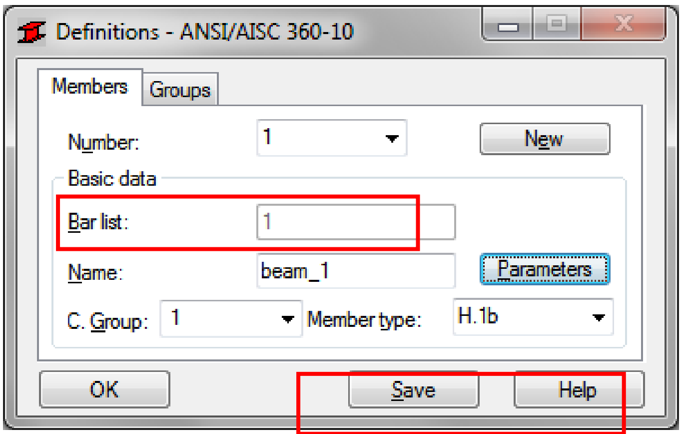
Save the newly-created member type under a new name, e.g. "H.1b 1".

MEMBER DEFINITION–PARAMETERS dialog box defined for this verifications looks like:



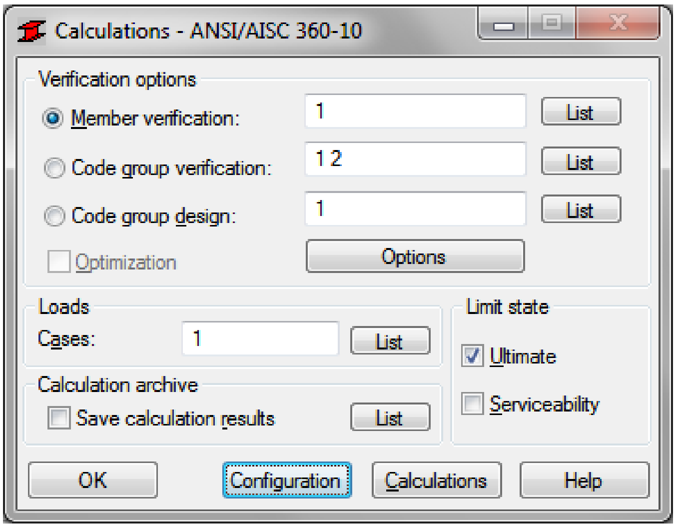
In DEFINITIONS dialog box number of the member must be assigned to the appropriate name of *Member type.*

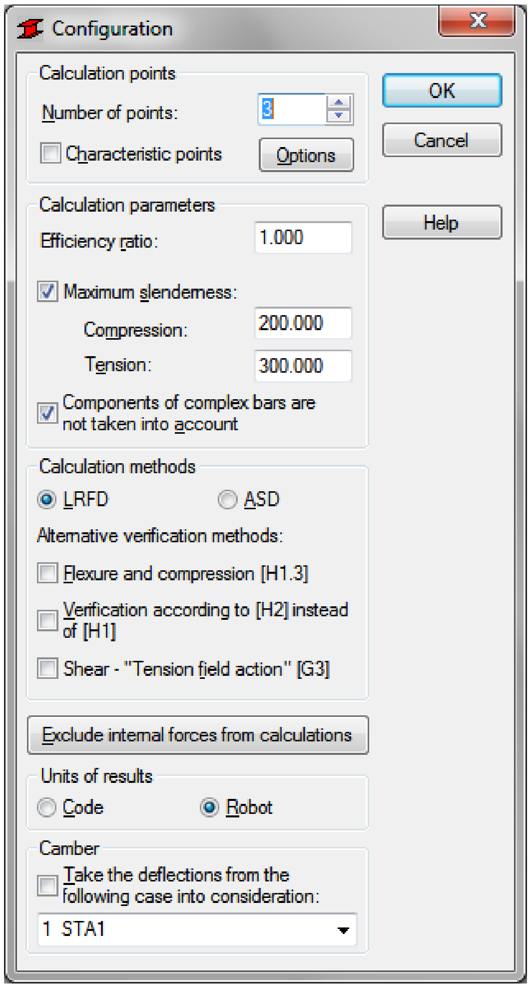
(It is very important when you verify different member types).



In the CALCULATIONS dialog box set for this task :

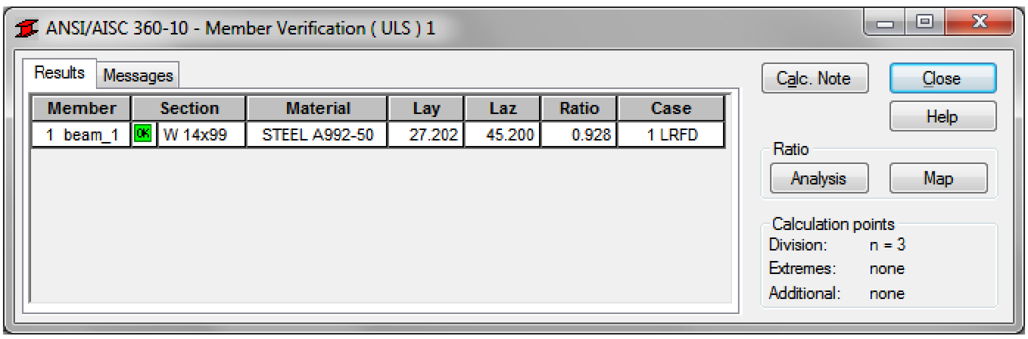
- *Verification option* → Member Verification
- *Loads cases* → for LRFD design (defined as n° 1)
- *Limit state* → only Ultimate Limit state will be analyzed so switch off *Limit stat Serviceability*.
- *Calculation method* → *switch on LRFD radio button* in CONFIGURATION dialog box, opened by [Configuration] button.





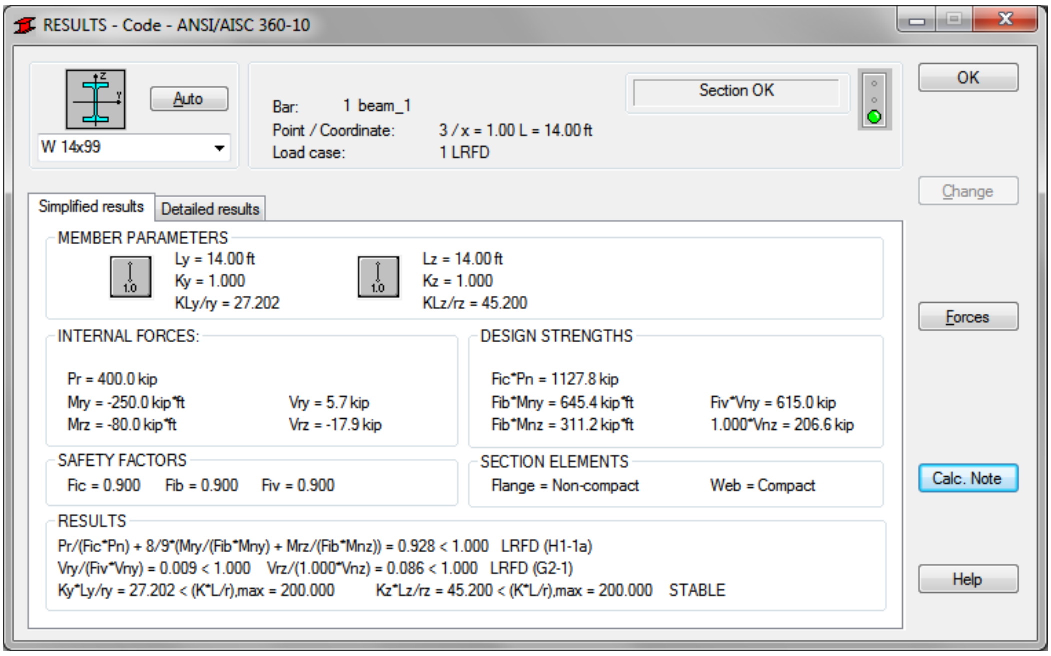
Now, start verifications by pressing *[Calculations]* button.

MEMBER VERIFICATION dialog box with most significant results data will appear on screen.

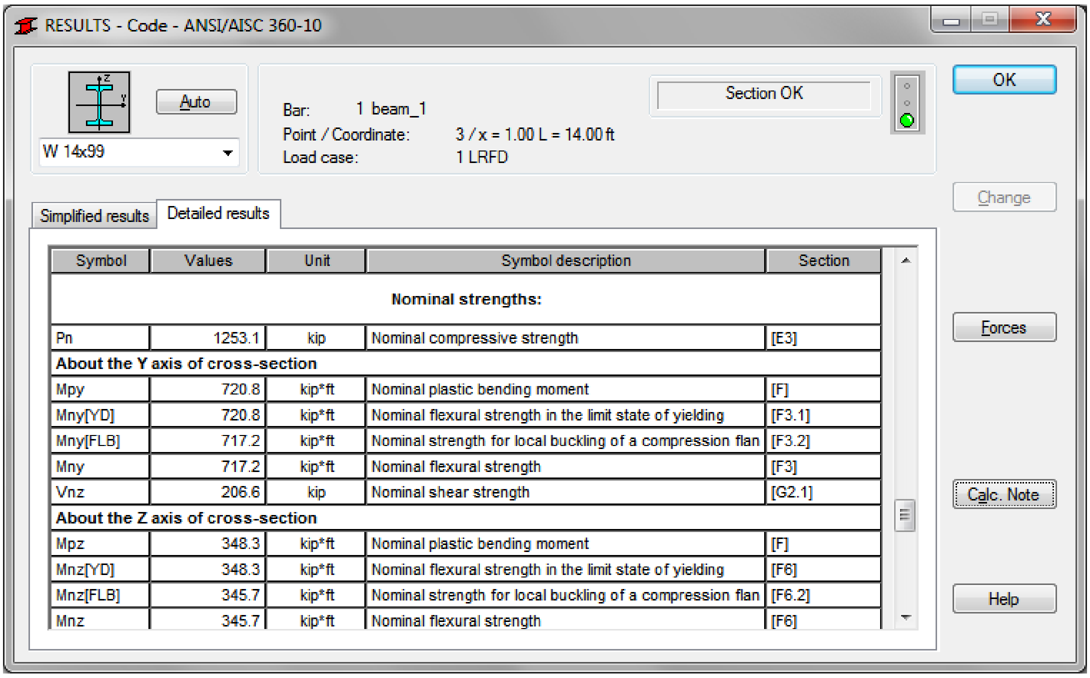


Pressing a line with results for the member 1 opens the RESULTS dialog box with detailed results for the analyzed member. The view of the RESULTS windows are presented below.

Simplified results tab



Detailed results tab



Pressing the *[Calc.Note]* button in "RESULTS –Code" dialog box opens the printout note for the analyzed member. You can obtain *Simplified results printout* or *Detailed results printout* . It depends on which tab is active .

The printout note view of *Simplified results* is presented below.

RESULTS for LRFD method:

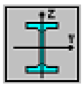
STEEL DESIGN

CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 1 beam_1 **POINT:** 3 **COORDINATE:** x = 1.00 L = 14.00 ft

LOADS:
Governing Load Case: 1 LRFD

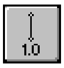
MATERIAL:
STEEL A992-50 Fy = 50.0 ksi Fu = 65.0 ksi E = 29000.0 ksi

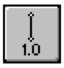


SECTION PARAMETERS: W 14x99

d=14.200 in	Ay=22.78 in2	Az=6.89 in2	Ax=29.10 in2
bf=14.600 in	Iy=1110.00 in4	Iz=402.00 in4	J=5.37 in4
tw=0.485 in	Sy=156.34 in3	Sz=55.07 in3	
tf=0.780 in	Zy=173.00 in3	Zz=83.60 in3	

MEMBER PARAMETERS:





Ly = 14.00 ft	Lz = 14.00 ft
Ky = 1.000	Kz = 1.000
KLy/ry = 27.202	KLz/rz = 45.200

INTERNAL FORCES: / **DESIGN STRENGTHS**

Pr = 400.0 kip		Fic*Pn = 1127.8 kip	
Mry = -250.0 kip*ft	Vry = 5.7 kip	Fib*Mny = 645.4 kip*ft	Fiv*Vny = 615.0 kip
Mrz = -80.0 kip*ft	Vrz = -17.9 kip	Fib*Mnz = 311.2 kip*ft	1.000*Vnz = 206.6 kip

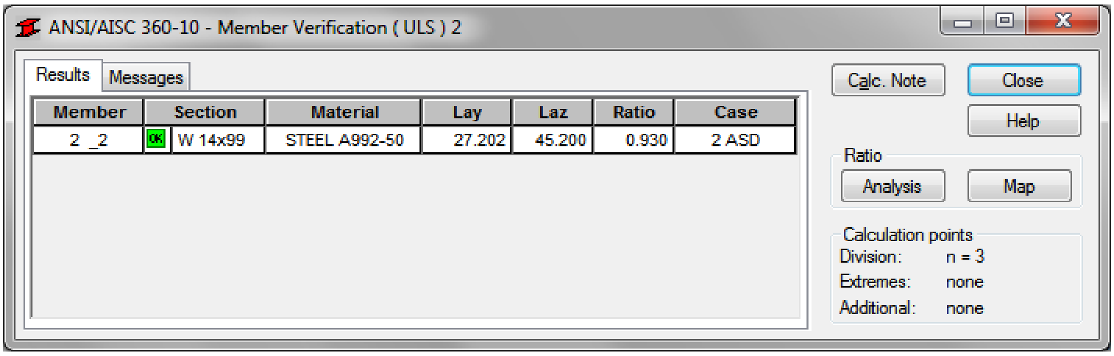
SAFETY FACTORS
Fib = 0.900 Fic = 0.900 Fiv = 0.900

SECTION ELEMENTS:
Flange = Non-compact Web = Compact

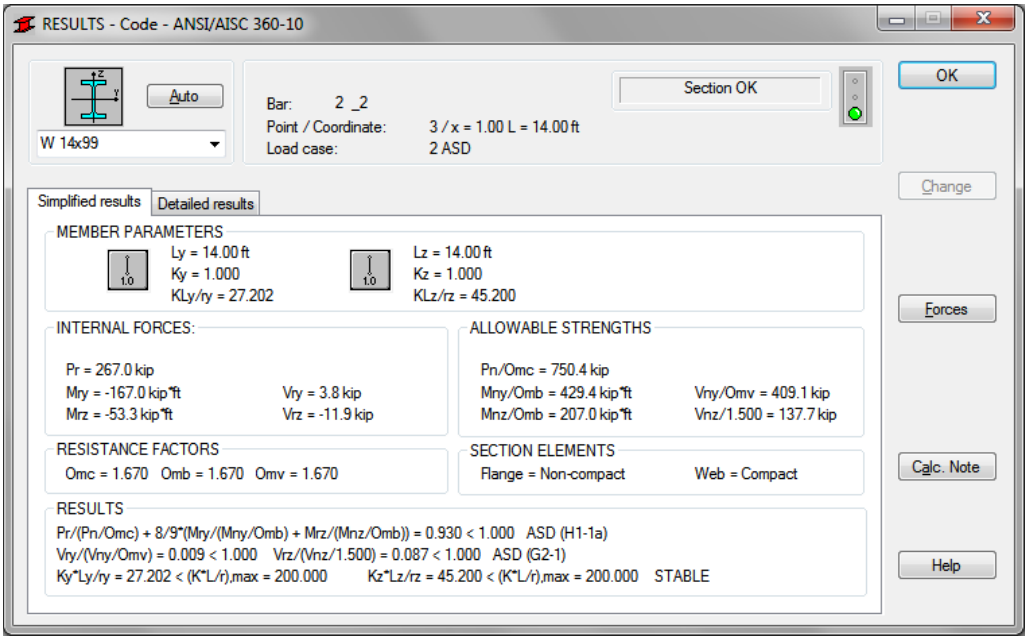
VERIFICATION FORMULAS:
Pr/(Fic*Pn) + 8/9*(Mry/(Fib*Mny) + Mrz/(Fib*Mnz)) = 0.928 < 1.000 LRFD (H1-1a) Verified
Vry/(Fiv*Vny) = 0.009 < 1.000 LRFD (G2-1) Verified
Vrz/(1.000*Vnz) = 0.086 < 1.000 LRFD (G2-1) Verified
Ky*Ly/ry = 27.202 < (K*L/r),max = 200.000 Kz*Lz/rz = 45.200 < (K*L/r),max = 200.000 STABLE

Section OK !!!

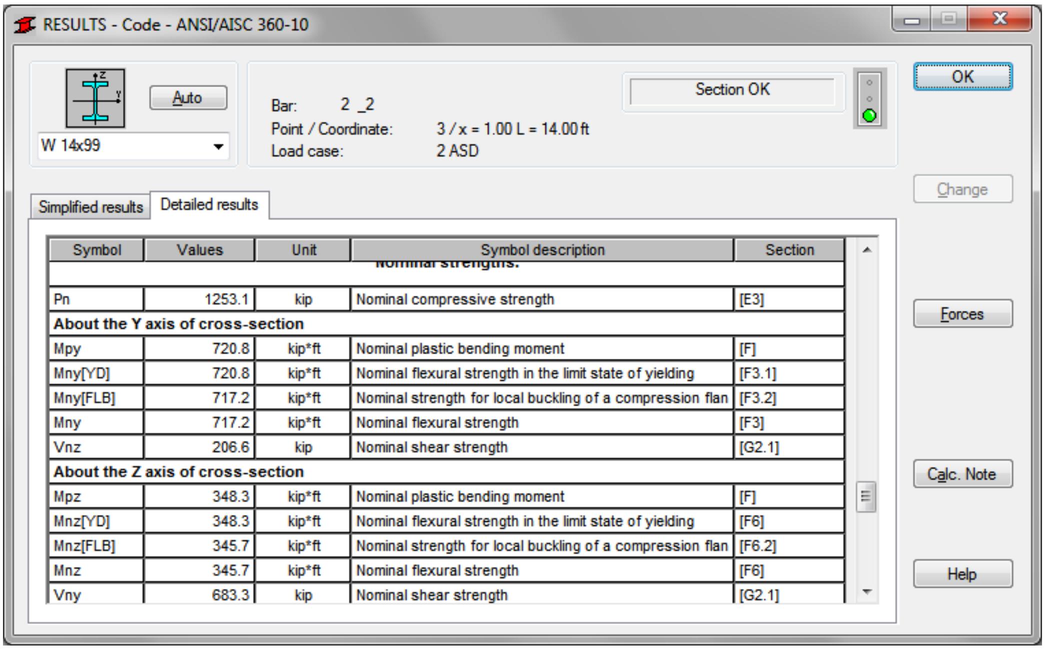
RESULTS for ASD method:



Simplified results tab



Detailed results tab



Pressing the *[Calc.Note]* button in "RESULTS –Code" dialog box opens the printout note for the analyzed member. You can obtain *Simplified results printout* or *Detailed results printout* . It depends on which tab is active .
The printout note view of *Simplified results* for ASD is presented below.

STEEL DESIGN

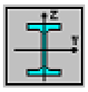
CODE: *ANSI/AISC 360-10 An American National Standard, June 22, 2010*
ANALYSIS TYPE: Member Verification

CODE GROUP:
MEMBER: 2 _2 **POINT:** 3 **COORDINATE:** x = 1.00 L = 14.00 ft

---

LOADS:
Governing Load Case: 2 ASD

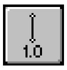
MATERIAL:
STEEL A992-50 Fy = 50.0 ksi Fu = 65.0 ksi E = 29000.0 ksi

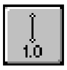


SECTION PARAMETERS: W 14x99

d=14.200 in	Ay=22.78 in2	Az=6.89 in2	Ax=29.10 in2
bf=14.600 in	Iy=1110.00 in4	Iz=402.00 in4	J=5.37 in4
tw=0.485 in	Sy=156.34 in3	Sz=55.07 in3	
tf=0.780 in	Zy=173.00 in3	Zz=83.60 in3	

MEMBER PARAMETERS:





Ly = 14.00 ft	Lz = 14.00 ft
Ky = 1.000	Kz = 1.000
KLy/ry = 27.202	KLz/rz = 45.200

INTERNAL FORCES:		**ALLOWABLE STRENGTHS**	
Pr = 267.0 kip		Pn/Omc = 750.4 kip	
Mry = -167.0 kip*ft	Vry = 3.8 kip	Mny/Omb = 429.4 kip*ft	Vny/Omv = 409.1 kip
Mrz = -53.3 kip*ft	Vrz = -11.9 kip	Mnz/Omb = 207.0 kip*ft	Vnz/1.500 = 137.7 kip

---

RESISTANCE FACTORS
Omb = 1.670 Omc = 1.670 Omv = 1.670

SECTION ELEMENTS:
Flange = Non-compact Web = Compact

VERIFICATION FORMULAS:
Pr/(Pn/Omc) + 8/9*(Mry/(Mny/Omb) + Mrz/(Mnz/Omb)) = 0.930 < 1.000 ASD (H1-1a) Verified
Vry/(Vny/Omv) = 0.009 < 1.000 ASD (G2-1) Verified
Vrz/(Vnz/1.500) = 0.087 < 1.000 ASD (G2-1) Verified
Ky*Ly/ry = 27.202 < (K*L/r),max = 200.000 Kz*Lz/rz = 45.200 < (K*L/r),max = 200.000 STABLE

Section OK !!!

COMPARISON:

verifications parameters, interaction expression	Robot	Handbook
LRFD Fib=0.90		
- Required compressive strength [kips] P_r	400	400
- Design compressive strength [kips] $Fic*P_n$	1127,8	1130
$P_r < Fic*P_n$	400< 1127,8	400< 1130
- Required flexural strength [kip*ft] M_{ry} ; M_{rz}	250 ; 80	250 ; 80
- Design compressive strength [kip*ft] $Fic*M_{ny}$; $Fic*M_{nz}$	645,4 ; 311,2	642 ; 311
$M_{ry} <$ Fib* M_{ny}	250 < 645,4	250 < 642
$M_{rz} <$ Fib* M_{nz}	80 < 311,2	80 < 311
interaction expression for Pr / (Fic*Pn) > 0,2	0,355	0,354
Mry / (Fib*Mny)	0,387	0,389
Mrz / (Fib*Mnz)	0,257	0,257
Pr/(Fic*Pn) + 8/9*(Mry/(Fib*Mny) + Mrz/(Fib*Mnz)) = < 1.0 (H1-1a)	**0,9275**	**0,928**
ASD Omc =1.67		
- Required compressive strength [kips] P_r	267	267
- Design compressive strength [kips] P_n/Omc	750,4	750
$P_r < P_n$/Omc	267 < 750,4	267 < 750
- Required flexural strength [kip*ft] M_{ry} ; M_{rz}	167 ; 53,3	167 ; 53,3
- Design compressive strength [kip*ft] M_{ny}/Omc ; M_{nz}/Omc	429,4 ; 207,0	428 ; 207
$M_{ry} < M_{ny}$ /Omc	167 < 429,4	167 < 428
$M_{rz} < M_{nz}$ /Omc	53,3 < 207,0	53,3 < 207
interaction expression for Pr / (P_n/Omc) > 0,2	0,356	0,356
M_{ry} / (M_{ny} /Omc)	0,389	0,390
M_{rz} /(M_{nz} /Omc)	0,257	0,257
Pr/(Fic*Pn) + 8/9*(Mry/(Fib*Mny) + Mrz/(Fib*Mnz)) = < 1.0 (H1-1a)	**0,9306**	**0,931**

CONCLUSIONS:
Agreement of results.
The small differences are caused by different accuracy of parameters in calculations .

GENERAL CONCLUSIONS

More examples from “AISC Design Examples v. 14.0, Steel Construction Manual” were made using Robot program. In the last column of the following table it was shown the comparison between Robot results and “AISC Design Examples” results .

1		Examples	Description	Section	ok ?
2			**TENSION**		
3	1	MAN_ex_D1.rtd	W-Shape Tension Member - shear lag effect	W 8x21	100%
4	2	MAN_ex_D2.rtd	Single-Angle Tension Member - shear lag effect	L 4x4x0,5	100%
5	3	MAN_ex_D3.rtd	WT-Shape Tension Member - shear lag effect	WT 6x20	100%
6	4	MAN_ex_D4.rtd	Rectangular HSS Tension Member	HSS 6x4x0,375	100%
7	5	MAN_ex_D5.rtd	Round HSS Tension Member	HSS 6x500	100%
8	6	MAN_ex_D6.rtd	Double-Angle Tension Member- shear lag effect	2L 4x4x0.5	100%
9			**COMPRESSION**		
10	7	MAN_ex_E1d.rtd	W-Shape	W 14x90	100%
11	8	MAN_ex_E2_plus.rtd	Built-up Column with a Slender Web	I 15x8x1x0,25	100%
12	9	MAN_ex_E3.rtd	Built-up Column with Slender Flanges	I 10,5x7,25x0,375x0,25	100%
13	10	MAN_ex_E7.rtd	WT Compression Member without Slender Elements	WT 7x34	100%
14	11	MAN_ex_E8.rtd	WT Compression Member with Slender Elements + LTB	WT 7x15	100%
15	12	MAN_ex_E9.rtd	Rect HSS Compression Member without Slender Elements Ky=Kz=0.8	HSRE 12x10x0.375	100%
16	13	MAN_ex_E11_plus.rtd	Pipe Compression Member Ky=1,Kz=1	Pipe P10	100%
17	14	MAN_ex_E12_plus.rtd	Built-up I-Shaped Member with Different Flange Sizes Ky=Kz=1, + LTB	I-ASYM 10,5x8x5x3/8x3/4	100%
18			**BENDING**		
19	15	MAN_ex_F1_3B.rtd	W- Flexural el. Design in Strong-Axis Bending, Braced at Midspan, LTB, CB=auto	W18x50	100%
20	16	MAN_ex_F2_2B.rtd	Compact Channel Flexural el. with Bracing at End and Fifth Points LTB, CB=1.0	C 15x33,9	100%
21	17	MAN_ex_F3B.rtd	W-Shape Flexural braced Member with NC Flanges in Strong-Axis Bending,no LTB	W 21x48	100%
22	18	MAN_ex_F7B.rtd	Rect HSS Flexural Member with Noncompact Flanges	HSS 10x6x3/16	100%
23	19	MAN_ex_F10_plus.rtd	WT Shape Flexural Members el.1	WT 5x6	100%
24	20	MAN_ex_F11_plus.rtd	Single Angle Flexural Member	L 4x4x1/4	100%
25	21	MAN_ex_F12.rtd	Rectangular Bar in Strong-Axis Bending	RECT 5x3	100%
26	22	MAN_ex_F13.rtd	Round Bar in Bending	RB 1	100%
27			**SHEARING**		
28	23	MAN_ex_G1.rtd	W-Shape in Strong-Axis Shear	W 24x62	100%
29	24	MAN_ex_G2b.rtd	C-Shape in Strong-Axis Shear	C 15x33,9	100%
30	25	MAN_ex_G3_Fy_36_105.rtd	Angle in Shear	L 5x3x1/4	100%
31	26	MAN_ex_G5.rtd	Round HSS in Shear	HSRO 16x0,375	100%
32	27	MAN_ex_G6.rtd	Doubly-Symmetric Shape W in Weak-Axis Shear	W 21x48	100%
33	27	MAN_ex_G7_plus.rtd	Singly-Symmetric Shape C in Weak-Axis Shear (both directions)	C9x20	100%
34	28	MAN_ex_G8b.rtd	Built-up I-Shaped Member without & with stiffeners (tension field action)	I-SYM_2 33/0.31 x 12/1.5	100%
35			**INTERACTION M, N, V**		
36	29	MAN_ex_H1b.rtd	Nc+MY+MZ - W shape - &H1	W 14x99	100%
37	30	MAN_ex_H2.rtd	Nc+MY+MZ - W shape - &H2	W14x99	100%
38	31	MAN_ex_H3.rtd	Nt+MY+MZ - W shape - &H1 - (exmp. for Nt+M H1.2 -> [a*Cb])	W14x82	100%
39	32	MAN_ex_H5a.rtd	Torsional Strength HSS rect	HSS 6x4x1/4	100%
40	33	MAN_ex_H5b.rtd	Torsional Strength HSRO tube	HSRO 5x0,25	100%