Autodesk[®] Robot[™] Structural Analysis Professional

VERIFICATION MANUAL FOR STEEL MEMBERS DESIGN

March 2014

© 2014 Autodesk, Inc. All Rights Reserved. Except as otherwise permitted by Autodesk, Inc., this publication, or parts thereof, may not be reproduced in any form, by any method, for any purpose. Certain materials included in this publication are reprinted with the permission of the copyright holder.

Disclaimer

THIS PUBLICATION AND THE INFORMATION CONTAINED HEREIN IS MADE AVAILABLE BY AUTODESK, INC. "AS IS." AUTODESK, INC. DISCLAIMS ALL WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE REGARDING THESE MATERIALS.

Trademarks

The following are registered trademarks of Autodesk, Inc., in the USA and/or other countries: Autodesk Robot Structural Analysis Professional, Autodesk Concrete Building Structures, Spreadsheet Calculator, ATC, AutoCAD, Autodesk, Autodesk Inventor, Autodesk (logo), Buzzsaw, Design Web Format, DWF, ViewCube, SteeringWheels, and Autodesk Revit. All other brand names, product names or trademarks belong to their respective holders.

Third Party Software Program Credits

ACIS Copyright© 1989-2001 Spatial Corp. Portions Copyright© 2002 Autodesk, Inc. Copyright© 1997 Microsoft Corporation. All rights reserved. International CorrectSpell™ Spelling Correction System© 1995 by Lernout & Hauspie Speech Products, N.V. All rights reserved. InstallShield™ 3.0. Copyright© 1997 InstallShield Software Corporation. All rights reserved. PANTONE® and other Pantone, Inc. trademarks are the property of Pantone, Inc.© Pantone, Inc., 2002. Portions Copyright© 1991-1996 Arthur D. Applegate. All rights reserved. Portions relating to JPEG © Copyright 1991-1998 Thomas G. Lane. All rights reserved. Portions of this software are based on the work of the Independent JPEG Group. Portions relating to TIFF © Copyright 1997-1998 Sam Leffler. © Copyright 1991-1997 Silicon Graphics, Inc. All rights reserved.

Government Use

Use, duplication, or disclosure by the U.S. Government is subject to restrictions as set forth in FAR 12.212 (Commercial Computer Software-Restricted Rights) and DFAR 227.7202 (Rights in Technical Data and Computer Software), as applicable.

AMERICAN CODE ANSI/AISC 360-10 JUNE 22, 2010	1
INTRODUCTION	2
GENERAL REMARKS	3
VERIFICATION PROBLEM 1 DESIGN OF MEMBERS FOR COMPRESSION	9
VERIFICATION PROBLEM 2 LATERAL-TORSIONAL BUCKLING OF BEAMS	19
VERIFICATION PROBLEM 3 COMBINED COMPRESSION AND BENDING ABOUT BOTH AXES	29
GENERAL CONCLUSIONS	36

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:

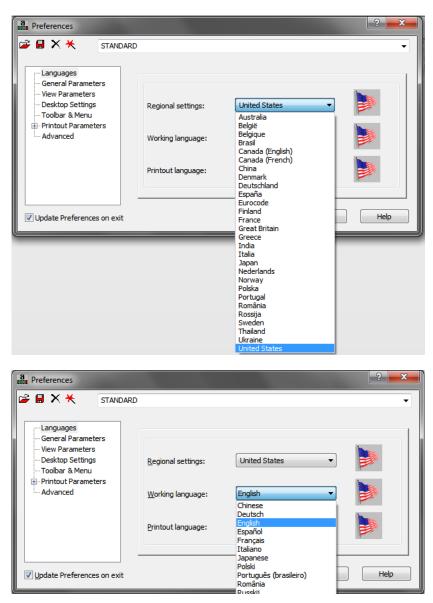
- title of the problem
- specification of the problem
- Robot solution of the problem
- outputs with calculation results and calculation notes
- comparison between Robot results and exact solution
- conclusions

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] :

Job Preferences			? X
EURIC Units and Formats Units and Formats Dimensions Dimensions Other Unit Edition Materials Databases Databases Loads Loads Structure Analysis Work Parameters	URD Steel/Aluminum structures: Steel connections: Iimber structures: <u>B</u> C structures: <u>G</u> eotechnical:	EN 1993-1:2005 EN 1993-1-8:2005 PN-8-03150 PN-8-03264 (2002) PN-81/8-03020 More codes	• • • •
📄 🖳 🕰	ult parameters		
_	rameters as default	OK Cancel	Help

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 :

In Job Preferences			? ×
Coads Work Parameters Work Parameters Work Parameters Work Parameters	AULTS <u>C</u> ode combinations: Snow/ <u>w</u> ind loads: <u>S</u> eismic loads:	LRFD ASCE 7-05 UBC97 More codes	
🖳 🔤 Open default p	parameters		
Save current param	neters as default	OK Cancel	Help

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

K Configuration of Code List					×
Codes:				Current codes:	
Steel / aluminum		•		Set as current	
Steel / aluminum Steel connections RC Timber Geotechnical Load combinations Snow/wind loads Seismic loads				Code ANSI/AISC 360-05 ANSI/AISC 360-10 ASD: 1989 Ed.9th EIA	
AS 4100-1998	Australia		T	LRFD2000	
ASD: 1989 Ed.9th Add80	USA France		≤	LRFD: 1994 Ed. 2nd	
BS 5950:2000	UK				
BS-EN 1993-1:2005/NA:2008/AC:2009	UK EC3	-			
•		۱.		۰ III	•
OK Cancel				Ŀ	lelp

Codes:			Current codes:
Load combinations		•	Set as current
Code	Country	*	Code
API/ASD	US		ACI318
LRFD ASCE 7-10	USA		≥ ACI318_2002
ACI318	USA		ASD
ACI318_2002	USA		LRFD
ASD ASCE 7-10	USA		LRFD
LRFD	USA ASCE 7-05		
ASD	USA ASCE 7-05		
ACI318_2002_geo	USA Geotechnic		
ACI	USA Geotechnic	-	-
•	1	P.	< III

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 .

K Configuration of Code List				×
Codes:		•	Current	codes: Set as current
Code	Country		Code	
СНиП 2.01.07-85	Россия		ACI318	
СП 20.13330.2011	Россия		≥ ACI318_2	002
ACI318_2002_geo	USA Geotechnic		ASD	
ACI	USA Geotechnic		ASD ASCE	7-10
LRFD	USA ASCE 7-05		LRFD	
ASD	USA ASCE 7-05		≤ LRFD	
LRFD ASCE 7-10	USA		LRFD ASC	E 7-10
ACI318	USA			
ACI318_2002	USA	-		
<		•	•	4
OK Cancel				Help

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

K Save Job Prefe	erences	×
Save įn:	🔰 CfgUsr 🗸 🗸	G 🤌 📂 🛄 -
(Ca)	Name	Date modified Type
Recent Places	ASD_2010.cov	2013-08-07 19:11 COV File 2013-08-07 11:27 COV File
Desktop	i defcfg	2013-08-07 11:24 Shortcut 2013-08-07 19:07 COV File
Libraries		
Computer		
(interview of the second secon	III File name: LRFD 2010 cov	→ Save
	Save as type: Job Preferences (*.cov)	✓ Cancel

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*"

Job Preferences		? 🔫	
Units and Formats	SD_2010 FAULTS FD_2010 <u>C</u> ode combinations: Snow/ <u>w</u> ind loads: <u>S</u> eismic loads:	ASD ASCE 7-10 ✓ ASCE 7-05 ✓ UBC97 ✓ More codes ✓	
	ameters as default	OK Cancel Help	

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.

	Preferen	nces He	elp																
:		ASD A	SCE 7-10			Ven	sion:	24	ļ										
	Nat	ture	Subnature	у́тах	Ymin	γs	γa	$ \Psi_{0,1} $	$\Psi_{0,2}$	$\Psi_{0,3}$	$\Psi_{0,n}$	Ψ_1	$\Psi_{2,1}$	$\Psi_{2,n}$	Ψ_{K}	ξı	ξĩ		
	Dead		1 i	1	0.6	1	1											-	
	Live			1		1		1	0.75						0.75				
	Wind			1		1		0.6	0.75						0.45				
	Snow			1		1		1	0.75						0.75				
	Snow			1		1		1											
	Snow		Rain	1		1		1											
	Temperat																		
	Accidenta	al					1											_	
0	Seismic						0.7								0.75			_	
_																	_		
		Combin ation	User-defined ty	pe		Dead				Live		ads		cident			Seise	mic	
			User-defined ty			Dead		[34)		Live	e			ccident			Seisi	mic	
	ULS		User-defined ty 3. D+S	(2)			Y ⁽ⁱ⁾ _{max}	(34)	Ψ _{0,1}		e		(0)	ccident	al (0)		Seisi	mic	
		ation type		(2)	$\sum_{i\geq i}$	$G_i \cdot$	γ ⁽ⁱ⁾ _{max}		$\Psi_{0,1}$	$\cdot \sum_{i \ge 1} S_i$	$\cdot \begin{cases} \boldsymbol{\gamma}_{\mathrm{m}}^{(i)} \\ 0 \end{cases}$) ax	(0)	ccident			Seisi	mic	
3	ULS	ation type USR	3. D+S 4.	(2)		$G_i \cdot$ $G_i \cdot$	$\mathcal{Y}_{_{\mathrm{max}}}^{(i)}$	(36) $\sum_{i 21} L_i$	$\Psi_{0,1}$ $\cdot \Psi_{0,2} \cdot \left\{ \Psi_{0,1} \cdot \right\}$	$\frac{\sum_{i\geq 1} S_i}{\sum_{j\geq 1} S_i}$	$\begin{cases} \mathcal{Y}_{m}^{(i)} \\ 0 \end{cases} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$) ax ,,{0,2} . { y	(0)	ccident	- (0)		Seisi	mic	
4	ULS	USR USR	3. D+S 4. D+0.75L+0.75S/Lr	(2) r/R		$G_i \cdot$ $G_i \cdot$	$\gamma_{max}^{(i)}$	(36) $\sum_{i 21} L_i$	$\cdot \Psi_{0,2} \cdot \left\{$	$\frac{\sum_{i\geq 1} S_i}{\sum_{j\geq 1} S_i}$	$\begin{cases} \mathcal{Y}_{m}^{(i)} \\ 0 \end{cases} \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\ \\$) ax ,,{0,2} . { y	(0) (0)	cident	- (0) - (0)	· -	Seise $\sum_{i=1}^{n} S_i \cdot c_i$	mic $\left[\begin{array}{c} \gamma_{a}^{(i)}\\ -\gamma_{a}^{(i)}\end{array}\right]$	

C. Calculation method

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

- 1. calculation method,
- 2. load code combination \rightarrow 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.

💋 Calculations - ANSI/AISC 360-10						
Verification options						
Member verification:	1	List				
Code group verification:	12	List				
Code group <u>d</u> esign:	2	List				
Optimization	Options					
Loads	_	Limit state				
Cases: 1to5 8	List	✓ Ultimate				
Calculation archive	List	Serviceability				
OK Configur	ation <u>C</u> alcula	tions Help				

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

🗲 Configuration		×
Calculation points		ОК
Number of points:	3	
Characteristic points	Options	Cancel
Calculation parameters		
Efficiency ratio:	1.00	Help
Maximum <u>s</u> lenderness:		
Compression:	200.00	
Tension:	300.00	
Components of complex not taken into <u>a</u> ccount	x bars are	
Calculation methods		
<u>L</u> RFD	<u>A</u> SD	
Alternative verification met	hods:	
Elexure and compression	on [H1.3]	
Verification according t of [H1]	o [H2] instead	
Shear - "Tension field a	ection" [G3]	
Exclude internal forces fro	m calculations]
Units of results		
○ <u>C</u> ode ● <u>R</u>	obot	
Camber		
Take the deflections from following case into consistent of the second secon		
1 STA1	•	

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 :

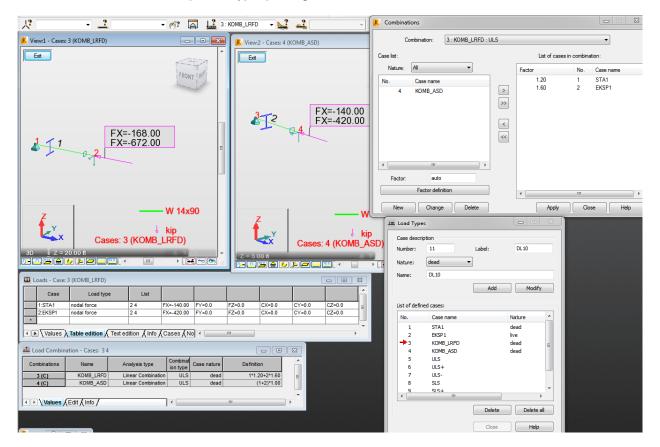
- 1st way expand *Design codes*, click on *Loads* tab from the left list view and choose proper load codes from combo box or from [*Configuration of Code List*] dialog box which is opened after pressing [*More codes…*] button
- 2nd way -- select earlier prepared job preferences by clicking its name from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

Han Job Preferences		? 💌
Units and Formats Materials Databases Design codes Loads Structure Analysis Work Parameters Meshing	SD_2010 <u>C</u> ode combinations: Snow/ <u>w</u> ind loads: <u>S</u> eismic loads:	ASD ASCE 7-10 ASD ASCE 7-10 ASD ASCE 7-10 LRFD ASD ACI318_2002 ACI318 LRFD LRFD LRFD ASCE 7-10 More
😤 Open defau	lt parameters	
🖳 <u>S</u> ave current par	ameters as default	OK Cancel Help

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.

Kiew - Cases: 3 (KOMB_LRFD)			🗲 Internal bracings	
Scalculations - ANSI/AISC 360-10	Member Definition - Parameters - ANSI/AISC 360-10	8	zł Buc	:kling Z 🛛 💟
Verification options Member verification:	Hende the man	lave		¥ 2
Code group verification: 12	Buckling (Y axis) Buckling (Z axis) C Member length ly: Member length lz:	lose		· ·
Code group design: 2	Real Real Coefficient Coefficient	ervice		
Qptimization Options	Buddes leasth coefficient V: Buddes leasth coefficient 7:	xe	1000	
Loads Limit state Cases: 3 List Vitimate	Ky: 1.00 E			30.00 m
Calculation archive	E Flexural-torsional buckling	feners		
Save calculation results	Lateral buckling parameters			
OK Configuration Galculations Help	Lateral buckling Lateral buckling Lateral buckling Lower flange			NT I I I I I I I I I I I I I I I I I I I
Definitions - ANSI/AISC 360-10	Cb: 1.00 (b)			
Members Groups	Seismic analysis parameters		Test for member: 1 _1	
Number: 1 • New	Seismic calculations - ANSI/AISC 341-10		Buckling Y Buckling Z Lateral buckling upper flange Lateral buckling is	
Basic data	System: [SMP] Special Moment Frames +		Define segments between bracings	Buckling coefficients of component segments
Barlist: 1	Element type: beam •	telp	Define manually coordinates of the existing bracings	Studure © Sway
Name: _1 Parameters			0.50 · L	h at to to to the Non-sway
C. Group: 1 • Member type: best •		_	🗇 real 🔹 relative	1.00, 1.00
OK Save Help			Add automatically coordinates of bracings	Bracing detection preview
)	_	i at points with adjoining elements in the buckling plane	For member no.: 1_1
7 1 1 1	FX=-168.00 W1	4x90	at all points where internal nodes are located	For load case: 1 STA1 +
	2 kip		at points where bending moments equal zero	۰۲.
	Cases: 3 (KOMB_LRFD))		
30 Z = 0.00 ft - 6			OK Cancel	Help
· · · · · · · · · · · · · · · · · · ·	,			2553
Loads - Case: 3 (KOMB_LRFD)		00		P
Case Load type List 1:STA1 nodal force 2.4 FX=-140.00 FY=0.0	Combinations Name Analysis type ation Case nature	Definition		
2.EXSP1 nodal force 2.4 FX=-420.00 FY=0.0	3(C) KOMB_LAFD Linear Combination ULS dead	1*1.20+2*1.6	e -	× 4
			Ų	
Values Table edition T C	Values (Edit (Info /			🗛 AUTODESK. 🖬

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.

Definitions - AN	SI/AISC 360-10	
Members Groups		
Number:	2 🔹	New
Basic data		
<u>B</u> ar list:	2	
Name:	_2	Parameters
C. Group: 2	✓ Member type:	Simple bar
		Simple bar
ОК	Save	- Column Beam
		Pret

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

Member Definition - Para	ameters - ANSI/AISC 360-10	×
Member type: Simple ba	r	Save
Buckling (Y axis) Member length ly:	Buckling (Z axis) Member length lz:	Close
 <u>Real</u> <u>Coefficient</u> 	 Real 1.00 Coefficient 	Service
Buckling length coefficient <u>Ky:</u> 1.00	Y: Budding length coefficient Z: Kz: 1.00 $\begin{bmatrix} 1\\ 1.0 \end{bmatrix}$	More
Flexural-torsional bucklin	g	Stiffeners
Lateral buckling parameters	Lateral buckling length coefficient	
Seismic analysis parameters		
	Special Moment Frames 👻	
Element type; Other	v	Help

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.

5 Buckling Diagrams	×
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	OK Cancel Help

Click second to last icon.

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

📁 Internal bracings Buckling Z z 0.5 30.00 Test for member: 1_1 Buckling Y Buckling Z Lateral buckling-upper flange Lateral buckling-lower flange Buckling coefficients of component segments Define segments between bracings Structure Define manually coordinates of the existing bracings Sway I I 0.5 2.0 T Ĩ 0.7 Î 1.0 0.50 •L Non-sway relative 🔘 real 1.00, 1.00 Add automatically coordinates of bracings Bracing detection preview logical at points with adjoining elements in the buckling plane For member no. 1 STA1 For load case: at all points where internal nodes are located •L at points where bending moments equal zero OK Cancel Help

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" :

Member Definition - Param	eters - ANSI/AISC 360-10	×
Member type: test		Save
Buckling (Y axis) Member length ly:	Buckling (Z axis) Member length lz:	Close
© <u>R</u> eal © <u>C</u> oefficient	© Real © Coefficient	<u>S</u> ervice
Buckling length coefficient Y:	Buckling length coefficient Z: Kz: Auto	<u>M</u> ore
Elexural-torsional buckling		<u>S</u> tiffeners
Lateral buckling parameters Lateral buckling Lateral buckling Lb: 1.00 Lb L0	Lateral buckling length coefficient Upper flange Lb = 1 Lb = 1 Lb = 1	
Seismic analysis parameters	NSC 341-10	
System: [SMF] Spe	cial Moment Frames 🔍	
Element type: Beam	•	
		Help

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

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

🗲 Definitions - ANSI/A	ISC 360-10	
Members Groups		
N <u>u</u> mber:	1 🔹	New
Basic data		
<u>B</u> ar list:	1	
<u>N</u> ame:	_1	Parameters
C. <u>G</u> roup: 1	✓ Membertype:	test 🔻
ОК	<u>S</u> ave	Help

In the CALCULATIONS dialog box set for this task:

• Verification option \rightarrow Member Verification

Calculations - ANSI/AISC 360-10

Verification options

Member verification:

Code group <u>d</u>esign:

Optimization

Loads

Code group 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 box, opened by [Configuration] button.

1

12

1

Options

🗲 Configuration		×
Calculation points <u>N</u> umber of points: Characteristic points	Deptions	OK Cancel
Calculation parameters Efficiency ratio:	1.000	Help
Maximum <u>s</u> lendemess: Compression: T <u>e</u> nsion: Components of complex not taken into account	200.000 300.000 t bars are	
Calculation methods LRFD Alternative verification methods 	<u>A</u> SD nods:	
Eexure and compressio Verification according to of [H1] Shear - "Tension field a	[H2] instead	
Exclude internal forces from	m calculations	
© Code Ro Camber Take the deflections fro following case into cons 1 STA1	m the	

 Cases:
 3
 List

 Calculation archive
 Image: Calculation results
 Image: Calculation results

 Save calculation results
 Image: Calculation results
 Image: Calculation results

 OK
 Configuration
 Calculations
 Help

Now, start calculations by pressing Calculations button.

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

Limit state

List

List

List

1	ANSI/AISC 360-	-10 - Member Ver	ification (ULS) 1					
	Results Message	S						Calc. Note Close
IJ	Member	Section	Material	Lay	Laz	Ratio	Case	Help
l	1_1	W 14x90	STEEL A992-50	58.63	48.70	0.91	3 KOMB_LRFD	Ratio
								Analysis Map
								Calculation points Division: n = 3 Extremes: none Additional: none

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

KESULTS - Code - ANSI/AISC 360-10		X
Auto Bar: 1_1 W 14x90 Image: Normalized Coordinate: Load case:	Section OK 1 / x = 0.00 L = 0.00 ft 3 KOMB_LRFD 1*1.20+2*1.60	ОК
Simplified results Detailed results		Change
Ky = 1.00	Lz = 15.00 ft Kz = 1.00 KLz/rz = 48.70 DESIGN STRENGTHS Fic*Pn = 927.45 kip	Forces
SAFETY FACTORS	SECTION ELEMENTS Range = Nonslender Web = Nonslender	Calc. Note
RESULTS Pr/(Fic*Pn) = 0.91 < 1.00 LRFD (H1-1a)		Help
Ky*Ly/ry = 58.63 < (K*L/r),max = 200.00 Kz*Lz/rz =	= 48.70 < (K*L/r),max = 200.00 STABLE	

Detailed results tab

RESULTS - Co	de - ANSI/AISC	360-10				
V 14x90	Auto	Bar: Point / Coo Load case:		Section OK	• • •	ОК
implified results	Detailed results	3				<u>C</u> hange
Symbol	Values	Unit	Symbol description	Section	~	
ClassF_N	Nonslender		Flange class	[Table B4.1a]	1	
Lamw_r_N	35.88		Limiting slenderness for nonslender web	[Table B4.1a]	1	
ClassW_N	Nonslender		Web class	[Table B4.1a]	1	<u>Forces</u>
			rameters of buckling analysis:			
About the Y	axis of cross-s					
Ly	30.00	ft	Laterally unbraced buckling length	[E2]		
Ку	1.00		Effective buckling length coefficient	[E2]	=	
Ky*Ly/ry	58.63		Buckling slenderness of a member	[E2]		Calc. Note
Fey	83.26	ksi	Elastic critical buckling stress	[E3]		
Fory	38.89	ksi	Critical flexural buckling stress	[E3]		
Pny	1030.50	kip	Nominal compressive strength of a member	[E3]		
About the Z	axis of cross-s	ection				Help
Lz	15.00	ft	Laterally unbraced buckling length	[E2]	-	· · ·

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.

	STEEI	DESIGN	4
CODE: ANSI/A ANALYSIS TYPE: Men		an National Standard, Ju	une 22, 2010
CODE GROUP: MEMBER: 1_1	POINT: 1	COORD	INATE: $x = 0.00 L = 0.00 ft$
LOADS: Governing Load Case: 3	KOMB_LRFD 1*1.20+2*	*1.60	
MATERIAL: STEEL A992-50 Fy = 50	0.00 ksi Fu = 65.00 ksi	E = 29000.00 ksi	
	AMETERS: W14x90		
d=14.00 in	Ay=20.590 in2	Az=6.160 in2	Ax=26.500 in2
bf=14.50 in tw=0.44 in	Iy=999.000 in4	Iz=362.000 in4 Sz=49.931 in3	J=4.060 in4
tf=0.71 in	Sy=142.714 in3 Zy=157.000 in3	Zz=75.600 in3	E
MEMBER PARAMETER	S:		
1	1		
	Lz = 15.00 ft		
Ky = 1.00 KLy/ry = 58.63	$K_z = 1.00$		
KLy/fy = 38.03	KLz/rz = 48.70		
INTERNAL FORCES: Pr = 840.00 kip		DESIGN STRENG Fic*Pn = 927.45 kip	THS
SAFETY FACTORS	Fic = 0.90		
SECTION ELEMENTS: Flange = Nonslender	Web = Nonslender		
VERIFICATION FORMU Pr/(Fic*Pn) = 0.91 < 1.00 J Ky*Ly/ry = 58.63 < (K*L/r	LRFD (H1-1a) Verified	z/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.

Auto Bar: 1_1 W.12x87 Load case: Load case:	Incorrect section	ОК
Simplified results Detailed results		Chan
Ky = 1.00 K	z = 15.00 ft z = 1.00 Lz/rz = 58.67 DESIGN STRENGTHS Fic*Pn = 830.01 kip	<u>F</u> orce
SAFETY FACTORS Fic = 0.90	SECTION ELEMENTS Range = Nonslender Web = Nonslender	C <u>a</u> lc. N
RESULTS Pr/(Fic*Pn) = 1.01 > 1.00 LRFD (H1-1a) Ky*Ly/ry = 66.96 < (K*L/r),max = 200.00 Kz*Lz/rz =	58.67 < (K*L/r),max = 200.00 STABLE	Help

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

	STEEL	DESIGN	
CODE: ANSI/A ANALYSIS TYPE: Mem		n National Standard, Ju	ne 22, 2010
CODE GROUP: MEMBER: 1_1	POINT: 1	COORDI	NATE: 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	0.00 ksi Fu = 65.00 ksi	E = 29000.00 ksi	
SECTION PAR	AMETERS: 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 PARAMETER	S:		
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 STRENGT Fic*Pn = 830.01 kip	THS
SAFETY FACTORS	Fic = 0.90		
SECTION ELEMENTS: Flange = Nonslender	Web = Nonslender		
VERIFICATION FORMU Pr/(Fic*Pn) = 1.01 > 1.00 I Ky*Ly/ry = 66.96 < (K*L/r	LRFD (H1-1a) Not verifie		= 200.00 STABLE

Incorrect section !!!

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

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

Simplified results tab

FRESULTS - Code - ANSI/AISC 360-10		X
Auto Bar: 1_1 W 14x90 Load case: 4 k	Section OK	ОК
Simplified results Detailed results		Change
Ky = 1.00 Kz =	15.00 ft 1.00 rz = 48.70 ALLOWABLE STRENGTHS Pn/Omc = 617.07 kip	<u>F</u> orces
RESISTANCE FACTORS Omc = 1.67	SECTION ELEMENTS Range = Nonslender Web = Nonslender	Calc. Note
RESULTS Pr/(Pn/Omc) = 0.91 < 1.00 ASD (H1-1a) Ky*Ly/ry = 58.63 < (K*L/r),max = 200.00 Kz*Lz/rz = 48.7	70 < (K*L/r),max = 200.00 STABLE	Help

Detailed results tab

RESULTS - Co	ode - ANSI/AISC	360-10				- C X
W 14x90	Auto	Bar: Point / Coo Load case:		Section OK	• • •	ОК
Simplified results	3 Detailed results	;				Change
Symbol	Values	Unit	Symbol description	Section		
rz	3.70	in	Radius of gyration - Z-axis			
			Material:			<u>F</u> orces
Name	ļ		STEEL A992-50			
Fy	50.00	ksi	Specified minimum yield strength of material		=	
Fu	65.00	ksi	Specified minimum tensile strength			
E	29000.00	ksi	Longitudinal elasticity coefficient			
		А	llowable stress method ASD			Calc. Note
Omc	1.67		Safety factor for compression	[E1]		
			Local buckling			
				TT-bls D4 4- bl		
Lamf	10.21		Width-thickness ratio for a flange	[Table B4.1a,b]		Help

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

		STEEL	DESIGN	
CODE: ANALYSIS TYPE			an National Standard, J	lune 22, 2010
CODE GROUP: MEMBER: 1_1		POINT: 1	COORD	DINATE: x = 0.00 L = 0.00 ft
LOADS: Governing Load C	Case: 4 KOMB_	ASD (1+2)*1.00		
MATERIAL: STEEL A992-50	Fy = 50.00 ksi	Fu = 65.00 ksi	E = 29000.00 ksi	
SECTIO		S. W 14+00		
d=14.00 in		.590 in2	Az=6.160 in2	Ax=26.500 in2
bf=14.50 in	-		Iz=362.000 in4	J=4.060 in4
tw=0.44 in			Sz=49.931 in3	
tf=0.71 in	Zy=15	7.000 in3	Zz=75.600 in3	
MEMBER PARA Ly = 30.00 ft Ky = 1.00 KLy/ry = 58.63	Lz = 15 Kz = 1	.00		
INTERNAL FOR Pr = 560.00 kip	CES:		ALLOWABLE STI Pn/Omc = 617.07 kip	
RESISTANCE FA	ACTORS Omc =	1.67		
SECTION ELEM Flange = Nonslend		Nonslender		
VERIFICATION I Pr/(Pn/Omc) = 0.91 Ky*Ly/ry = 58.63 <	<1.00 ASD (H		z/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 W18x50 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.

人 104	5 Internal bracings
Verw - Castes 3 (KOMB_LR5D) Calculations - ANSI/ASC 360-10 Vertication optiona Member vertication: 1 Code grap, design: Code grap, design: Code grap, design: Code grap, design: List Code grap, design: Code grap, design: List Code grap, design: List Code (Code	
Cenes 3 Lati V Ulimate Index (r stal) Dubring (r stal) Dubring (r stal) Caluation and/w Swe caluation musta Lati V Swe caluation 0 Read 1.000 OK Configuration Edulations Help Kr Loop Kr Kr Loop V Personal turnional building Software Software Software Software	Test for member: 1 beam_1
Later al buckling parameters Under a buckling Later al buckling	Define segments between bracings Buckding coefficients of component segments ID office sexually coefficients of component segments Image: Component segments ID office sexually coefficients of component segments Image: Component segments Image: Component segment segm
Image: Contraction of the dedicon of the form of the dedicon	on ULS dead (1+2)*1.000 Barlist: 1

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.

1 Definitions - ANSI	AISC 360-10	
Members Groups		
Number: Basic data	1 •	New
<u>B</u> ar list:	1	
<u>N</u> ame:	beam_1	Parameters
C. <u>G</u> roup: 1	▼ Member type:	Simple bar
ОК	Save	Column Beam Pret

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

Member type: S	mple bar	Save
Buckling (Y axis) Member lengt	Buckling (Z axis) h ly: Member length lz:	Close
○ <u>R</u> eal	000 © R <u>e</u> al 000 © C <u>o</u> efficient	Service
Buckling length coe	fficient Y: Buckling length coefficient Z $\hat{1}_{10}$ $K_{\underline{Z}}$: 1.000	<u>M</u> ore
Flexural-torsiona	l buckling	Stiffeners
Lateral buckling para		
🔽 Lateral buckli		
<u>C</u> b: 1.000	Upper flange Lower flange Lb Lb = I	J
Seismic analysis para	ameters	
Seismic calculatio	ns - ANSI/AISC 341-10	
System:	[SMF] Special Moment Frames	-
Element type:	Other	

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 :

📁 Parameter Cb	×
	OK Cancel Help

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

• define bracings for Lateral buckling and Buckling Z.

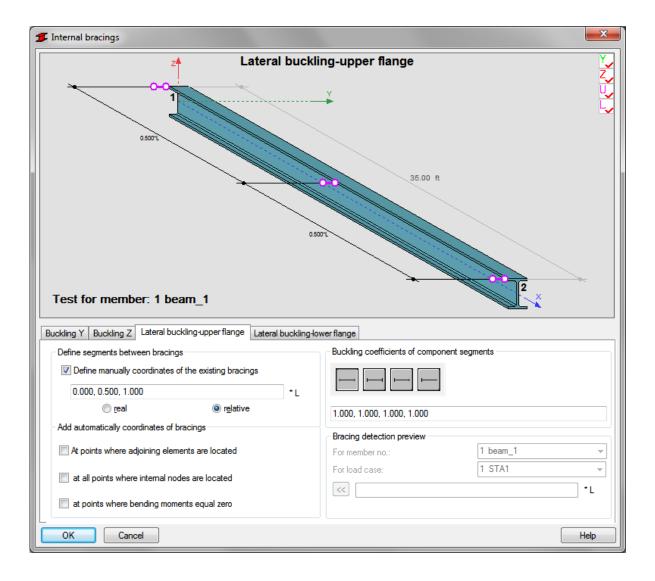
To define *Lateral buckling length coefficient* for this structure, press *Upper flange* button. It opens LATERAL BUCKLING LENGTH COEFFICIENTS dialog box.

🗲 Lateral buckling length coefficients 🔜				
	Lb = 21	ОК		
	LD = 21	Cancel		
	Lb = I	Help		
	Lb = 0.51			
	Lb 1.000 I			
X				
I	Intermediate bracings			

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.

	Member Definition - Parameters - ANSI/AISC 360-10	×
Save the newly-created		
member type,	Member type: LB 0,5l_up	Save
e.g. as "LB 0,5l up"	Buckling (Y axis) Buckling (Z axis) Member length ly: Member length lz: Real 0.000 © Coefficient 0.000	Close <u>S</u> ervice
	Buckling length coefficient Y: Buckling length coefficient Z: Ky: Auto Sway Sway	More
	Flexural-torsional buckling	Stiffeners
	Lateral buckling parameters Lateral buckling Lateral buckling Lateral buckling length coefficient Lateral buckling Lateral buckling length coefficient Cb: Cb(Mi) Cb: Cb(Mi) Lateral buckling Lower flange Id = (Id1,Id2,) Lb = I	
	Seismic analysis parameters	
	Seismic calculations - ANSI/AISC 341-10	
	System: [SMF] Special Moment Frames	
	Element type: Beam	
		Help

Number of the member must be assigned to the appropriate name of <i>Member type</i> .	Definitions - ANSI/ Members Groups	/AISC 360-10	
(It is very important when you verify different member types.)	N <u>u</u> mber: Basic data <u>B</u> ar list: <u>N</u> ame: C. <u>G</u> roup: 1 OK	1 beam_1 Member type: <u>S</u> ave	N <u>e</u> w Parameters LB 0.51_up ▼ Help

5 Configuration

Calculation points

Number of points:

3

*

In the CALCULATIONS dialog box set for this task :

• Verification option \rightarrow Member Verification

1

- Loads cases \rightarrow for LRFD design (defined as n° 3)
- Lin ana
- Ca in [Co

	<i>mit state</i> \rightarrow only Ultimate Limit state will be nalyzed so switch off <i>Limit stat Serviceability</i> .			Options	Cancel
alculation method \rightarrow switch on LRFD radio button \cap CONFIGURATION dialog box, opened by			Calculation parameters Efficiency <u>r</u> atio:	1.000	Help
Configuration] button.	2	- 1	Maximum <u>s</u> lenderness:		
			Compression:	200.000	
			Tension:	300.000	
			Components of complex not taken into <u>a</u> ccount	c bars are	
Coloulations ANGLIATEC	260.10	n	Calculation methods		
Calculations - ANSI/AISC	360-10			<u>A</u> SD	
Verification options			Alternative verification meth	nods:	
Member verification:	1 List		Eexure and compressio	n [H1.3]	
Code group verification:	12 List	Ш	Verification according to of [H1]	o [H2] instead	
Code group <u>d</u> esign:	1 List	Ш	Shear - "Tension <u>f</u> ield a	ction" [G3]	
Optimization	Options	Ш	Exclude internal forces from	m calculations	
Loads	Limit state		Units of results		
Cases: 3	List VItimate	ш	© <u>C</u> ode ● <u>R</u> o	bot	
Calculation archive	List		Camber <u>Take the deflections fro</u> following case into cons		
OK	ation Calculations Help		1 STA1	•	

Now, start verifications by pressing [Calculations] button.

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

1	🕼 ANSI/AISC 360-10 - Member Verification (ULS) 1							
IF	Results Messag	es						Calc. Note Close
	Member	Section	Material	Lay	Laz	Ratio	Case	Help
Ш	1 beam_1	W18X50	STEEL A992-50	56.933	254.294	0.925	3 KOMB_LRFD	Ratio
								Analysis Map
								Calculation points
								Division: n = 3
								Extremes: none Additional: none
]

- 22

OK

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

1 RESULTS - Code - ANSI/AISC 360-10	RESULTS - Code - ANSI/AISC 360-10				
Auto Bar: 1 beam_1 W18X50 Image: With the second se					
Simplified results Detailed results	Change				
MEMBER PARAMETERS Ly = 35.00 ft Ly = 35.00 ft Kz = 35.00 ft Kz = 1.000 Kz = 1.000 KLz/rz = 254.294 KLz/rz = 254.294 DESIGN S	Lb = 17.50 ft Cb = 1.299				
Mry = 266.44 kip*ft Fib*Mny =	= 287.97 kip"ft				
	ELEMENTS Compact Web = Compact Calc. Note				
Mry/(Fib*Mny) = 0.925 < 1.000 LRFD (H1-1b)	Help				

Detailed results tab

RESULTS - Cod	ESULTS - Code - ANSI/AISC 360-10					
V18X50	Auto	Bar: Point / Coo Load case:	1 beam_1 rdinate: 2 / x = 0.50 L = 17.50 ft	ction OK	• •	ОК
implified results	Detailed results	;				<u>C</u> hange
Symbol	Values	Unit	Symbol description	Section	^	
	Nominal strengths:					
About the Y axis of cross-section						
About the Y a	axis of cross-s	ection				<u>F</u> orces
About the Y a	axis of cross-s 420.83	ection kip*ft	Nominal plastic bending moment	[F]		<u>F</u> orces
			Nominal plastic bending moment Nominal flexural strength in the limit state of yielding	[F] [F2.1]		<u>F</u> orces
Мру	420.83	kip*ft	· · ·			Forces
Mpy Mny[YD]	420.83 420.83	kip*ft kip*ft	Nominal flexural strength in the limit state of yielding	[F2.1]		Forces
Mpy Mny[YD] Mny[LTB]	420.83 420.83 319.97	kip*ft kip*ft kip*ft	Nominal flexural strength in the limit state of yielding Nominal lateral-torsional buckling strength	[F2.1] [F2.2]		<u>F</u> orces
Mpy Mny[YD] Mny[LTB] Mny1[LTB]	420.83 420.83 319.97 246.38	kip*ft kip*ft kip*ft kip*ft	Nominal flexural strength in the limit state of yielding Nominal lateral-torsional buckling strength Nominal lateral-torsional buckling strength (Cb = 1.0)	[F2.1] [F2.2] [F2.2]		
Mpy Mny[YD] Mny[LTB] Mny1[LTB] Mny	420.83 420.83 319.97 246.38	kip*ft kip*ft kip*ft kip*ft kip*ft	Nominal flexural strength in the limit state of yielding Nominal lateral-torsional buckling strength Nominal lateral-torsional buckling strength (Cb = 1.0) Nominal flexural strength	[F2.1] [F2.2] [F2.2]		
Mpy Mny[YD] Mny[LTB] Mny1[LTB] Mny	420.83 420.83 319.97 246.38 319.97	kip*ft kip*ft kip*ft kip*ft kip*ft	Nominal flexural strength in the limit state of yielding Nominal lateral-torsional buckling strength Nominal lateral-torsional buckling strength (Cb = 1.0) Nominal flexural strength	[F2.1] [F2.2] [F2.2]		
Mpy Mny[YD] Mny[LTB] Mny1[LTB] Mny About the Y a	420.83 420.83 319.97 246.38 319.97 xxis of cross-s	kip*ft kip*ft kip*ft kip*ft kip*ft ection	Nominal flexural strength in the limit state of yielding Nominal lateral-torsional buckling strength Nominal lateral-torsional buckling strength (Cb = 1.0) Nominal flexural strength Design strengths:	[F2.1] [F2.2] [F2.2] [F2]		Eorces

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:

CODE: ANSI/A ANALYSIS TYPE: Mem		n National Standard, June 2	2, 2010
CODE GROUP: MEMBER: 1 beam_1	POINT: 2	COORDINAT	E: x = 0.50 L = 17.50 f
LOADS: Governing Load Case: 3	KOMB_LRFD 1*1.200+2	2*1.600	
MATERIAL: STEEL A992-50 Fy = 50	0.00 ksi Fu = 65.00 ksi	E = 29000.00 ksi	
	AMETERS: 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 tf=0.57 in	Sy=88.938 in3 Zy=101.000 in3	Sz=10.700 in3 Zz=17.000 in3	
MEMBER PARAMETER	 S:		
\mathbf{X}	X	Ch Ch	
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 FORMU Mry/(Fib*Mny) = 0.925 < 1		ified	

RESULTS for ASD method:

1	ANSI/AISC 360-10 - Member Verification (ULS) 1							
	Results Messa	iges						Calc. Note Close
	Member	Section	Material	Lay	Laz	Ratio	Case	Help
	1 beam_1	W18X50	STEEL A992-50	56.933	254.294	0.959	4 KOMB_ASD	Ratio
								Analysis Map
								Calculation points Division: n = 3
								Extremes: none
								Additional: none
Ľ								1

Simplified results tab

Auto Bar: 1 beam_1 W18X50 ▼	Section OK	ОК
Simplified results Detailed results		<u>C</u> hange
Ky = 1.000	Lz = 35.00 ft Kz = 1.000 KLz/rz = 254.294 ALLOWABLE STRENGTHS Mny/Omb = 191.60 kip ft	Forces
RESISTANCE FACTORS Omb = 1.670	SECTION ELEMENTS Flange = Compact Web = Compact	Calc. Note
RESULTS Mry/(Mny/Omb) = 0.959 < 1.000 ASD (H1-1b)		Help

Detailed results tab

ESULTS - Code - ANSI/AISC 360-10						
V18X50	<u>A</u> uto	Bar: 1 Point / Coor Load case:	beam_1 dinate: 2 / x = 0.50 L = 17.50 ft 4 KOMB_ASD (1+2)*1.000	Section OK	• • •	ОК
implified results	Detailed results	3				Change
Symbol	Values	Unit	Symbol description	Section	*	
		AI	lowable stress method ASD			
Omb	1.670		Safety factor for flexure	[F1.(1)]		<u>F</u> orces
			Local buckling		_	
Lamf	6.575		Width-thickness ratio for a flange	[Table B4.1a,b]	≡	
Lamw	45.211		Width-thickness ratio for a web	[Table B4.1a,b]		
Section class	for simple be	ending (My m	noment)			
Lamf_p_My	9.152		Limiting slenderness for compact flange	[Table B4.1b]		Calc. Note
Lamf_r_My	24.083		Limiting slenderness for noncompact flange	[Table B4.1b]		
ClassF_My	Compact		Flange class	[Table B4.1b]		
Lamw_p_My	90.553		Limiting slenderness for compact web	[Table B4.1b]		
	137.274		Limiting slenderness for noncompact web	[Table B4.1b]		Help
Lamw_r_My	101.214					

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/A ANALYSIS TYPE: Mem		an National Standard, Ju	une 22, 2010
CODE GROUP: MEMBER: 1 beam_1	POINT: 2	COORD	INATE: x = 0.50 L = 17.50 ft
LOADS: Governing Load Case: 4	KOMB_ASD (1+2)*1.00	0	
MATERIAL: STEEL A992-50 Fy = 50	0.00 ksi Fu = 65.00 ksi	E = 29000.00 ksi	
	AMETERS: 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 PARAMETER	S:		
\mathbf{X}	\mathbf{X}	СЬ	
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 STF Mny/Omb = 191.601	
RESISTANCE FACTOR Omb = 1.670	S		
SECTION ELEMENTS: Flange = Compact	Web = Compact		
VERIFICATION FORMU Mry/(Mny/Omb) = 0.959 <		rified	
Section OK !!!			

COMPARISON:

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

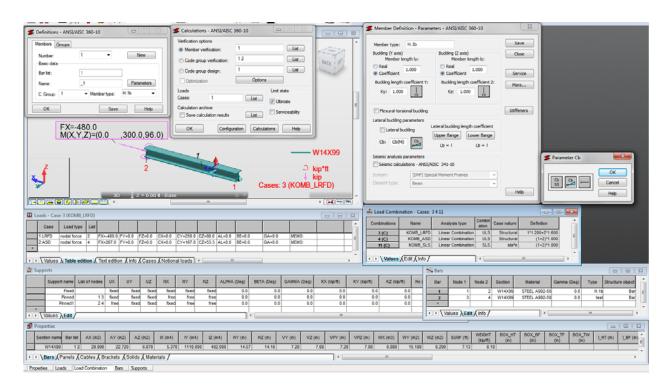
Example H.1 b -- W-shape Subjected to Combined Compression and Bending About Both Axes (braced frame).

SPECIFICATION:

Verify if an ASTM A992 W14x99 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
<i>Pu</i> = 400 kips	<i>Pa</i> = 267 kips
<i>Mux</i> = 250 kip-ft	<i>Max</i> = 167 kip-ft
<i>Muy</i> = 80.0 kip-ft	<i>May</i> = 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.

🗲 Definitions - ANSI	/AISC 360-10	
Members Groups		
Number:	1 •	New
Basic data Bar list:	1	
Name:	beam_1	Parameters
		Simple bar
C. <u>G</u> roup: 1	 Member type: 	Simple bar
ОК	<u>S</u> ave	Column Beam Pret

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:

Member Definit	ion - Paramet	ters - ANSI/AISC 360-10	×			
Member type:	H. 1b		Save			
Buckling (Y axis) Member len	gth ly:	Buckling (Z axis) Member length lz:	Close			
○ <u>R</u> eal Or Coefficient	1.000	© R <u>e</u> al	Service			
Buckling length o	Defficient Y:	Buckling length coefficient Z: Kz: 1.000	<u>M</u> ore			
E Flexural-torsio	nal buckling		Stiffeners			
Lateral buckling parameters Lateral buckling Lateral buckling length coefficient Upper flange Lower flange Cb: Cb(Mi) Lb Lb						
Seismic analysis pa		SC 341-10				
System:	[SMF] Speci	al Moment Frames 🔍				
Element type:	Beam		Help			

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).

Definitions - ANSI/AISC 360-10						
Members Groups						
N <u>u</u> mber:	1 -	New				
Basic data						
<u>B</u> ar list:	1					
<u>N</u> ame:	beam_1	Parameters				
C. <u>G</u> roup: 1	 Member type: 	H.1b 👻				
ОК	<u>S</u> ave	Help				

In the CALCULATIONS dialog box set for this task :

Verification option NMember Verification	T Configuration
 Verification option → Member Verification 	Calculation points
 Loads cases → for LRFD design (defined as n° 1) 	Number of points:
 Limit state → only Ultimate Limit state will be analyzed so switch off Limit stat Serviceability. 	Cancel
 Calculation method → switch on LRFD radio button 	Calculation parameters Help
in CONFIGURATION dialog box, opened by	Efficiency ratio: 1.000
[Configuration] button.	Maximum <u>s</u> lendemess:
	Compression: 200.000
	Tension: 300.000
	Components of complex bars are not taken into <u>a</u> ccount
Calculations - ANSI/AISC 260-10	Calculation methods
Calculations - ANSI/AISC 360-10	
Verification options	Alternative verification methods:
<u>Member verification:</u>	Exure and compression [H1.3]
Code group verification:	Verification according to [H2] instead of [H1]
Code group <u>d</u> esign: 1	Shear - "Tension <u>f</u> ield action" [G3]
Optimization Options	
Loads	Exclude internal forces from calculations
	Units of results
<u>U</u> timate	© <u>C</u> ode
Calculation archive	Camber
Save calculation results	Take the deflections from the following case into consideration:
OK Configuration Calculations Help	1 STA1 👻

Now, start verifications by pressing [Calculations] button.

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

1	ANSI/AISC 360-10 - Member Verification (ULS) 1									
	Results Mes	sages	Calc. Note Close							
J.	Member	Section	Material	Lay	Laz	Ratio	Case	Help		
L	1 beam_1	W 14x99	STEEL A992-50	27.202	45.200	0.928	1 LRFD	Ratio		
l								Analysis Map		
l								Calculation points Division: n = 3		
L								Extremes: none		
								Additional: none		

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

RESULTS - Code - ANSI/AISC 360-10			
14 14 00	3 / x = 1.00 L = 14.00 ft	Section OK	
V 14x39 Load case:	1 LRFD		
Simplified results Detailed results			<u>C</u> hange
MEMBER PARAMETERS]
	= 14.00 ft		
1.0 .0	= 1.000 z/rz = 45.200		
INTERNAL FORCES:	DESIGN STRENGTHS		Forces
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	SECTION ELEMENTS		
Fic = 0.900 Fib = 0.900 Fiv = 0.900	Flange = Non-compact	Web = Compact	Calc. Note
RESULTS			
Pr/(Fic*Pn) + 8/9*(Mry/(Fib*Mny) + Mrz/(Fib*Mnz)) = 0.928	< 1.000 LRFD (H1-1a)		
Vry/(Fiv*Vny) = 0.009 < 1.000 Vrz/(1.000*Vnz) = 0.086 <			Help
Ky*Ly/ry = 27.202 < (K*L/r),max = 200.000 Kz*Lz/rz =	= 45.200 < (K*L/r),max = 200.000 S	TABLE	Lineip

Detailed results tab

RESULTS - Cod	ESULTS - Code - ANSI/AISC 360-10						
Auto Bar: 1 beam_1 Point / Coordinate: 3 / x = 1.00 L = 14.00 ft Load case: 1 LRFD							
Simplified results	Detailed results	;				Change	
Symbol	Values	Unit	Symbol description	Section	^		
			Nominal strengths:				
Pn	1253.1	kip	Nominal compressive strength	[E3]]	<u>F</u> orces	
About the Y a	axis of cross-s	ection					
Мру	720.8	kip*ft	Nominal plastic bending moment	[F]]		
Mny[YD]	720.8	kip*ft	Nominal flexural strength in the limit state of yielding	[F3.1]			
Mny[FLB]	717.2	kip*ft	Nominal strength for local buckling of a compression flan	[F3.2]			
Mny	717.2	kip*ft	Nominal flexural strength	[F3]	1		
			Nominal shear strength	[G2.1]	1	Calc. Note	
Vnz	206.6	kip	Nominal shear su engui	[62.1]			
	206.6 axis of cross-s		Nonima Shear Sulengui	[02.1]	Ξ	<u>i</u>	
			Nominal plastic bending moment	[62.1] [F]		<u>(</u>	
About the Z a	axis of cross-s	ection	-			(
About the Z a	axis of cross-s 348.3	ection kip*ft	Nominal plastic bending moment Nominal flexural strength in the limit state of yielding	(F)		Help	

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/A ANALYSIS TYPE: Men		can National Standard, June 22	2, 2010
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	0.0 ksi Fu = 65.0 ksi	E = 29000.0 ksi	
SECTION PAR	AMETERS: 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 PARAMETER	Î 1.0		
Ly = 14.00 ft Ky = 1.000	Lz = 14.00 ft Kz = 1.000		
$K_y = 1.000$ $K_y = 27.202$	KLz/rz = 45.200		
INTERNAL FORCES: Pr = 400.0 kip		DE SIGN STRENGTHS Fic*Pn = 1127.8 kip	
Mry = -250.0 kip*ft Mrz = -80.0 kip*ft	Vry = 5.7 kip Vrz = -17.9 kip	Fib*Mny = 645.4 kip*ft Fib*Mnz = 311.2 kip*ft	Fiv*Vny = 615.0 kip 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 FORMU	JLAS: ib*Mny) + Mrz/(Fib*M 000 LRFD (G2-1) Veri 1.000 LRFD (G2-1) Veri		-
~ · · · · · · · · · · · · · · · · · · ·			

Section OK !!!

RESULTS for ASD method:

1	ANSI/AISC 360-10 - Member Verification (ULS) 2									
	Results Mess	ages						Calc. Note Close		
	Member	Section	Material	Lay	Laz	Ratio	Case	Help		
	2_2	W 14x99	STEEL A992-50	27.202	45.200	0.930	2 ASD			
								Analysis Map		
L								Calculation points		
								Division: n = 3 Extremes: none		
								Extremes: none Additional: none		

Simplified results tab

14/14/00	3 / x = 1.00 L = 14.00 ft 2 ASD	Section OK	ОК
Simplified results Detailed results			Change
	r = 14.00 ft		
1.0 1.0	2 = 1.000 .z/rz = 45.200		F arras
INTERNAL FORCES:	ALLOWABLE STRENGTHS		<u>F</u> orces
Pr = 267.0 kip	Pn/Omc = 750.4 kip		
Mry = -167.0 kip*ft Vry = 3.8 kip Mrz = -53.3 kip*ft Vrz = -11.9 kip	Mny/Omb = 429.4 kip*ft Mnz/Omb = 207.0 kip*ft	Vny/Omv = 409.1 kip Vnz/1.500 = 137.7 kip	
RESISTANCE FACTORS	SECTION ELEMENTS		
Omc = 1.670 Omb = 1.670 Omv = 1.670	Flange = Non-compact	Web = Compact	Calc. Note
RESULTS			
Pr/(Pn/Omc) + 8/9*(Mry/(Mny/Omb) + Mrz/(Mnz/Omb)) = Vry/(Vny/Omv) = 0.009 < 1.000 Vrz/(Vnz/1.500) = 0.087			Help

Detailed results tab

RESULTS - Coo	de - ANSI/AISC	360-10				-
V 14x99	Auto	Bar: 2 Point / Coor Load case:	_2	on OK	° ♦	ОК
implified results	Detailed results	;				<u>C</u> hange
Symbol	Values	Unit	Symbol description	Section	^	
Pn	1253.1	kip	Nominal compressive strength	[E3]	1	Forces
About the Y	axis of cross-s	ection		-		roices
Мру	720.8	kip*ft	Nominal plastic bending moment	[F]		
Mny[YD]	720.8	kip*ft	Nominal flexural strength in the limit state of yielding	[F3.1]		
Mny[FLB]	717.2	kip*ft	Nominal strength for local buckling of a compression flan	[F3.2]		
Mny	717.2	kip*ft	Nominal flexural strength	[F3]		
Vnz	206.6	kip	Nominal shear strength	[G2.1]	1	
About the Z	axis of cross-s	ection				Calc. Note
		kip*ft	Nominal plastic bending moment	(F)	Ξ	
Mpz	348.3	Kip it				
Mpz Mnz[YD]	348.3 348.3	kip*ft	Nominal flexural strength in the limit state of yielding	[F6]		
			Nominal flexural strength in the limit state of yielding			
Mnz[YD]	348.3	kip*ft	Nominal flexural strength in the limit state of yielding	[F6]		Help

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/A ANALYSIS TYPE: Men		an National Standard, June 22	2, 2010
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	0.0 ksi Fu = 65.0 ksi	E = 29000.0 ksi	
	AMETERS: W14x99		
d=14.200 in	Ay=22.78 in2	Az=6.89 in2	Ax=29.10 in2
bf=14.600 in tw=0.485 in	Iy=1110.00 in4 Sy=156.34 in3	Iz=402.00 in4 Sz=55.07 in3	J=5.37 in4
tf=0.780 in	Zy=173.00 in3	Zz=83.60 in3	
MEMBER PARAMETER	S: 10 Lz = 14.00 ft Kz = 1.000 KLz/rz = 45.200		
INTERNAL FORCES: Pr = 267.0 kip		ALLOWABLE STRENG Pn/Omc = 750.4 kip	IHS
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 FACTOR Omb = 1.670	S Omc = 1.670	Omv = 1.670	
SECTION ELEMENTS: Flange = Non-compact	Web = Compact		
VERIFICATION FORMU Pr/(Pn/Omc) + 8/9*(Mry/(I Vry/(Vny/Omv) = 0.009 < 1 Vrz/(Vnz/1.500) = 0.087 < 1 Ky*Ly/ry = 27.202 < (K*L	Mny/Omb) + Mrz/(Mnz/C 1.000 ASD (G2-1) Verifie .000 ASD (G2-1) Verifie		-
Section OK !!!			

COMPARISON:

verifications parameters, interaction ex	pression	Robot	Handbook
LRFD Fib=0.90			
- Required compressive strength [kips] - Design compressive strength [kips]	Pr Fic*P _n Pr < Fic*P _n	400 1127,8 400< 1127,8	400 1130 400< 1130
 Required flexural strength [kip*ft] Design compressive strength [kip*ft] 	M _{ry} ; M _{rz} Fic*M _{ny ;} Fic*M _{nz}	250 ; 80 <u>645,4</u> ; 311,2	250 ; 80 <u>642</u> ; 311
	M _{ry} < Fib* M _{ny} M _{rz} < Fib* M _{nz}	250 < <u>645,4</u> 80 < 311,2	250 < <u>642</u> 80 < 311
interaction expression for Pr / (Fic*Pn) > 0,2	Mry / (Fib*Mny) Mrz / (Fib*Mnz)	0,355 0,387 0,257	0,354 0,389 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] - Design compressive strength [kips]	P _r P _n /Omc P _r < P _n /Omc	267 750,4 267 < 750,4	267 750 267 < 750
 Required flexural strength [kip*ft] Design compressive strength [kip*ft] 	$M_{ry}; M_{rz}$ $M_{ny}/Omc; M_{nz}/Omc$ $M_{ry} < M_{ny} / Omc$ $M_{rz} < M_{nz} / Omc$	167 ; 53,3 <u>429,4</u> ; 207,0 167 < <u>429,4</u> 53,3 < 207,0	167 ; 53,3 <u>428</u> ; 207 167 < <u>428</u> 53,3 < 207
interaction expression for Pr / (P _n /Omc) > 0,2	M _{ry} / (M _{ny} /Omc) M _{rz} /(M _{nz} /Omc)	0,356 0,389 0,257	0,356 0,390 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 .

	TENSION		
MAN ex D1.rtd	W-Shape Tension Member - shear lag effect	W 8x21	100%
MAN ex D2.rtd	Single-Angle Tension Member - shear lag effect	L 4x4x0,5	%001
MAN ex D3.rtd	WT-Shape Tension Member - shear lag effect	WT 6x20	100%
MAN ex D4.rtd	Rectangular HSS Tension Member	HSS 6x4x0,375	100%
MAN ex D5.rtd	Round HSS Tension Member	HSS 6x500	100%
MAN ex D6.rtd	Double-Angle Tension Member- shear lag effect	2L 4x4x0.5	100%
	COMPRESSION		
MAN ex E1d.rtd	W-Shape	W 14×90	100%
MAN ex E2 plus.rtd	Built-up Column with a Slender Web	I 15x8x1x0,25	100%
MAN ex E3.rtd	Built-up Column with Slender Flanges	I 10,5x7,25x0,375x0,25	100%
MAN ex E7.rtd		WT 7x34	100%
MAN_ex_E8.rtd	WT Compression Member with Slender Elements + LTB	WT 7x15	100%
MAN ex E9.rtd	Rect HSS Compression Member without Slender Elements Ky=Kz=0.8	HSRE 12x10x0.375	100%
MAN ex E11 plus.rtd	Pipe Compression Member Ky=1,Kz=1	Pipe P10	100%
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%
	BENDING		
MAN ex F1 3B.rtd	W- Flexural el. Design in Strong-Axis Bending, Braced at Midspan, LTB, CB=auto	W18×50	100%
MAN ex F2 2B.rtd	Compact Channel Flexural el. with Bracing at End and Fifth Points LTB, CB=1.0	C 15x33,9	100%
MAN_ex_F3B.rtd	W-Shape Flexural braced Member with NC Flanges in Strong-Axis Bending, no LTB	W 21x48	100%
MAN ex F7B.rtd	Rect HSS Flexural Member with Noncompact Flanges	HSS 10x6x3/16	100%
MAN ex F10 plus.rtd	WT Shape Flexural Members el.1	WT 5x6	100%
	Single Angle Flexural Member	L 4x4x1/4	100%
MAN_ex_F12.rtd	Rectangular Bar in Strong-Axis Bending	RECT 5x3	100%
MAN ex F13.rtd	Round Bar in Bending	RB 1	100%
	SHEARING		
MAN ex G1.rtd	W-Shape in Strong-Axis Shear	W 24x62	100%
MAN ex G2b.rtd	C-Shape in Strong-Axis Shear	C 15x33,9	100%
MAN ex G3 Fy 36 105.rtd	I Angle in Shear	L 5x3x1/4	100%
MAN ex G5.rtd	Round HSS in Shear	HSRO 16x0,375	100%
MAN ex G6.rtd	Doubly-Symmetric Shape W in Weak-Axis Shear	W 21×48	100%
MAN_ex_G7_plus.rtd	Singly-Symmetric Shape C in Weak-Axis Shear (both directions)	C9x20	100%
MAN_ex_G8b.rtd	Built-up I-Shaped Member without & with stiffeners (tension field action)	I-SYM_2 33/0.31 × 12/1.5	100%
	INTERACTION M, N, V		
MAN_ex_H1b.rtd	Nc+MY+MZ - W shape - &H1	W 14x99	100%
MAN ex H2.rtd	Nc+MY+MZ - W shape - &H2	W14×99	%001
	Nt+MY+MZ - W shape - &H1 - (exmp. for Nt+M H1.2 -> [a*Cb])	W14x82	100%
MAN ex H5a.rtd	Torsional Strength HSS rect	HSS 6x4x1/4	100%
MANI LICK 44			10001