

ES10885

# Into the Woods: Robot Structural Analysis for Wood Design Per NDS 2012

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## Learning Objectives

- Learn how to properly model wood members and configure wood member databases in Robot Structural Analysis Professional 2016
- Learn how to identify key settings and their functions in wood member definition for design
- Discover key settings and their functions for NDS design calculation settings
- Learn how to analyze and comprehend wood design results in Robot Structural Analysis Professional 2016

## Description

We'll take a close look at the exciting new capabilities of Robot Structural Analysis 2016 software for wood design per NDS 2012. Learn about the key features, settings, and modeling techniques to take full advantage of these new design modules. We will share real-world examples worked in Robot Structural Analysis Professional software.

## Your AU Experts

**Ken Marsh** *Is the author of Autodesk Robot Structural Analysis Professional 2015 – Essentials. Ken is a former structural engineer and former Autodesk, Inc., employee. After 7 years as a structural engineer, Ken joined Autodesk as a quality assurance analyst working on the Revit software product line. Ken is the owner of Marsh API, which is dedicated to advancing Building Information Modeling (BIM)-based structural engineering through the Revit software API add-ons, consulting, and training. He loves to discuss Autodesk technology as it relates to the architecture, engineering, and construction industry.*

**Lin Gallant** *Lin is a senior forensic structural engineer at the Vertex Companies based in Weymouth, MA. Lin is a professional structural engineer with 10 years of experience in the design and evaluation of buildings and other structures. He has been using Autodesk products (AutoCAD, Revit, Robot Structural Analysis Professional) for over 10 years. Lin has a passion for blending engineering and technology to improve efficiency and foster innovative design. He has authored white papers on AISC's Direct Analysis Method and wind simulation, and has lectured on these subjects and BIM. He provides technical guidance, user experience review, and workflow analysis to software developers to enhance engineering analysis and design software. Lin received his B.S. and M.S. degrees in Civil Engineering (structural focus).*



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# Basic Wood Design Workflow

Assuming that load combinations have previously been generated, in Robot the basic wood design workflow is nearly identical to the steel design workflow:

- 1- Assign code parameters to all elements you wish to check/design
- 2- Create initial code groups (group similar members at first and refine later)
- 3- Configure Calculation Configuration Options
- 4- Perform code group design for strength with optimization
- 5- Update members based on strength design
- 6- Perform Member Verification for Ultimate and Service, note any that fail for service
- 7- Perform serviceability design for code groups with failing members
- 8- Update members based on serviceability design.
- 9- Perform member verification to check all members for both strength and serviceability
  - a. Optionally review utilization ratio analysis and identify groups of members which can be re-designed more optimally, create new code groups for these members and iterate their design.
- 10- Iterate any individual members which still fail by creating a new code group specifically for each type of member which needs special attention.
- 11- Perform final member verification

## Robot Wood Design Capabilities

Robot wood and timber design capabilities have been expanding. In addition to support for several European design codes, the 2016 version of Robot Structural Analysis has added support for the American Wood Council National Design Specification (AWC-NDS) 2012 for both ASD and LRFD design.

### Here is the current list of supported codes:

USA: AWC NDS – 2012 ASD/LRFD

France: CB71/ CB71 + Kerto

France EC5: NF EN 1995-1:2015/NA:2010/A2:2014

Eurocode5: EN 1995 – 1:2004 / A2:2014



Eurocode: ENV1995-1-1:1992

Finland EC5: ENV 1995-1:1992 NAD Finland

Poland: PN-B-03150

Poland EC5: PN-EN 1995-1:2005/NA2010:A2:2014

### **Overall Design Capabilities per AWC-NDS-2012:**

1. All materials governed by NDS 2012 Supplement tables 4A through 6b meaning Sawn Lumber including Beams and Stringers, Heavy Timbers (larger than 5"x5"), Piles and Poles, and Glued Laminated Beams/Columns of both Western Species and Southern Pine referred to in the software as (GWS and GSP respectively). Designs may be calculated in either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD) per the AWC NDS 2012.
2. Robot will not currently perform design or code checking of Structural Composite Lumber (SCL) including Laminated Veneer and Parallel Strand Composite Lumber.
3. Robot will not currently perform design or code checking of I-Joists per NDS
4. Robot will not currently perform design or code checking for structural panels or mechanical fasteners.

### **Current Limitations:**

#### STRICT WIDTH LIMITS BASED ON SUPPLEMENT TABLES:

Current material tables have been created with consideration of the allowable member size to be designed with the values in the table. In other words if NDS Supplement Table 4A says minimum width is 2", that is what has been set for all the predefined materials. While this seems innocuous, the software does not currently take into consideration the dressed size of the members to be designed properly. Meaning that the material table says 2" min width and a sawn lumber 2x (2" wide nominally) has a dressed width of 1.5". Robot flags this member as not meeting the minimum width requirements of the design table and refuses to consider the member for design. You can work around this issue by changing the minimum width of members allowed for the material to the dressed size of the material you wish to design.

#### DESIGN MODIFICATION FACTORS NOT APPLIED TO YOUNG'S MODULUS

Currently Robot does not apply design adjustment factors to Young's Modulus (E) in order to calculate an E' for use in deflection calculations. Please note that for any applications where one of the applicable adjustment factors for E are required, you will want to adjust your allowable deflections to suit or run the model two times with different values of E for proper



deflection calculations. Luckily it is fairly rare that we need incising, or hot/wet conditions for most members though if you do, design/code checking will require a bit more work.

#### ROUGH SAWN MEMBERS NOT IN STANDARD SECTION LIBRARY

The pre-populated section database has section sizes for Timbers and Beams/Stringers but they are all set to the dressed timber dimensions and there is no consideration for Rough Sawn lumber. If you wish to use Rough Sawn lumber, you will need to add a custom parametric section as shown below.

#### NO SUPPORT FOR DOUBLE TAPERED CURVED MEMBERS

While curved members of constant cross section can be checked/designed, as well as single and double taper (presumably compression flange only), no support is available for double tapered curved beams.

## Wood Databases/Section Properties

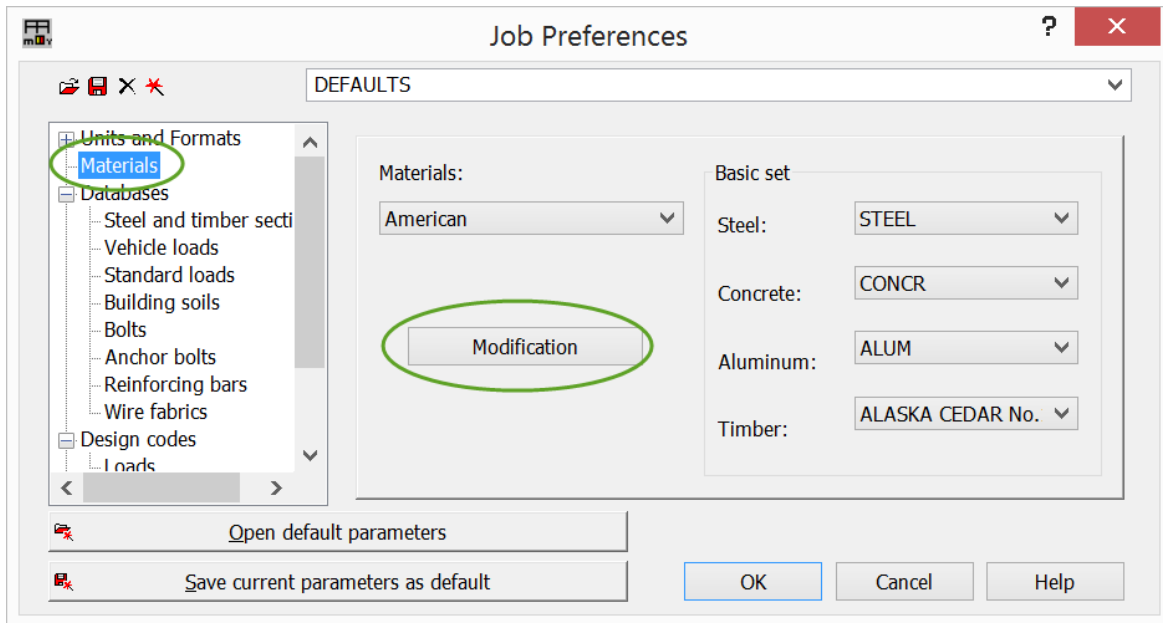
The included database for AWC-NDS comes pre-populated with full NDS Supplement Materials (Tables 4A through 6b), and sections for standard lumber, timber, and glued laminated beams.

### Adding Materials to Your Project

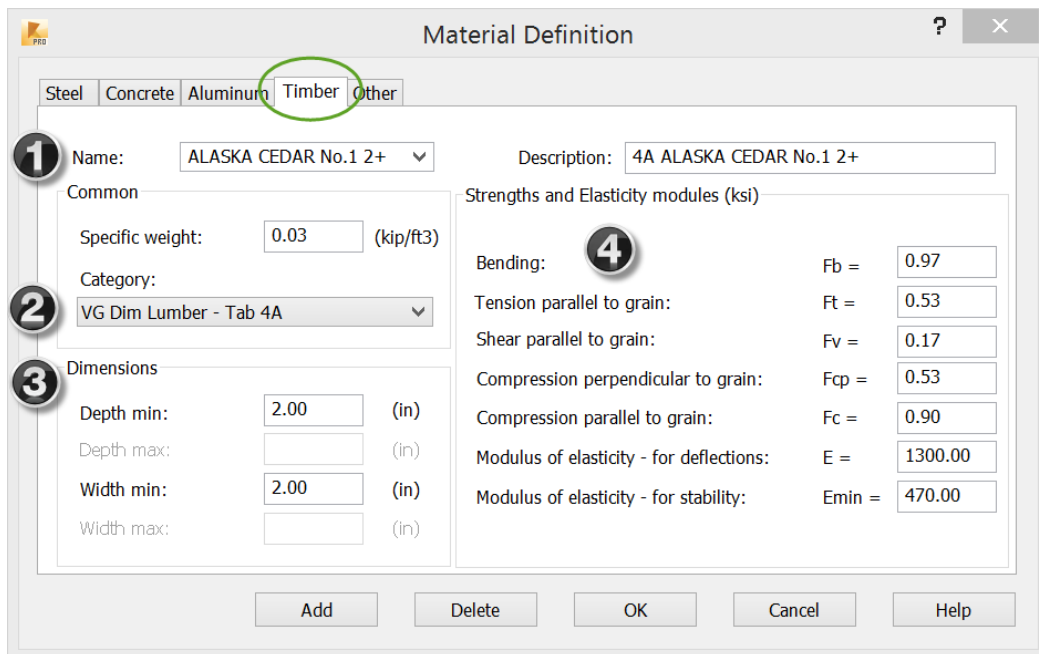
In order to perform code checking or design with a particular species of wood, you will first need to add that species to your project. Furthermore, you will need to add it for as many design tables as you plan to need design values. By this, I mean that if you need to do code checking for Douglas Fir Larch dimensional lumber (Table 4A) and Douglas Fir Larch Beams and Stringers (Table 4D Beams and Stringers) and you also have some heavy timbers also in Douglas Fir Larch (Table 4D but Piles and Timbers this time) You'll need to add three different material definitions to your project (and then again as many as you have different grades though most designers will work with a single grade of each type. E.g., "Select Structural").

You can access the project materials from **Tools>Job Preferences...** This will bring up the Job Preferences dialog where you can select "Materials" from the list at the left:





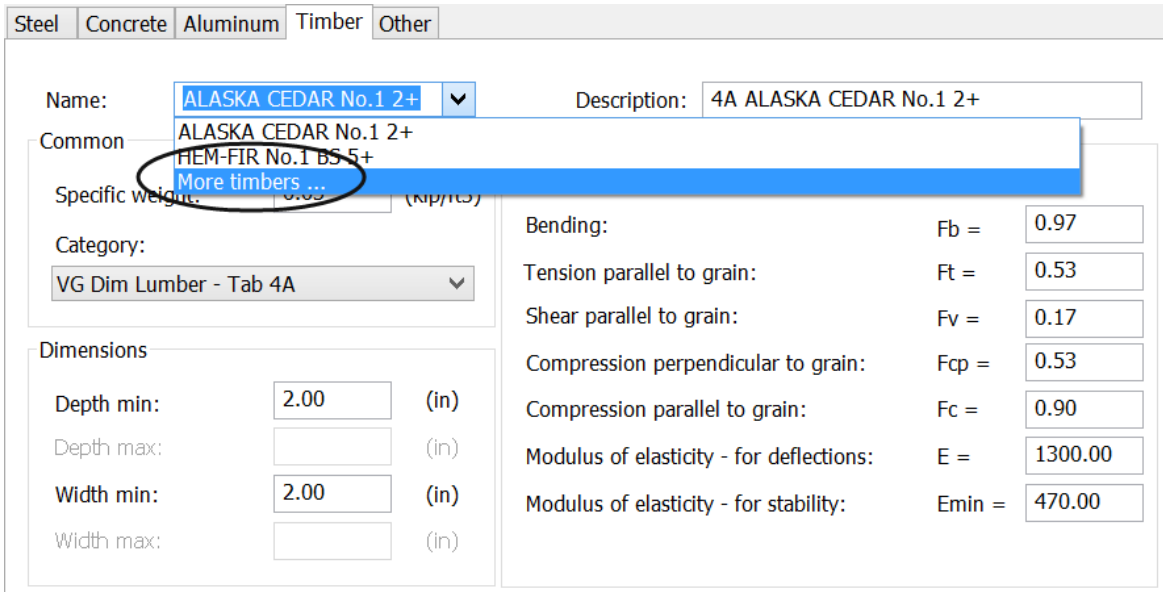
From here you can select “Modification” to access the Material Definition editor:



1: Material Definition Dialog

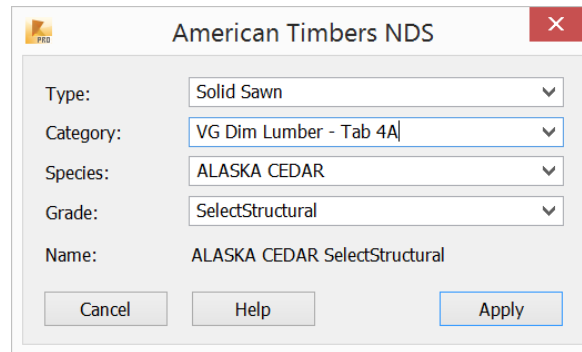
**1. Name:** This is actually a dual-purpose dropdown. It is the name field for a new material definition but it is also an access to the tabulated species design values in tables 4A through 6b. The tabular values can be a starting point for your material creation.

Access the tabulated design values by selecting the Name dropdown and choosing “More timbers...”



This will present you with the American Timbers NDS selection dialog:

Illustration



2: American Timbers NDS Supplement Access

This dialog effectively gives you access to the NDS tables 4A through 6b for initially populating the fields of the material modification dialog.

**Type:** Choice of Solid Sawn, Glued-Laminated, and Poles/Piles. This setting controls what “Categories” are available in the next drop down.

**Category:** Select the desired table from this drop down. The contents of this dropdown depend on the current setting in the “Type” dropdown above.

**Species:** Select the species to be used in code checking/design. Note that options in this dropdown will change based on the setting of “Category” dropdown above. For instance, if you have Table 4D selected, each “Species” in this dropdown will have two entries: Species BS (beams and stringers) and Species PT (piles and timbers). You will need to select the appropriate sub-division for the type of member that you are intending to check/design.

**Grade:** This will be the particular grade of interest under the species sub-division. If you flip through a few of these different combinations you should be able to identify that Robot is selecting the appropriate values from the Supplement tables.

**Name:** This is the initial setting of the material name which will reflect several of the major properties of this “material” definition including the species name and the grade. You will likely want to give further refinement to this naming to reflect any subdivisions (BS/PT) or whether solid sawn, glued-laminated, or piles/poles.

Note that the selections in this dialog simply populate the fields of the material modification dialog with values from the NDS Supplement table. From there, you may modify as needed.

As you can see for the situation described above: We need to design 2xs, some beams/stringers as well as some heavy timber all in Douglas Fir Larch, we would need 3 different materials:

1. Solid sawn, Table 4A, Douglas Fir Larch, Select Structural.
2. Solid Sawn, Table 4D, Douglas Fir LarchBS, Select Structural
3. Solid Sawn, Table 4D, Douglas Fir LarchPT, Select Structural

If you had some glued laminated beams you would need yet another material for that.

*---Back to the Material Definition Dialog ---*

**2. Category:** This setting in the modification of timber materials dialog allows you to specify which table should be associated with the material definition. This setting is going to control which design adjustment factors are applied to the design values at code check/design time. For instance, if you select Table 4D (has no repetitive member factor  $C_r$ ) and then specify that Robot should apply the  $C_r$  factor to the design/code-check, it will ignore the  $C_r$  factor based on the selection of Table 4D for the “Category” setting in the Materials Definition Dialog.



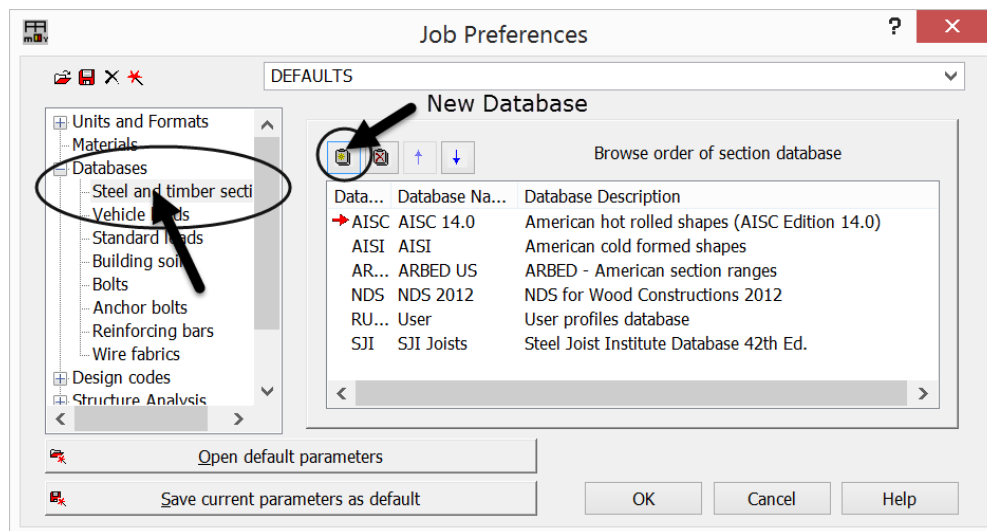


**3. Dimensions:** The NDS Supplement tables often specify a range or applicable member dimensions to which the table applies. For instance, Table 4A specifies that it applies to members which are Min 2” nominal thick, to Max 4” nominal thick. Robot will check member sizes in code-check/design to make sure that they fall within the allowable range set here and will not allow any members which do not fit these criteria to be designed. However, the maximum fields don't currently allow you to specify maximums.

**4. Design Values:** These values will initially be set to the values taken from the NDS Supplement. You may modify them as you see fit. In most cases you would ideally want to use what is suggested by the NDS Supplement but if you happen to be working with an unusual species you could specify custom values here.

### Adding the NDS section catalog to your project:

If you haven't already done so, for the next section you'll want to add the NDS wood sections database to your project. Again from **Tools>Job Preferences...** Databases tab, select “Steel and Timber Sections”. Use the “New Database” button to configure the NDS database for use.

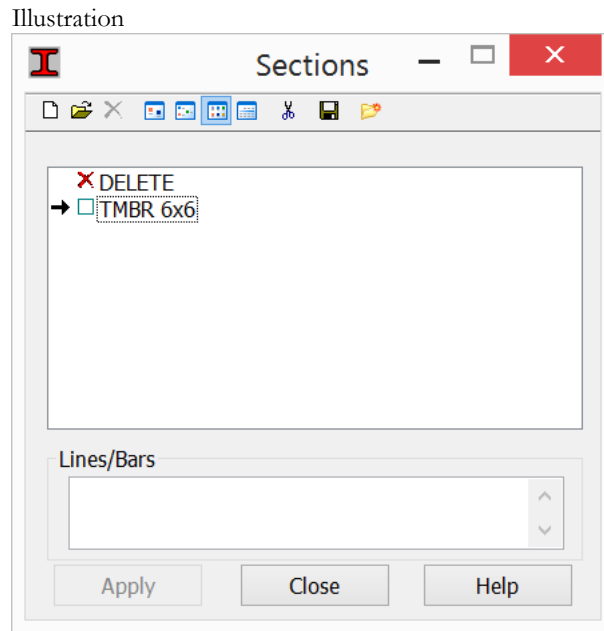


### Specifying and Assigning Wood Sections to Members:

Robot has included an NDS member sections database which covers the most commonly used dressed dimensional lumber, typical beams/stringers, typical timbers, typical Glued Laminated sections, and post/pile sections. The one thing to keep an eye on is that the database covers standard dressed, it does **not** include traditional “rough sawn” sections. Should you need to use “rough sawn” sections you will need to specify them as parametric wood sections supplying the width/height yourself.



To begin specifying sections for use in modeling timber structures, begin by going to **Geometry>Properties>Sections...** which will bring up the Sections configuration and application dialog:

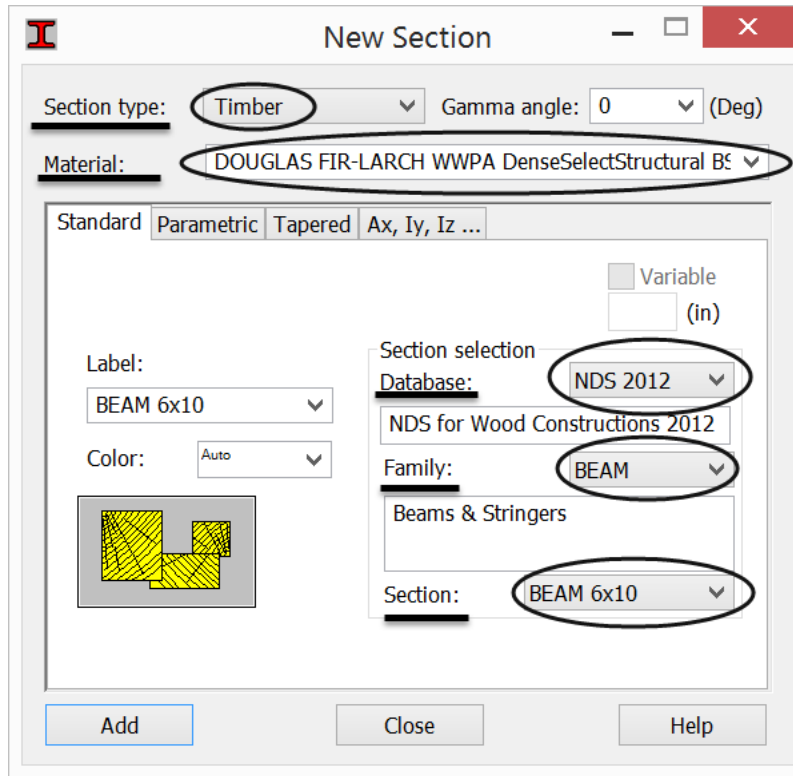


You will note that this dialog is a typical Robot label definition/application dialog.

To add a new section press the “new” button:  Which will bring up the New Section Dialog:

Select “Timber” for Section type, then choose the material you'd like to use. Remember that Robot's sense of the material will incorporate a sense of the types of members for which the Supplement is intended. Therefore, if you select a Table 4A material, the “Family” dropdown will only include “LMBR” (for dimensional lumber). If you want to want to use a beam or heavy timber section with this material (not recommended), you'll need to select “ALL” in the “Family” dropdown.

Illustration



This will have standard sizes of dimensional lumber, beams/stringers, glued-laminated beams, and heavy timbers. If you have a non-standard size (“rough sawn”), or need to specify pile or pole sizes you'll need to select the “Parametric” tab in this dialog to specify the exact dimensions.

In the “Label” textbox, enter the text that will show for this section type. Because the section type is material specific, you will want to include some indication of the material if you have multiple materials in use on one project.

In order to verify the member dimensions for the section (since the database sections do not show you the dimensions during configuration) you can always use the “Properties” table and use “Table Columns” to show the cross section dimensions of bars and you can easily verify the section properties:

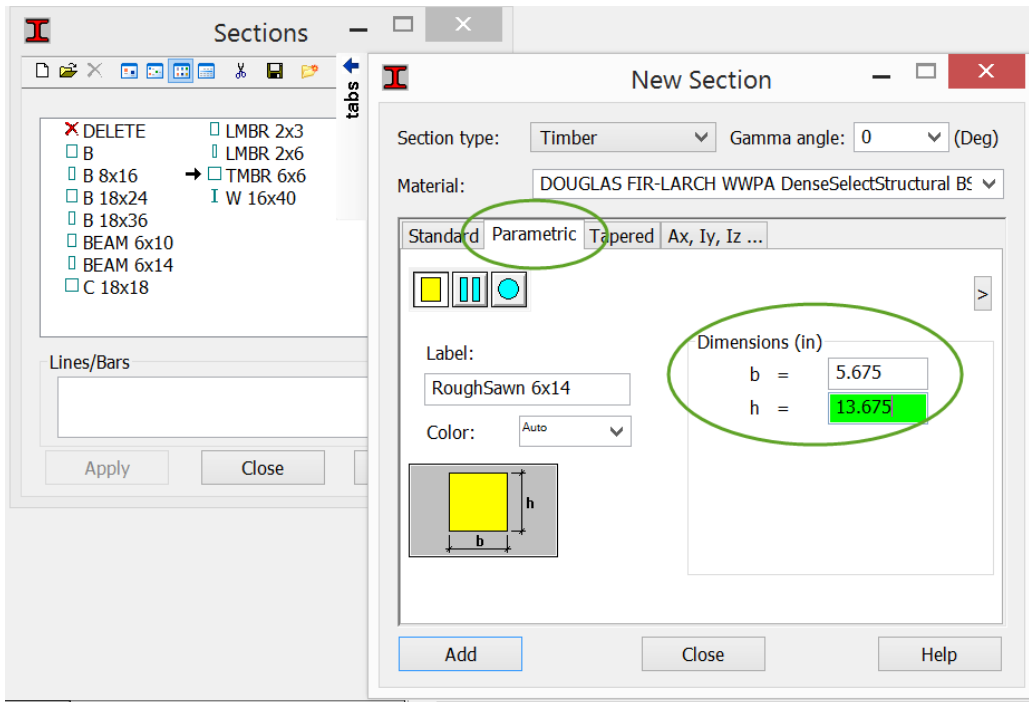
I

Properties								
	Section name	Bar list	HY (in)	HZ (in)	VY (in)	VZ (in)	VPY (in)	VPZ (in)
	BEAM 6x14 DFL BS	1	5.50	13.50	2.75	6.75	2.75	6.75

Remember that only sections currently in use in the project will be shown in this table.



To Add a Rough Sawn 6x14 select the proper material and select the “Parametric” tab of the “New Section” dialog to enter appropriate section dimensions:



6: Adding a Custom Timber Section

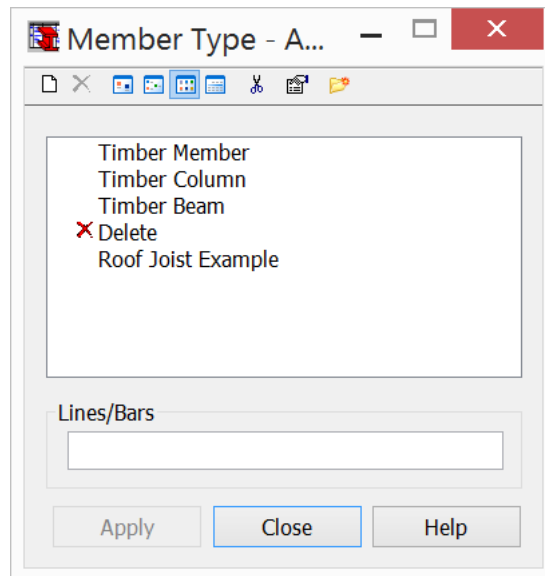
## Configuring NDS 2012 Code Properties

After you have configured necessary materials, added necessary timber sections, applied them to your beams/columns, and run your analysis, you're ready to configure the Code Parameters which will be associated with each bar. This is almost exactly the same process as for steel members. We will look at the parameters available in the NDS member settings then in the next section we'll talk about running code-checks or designs in Timber.


### Configuring Code Parameters:

To launch the AWC NDS 2012 code parameters, first make sure that you have the AWC NDS 2012 code selected for timber design in the job preferences (**Tools>Job Preferences...>Design Codes**) for more information on this refer to project setup. Then from the menu, select **Design>Timber Members Design – Options>Code Parameters...** to launch the AWC NDS 2012 Member Type label dialog:





There are three default member types which cannot be deleted from the label list: Timber Member, Timber Column, and Timber Beam. You can use these as starting points for your own member types or create new ones from scratch.

Click the “New” button to start a new member type definition:  This will launch the AWC NDS 2012 Code Parameters Dialog:

This dialog is used to configure design and code checking parameters for members you want to have checked per AWC-NDS. You will need to configure a different member type for each specific condition of use, braced length, bending/compression, or other special conditions. For instance, if you have two joists which are exactly the same except that one has allowable notches at the end, and the other doesn't, you'll need two different "Member Definitions". Likewise, if you have two stringers which are exactly the same except they have different brace points, you'll need different member definitions. Create as many member definitions as you feel you need to fully and accurately describe your member configurations for design/code-checking.



THE AWC-NDS 2012 MEMBER DEFINITION DIALOG:

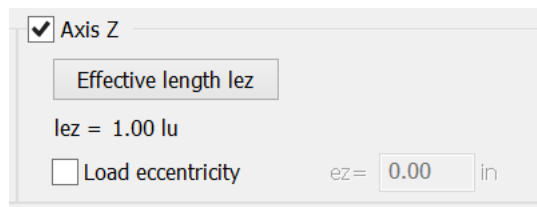
**1. Name:** Timber Member, Timber Beam, and Timber Column are reserved names and cannot be modified. Supply your own descriptive name for the set of parameters you want to assign to members. With exception of the reserved names, saving an existing name will overwrite the definition. (You will be prompted to overwrite the definition if you do. Note that any changes overwritten will affect all members to which that set of code parameters has been assigned.) If you supply a new member type name and then save, that label will be added to the list of member type labels though there is no feedback that this has been done. You'll have to check the Member Type labels dialog to see it and apply it to elements.

**2. Cantilever:** If the member is a cantilevered beam, select this box. If you wish, you can break your member into two sub-members in order to apply this setting to the member definition for the cantilevered portion of the beam. Note that options available in the lateral buckling  $l_{et}$  settings (Item 4 below) will change based on whether this checkbox is ticked or not.

**3. Buckling check:** These settings control the application of buckling checks in the code-checking/design routines. These checks are independent of the lateral compression flange checks in the "lateral-torsional" buckling check in item 4 below.

If you leave these checkboxes unchecked, no buckling check will be performed in the direction indicated (recall that Axis Y is the Major Bending axis and Axis Z is the minor bending axis).

Checking either Axis Y or Axis Z will allow you to configure the effectively length of the member for compression about the selected axis. Each axis may be configured independently. For example, the Axis Z settings:



Pressing the "Effective length lez" will open a dialog allowing you to configure standard unbraced length/effective length settings or specify your own:

BUCKLING MODES	THEORETICAL VALUE	NDS RECOMMENDED VALUE
Both ends fixed	<input type="radio"/> $le = 0.50 lu$	<input type="radio"/> $le = 0.65 lu$
Bottom end fixed - Top end pinned	<input type="radio"/> $le = 0.70 lu$	<input type="radio"/> $le = 0.8 lu$
Bottom end fixed - Top end free translation	<input type="radio"/> $le = 1.00 lu$	<input type="radio"/> $le = 1.20 lu$
Both ends pinned	<input type="radio"/> $le = 1.00 lu$	<input type="radio"/> $le = 1.00 lu$
Bottom end pinned - Top end free translation	<input type="radio"/> $le = 2.00 lu$	<input type="radio"/> $le = 2.40 lu$
User defined length	<input type="radio"/> $le = $ <input type="text" value="1.00"/> $ lu$	
Lateral bracings	<input type="radio"/> $le = (le1, le2,...)$	<input type="button" value="Lateral Bracings"/>

7: AWC-NDS Effective Length for Compression Members

You will note that the options available here are a reproduction of Appendix G table G1 and include as standard, the theoretical and recommended effective lengths based on end conditions. You may also select your own effective length factor by selecting “User defined length”.

If you have distinct points of bracing you may want to use the “Lateral Bracings” dialog to configure specific locations of bracing.

Selecting the “Load Eccentricity” checkbox will result in Robot invoking the equations in section 15.4 which require the eccentricity of the load to be specified for the calculation of combined loading with eccentricity per AWC-NDS 2012 Section 15.4.1.

--- Continuing with the Member Definition Dialog ---

**4. Lateral-Torsional Buckling Check:** These settings allow you to control the specification of lateral bracing of the compression flange with different settings available for top flange and bottom flange.

Leaving the checkbox unchecked will result in Robot not performing any lateral torsional buckling checks ( $C_L$  will be 1.0) for the flange. If the member is laterally supported on both top and bottom, leave these unchecked to have Robot use a  $C_L$  of 1.0.

Selecting the “Effective length  $le_t$ ” button will bring up the Effective Length for Beams, between Supports dialog:





Effective Length for Beams, between Supports - ANSI/AWC NDS-2012 ASD

SINGLE SPAN BEAMS

	Uniformly distributed load	<input checked="" type="radio"/> $l_e = 2.06 l_u$ where $l_u/d < 7$ or $1.63 l_u + 3d$ where $l_u/d \geq 7$
	Concentrated load at center with no intermediate lateral support	<input type="radio"/> $l_e = 1.80 l_u$ where $l_u/d < 7$ or $1.37 l_u + 3d$ where $l_u/d \geq 7$
	3 equal concentrated loads at 1/4 points with lateral support at 1/4 points	<input type="radio"/> $l_e = 1.54 l_u$
	Equall end moments	<input type="radio"/> $l_e = 1.84 l_u$
	Other single span bending members	<input type="radio"/> $l_e = 2.06 l_u$ where $l_u/d < 7$ or $1.63 l_u + 3d$ where $7 \leq l_u/d \leq 14.3$ or $1.84 l_u$ where $l_u/d > 14.3$
	User defined length	<input type="radio"/> $l_e = 1.00$ $l_u$

ADDITIONAL DEFINITION OF BRACINGS POSITIONS

Lateral bracings   $l_e = (l_{e1}, l_{e2}, \dots)$

8: AWC-NDS 2012 Effective Length for Beams, between Supports

Standard options per the NDS Table 3.3.3 are available here. You will notice that cantilevered options are not available here. In order for this dialog to contain the cantilevered settings you will need to select the “Cantilevered” checkbox in Item 2 above.

Again, if you have distinct points of bracing you may want to use the “Lateral Bracings” dialog to configure specific locations of bracing.

**5. Factors:** Here you have the option to invoke several standard factors.

- a) Repetitive Member:  $C_r$
- b) Incising Factor:  $C_i$
- c) Moisture Factor:  $C_m$  by setting “In-Service Moisture Conditions” dropdown to
- d) Temperature Factor:  $C_t$  by setting the “Temperature” dropdown.
- e) Buckling Stiffness Factor:  $C_T$  invoking section 4.4.2 for members used as truss chords with plywood sheathing.

**6. Limit deflections and displacements:** This checkbox allows you to set Robot to check live, dead and total load deflections. Once you select the checkbox, you may press the “Service” button to the right and configure all settings related to limits on member deflections.

9: AWC-NDS Serviceability limits

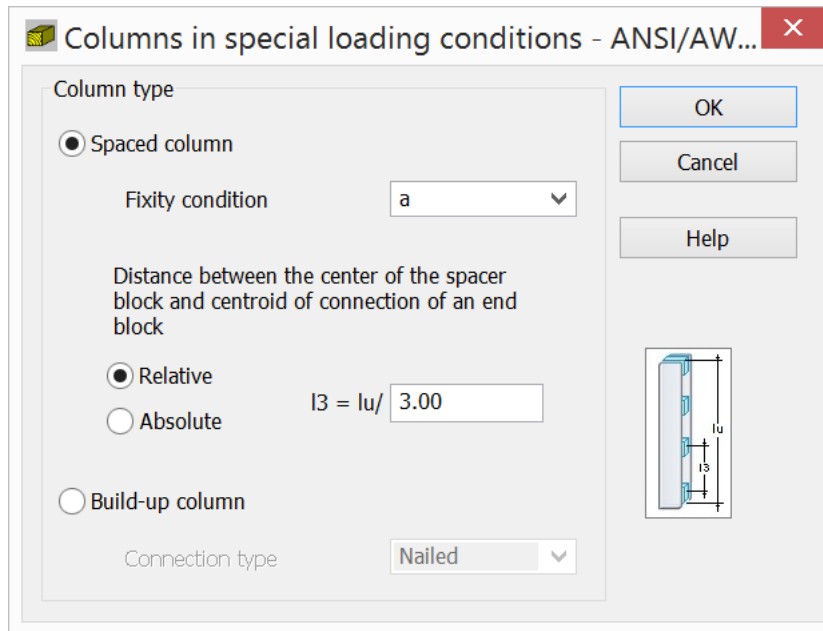
When configuring these settings, recall that “uzd” is the deflection caused by major axis bending. (The “vertical” deflection of a horizontal beam/joist element) The member local z axis is the minor bending axis of a member and therefore deflections along the z axis are perpendicular to the major axis which is the y axis.

You will also notice that long term creep check (per 3.5.2 and Appendix F) can be specified here. Robot will look at the long term loading specified (based on load durations which are configured in the AWC-NDS Calculation Configuration options. See below).

You can configure both absolute and relative deflection checks for the member.

**7. Columns in special loading conditions:** This will allow you to specify the configuration of stitched columns or built-up columns and thereby invoke the provisions of AWC-NDS 15.2 or 15.3.



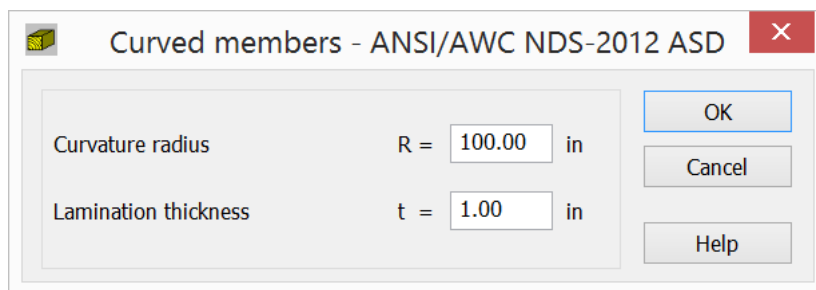


10: AWC-NDS Columns in Special loading conditions

Selecting “Spaced column” will use 15.2 and allow you to select the end block condition per 15.2.2. You can also specify the center to center distance of the spacer blocks.

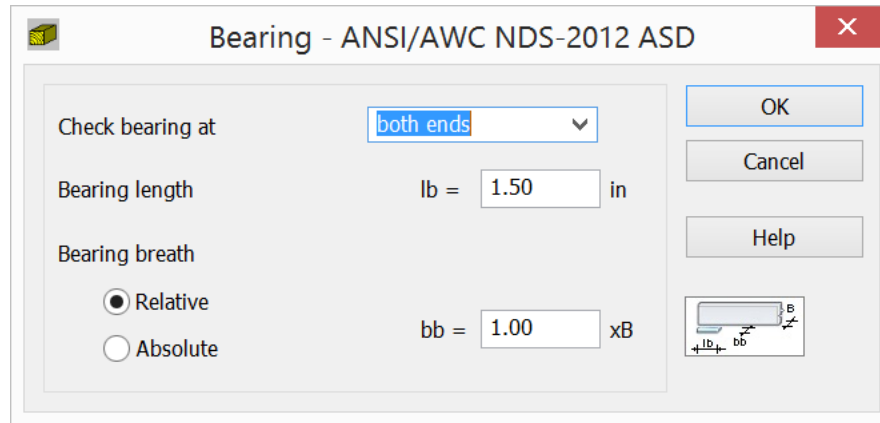
Selecting “Build-up column” will invoke the provisions of 15.3 and allow you to specify whether this member is mechanically laminated by nailing or bolting per 15.3.3 or 15.3.4.

**8. Curved bending members:** This checkbox allows you to configure parameters for calculations of Curvature factor  $C_c$  per section 5.3.8 for use with curved glued laminated timbers. Pressing “Curved” will bring up the Curved Members dialog:



**9. Bearing at ends:** This checkbox invokes bearing checks per 3.10 perpendicular to grain and calculates and applies  $C_b$  factor if appropriate based on the settings here. The design check basically applies the  $C_b$  factor but does not take into account the distance to the end of the member. So if you choose to use this check make sure that you have a situation where  $C_b$  applies.

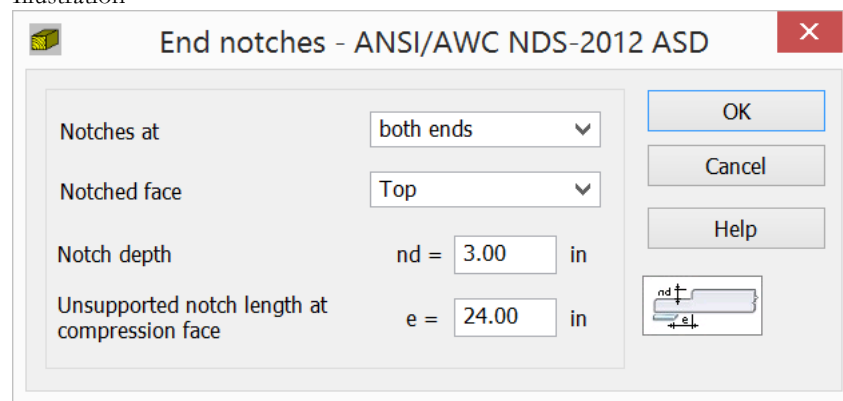
Illustration



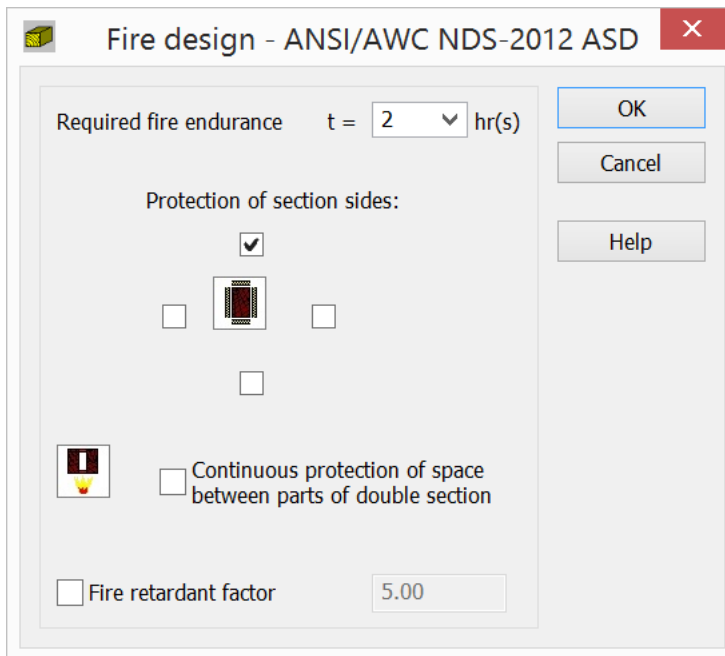
You can ask Robot to check bearing at either or both ends of the member to which this definition is assigned, you may also configure the bearing length and width. Robot will use the smaller of these values in calculating  $C_b$  factor apply.

**10. End Notches:** Using the End Notches dialog you can configure parameters of notches in the ends of the member. Robot will check the notches for allowable limits and apply shear calculations per section 3.4.3. The End Notches dialog will allow you to configure notches at either or both ends but only top or bottom notches.

Illustration



**11. Fire Design:** The fire design options will allow you to invoke calculations of the section reduced by fire char. You will find option for fire duration, protection of sides, and an additional fire retardant factor.



If protection is selected for one or more sides, Robot will ignore those sides in calculating the reduced section. Section reductions are calculated per the char rate equation given in AWC-NDS 2012 16.2-1. The fire retardant factor will be applied to design values as a direct multiplier of the design value and is assumed to be provided by the fire retardant manufacturer.

### Wrapping up Timber Design Setup:

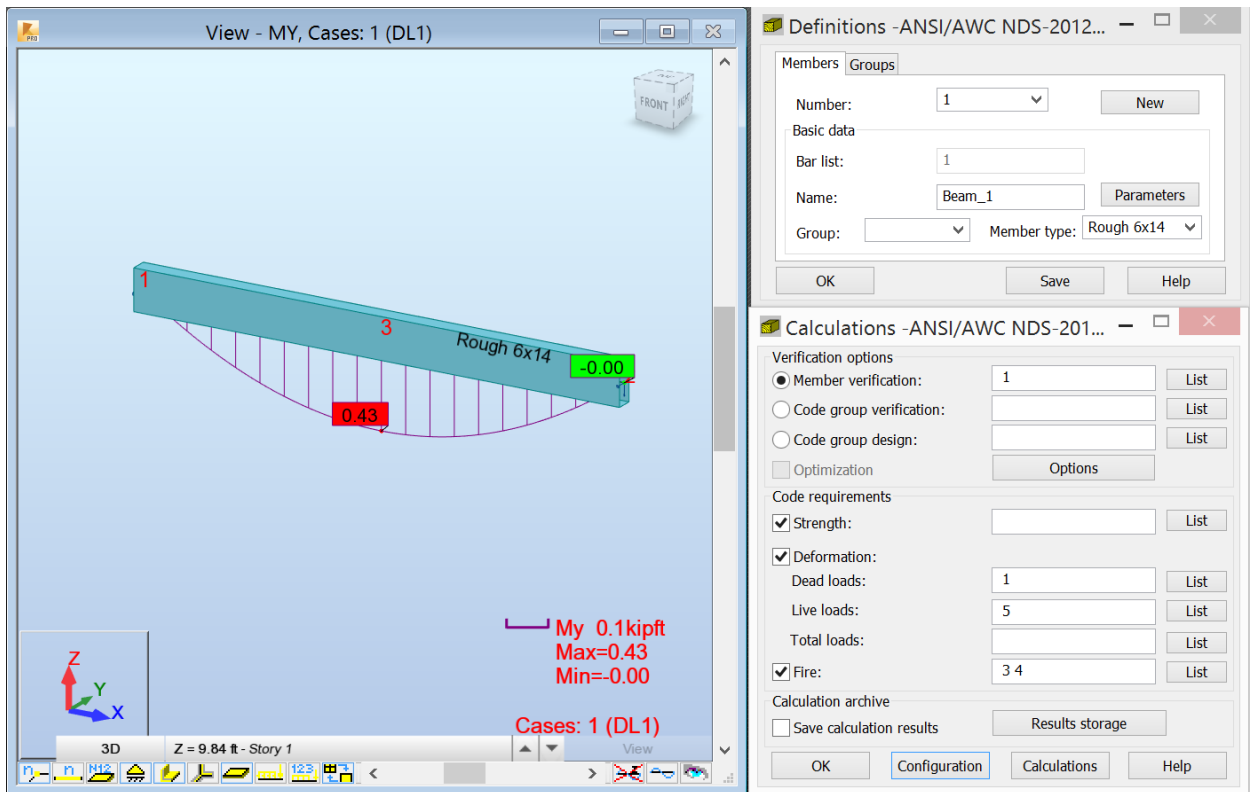
Once you have configured and applied all required AWC-NDS member types to the members you wish to check/design, if you want to perform design, you will need to further configure design groups. This is standard functionality in Robot and applies to Steel/Aluminum, Required Reinforcing, and Timber design. All design in Robot is performed on design groups.

## Wood design layout

The wood design layout may be accessed from the layout manager dropdown or from the menu Design>Timber Members Design...

You will notice that the layout includes the Members/Groups dialog where you may configure super members (comprised of smaller calculation members if you have this situation) and/or Design Groups.

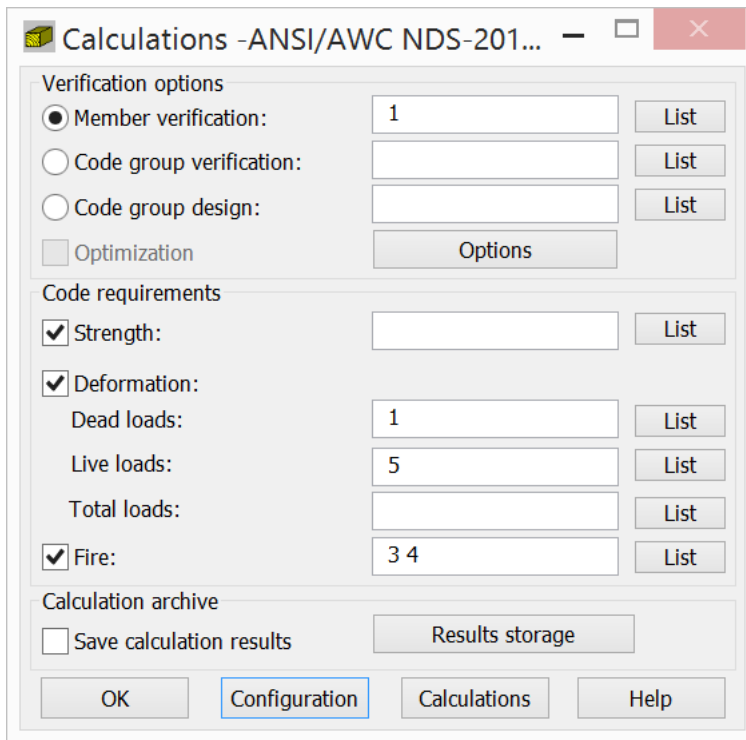




## Calculations Dialog

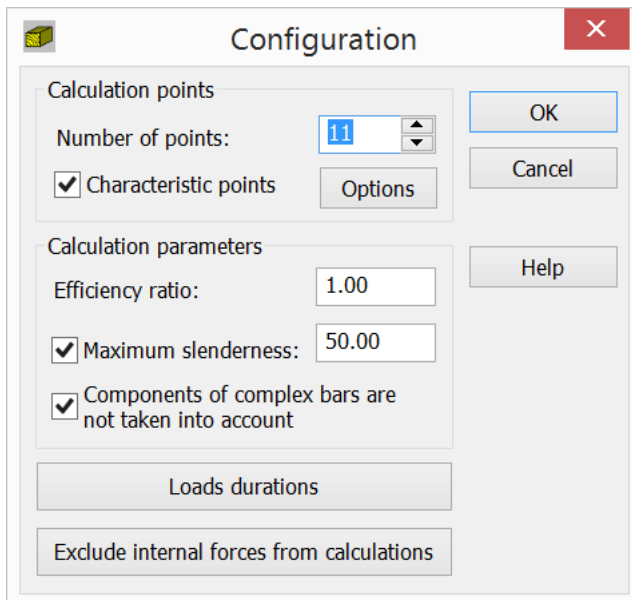
The calculations dialog is very similar to the steel design dialog with the exception of the addition of Fire load cases/combinations as an additional option.





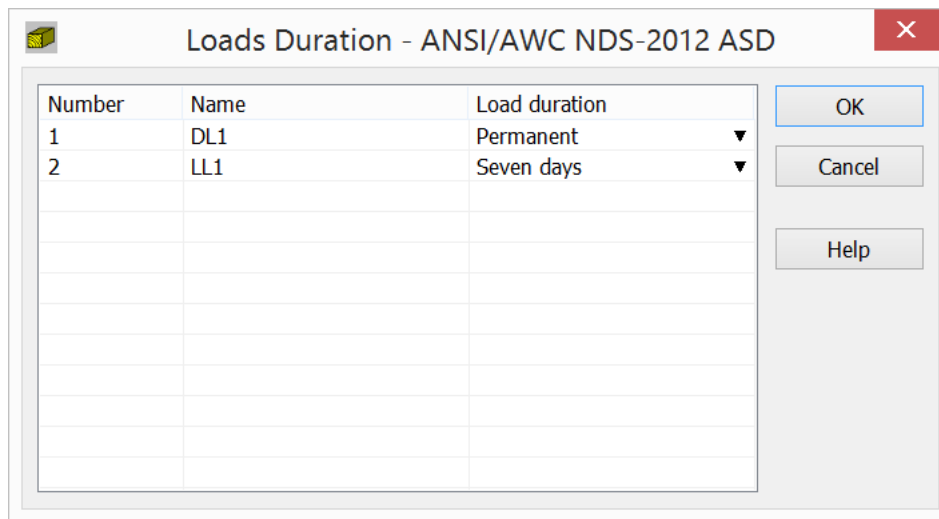
The “Configuration” options provide some of the standard options as well as one very important aspect of wood design: Load Durations!

Here is the configuration options dialog:

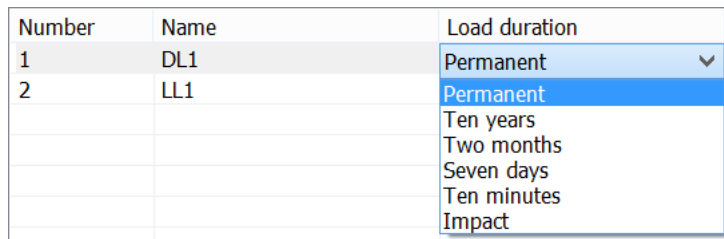


As always with Robot design you will want to make sure that you have selected an adequate number of calculation points along the member and also configured any characteristic points or locations at which you would like to force design calculations to be made. (e.g., points of max member force, specific locations of interest along members).

Most importantly for timber/wood design, the “Load Durations” button will give you access to configure loading durations associated with the load cases you have previously defined:



All configured load cases will be shown here and the dropdowns to the right of the case name offer access to code load durations:



Once these settings have been properly configured, you are ready to start design calculations.