Interactive Online Figures for Demonstrating Structural Steel Design

Instructor Guide

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Overview

These interactive figures cover the core concepts and topics in a typical undergraduate structural steel design course. Specifically, they are aimed at allowing students to develop rich connections between AISC *Specification* equations and the related engineering and physical concepts. A primary intention is to combat the "plug-and-chug" mentality students can sometimes develop in design courses by emphasizing the physical meaning and physical concepts to drive engagement and promote understanding. These interactive depictions can be unique study aids for students or demonstration tools for instructors.

How it works

The two general kinds of activities are conceptual overviews and more detailed summaries of AISC *Specification* equations or design related calculations. Each activity has a (i) brief primer on the topic being presented, (ii) prompt, and (iii) set of learning objectives.

- Sliders and dropdown menus change parameters like member dimensions, loads, steel shapes, materials, and boundary conditions that affect the presented equations or design scenario. Graphics, plots, equations, and other results update in real time offering instant feedback..
- Equations, results, plots, references, and more can be hidden, allowing students to practice many customizable scenarios rather than being restricted to just a few static pre-solved examples. This makes the applets powerful study tools to encourage students and to drive their understanding of concepts rather than "plugging and chugging."

Just playing with the figures can convey a sense for the structural behavior and quickly provide students exposure to a wide range of scenarios, quickly building their experience and "feeling" for structural design.

How to use these interactive figures

In practice, students are expected to skip right to playing with the figures, selecting various parameter settings and playing with the sliders to see how the figures and calculations change. The hope is that this playful nature of the activities will spur curiosity about the relationships being shown or that the user will find them enlightening (e.g, "oh, that's how that works"). Students may read the description in search of an answer to a question, or just to see the concept at hand described in a way that may differ from their instructor or textbook.

Keep in mind that these activities are for teaching the fundamentals and are not meant to be practical design tools. They are not comprehensive of pragmatic design situations - it's just the basics.

Key Highlights

The topics include those typically covered in a first undergraduate course in structural steel design: gravity framing; basic design of tension, compression, and flexural members; basic design of bolted and fillet welded tension-transfering connections; and combined loading with the approximate second order analysis method.

Quick Use Guide	Students		Instructors		
	Practice Calculations [1]	Understand Core Concepts [2]	Lecture Aids: Demonstrate Concepts [3]	Lecture Aids: Examples [4]	Homework Assignments [5]
Steel Framing					
Floor Framing and Tributary Area	✔	✔		✔	✔
Live Load Reduction	✔	✔		✔	✔
Irregular Floor Plan and Tributary Area	✔	✔			✔
Flow of Gravity Forces		✔	✔		
Lateral Framing Basics		✔	✔		
Steel Material Behavior					
Tensile Behavior		✔	✔		
Expected vs. Nominal Material Strengths		✔	✔		
Tension Members and Simple Connections					
Overview of Tension Limit States		✔	✔		
Welded Tension Members	✔			✔	✔
Bolted Tension Members	✔			✔	✔
Block Shear	✔		✔	✔	✔
Compression Members					
Introduction to Residual Stress		✔	✔		
Flexural Buckling of W-Shapes	✔			✔	✔
Local Buckling	✔			✔	✔
Flexural Members					
Overview of Flexural Limit States		✔	✔		
Beam Yielding (Plastic Moment)	✔			✔	✔
Lateral Torsional Buckling (LTB)	✔			✔	✔
Flange Local Buckling	✔			✔	✔
Introduction to Beam Design	✔			✔	✔
Combined Loading					
Introduction to Second-Order Effects		✔		✔	
Combined Loading	✔		✔	✔	✔
Introduction to the Approximate Second-Order Analysis Method		✔	✔		

Quick Use Guide Footnotes

Students

[1] Practice Calculations
Most similar to traditional practice problems. Hide the answers, select a scenario, and carry out the calculations yourself. Then, reveal the answers to check your work. If you get stuck along the way, many of these will have intermediate steps you can work through progressively.

[2] Understand core concepts
These activities are meant to qualitatively explain some ideas, processes, or structural behavior(s) that are sometimes difficult to visualize or relate to, especially as a student.

Instructors

[3] Lecture aids to demonstrate concepts
These activities could be used in lecture as a qualitative demonstration to explain some ideas, processes, or structural behavior(s) that are sometimes difficult for students to visualize or are hard to describe with words or static pictures.

[4] Examples in lecture
These could be used to quickly and efficiently show the calculation steps in lecture, saving you time in coming up with custom problems and/or giving you the ability to effortlessly change a variable in class to make a point (e.g., Use the applet to carry out a column example in class then change the boundary conditions for this column and demonstrate how drastically the capacity changes.)

[5] Homework Assignments
Most similar to traditional practice problems. You could use these to design unique assignments focused on parameter investigations or reverse engineering various results (e.g., "Find a column design that has x- and y-axis braces but results in the x-axis controlling the flexural buckling capacity.")

Activity Overview and Suggestions for Use

Steel Framing	
Floor Framing and Tributary Area	This activity demonstrates the fundamental concepts for understanding how gravity forces flow through a common concrete slab-on-metal-deck floor system. The user can generate several simple gravity framing scenarios to practice the calculations. Free-body diagrams are provided to illustrate and further support the understanding of load path for gravity forces.
Live Load Reduction	This activity introduces the concept of live load reduction (LLR) and provides an example for practicing the calculations. The user can generate several LLR scenarios for use during teaching or for practice outside of class. The activity also helps visually illustrate how the LLR changes with tributary area, as well as how tributary areas and LLR vary between components and how they change with a change in floor plan.
Irregular Floor Plan and Tributary Area	With this irregular floor plan, users can generate gravity loading scenarios and practice different ways to estimate the total loads on the columns. The main point to reinforce is that tributary areas can get tricky when floor plans are irregular. Therefore, the designer needs to fully consider the load path for gravity forces and understand how steel members are framed together.
Flow of Gravity Forces	This qualitative activity demonstrates the flow of gravity forces in a multistory building.. It can be used to help students visualize the load path, as it points out each "step" along the way -- from load application to the transfer of forces through the structure and down to the foundation.
Lateral Framing Basics	This qualitative activity demonstrates the flow of lateral forces to promote student visualization. It highlights the difference between wind and seismic lateral force application (i.e., pressure applied externally versus inertial force, respectively). It can be used to point out each "step" along the way – from load application to the transfer of forces through the structure and down to the foundation, as well as the effect of loads on lateral force resisting components.

Steel Material Behavior	
Tensile Behavior	This graphical animation of tensile coupon tests illustrates steel's stress-strain behavior. It can help reinforce students' understanding of the true scale of steel's ductility (in uniaxial tension), as well as the difference in behavior for different steels. It also shows the idealized behavior that is used so much within the AISC *Specification*.
Expected vs. Nominal Material Strengths	This activity demonstrates the concept of *expected yield stress* through graphical animations of steel coupon tests. Users can "run" the (randomly generated) tests and then practice calculating R_y and R_t . Even in a course that does not cover seismic design, this applet can be used to illustrate the concept of *minimum* yield stress and *expected* yield stress. It may also be illustrative to ask students to compare R_y for A36 and A992, which provides an opportunity to discuss their different ASTM requirements. Note that the applet only uses three coupons for illustrative purposes; instructors should make it clear that R_y is determined from more than three samples.

Tension Members and Simple Connections	
Overview of Tension Limit States	This applet provides a compilation of all* basic limit states for tension members and simple tensile connections. Having them together in one place allows students to visually compare the limit states and also see the larger structural implication of failure for the provided example. Instructors can use this applet to introduce tension limit states graphically in order to give students a broader context before jumping into calculations. * "all" meaning those commonly taught in an undergraduate course
Welded Tension Members	The user can generate many basic fillet weld connection scenarios for practicing calculations and/or for use during teaching. This is a customizable example, as one might see in a textbook, that allows for several different configurations. Steps of the provided solution are hideable for extra practice. Some combinations of available design parameters do not dimensionally work. This provides instructors with a simple visual aid for explaining why certain combinations may not work and to point out where to find the limits in the AISC *Specification*.
Bolted Tension Members	The user can generate many bolted scenarios for practicing calculations and/or for use during teaching. This is a customizable example, as one might see in a textbook with many different possible configurations. Steps of the provided solution are hideable for extra practice.Some combinations of available design parameters do not dimensionally work. This provides instructors with a simple visual aid for explaining why certain combinations may not work and to point out where to find the limits in the AISC *Specification*. Bolt thread conditions are also illustrated to demonstrate the implication on the strength.
Block Shear	The user can generate many bolted scenarios for practicing calculations and/or for use during teaching. This is a customizable example, as one might see in a textbook, with many different possible configurations. Steps of the provided solution are hideable for extra practice. Students may find the color coding for tensile and shear planes useful. There are configurations that do not satisfy dimensional requirements, providing a visual illustration and opportunity for discussion. The user can also switch between block shear cases that must be checked, and see the two calculations side by side.

Compression Members	
Introduction to Residual Stress	This conceptual model explains, step-by-step, how and why residual stress forms in hot-rolled structural steel shapes. The animation and graphics show the heating, rolling, and cooling process, along with the stress plots for the flanges and web. This should provide a good visual/physical conceptual connection for students.
Flexural Buckling of W-Shapes	This applet can generate many scenarios for calculating flexural buckling of compression members. It is a customizable example, as one might see in a textbook, with all the solution steps provided (hideable), but with many different possible configurations. It aims to connect the column configurations with the flexural buckling curve, further connecting to the AISC *Specification* equations and helping students put it all together to form a strong understanding. Adding bracing to each axis allows the user to (i) explore the effect and (ii) to clearly demonstrate which buckling axis is being braced and the implications on the calculations. Selecting high-strength steel highlights the effect of yield strength on the limiting slenderness ratio (i.e., as F_y increases, the limiting ratio *decreases*).
Local Buckling	Similar to the applet for flexural buckling, this applet allows the user to explore compression local buckling scenarios. Users can vary the cross section, member length, boundary conditions, and steel types to see the effects (for example, selecting high-strength steel highlights the effect of yield strength on the limiting slenderness ratios). They can also use the applet to practice computing the governing compressive strength. It also conceptually illustrates how slender elements affect the controlling compressive strength (i.e., the relation between local buckling stress of the element and the resulting effective area used in the flexural buckling equation), as this may not be abundantly evident to students when reading AISC 360-22 Chapter E7.

Flexural Members	
Overview of Flexural Limit States	This applet provides a compilation of all* flexural limit states for a wide-flange beam in one place where they can be easily compared. In addition to a visual representation of each failure mode, the bending stress distribution is also shown to illustrate that LTB and FLB can occur in plastic, inelastic, and elastic cross sectional stress conditions. Instructors might use this applet to introduce all* flexural limit states with this broader context before jumping into calculations, allowing students to relate and distinguish the limit states from one another while considering the bending stress and resulting moment carried by the member. * "all" meaning those commonly taught in an undergraduate course
Beam Yielding (Plastic Moment)	This activity connects the familiar elastic bending theory to inelastic and plastic bending limit states in a number of ways, while allowing the user to increase and decrease the applied moment on the section. Additionally, plastic section modulus, Z_x, calculations are shown for a few W and WT sections. Instructors can use this applet to convey this fundamental topic to students in class, by illustrating how the stress along the cross section transitions from elastic to plastic as well as how a plastic hinge is formed. It also can be used to visually demonstrate the meaning of Z_x is and how it can be calculated together with M_p.
Lateral Torsional Buckling (LTB)	This activity provides a unique dynamic view of LTB and C_b, and how beams with various loadings and L_b fall on the "LTB curve." It is intended to help students connect the design equations with the M_n-L_b relationship and to emphasize how to find the C_b factor and avoid common errors. Note, force magnitudes are intentionally omitted on the beam diagram so that instructors can (i) encourage students to compute a desired moment diagram themselves and/or (ii) use this applet for homework assignments for strength check problems.
Flange Local Buckling	Users can explore flange local buckling by considering a custom (fictitious) cross section. While varying the flange width and thickness, users can see how the cross section changes as well as the flexural strengths with respect to bending stress and flange slenderness ratio. The custom cross section allows instructors and students to not only conceptually explore flange local buckling but also to generate examples of how to calculate the flexural strength. In addition to the custom cross section, several wide-flange shapes are available for selection.
Introduction to Beam Design	This activity introduces the design of a non-composite beam ((with full lateral support) while considering both strength and serviceability limits. Several beam load configurations are included along with customizable dead and live loads. Through a controlled sequence of steps, the user can see the necessary calculations for moment and shear demands, maximum deflection, minimum required moment of inertia , minimum required plastic modulus, and shear capacity. Then, a design summary is provided with selection of a beam size from a predetermined list of cross sections. Each step in the process can be hidden; completing the steps in order will help facilitate student practice.

Combined Loading	
Introduction to Second-Order Effects	Students likely have very little, if any, experience with the concept of second-order analyses. This activity provides two examples demonstrating the concepts by building upon simple, familiar first-order analyses. The magnitude of the moment amplification can be controlled with an axial force slider, and the simple illustrations update accordingly. Instructors can use this in class as an animated visual aid. Students can use it to reinforce their understanding of a second-order analysis and why it is so important to consider in design. This activity can help students develop a conceptual understanding before the instructor dives into the methodical details.
Combined Loading	By exploring custom combinations of the forces applied to various W-shapes, students can use this activity to gain a feeling for the importance of checking combined moment and axial forces. Instructors can use this to generate examples in class. Students can use it as a studying tool for additional calculation practice. Note that the B_1 calculations from the approximate second-order method are included.
Introduction to the Approximate Second-Order Analysis Method	The goal of this applet is to convey the "physical" meaning of the two analyses required in the approximate second-order analysis method, the lateral translation (*lt*) and no lateral translation (*nt*) analyses. The activity builds the approximate method equations step-by-step, showing a representative structure and corresponding moment diagrams, which are amplified by the B_1 or B_2 factors accordingly. This can help students develop a conceptual understanding before diving into the details of the method.