

A New Way to Teach Structural Steel to Construction Management Students

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Abstract

Structural Steel is taught in engineering, construction management (CM) and architecture programs all around the world. It has been recognized that students in these three disciplines should be taught differently so that they are able to accomplish the tasks they are assigned in their professional careers. For example, it is appropriate to teach rigorous design of beams, columns and connections to engineering students, whereas, the topics appropriate for CM students are, (i) materials and specifications, (ii) shop drawings, (iii) basic structural concepts of beams and columns, (iv) construction loads due to equipment, (v) worker safety, (vi) trouble shooting field problems (vii) design and selection of temporary structures for construction and (viii) steel fabrication for constructability and safety etc. This paper presents the teaching aids developed by the author and other faculty members as well as AISC in the form of PowerPoint presentations, selected videos as well as Steel Sculpture used for instruction. This effort is ongoing so many revisions to the resources presented in this paper are being made. This is primarily an informational paper with the objective of helping faculty members in construction programs responsible for teaching structural steel to find construction management specific teaching materials.

Keywords

Steel beams, Columns, Base Plates, High Strength Bolts, Structural Connections.

1. Introduction

It may be noted that many undergraduate CM programs in the US offer only one three hour structures course that covers structural concepts of concrete, steel and wood. The American Council of Construction Education (ACCE), the accreditation agency in the US, requires more emphasis on management, estimating, scheduling and safety and only basic understanding of structural aspects of steel and concrete. This thinking, although correct for training future construction managers, limits the number of hours that can be spent to teach structural steel. It, therefore, becomes more important that topics appropriate for CM students are carefully selected and taught. At Rinker School two structures courses; one for concrete and another for structural steel; were recently combined to a single course to align the program with the general norms of CM education in the US.

Reduced focus on teaching structures to CM students has led to a dearth of appropriate text books for these students. Few that have been written are not updated to reflect all the revisions in Steel Manuals and Building Codes. Many books, however, are available to address the needs of engineering students. Construction management professors generally use selected topics from these engineering books to teach their students as well. However this approach, because of the adopted text, leads their course to be still focused on engineering and design and leaves many important topics uncovered.

The author has been teaching structures courses in the Rinker School, University of Florida, for the past twenty-two years to undergraduate and graduate students. The author has also completed a research grant on steel structures curriculum development for CM students funded by the American Institute of Steel Construction (AISC). This paper describes essential topics appropriate for CM students as determined by the Partners in Education (PIE) committee of AISC as well as several experts associated with the steel industry. This informational paper describes detailed listing of topics, content and resources available to the CM faculty. Many resources are freely available at the AISC website <http://www.aisc.org/content.aspx?id=638> and the author's website <http://ajayshanker.com> in the CITC8 folder. The files include PowerPoint presentations, videos, digital project images, Steel Sculpture, steel frame model for laboratories and shop drawings. The paper provides information for the following essential topics

- i. Structural shapes and section properties using AISC manual.
- ii. ASTM standards and material properties
- iii. Beam design, plastic section modulus and lateral support.
- iv. Steel Sculpture for understanding connections
- v. Steel construction videos
- vi. Shop drawings, notations and bill of materials
- vii. Composite construction with steel beams and metal deck
- viii. Open web steel joists: types, selection and installation
- ix. Column base plate design and details
- x. Architecturally exposed structural steel
- xi. Crane selection for steel frame projects
- xii. OSHA steel erection rules and site safety
- xiii. Design and selection of columns and braced column
- xiv. Bolted connections: high strength bolts
- xv. Welded connections, AWS weld symbols and details

A brief description of the necessity of abovementioned topics and available resources is presented below

(i) Structural shapes, section properties using AISC manual.

Table 1-1
W Shapes
Dimensions

Actual depth

Shape	Area, A in. ²	Depth, d in.	Web		Flange		Distance				Work- able Gage in.		
			Thickness, t _w in.	t _w /2 in.	Width, b _f in.	Thickness, t _f in.	k _{ext} in.	k _{int} in.	k ₁ in.	r in.			
W44x335	98.5	44	1.03	1	1/2	15.9	16	1.77	2.56	2 1/8	1 1/8	38 1/4	5 1/2
>290	85.4	43.6	3/4	0.865	7/8	15.8	15 1/8	1.58	2 3/8	2 1/8	1 1/4		
>262	76.9	43.3	3/4	0.785	1 1/8	15.8	15 3/8	1.42	2 1/4	2 1/4	1 1/8		
>230	67.7	42.9	3/4	0.710	1 1/8	15.8	15 1/2	1.22	2 1/4	2 1/4	1 1/8		

Cross-sectional

area

CM students need to be fully aware of all steel shapes, notations, weights, structural properties and their appropriate uses. The latest AISC manual 14th edition covers all shapes that include Wide-flange (W), Miscellaneous (M), American Standard Shapes (S), Piles (HP), Channels (C), Angles (L), Hollow structural Shapes (HSS) etc. The latest entire shapes database **AISC Shapes Database V14.0 - Current** can be freely downloaded from <http://www.aisc.org/content.aspx?id=2868> AISC has an educational discount program wherein students can also buy the AISC manual at a substantial discount. A detailed

PowerPoint presentation, **Structural Shapes and ASTM Standards**, has been developed by the author and can be downloaded from <http://ajayshanker.com> from the conference folder. The PowerPoint describes all shapes with detailed animations.

(ii) ASTM standards and material properties

Table 2-3
Applicable ASTM Specifications
for Various Structural Shapes

Steel Types

Preferred Specification

Limited availability

Structural Steel is available in many chemical compositions, e.g., carbon, high strength low alloy, corrosion resistant high strength low alloy, quenched and tempered alloy and quenched and tempered low alloy to meet different construction requirements. Further each of the chemical composition can be made for various yield and ultimate strengths. CM students have to thoroughly understand steel specifications and strength properties as many cases of incorrect shipments from fabrication shops have been documented. These errors occur due to illegible or hand written ship marks. The PowerPoint presentation, **Structural Shapes and ASTM Standards** describes all the ASTM standards for rolled, plate stock as well

as connectors

(iii) Beam design, plastic section modulus, lateral support



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Although CM students may not be involved in the structural design they must fully understand the design process, the intended function of steel beams as well as construction situations where the moment capacity or stiffness may be compromised. They may also have to deal with various fabrication errors and decide if those errors are acceptable or need to be rectified. Author has develop a PowerPoint presentation **Plastic Sectional Modulus and Design of Steel Beams** that can be downloaded from

(iv) Steel Sculpture for understanding connections



Steel sculpture designed in early eighties at University of Florida has been constructed at more than hundred campuses across the US to teach structural steel connections. The sculpture is about eight ft. tall has most of the shear and moment connections, column and beam splices. Author has developed a detailed PowerPoint **Steel Sculpture** that describes every connection. The PowerPoint is available at <http://ajayshanker.com> Images of the sculpture made across many campuses are available at

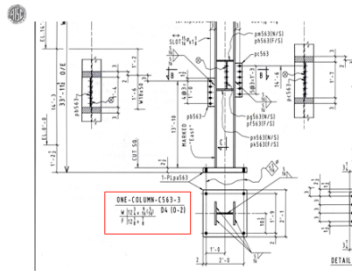
<http://www.facebook.com/media/set/?set=a.40275498817.48698.40249663817> Please visit <http://www.aisc.org/WorkArea/showcontent.aspx?id=3480> for downloading steel connection tool kit for detailed description of Steel Sculpture. Instructors can also email universityprograms@aisc.org or the author to get the shop drawings of the Steel Sculpture. AISC has already provided help to establish the Steel Sculpture in other countries and will be very happy to provide shop drawings as well as necessary guidance. Steel Sculpture is an excellent tool to make students understand the steel connections

(v) Steel construction videos

AISC has made available many steel construction videos suitable for CM students at <http://www.aisc.org/content.aspx?id=21520>. The titles of videos are (i) Fabrication Detailing, (ii) Single-Story Building, (iii) Structural Steel Erection, (iv) Structural Steel Production, (v) The Behavior of Columns, (vi) The Behavior of Unrestrained Steel Beams, and (vii) Today's Steel: Shaping the Future. These videos are of ten-to-twenty minute duration and are quite engaging. The author has been assigning the students to watch these videos as an out of class assignments. Student's response regarding understanding of steel construction by videos has been very positive. Author uses HW assignments and exam questions to ensure that students complete the video assignment.

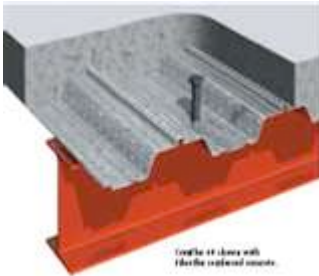
The author has also compiled a set of videos with titles, (i) Bending Hollow Steel Sections, (ii) Brick Cladding for Steel Frame Buildings, (iii) Cambering W-shape Beams, (iv) Precast Flooring with Asymmetrical W-Shape Beams, (v) Lateral Stability of Steel Frames, (vi) Oxyacetylene Cutting, (vii) Manufacturing Composite Metal Decks (viii) Shielded Metal Arc Welding (ix) Steel Column Splicing, (x) Continuous Casting for Making Steel (xi) Manufacturing Steel Tubes mostly from Corus Steel and other online resources. These videos are available at www.ajayshanker.com in the conference folder.

(vi) Shop drawings, notations, bill of materials



Review and approval of shop drawings is an important task of Construction managers. CM students have to learn each and every detail and notation called out on shop drawings and ensure the constructability of the assembly. Author has prepared a detailed PowerPoint **Shop Drawing** and has made available at ajayshanker.com

(vii) Composite construction with steel beams and metal deck



Composite construction with W-shape steel beams, composite deck and shear studs is very common in the US for floor construction of buildings. Composite construction reduces beam sizes and the construction costs. AISC provides a detailed PowerPoint presentation **Composite Construction** at <http://www.aisc.org/content.aspx?id=21476>

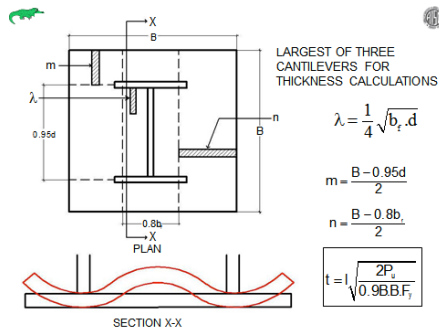
(viii) Open web steel joists: types, selection and installation



The Open Web Bar Joists serve large segment of construction industry especially the roof systems for single story retail buildings. Roof systems made with open web bar joists are extremely popular because of low cost and quick construction. Information about the steel joists can be obtained from www.steeljoist.org. This website offer many free publications, videos and CAD drawings to understand steel joists and the

industry. The website www.sdi.org provides all the information for galvanized steel roof decks, composite roof decks as well as floor decks. Author has also created an informational PowerPoint **Steel Joists** and is available at ajayshanker.com in the conference folder.

(ix) Column base plate design and details



Construction students should learn about the design detailing structural properties and detailing of column base plates in detail. In the US this part of steel columns creates many problems especially about the mis-alignment of the anchor bolts. The PowerPoints (i) **Shop Drawings** and (ii) **Column Base Plates** both provide adequate information about the base plates. Both PowerPoints are available in the conference folder at ajayshanker.com

(x) Architecturally exposed structural steel



Advance in steel fabrication and the bending equipment to shape structural members in circular, parabolic and other aesthetically pleasing shapes have given birth to a new industry called **Architecturally Exposed Structural Steel**. In US it is known by the acronym AESS. This type of construction utilizes welding, grinding and painting structural members in pleasing colors. This construction relies on sprinkler system for fire protection as structural members are not insulated. Extremely tight tolerances

can be used for bolted connections. US steel industry has developed specification for AESS and are available at www.steel.org. A good PowerPoint about AESS is also available at <http://www.aisc.org/content.aspx?id=21480>

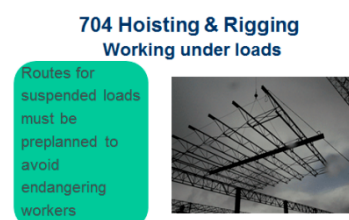
(xi) Crane selection for steel frame projects



Construction managers will have to ensure that appropriate crane type and of required capacity is selected and utilized. Besides selection, placement, working radius as well as scheduling of crane has to be planned. Steel construction utilizes cranes for lifting heavy structural members. Crane rentals are very expensive so planning, scheduling and appropriate size selection are very critical. AISC has developed a detailed PowerPoint for learning crane selection, crane

use optimization, lift evaluation and crane placement for steel frame buildings. The PowerPoint is available at <http://www.aisc.org/content.aspx?id=21478>. Literature of major crane manufacturers are available at www.grovetworldwide.com, www.linkbelt.com, www.terex.com, and www.tadanoamerica.com

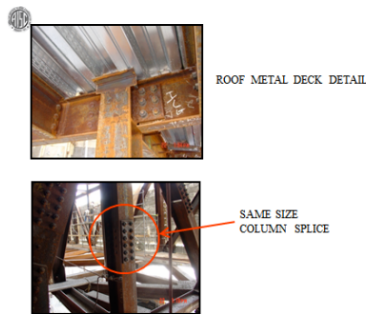
(xii) OSHA steel erection rules and site safety



Occupational Safety and Health Administration, OSHA, a federal agency in the US studied 673 fatalities of ironworkers in detail. OSHA constituted a committee, **Steel Erection Negotiated Rulemaking Advisory Committee, SENRAC**, to develop rules for protection of ironworker at steel frame construction projects. The rules took effect in 2001 and cover all

area of steel frame construction projects, such as, site layout, site specific erection plan and construction sequence, hoisting & rigging, structural steel assembly details, column anchorage, beams & columns, open web steel joists, systems engineered metal buildings, falling object protection, fall protection and training. Violation of these rules result in severe penalties that run into hundreds of thousands of dollars for contractors. Author has developed a PowerPoint **OSHA Steel Erection Rules** and is available at ajayshanker.com If additional information is needed www.osha.gov can be used to find needed information.

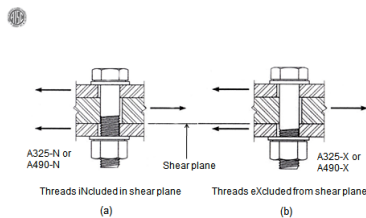
(xiii) Design and selection of columns and braced column



Construction students should know about shipping size, splicing, lifting holes and web plates to receive the floor beams. A good knowledge to identify shear and moment connections for floor beams is also needed. A mathematical exercise to show column capacities for different column heights and end conditions is also important. Other issues related to holes on perimeter columns for safety cables, painting and welding, material specifications are also important. Author has developed a PowerPoint **Design and Construction of Steel Columns** and is available at

ajayshanker.com.

(xiv) Bolted connections: high strength bolts



Construction management students will supervise field operations such as bolting and welding. It is extremely important that they know all issues related to structural bolts, such as, specifications; failure modes shear tension bearing block-shear; strength reduction if threading is in shear plane, installation procedures for bearing and slip critical bolts, bolt spacing for constructability, standard and slotted holes, bolts in single or double shear etc. As most structural failures only occur at connections and connections are supervised by CM

students a good understanding of all aspects of bolted construction is important. Author has developed a PowerPoint **Bolted Connections** and is available at ajayshanker.com. AISC has also made available PowerPoints **Bolting and Welding** and **Connections and Bracing** at <http://www.aisc.org/content.aspx?id=21476>

(xv) Welded connections, AWS weld symbols and details

	Types of Welds		
	Edge Preparation	Single	Double
Fillet	None		
Groove	Square		
	Bevel		
	Vee		
	J		
	U		

Welding is another field process that CM students should know in detail. Steel frame construction is increasingly done by using fillet welded moment connections for connecting floor beams to columns. Students should have expertise in reading shop drawings that show various weld symbols, weld sizes, lengths and specifications of electrodes. CM students should know types and uses of groove, butt and plug welds. Author has developed a PowerPoint **Weld Symbols** and is available at ajayshanker.com. The PowerPoints published by AISC and mentioned in previous Bolted connections also have slides for welding. American Welding Society,

www.aws.org is the main resource repository for the latest in welding industry. The website also has many publication that are free downloads.

References

AISC Steel Construction Manual, Fourteenth Edition, 2014