

## Night School 23: Topics on Industrial Building Design and Design of Non-building Structures

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**Session 8 – Non-building Buildings, Part 2**  
August 11, 2020



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## AISC Live Webinars

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## AISC Live Webinars

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### Course Description

#### Non-building Structures, Part 2 August 11, 2020

This session will focus on the design of plate structures. Basic geometry, stiffener layouts, design references, loads, details and analysis will be discussed. The session will also look at buckling of cylindrical shells, flat plates subjected to out-of-plane loads, and review the design of stiffeners.



## AISC Live Webinars

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### Learning Objectives

- Identify various plate and shell structures and design resources for each.
- List loads and load considerations for the design of various plate and shell structures.
- Describe the critical limit state of buckling in cylindrical shells.
- List the applicable design considerations for stiffener design of plate and shell structures.



# Night School 23: Industrial Structures

Session 8 – Non-building Structures, Part 2

August 11, 2020



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## Plate and Shell Structures



## Plate and Shell Structures

- Introduction
- Loads
- Buckling of cylindrical shells
- Analysis
- Stiffener design



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## Plate and Shell Structures

### Introduction



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## Introduction

### Structure Type Identified by Function

- Fluid storage: tanks
- Bulk solids storage/handling: silos, bins, hoppers, chutes, stacking tubes
- Gas transport/modification: stacks, ducts, pollution control equipment
- Support structures: tubular conveyor galleries, sign structures, wind turbines



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## Introduction

### Tanks



12

## Introduction

- AWWA (2011), *Welded Carbon Steel Tanks for Water Storage*, AWWA D100-11, American Water Works Association.
- API (2020), *Welded Tanks for Oil Storage*, API Standard 650, 13<sup>th</sup> Edition, American Petroleum Institute.
- API (2013), *Design and Construction of Large, Welded, Low-Pressure Storage Tanks*, API Standard 620, 12<sup>th</sup> Edition, American Petroleum Institute.



## Introduction

### Silos, Bins, Hoppers



## Introduction

- Gaylord, E.H. and Gaylord, C.N. (1984), *Design of Steel Bins for Storage of Bulk Solids*, Prentice-Hall.
- Rotter, J.M. (2001), *Guide for the Economic Design of Circular Metal Silos*, Spon Press.
- CEN (2007), *Silos*, Eurocode 3, Design of Steel Structures, Part 4-1, EN 1993-4-1, European Committee for Standardization.
- CEN (2006), *Silos and Tanks*, Eurocode 1, Actions on Structures, Part 4, EN 1991-4, European Committee for Standardization.
- AS (1996), *Loads on Bulk Solids Containers*, AS 3774-1996, Australian Standard.



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## Introduction

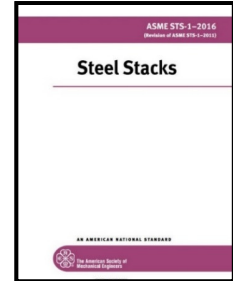
### Stacks



16

## Introduction

- ASME (2017), *Steel Stacks*, ASME STS-1-2016, The American Society of Mechanical Engineers.
- SMACNA (2011), *Guide for Free Standing Steel Stack Construction*, Sheet Metal and Air Conditioning Contractors National Association.
- CICIND (2010), *Model Code for Steel Chimneys*, International Committee on Industrial Chimneys.
- CICIND (2005), *The CICIND Chimney Book*, International Committee on Industrial Chimneys.



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## Introduction

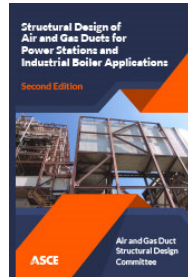
### Industrial Ducts



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## Introduction

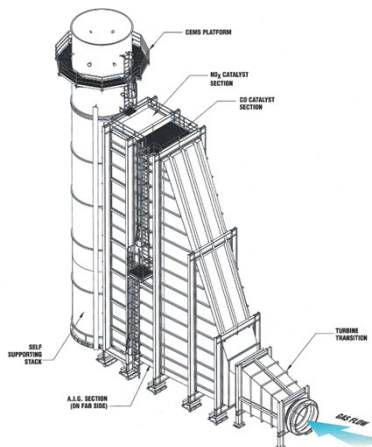
ASCE (2020), *The Structural Design of Air and Gas Ducts for Power Stations and Industrial Boiler Applications*, 2<sup>nd</sup> Edition, ASCE.



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## Introduction

### Pollution Control Equipment



ICAC (2002), *Structural Design Guide for Selective Catalytic Reduction Reactor Structures*, ICAC-SCR-2, Institute of Clean Air Companies

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## Introduction

- ICAC (2002), *Structural Design Guide for Selective Catalytic Reduction Reactor Structures*, ICAC-SCR-2, Institute of Clean Air Companies
- ICAC (2001), *Structural Design Guide for Fabric Filter Casings*, ICAC-F-8, Institute of Clean Air Companies
- ICAC (1993), *Structural Design Criteria for Electrostatic Precipitator Casings*, ICAC-EP-8, Institute of Clean Air Companies



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## Introduction

### Tubular Conveyor Galleries



22

## Introduction

- CEMA (2014), *Belt Conveyors for Bulk Materials*, 7<sup>th</sup> Edition, Conveyor Equipment Manufacturers Association.
- Troitsky, M.S. (1990), *Tubular Steel Structures-Theory and Design*, 2<sup>nd</sup> Edition, The James F. Lincoln Arc Welding Foundation.
- Troitsky, M.S. (1982), “Tubular Conveyor Galleries,” *Engineering Structures*, Vol. 4, No. 2.



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## Plate and Shell Structures

### Loads



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## Loads

### General

- Wind
- Seismic
- Dead
- Live
- Maintenance loads



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## Loads

### Tanks

- Fluid pressure

### Stacks

- Vortex shedding vibrations perpendicular to the wind direction
- Ovalizing wind vibrations

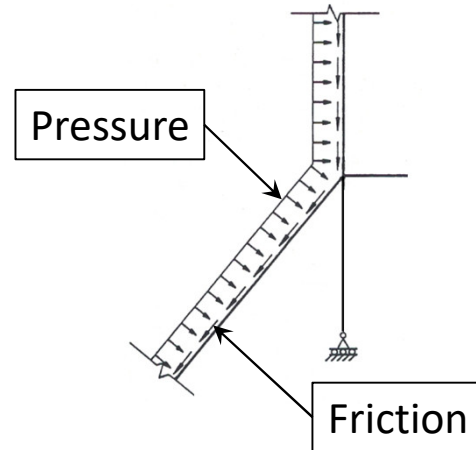


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## Loads

### Bulk Solids Storage

- Material pressure
- Material friction
- Dynamic impact
- Material expansion



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## Loads

### Chutes

- Material pressure
- Material friction
- Dynamic impact

### Tubular Conveyor Galleries

- Belt pull force during operation, startup and shutdown
- Thermal load



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## Loads

### Industrial Ducts

- Pressure
- Thermal load caused by gas temperature
- Ash/dust weight



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## Plate and Shell Structures

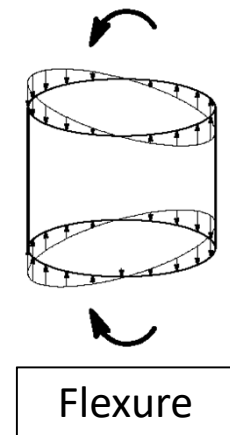
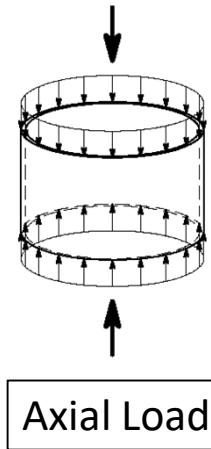
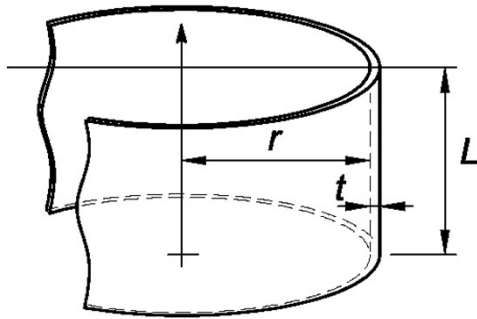
### Buckling of Cylindrical Shells



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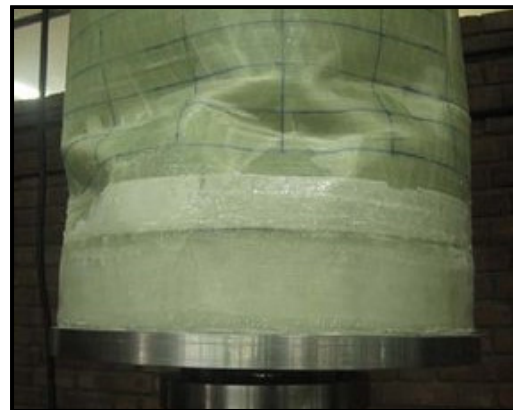
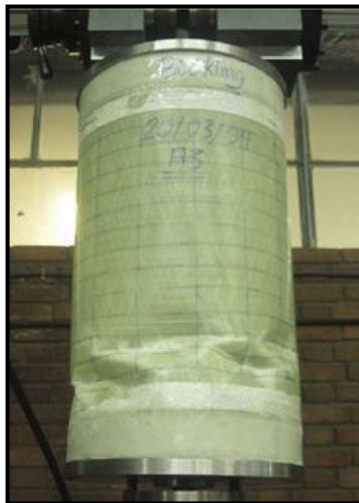
## Buckling of Cylindrical Shells

Buckling is the critical limit state of cylindrical shells with high  $r/t$  ratios subjected to compressive membrane stresses.



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## Buckling of Cylindrical Shells



Behrooz, F.T., Omidi, M. and Shokrieh, M.M. (2017), "Experimental and Numerical Investigation of Buckling Behavior of Composite Cylinders with Cutout," *Thin-Walled Structures*, Vol. 116.

32

## Buckling of Cylindrical Shells

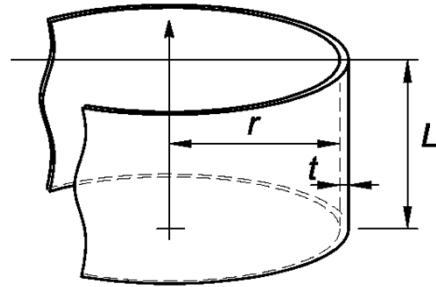
The theoretical buckling stress (classical elastic critical stress) of a perfect cylindrical shell subjected longitudinal compression is

$$\sigma_{cl} = \frac{E}{\sqrt{3(1-\nu^2)}} \frac{t}{r} = 0.605E \frac{t}{r}$$

$E$  = modulus of elasticity

$r$  = radius

$t$  = thickness



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## Buckling of Cylindrical Shells

Capacity reduction (knockdown) factors must be applied to the critical stress to address these effects:

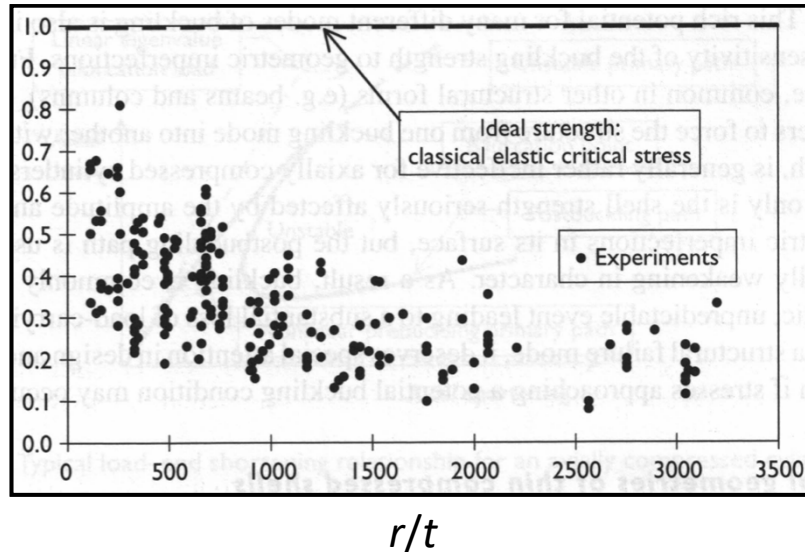
- Geometric imperfections
- Inelasticity
- Interaction of buckling modes



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## Buckling of Cylindrical Shells

Buckling Stress  
Ratio,  $\sigma_l/\sigma_{cl}$



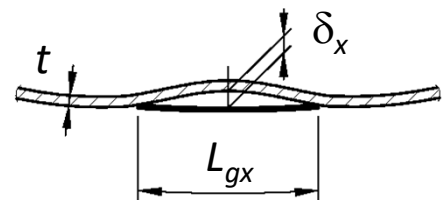
Teng, J.G. and Rotter, J.M. (2004), Buckling of Thin Metal Shells, Spon Press.

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## Buckling of Cylindrical Shells

### Geometric Imperfections

- Knockdown factors have been developed for various types of structures with different levels of fabrication quality
- The document that was used to calculate the buckling strength should also be used to determine the tolerances



Geometric  
Imperfection  
Tolerance



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## Buckling of Cylindrical Shells

### Further Information:

- API (2004a), *Bulletin on Stability Design of Cylindrical Shells*, API Bulletin 2U, Third Edition, American Petroleum Institute, June.
- ASME Code Cases N-284 and N-530 (and others)
- CEN (2007), *Strength and Stability of Shell Structures*, Eurocode 3, Design of Steel Structures, Part 1-6, EN 1993-1-6, European Committee for Standardization.



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## Buckling of Cylindrical Shells

- Ziemian, R.D. (2010), *Guide to Stability Design Criteria for Metal Structures*, Sixth Edition, John Wiley & Sons.
- ECCS (2008), *Buckling Strength of Steel Shells-European Design Recommendations*, 5<sup>th</sup> Edition, European Convention for Constructional Steelwork.
- Teng, J.G. and Rotter, J.M. (2004), *Buckling of Thin Metal Shells*, Spon Press.



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# Plate and Shell Structures

## Analysis



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## Analysis

### ***AISC Specification Section A1***

The *Specification* applies to “...structural steel buildings and other structures, where other structures are defined as structures designed, fabricated and erected in a manner similar to buildings, with building-like vertical and lateral load resisting elements.”



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## Analysis

The available strengths in the *AISC Specification* were not developed to be compared to the results from finite element models built with plate, shell or solid elements.

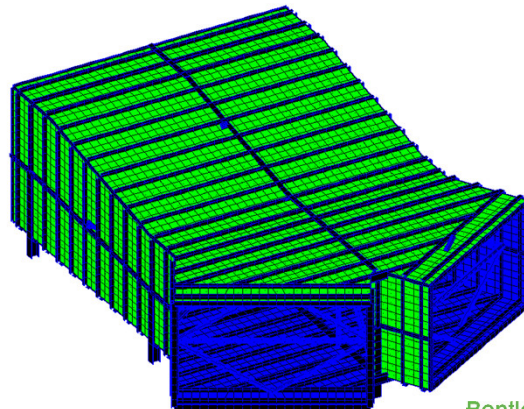
The safety factors (ASD) and resistance factors (LRFD) were calibrated to provide a specific target reliability when compared with required loads calculated using truss and beam elements in the structural analysis model.



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## Analysis

The analysis of plate and shell structures can be performed with finite element models, equations or a combination of the two methods.



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# Plate and Shell Structures

## Analysis

### Finite Element Models



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### Finite Element Models

Generally, three methods are used to model plate and shell structures:

1. Coarse mesh

- Large plate elements are used to distribute the applied loads to the stiffeners and supports
- Stiffeners can be designed within the software
- Plate stresses are not required to be accurate because the plates are designed manually



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## Finite Element Models

2. Fine mesh
  - Mesh refinement is required for accurate plate stresses
  - Required plate stresses are determined within the software
  - Available plate stresses are calculated manually
  - For further information, see API (2004b) and Spyrakos (1994)
3. Advanced analysis
  - The strength is determined within the software
  - For further information, see CEN (2007) and ECCS (2008)



API (2004b), *Design of Flat Plate Structures*, API Bulletin 2V, Third Edition, American Petroleum Institute, June.

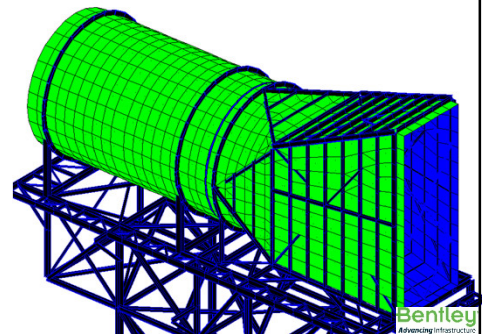
Spyrakos, C.C. (1994), *Finite Element Modeling in Engineering Practice*, Algor, Inc. Publishing Division.

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## Finite Element Models

Stiffeners are usually modeled with offset beam elements. This modeling technique captures the stiffener moment caused by loads that are applied in the plane of the plate (for example, thermal expansion/contraction).

- The offset is the distance from the plate centerline to the stiffener centroid
- The offset can be modeled with rigid links or an “offset” command in the software



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# Plate and Shell Structures

## Analysis

### Plate/Shell Stresses



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### Plate/Shell Stresses

- Stress concentrations and end effects can cause high local stresses in plate/shell finite element models
- “It is not necessary to evaluate every location just because stresses are computed there. It is important for the analyst to focus on the failure locations based on the flow of the loads and the stress magnitudes” (Hollinger and Hechmer, 2000)
- An appropriate design model will allow higher stresses in areas when the strength is not compromised



Hollinger, G. and Hechmer, J. (2000), “Three-Dimensional Stress Criteria—Summary of the PVRC Project,” *Journal of Pressure Vessel Technology*, American Society of Mechanical Engineers, Vol. 122, February, pp. 105-109.

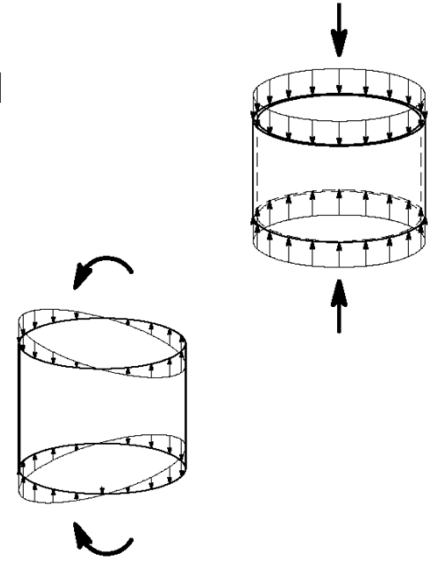
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## Plate/Shell Stresses

### Membrane Stress

Normal stress that is uniformly distributed across the plate thickness

- Remote from discontinuities
- Example: global bending and axial stresses in a cylindrical structure



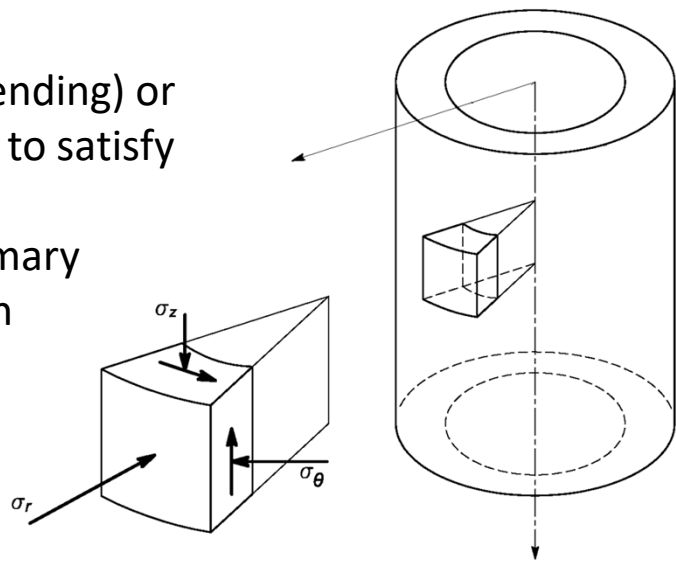
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## Plate/Shell Stresses

### Primary Stress

Any normal (membrane or bending) or shear stress that is necessary to satisfy the laws of equilibrium

- Results in failure if the primary stress exceeds the strength
- Not self-limiting



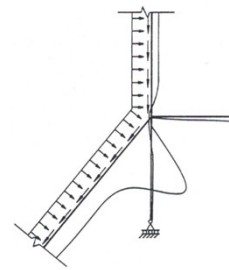
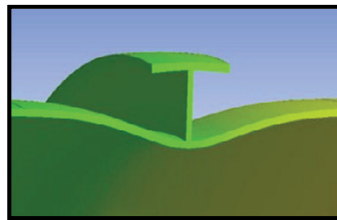
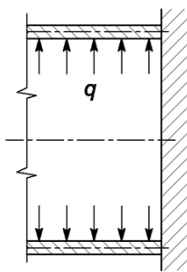
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## Plate/Shell Stresses

### Secondary Stress

A stress caused by constraint.

- Minor distortion caused by local yielding and relieve the stresses without failure
- Self-limiting



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## Plate/Shell Stresses

### Local Primary Membrane Stress

Membrane stress at a discontinuity such as an opening or a support.

- Local yielding causes a redistribution of stresses to adjacent parts of the structure
- Excessive distortion can limit proper stress redistribution
- A stressed region can be considered local for a distance is equal to or less than  $l_s$

$$l_s = \sqrt{rt}$$



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## Plate/Shell Stresses

### Peak Stress

Sum of primary and secondary stresses

- Caused by stress concentrations at local discontinuities
- Causes only minor distortions
- Considered only as a potential source of fatigue cracking or brittle failure



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## Plate/Shell Stresses

### Allowable Plate/Shell Stresses

- Primary membrane stress:  $F_c$
- Primary normal stress (membrane plus bending):  $1.5F_c$
- Local primary membrane stress:  $1.5F_c$
- Peak stress:  $3F_c$

$F_c$  = available stress



ASME Boiler and Pressure Vessel Code, American Society of Mechanical Engineers.

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## Plate/Shell Stresses

For tension stresses,  $F_c$  is the minimum of the available yield strength,  $F_{cy}$ , and the available rupture strength,  $F_{cu}$ .

$$F_{cy} = \phi_y F_y \text{ (LRFD)}, F_y / \Omega_y \text{ (ASD)}$$

$$F_{cu} = \phi_u F_u \text{ (LRFD)}, F_u / \Omega_u \text{ (ASD)}$$

For compressive primary membrane stresses,  $F_c$  is the available buckling strength from the appropriate code/document.



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## Plate and Shell Structures

### Analysis

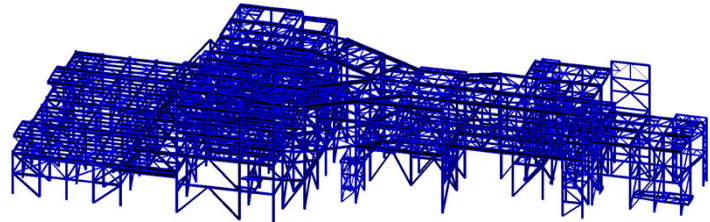
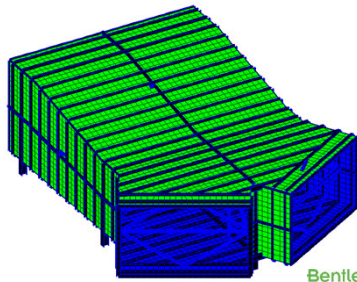
### Combined Models



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## Combined Models

For elevated plate structures that are supported by steel structures, separate finite element models are usually developed for each structure. Deformation compatibility between the two models is an important design consideration.



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## Combined Models

Generally, two methods are used to model the interface between the plate structure and the support structure.

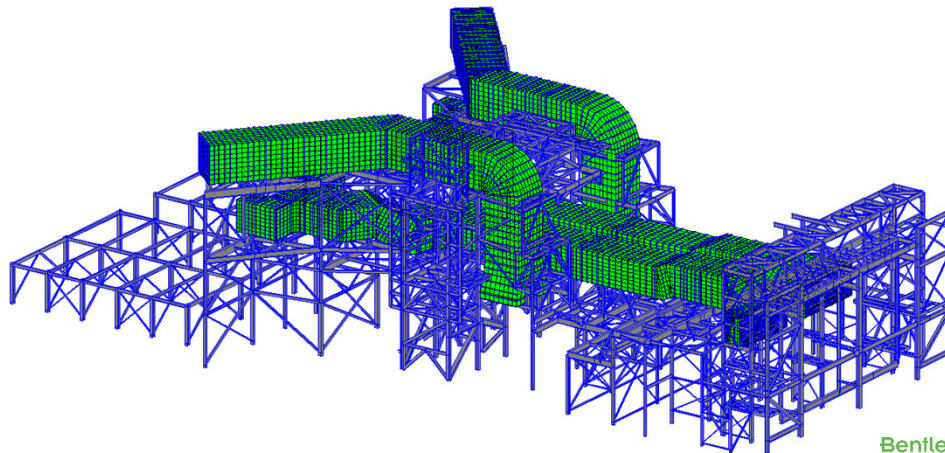
- Separate models, where the support loads from the plate/shell structures are added to the support structure
- Combined models, where the plate/shell models are imported into the support-structure model



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## Combined Models

Combined models often reveal support loads that are significantly different from the separate models.

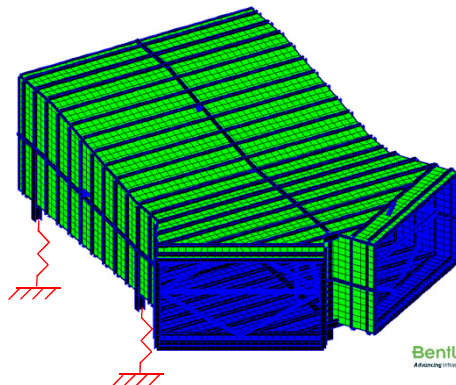


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## Combined Models

The accuracy of separate models can be increased by using spring supports in the plate/shell model based on the stiffness of the support-structure model.



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# Plate and Shell Structures

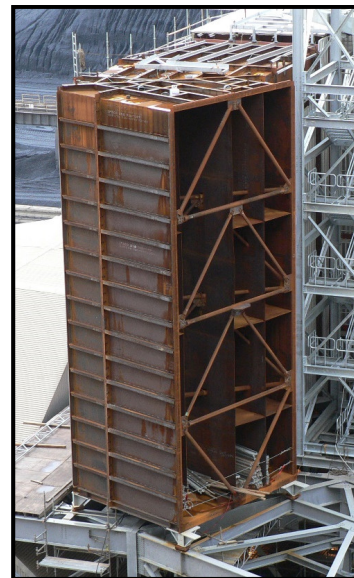
## Stiffener Design



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## Stiffener Design

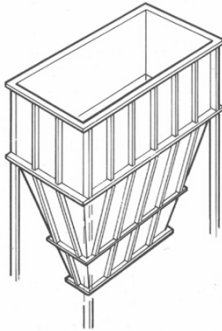
### Flat-Plate Stiffeners



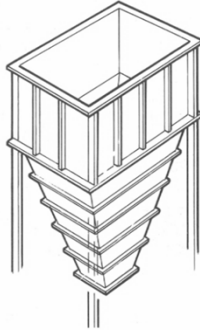
62

## Stiffener Design

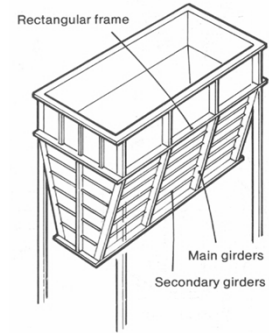
### Rectangular Hopper Stiffeners



Vertical stiffeners



Horizontal stiffeners



Two-way stiffeners



AWRA (1984), *Design and Construction of Welded Steel Bins*, AWRA Technical Note 14, Australian Welding Research Association.

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## Stiffener Design

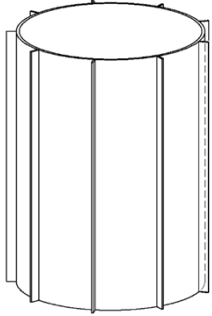
### Ring Stiffeners



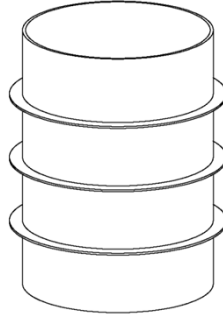
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## Stiffener Design

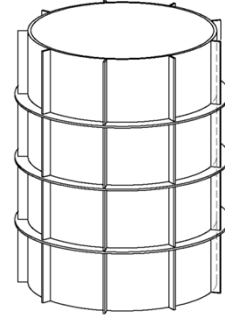
### Shell Stiffeners



Longitudinal stiffeners



Ring stiffeners



Two-way stiffeners



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## Stiffener Design

### Common Shapes



Bar



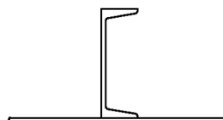
Angle-out



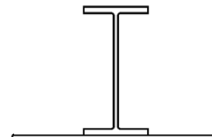
Angle-in



Tee



Channel



I-shape



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## Stiffener Design

### **AISC *Specification* Section A1**

The *Specification* applies to “...structural steel buildings and other structures, where other structures are defined as structures designed, fabricated and erected in a manner similar to buildings, with building-like vertical and lateral load resisting elements.” Therefore, the AISC *Specification* is not applicable to stiffener design in plate and shell structures.



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## Plate and Shell Structures

### Stiffener Design

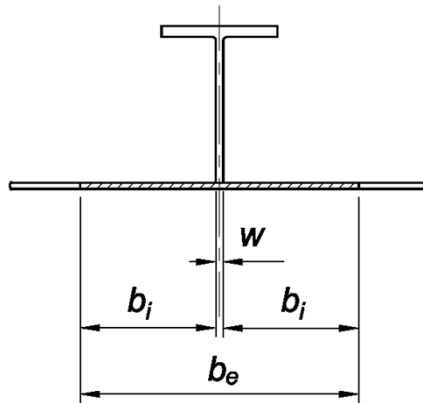
### Effective Plate Width



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## Effective Plate Width

A portion of the plate can be assumed to act compositely with the stiffener, increasing the sectional properties.



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## Effective Plate Width

The effective width is dependent on:

- For stiffeners subjected to flexure, the effective width can be limited by shear lag
- When the attached plate is subjected to axial or flexural compression, the effective can be limited by local buckling
- For stiffeners subjected to flexural compression, the smallest of the two limits for shear lag and local buckling is applicable



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## Effective Plate Width

### Design Values

- A wide range of effective width equations are available with varying degrees of complexity
- The effective width used in design varies, depending on the applicable design document

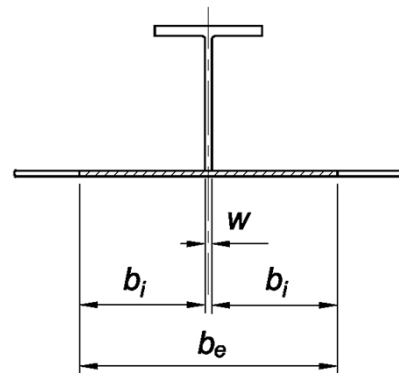


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## Effective Plate Width

### Simple Design Guidelines

- ASME STS-1-2016:  $b_e = 16t$
- Blodgett (1966):  $b_e = 24t$
- Bleich (1952):  $b_e = 30t$
- NAAMM (1992):  $b_e = 32t$
- Lambert (1968):  $b_e = 40t$



Blodgett, O.W. (1966), *Design of Welded Structures*, The James F. Lincoln Arc Welding Foundation.  
Lambert, F.W. (1968), *The Theory and Practical Design of Bunkers*, The British Constructional Steelwork Association.  
NAAMM (1992), *Metal Stairs Manual*, AMP 510-92, National Association of Architectural Metal Manufacturers.

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## Plate and Shell Structures

### Stiffener Design

#### Effective Plate Width: Shear Lag



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#### Effective Plate Width: Shear Lag

When limited by shear lag, the effective width is dependent on the length between flexural inflection points.

- For flat-plate stiffeners, the effective width is dependent on the span and the shape of the moment diagram
- For ring-stiffeners, the effective width is dependent on the radius of curvature and the bending mode



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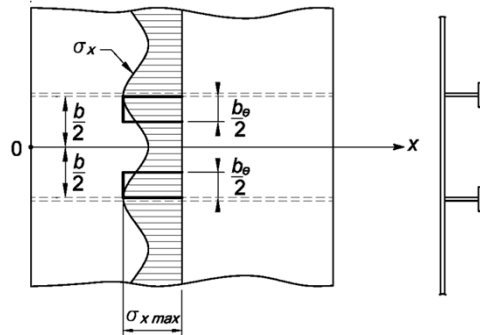
## Effective Plate Width: Shear Lag

For flat-plate stiffeners and longitudinal stiffeners at cylindrical shells (AISC *Specification* Section I3.1a; Bleich, 1952; CEN, 2006):

$$b_e = \text{Span}/4 \leq b$$

$b$  = stiffener spacing

$b_e$  = effective width



Bleich, F. (1952), *Buckling Strength of Metal Structures*, McGraw-Hill.

CEN (2006), *Design of Steel Structures-Part 1-5: Plated Structural Elements*, EN1993-1-5, European Committee for Standardization.

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## Effective Plate Width: Shear Lag

More accurate methods for flat-plate stiffeners are in API (2004), Paik and Thayamballi (2003) and Heins (1976)



API (2004), *Design of Flat Plate Structures*, Bulletin 2V, Third Edition, American Petroleum Institute, June.

Heins, C.P. (1976), *Applied Plate Theory for the Engineer*, Lexington Books.

Paik, J.K. and Thayamballi, A.K. (2003), *Ultimate Limit State Design of Steel-Plated Structures*, John Wiley & Sons.

76

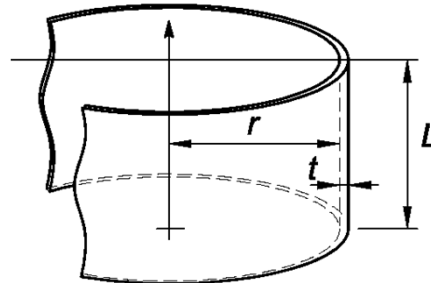
## Effective Plate Width: Shear Lag

For ring stiffeners

$$b_e = 1.56\sqrt{rt}$$

$r$  = radius

$t$  = thickness



At cone-cylinder junctions and splices with different plate thicknesses, see Rotter (2001).



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## Plate and Shell Structures

### Stiffener Design

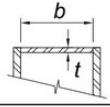
## Effective Plate Width: Local Buckling



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## Effective Plate Width: Local Buckling

Case 8 in AISC *Specification* Table B4.1a is conservative for flat-plate stiffeners.

TABLE B4.1a Width-to-Thickness Ratios: Compression Elements Members Subject to Axial Compression				
Case	Description of Element	Width-to-Thickness Ratio	Limiting Width-to-Thickness Ratio $\lambda_r$ (nonslender/slender)	Examples
8	All other stiffened elements	$b/t$	$1.49 \sqrt{\frac{E}{F_y}}$	



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## Effective Plate Width: Local Buckling

Using Case 8, solve for  $b$  to determine the effective width

$$b_e = 1.49t \sqrt{\frac{E}{F_y}}$$

$t$  = plate thickness

$E$  = modulus of elasticity

$F_y$  = specified minimum yield stress



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## Effective Plate Width: Local Buckling

A more accurate method uses AISC *Specification* Section E7 with  $k = 4.0$  in the classical plate buckling equation, resulting in an elastic buckling stress of

$$F_{el} = k \frac{\pi^2 E}{12(1 - \nu^2)(b/t)^2} = 3.62E \left( \frac{t}{b} \right)^2$$

In this case, the limiting width-to-thickness ratio is  $\lambda_r = 1.90 \sqrt{\frac{E}{F_y}}$



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## Effective Plate Width: Local Buckling

Using  $C_1 = 0.22$  in *Specification* Eqn. E7-3, the effective width is

$$\text{When } \lambda \leq \lambda_r \sqrt{\frac{F_y}{F_{cr}}} \quad b_e = b$$

$$\text{When } \lambda > \lambda_r \sqrt{\frac{F_y}{F_{cr}}} \quad b_e = 1.9t \sqrt{\frac{E}{F_{cr}}} \left( 1 - 0.42 \frac{t}{b} \sqrt{\frac{E}{F_{cr}}} \right)$$

$F_{cr}$  = critical stress for global buckling of the stiffener.  $F_{cr}$  can also be defined as the compression stress in the plate, or conservatively,  $F_y$  can be used.



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## Plate and Shell Structures

### Stiffener Design

### Global Buckling



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## Global Buckling

Generally, the strength of stiffeners can be calculated according to AISC *Specification* Chapters E, F and H for stiffeners subjected to axial compression and flexure.



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# Plate and Shell Structures

## Stiffener Design

### Global Buckling: Flat-Plate Stiffeners

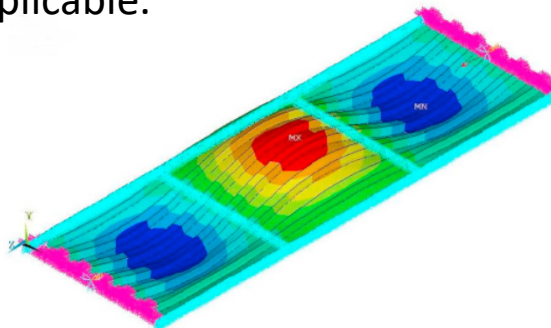


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### Global Buckling: Flat-Plate Stiffeners

#### Out-of-Plane (Flexural) Buckling

For out-of-plane buckling of stiffeners subjected to axial compression, the flexural buckling equations in *AISC Specification* Section E3 are applicable.



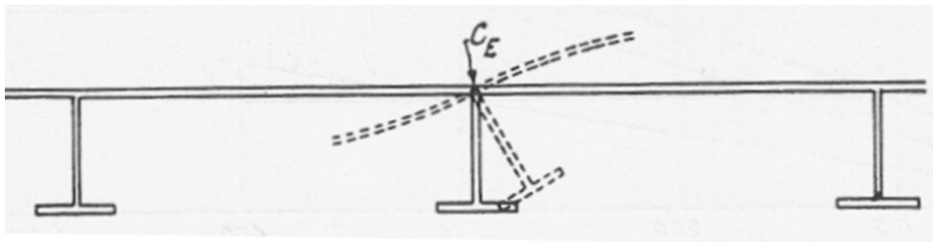
Haffar, M.Z., Kovesdi, B. and Adany, S. (2019), "On the Buckling of Longitudinally Stiffened Plates, Part 2: Eurocode-Based Design for Plate-Like Behavior of Plates with Closed-Section Stiffeners," *Thin-Walled Structures*, Vol. 145.

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## Global Buckling: Flat-Plate Stiffeners

### Stiffener Tripping

For stiffeners subjected to axial compression, the plate restrains flexural buckling in the plane of the plate. However, constrained-axis buckling can occur, where the stiffener buckles about an enforced axis of rotation.

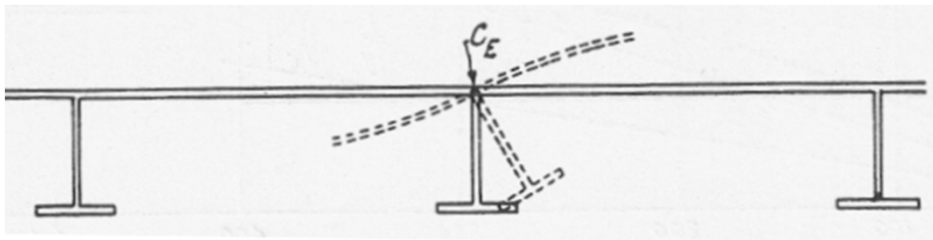


Bleich, F. (1952), *Buckling Strength of Metal Structures*, McGraw-Hill.

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## Global Buckling: Flat-Plate Stiffeners

- Plate axial resistance restrains translation
- Plate flexural resistance partially restrains torsional rotational of the stiffener



Bleich, F. (1952), *Buckling Strength of Metal Structures*, McGraw-Hill.

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## Global Buckling: Flat-Plate Stiffeners

There are several ways to design for in-plane buckling:

1. Neglect the bracing provided by the plate.
2. Assume the plate restrains only lateral translation. In this case, the limit state will be constrained-axis buckling, which is discussed on Slides 44-50 of Session 3.
3. Design the member using the plate for both lateral and torsional stability bracing. In this case, AISC *Specification* Section F12 is applicable, where  $F_{cr}$  is determined by analysis (finite element buckling analysis or calculations)



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## Global Buckling: Flat-Plate Stiffeners

For further information on stiffener tripping, refer to:

- API (2004), *Design of Flat Plate Structures*, Bulletin 2V, Third Edition, American Petroleum Institute, June.
- ABS (2004), *Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*, American Bureau of Shipping, April.
- Bleich, F. (1952), *Buckling Strength of Metal Structures*, McGraw-Hill.



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## Global Buckling: Flat-Plate Stiffeners

### Stiffeners Subjected to Flexure

For stiffeners subjected to flexure, the lateral-torsional buckling equations in *AISC Specification* Chapter F are applicable.

- Plate axial resistance restrains translation
- Plate flexural resistance partially restrains torsional rotational of the stiffener

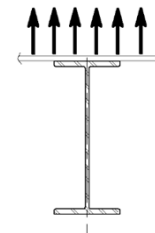
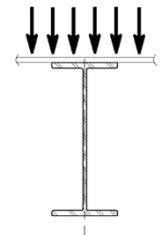


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## Global Buckling: Flat-Plate Stiffeners

Conservative design assumptions:

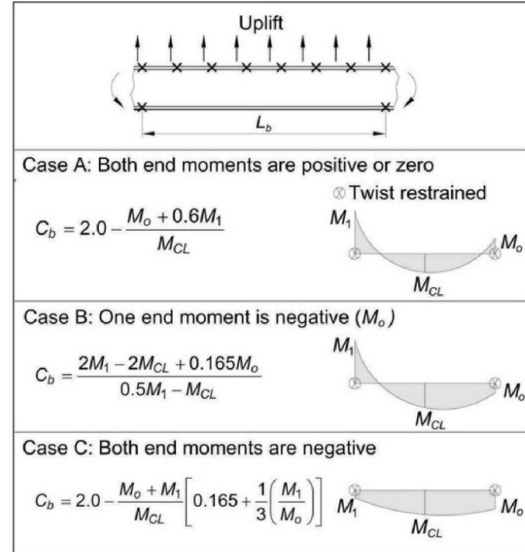
- Full bracing when the connected flange is subjected to compression
- No bracing when the non-connected flange is subjected to compression



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## Global Buckling: Flat-Plate Stiffeners

For I-shaped stiffeners with continuous lateral bracing at the tension flange subjected to a uniform suction load,  $C_b$  can be calculated according to *AISC Specification* Section F1 Commentary Figure C-F1.5.



## Plate and Shell Structures

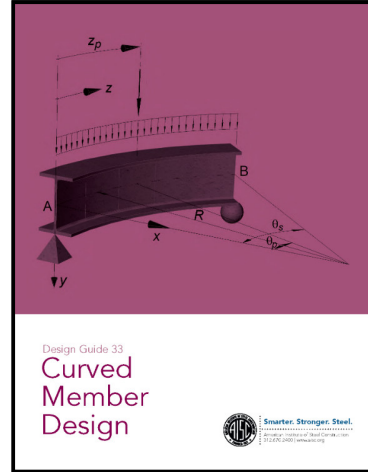
### Stiffener Design

## Global Buckling: Ring Stiffeners



## Global Buckling: Ring Stiffeners

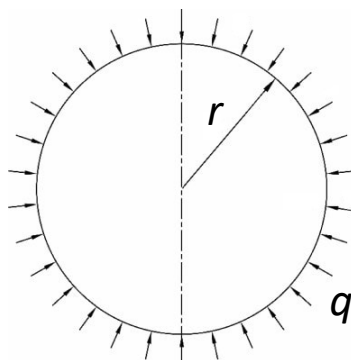
AISC Design Guide 33 can be used to design curved members as equivalent straight members.



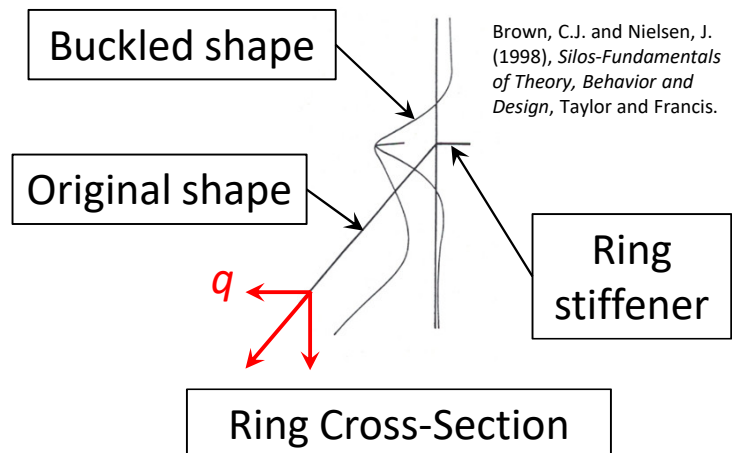
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## Global Buckling: Ring Stiffeners

In-plane buckling of a ring stiffener at a silo cone-cylinder junction



Plan



Ring Cross-Section



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## Global Buckling: Ring Stiffeners

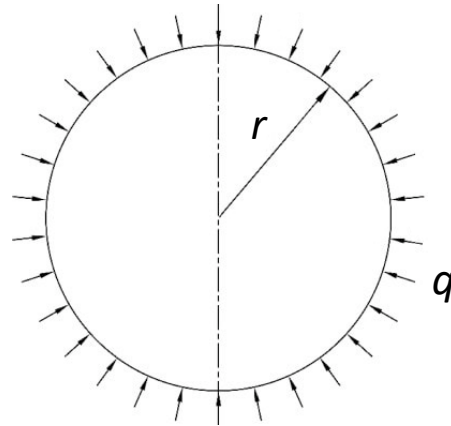
For ring stiffeners subjected to a uniform line load,  $q$ , the critical buckling load for in-plane buckling is

$$q_{cr} = \frac{3EI_i}{r^3}$$

$E$  = modulus of elasticity

$I_i$  = in-plane moment of inertia

$r$  = centroidal radius



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## Global Buckling: Ring Stiffeners

- To account for geometric and material imperfections, the stiffener can be designed as an equivalent straight column
- The flexural buckling provisions in AISC *Specification* Section E3 can be used with a modified effective length,  $L_c$
- The required axial load in the equivalent column is  $P_r = qr$
- $L_c$  is determined by setting the elastic column-buckling load ( $\pi^2EI/L_c^2$ ) equal to the ring-buckling load

$$L_c = \frac{\pi r}{\sqrt{3}} = 1.81r$$



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## Plate and Shell Structures

### Conclusions



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### Conclusions

- Design loads should be calculated with the best available code or document
- For cylindrical shells, the buckling strength is dependent on the geometric imperfection tolerances
- For plate elements, the maximum mesh size is dependent on the required accuracy of the stresses
- Flat-plate stiffeners are typically designed with the provisions in the *AISC Specification*
- Ring stiffeners can be designed with AISC Design Guide 33



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## Session 8 the End



# Thank you!

**AISC** | Questions?



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### PDH Certificates

- You will receive an email on how to report attendance from:  
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- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



## Individual Session Registrants

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### PDH Certificates

- Reporting site (URL will be provided in the forthcoming email).
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## Individual Session Registrants

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### PDH Certificates

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- The lists will be send out within 3 business days.



## 8-Session Registrants

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### PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.



## 8-Session Registrants

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### PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

Certificates will be issued following the deadline for Quiz 8 and the Final Exam.



## 8-Session Registrants

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### PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.

Certificates will be issued following the deadline for Quiz 8 and the Final Exam.

Quiz 8 Issued: August 13

Final Exam Issued: August 18

Deadline for Quiz 8 and Final Exam: September 8

Certificates Issued: September 11



## 8-Session Registrants

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### Access to the quiz

Information for accessing the quiz will be emailed to you by Thursday. It will contain a link to access the quiz. EMAIL COMES FROM [NIGHTSCHOOL@AISC.ORG](mailto:NIGHTSCHOOL@AISC.ORG).

### Quiz and attendance records

Posted Thursday mornings. [www.aisc.org/nightschool](http://www.aisc.org/nightschool) -- Click on Current Course Details.

### Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

*Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs*



## 8-Session Registrants

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### Access to the recording

Information for accessing the recording will be emailed to you by Thursday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM [NIGHTSCHOOL@AISC.ORG](mailto:NIGHTSCHOOL@AISC.ORG).

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## Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!



# 8-Session Registrants

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## Night School Resources



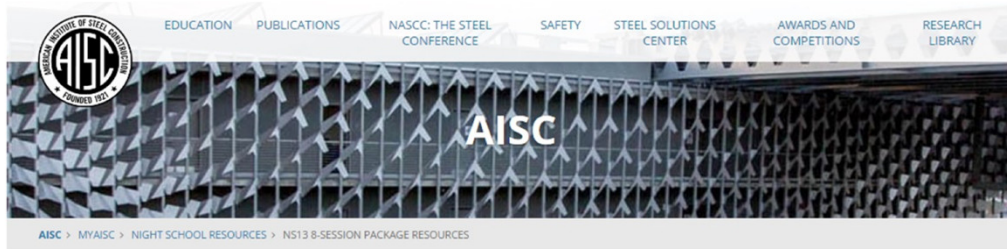
### Course Resources

Event	Start Date
NS 13 8-Session Package-Night School 13 - Design of Industrial Buildings	1/30/2017 7:00:00 PM
NS 14 8-Session Package-Night School 14 - Fundamentals of Stability	6/5/2017 7:00:00 PM



# 8-Session Registrants

## Night School Resources



Night School 13: Design of Industrial Buildings

### 8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	<a href="#">Handouts</a>	<a href="#">View</a> Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Enclosure and Building Guide	4/3/2017 7:00:00 PM	<a href="#">Handouts</a>	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending

# 8-Session Registrants

## Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at [www.aisc.org/nightschool23](http://www.aisc.org/nightschool23). Scroll down to Quiz and Attendance records.
  - Updated on Thursday mornings.

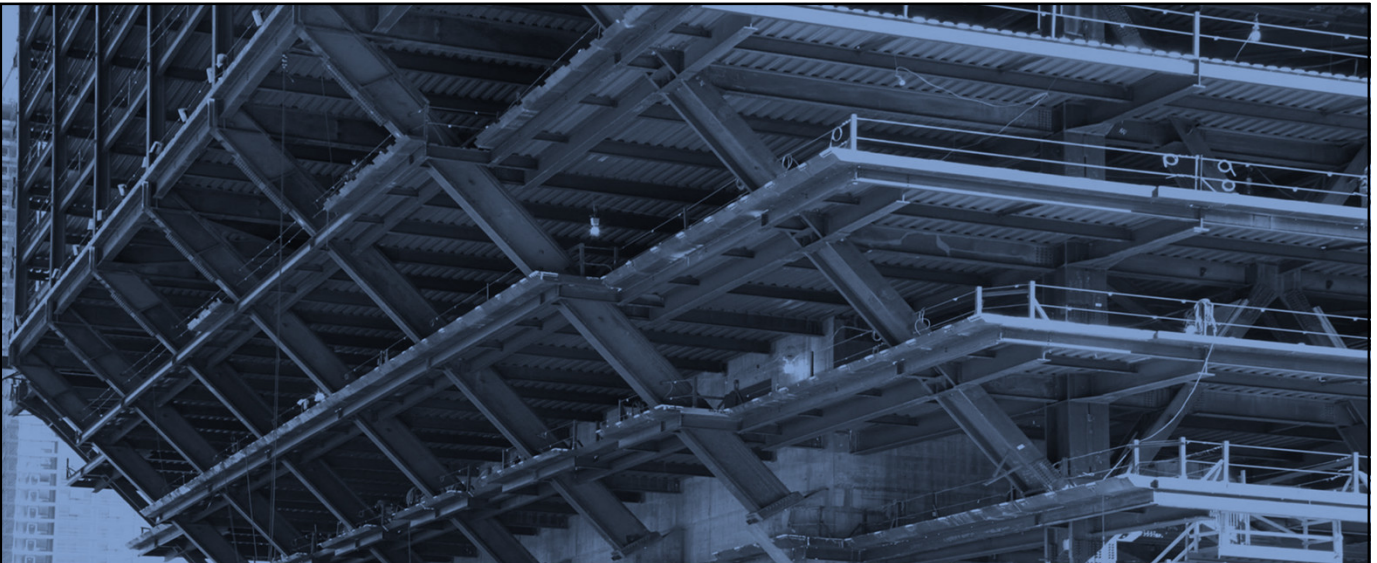


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### Night School Resources

- Webinar connection information
  - Reminder email sent out Tuesday mornings
- Links to handouts also found here



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