NASCC:
THE STEEL CONFERENCE

Heavy and Complicated Lifts

Risks, Uncertainties and What to look out for

PDH 81886

Who We Are

emasa ENGINEERING

www.emasa.eu

NETHERLANDS
THE HAGUE

BRAZIL
CURITIBA

MEYER | BORGMAN | JOHNSON

STRUCTURAL DESIGN + ENGINEERING

CIMOLAI

ALE
SMARTER, SAFER, STRONGER

ambev

ODEBRECHT

Etileno XXI

oas

HOCHTIEF

elecnor

Proyecto Punta Catalina

BUTEC

queiroz galvão

Presentation Outline

- Modularization Overall
  - Benefits Implementation
- General Uncertainties on a Heavy-Lift
- Code Approaches
- Specific Uncertainties
- Modelling Good Practices / Stability Check
- Questions

Engineered
On-Shore Lifts

Learning Outcome

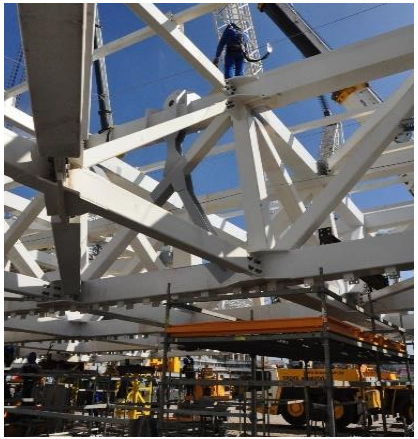
Identify the level of **Uncertainty**, and, therefore, the necessity of higher **Conservativeness**, of important aspects of a Heavy Lift.

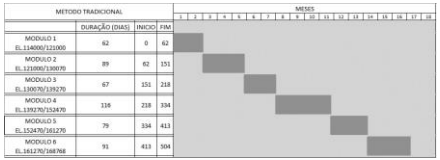
Large Modules Benefits

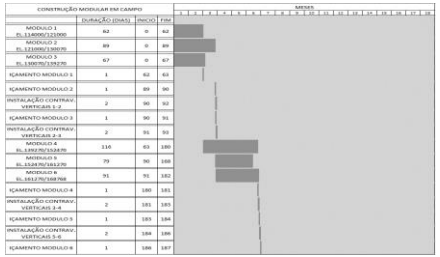
Parallelism

Safety

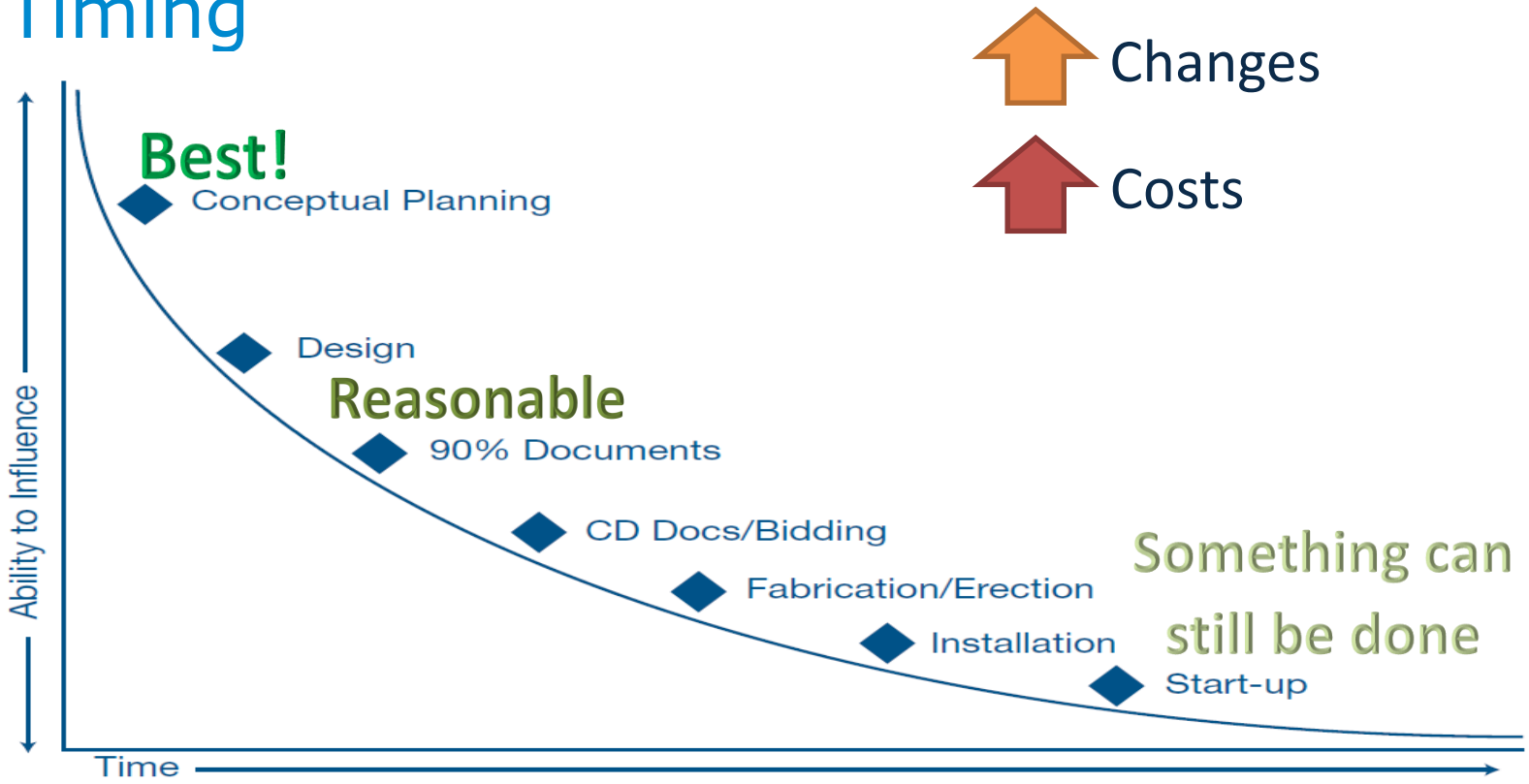
Efficiency





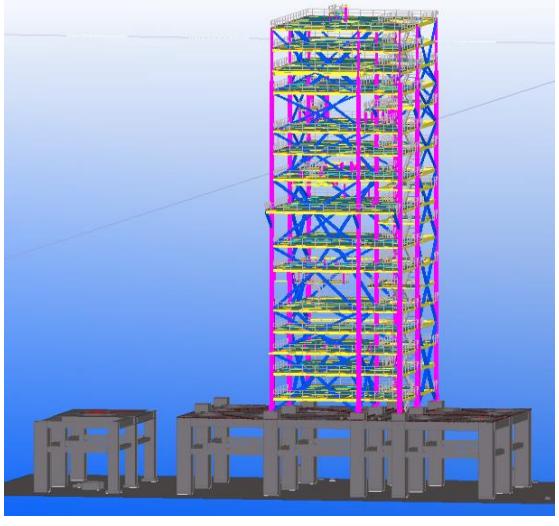


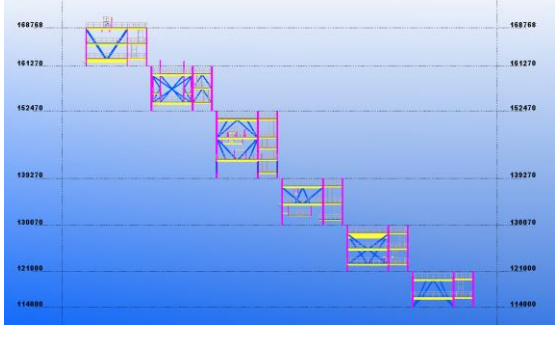
Timing



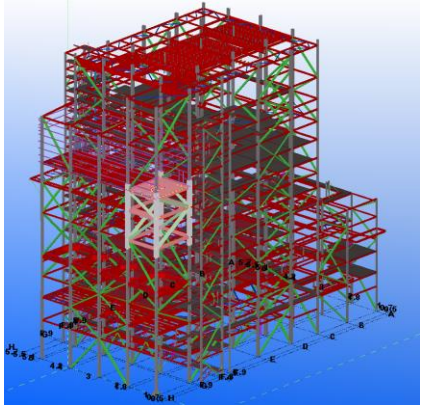
Source: AISC Design Guide 23 Constructability of Structural Steel Buildings

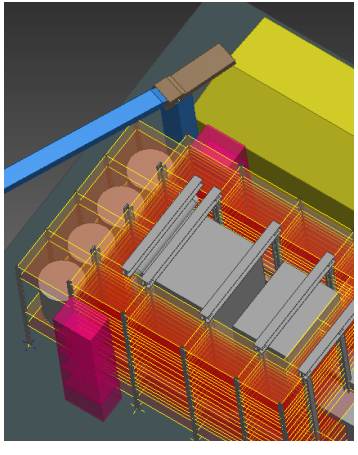
Large Module Identification



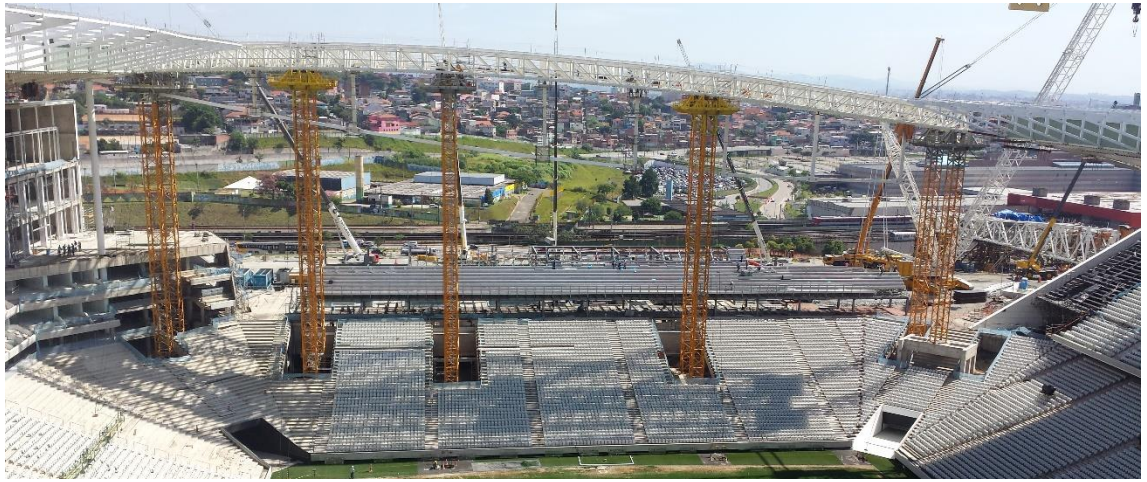


Large Module Identification



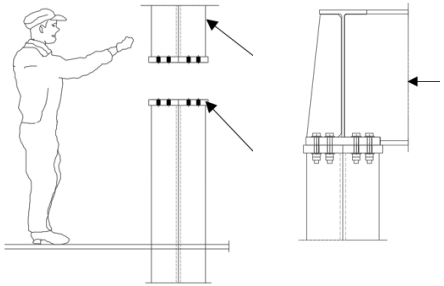


Large Module Identification

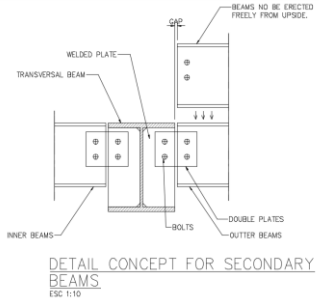


Design Adjustments

Column Splices

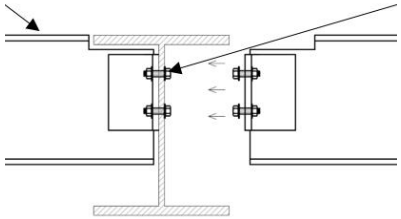


Beams

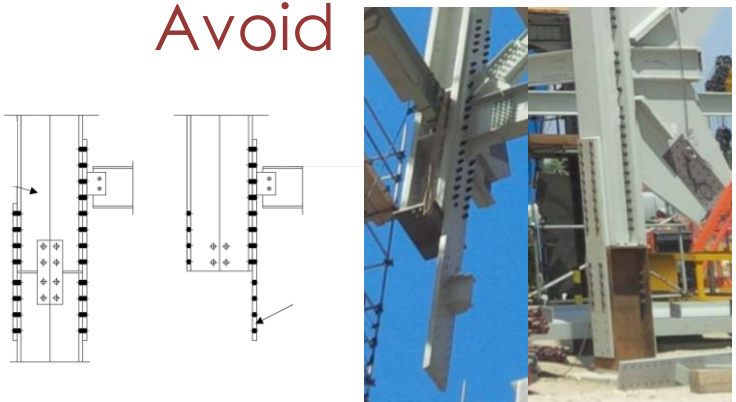


DETAIL CONCEPT FOR SECONDARY BEAMS
ESC 1:10

Avoid



Avoid



Additional Elements

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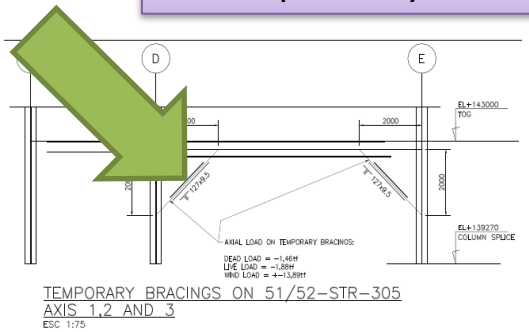
Preassembly on the Ground

Erecting a Structure

Temporary Bases

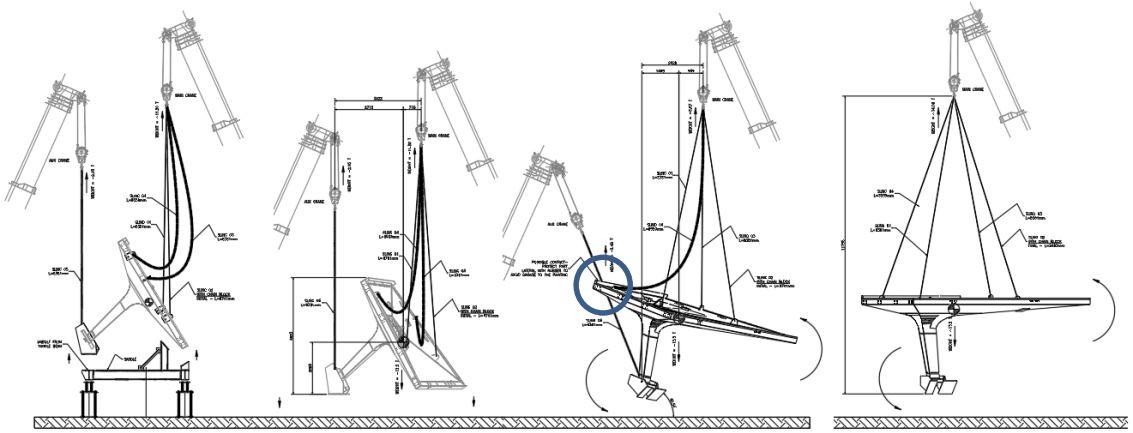
Ground Shoring

Temporary Members

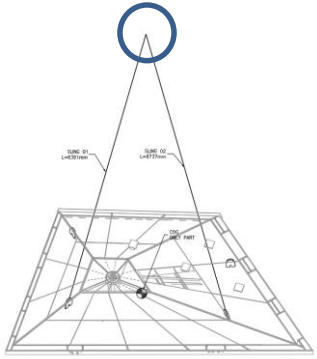


TEMPORARY BRACINGS ON 51/52-STR-305
AXIS 1,2 AND 3
ESC 1:75

Rotation

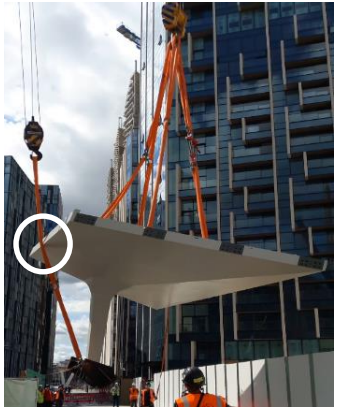


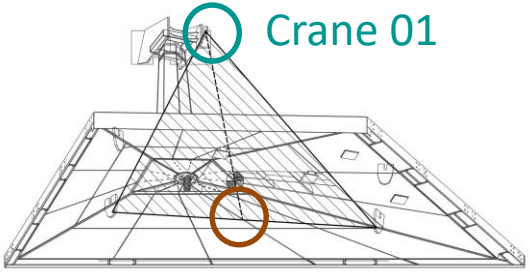
Instability



Front View

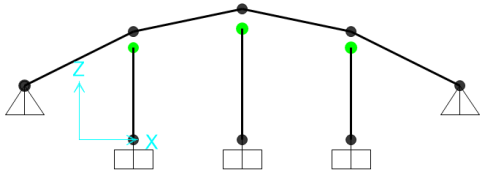
Sling Contact





Top-Down View

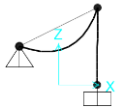
After Installation

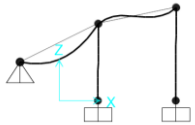


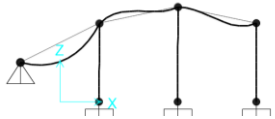
"All at Once"

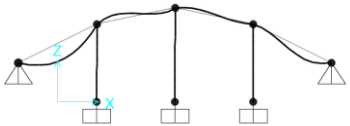
≠

Incremental



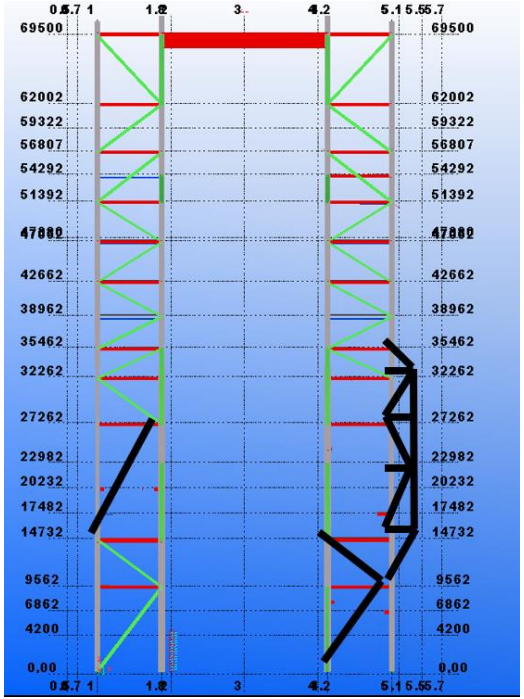






ASCE 37

Additional Bracing



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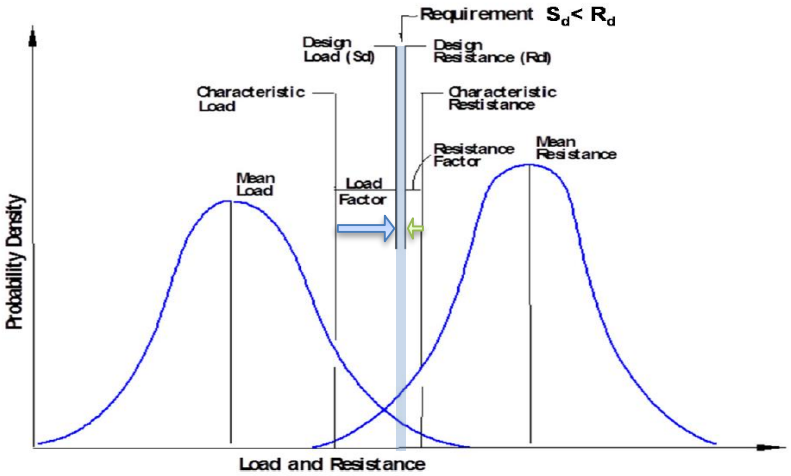
During Lifting

Probabilistic Design



Certain

Only Dead Weight

Uncertain

Weight

Density/Milling
Water Inside?
Paint/Welds/Bolts
CoG Position

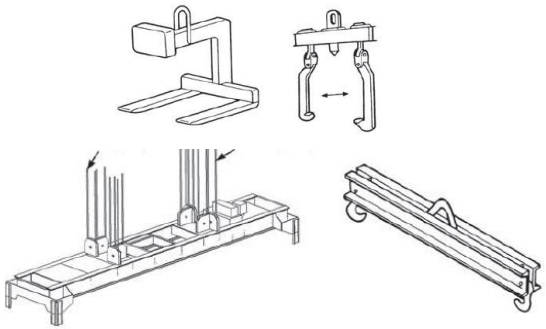
Dynamic Effects

Geometry

Imperfections
Sling Length

Codes - ASME BTH-1-2017

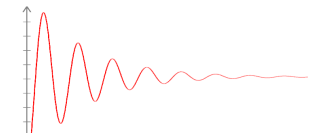
Devices



Similar to AISC-ASD

Yielding/Buckling	Ω=2.0 (~~Ω=1.67~~)
Connections	Ω=2.4 (~~Ω=2.00~~)

Safety Factors Include



What about

Rocking?
Sling Length?
CoG Position?

Marine Operation Rules

ISO 19901-6:2009

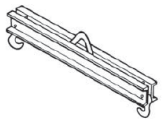
DNVGL-N001:2016

Uncertainties

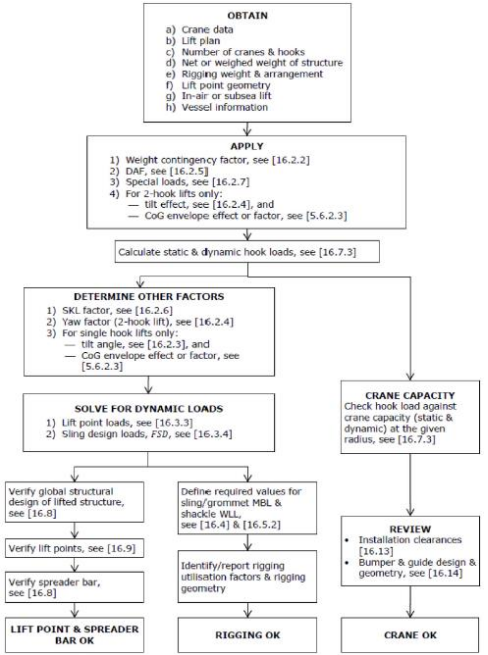
Load Factors

Requirements Vary





Comprehensive



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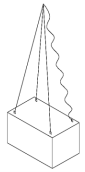
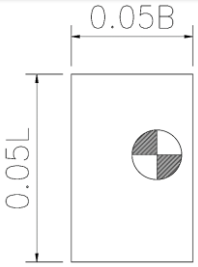
ISO 19901-6:2009 Load Factors



Weight Contingency

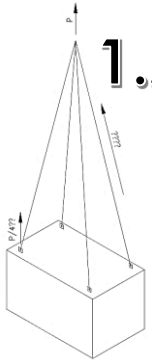
1.10 – Calculation
Min: **1.03** for weighed

Centre of Gravity

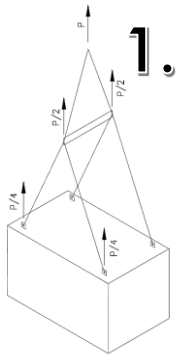


1.02
Or envelope

Skew Load



1.25



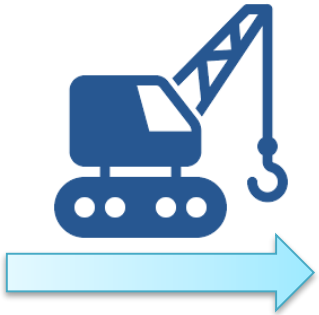
1.05

Yaw

1.05

ISO 19901-6:2009 Load Factors

Dynamic Amplification (DAF)



W ≤ 100	1.15	1.00
100 < W ≤ 1000	1.10	1.00
1000 < W ≤ 2500	1.05	1.00
2500 < W	1.05	1.00

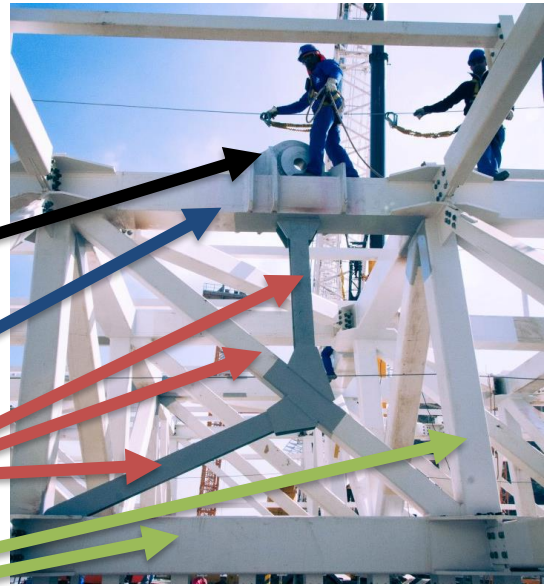
Metric Tons

ISO 19901-6:2009 Load Factors

Consequence

Use as a LRFD load factor

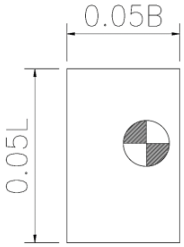
For Hook Load	$\gamma_{f,hl}$ =1.00
For Design of Slings, Grommets and Shackles	$\gamma_{f,s}$ =1.30
For Design of Lift Points	$\gamma_{f,lp}$ =1.30
For Design of Attachments of Lift Points to the Structure	$\gamma_{f,lp}$ =1.30
For Design of Members Directly Supporting or Framing into the Lift Points	$\gamma_{f,mf}$ =1.15
For Design of Other Structural Members	$\gamma_{f,m}$ =1.00



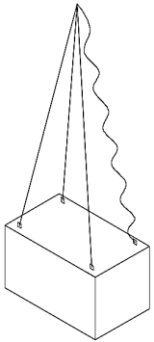
ISO 19901-6:2009 Load Factors

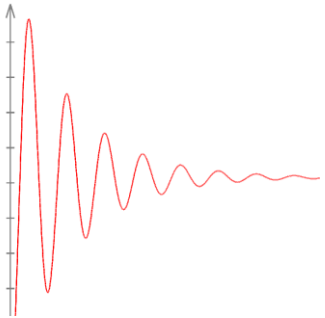
General Structural Check

Design Load



Design Strength



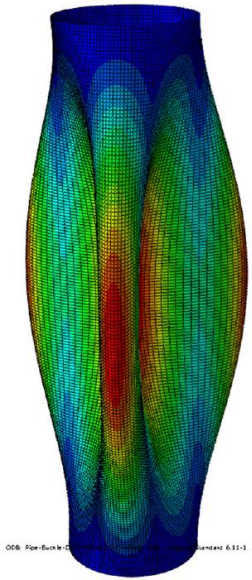


LRFD

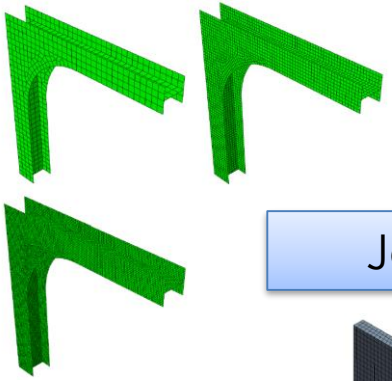
Non-Linear FE RP

DNVGL-RP-C208:2016

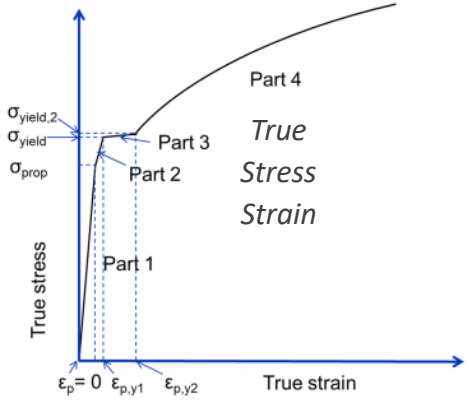
Buckling



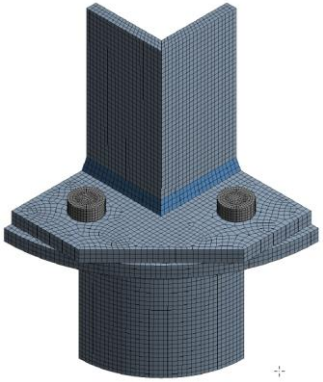
Mesh



Material



Joints



Very Practical!

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Sling Arrangement

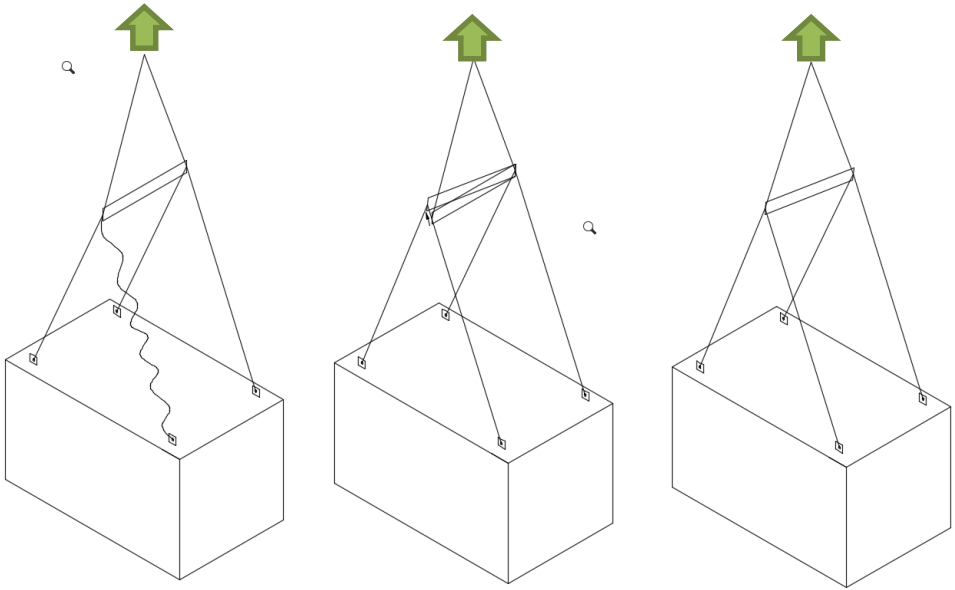
Crane Boom

Clashes

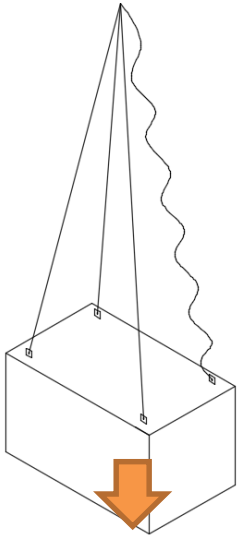
Reusability

Sling Arrangement

Determinate



Indeterminate



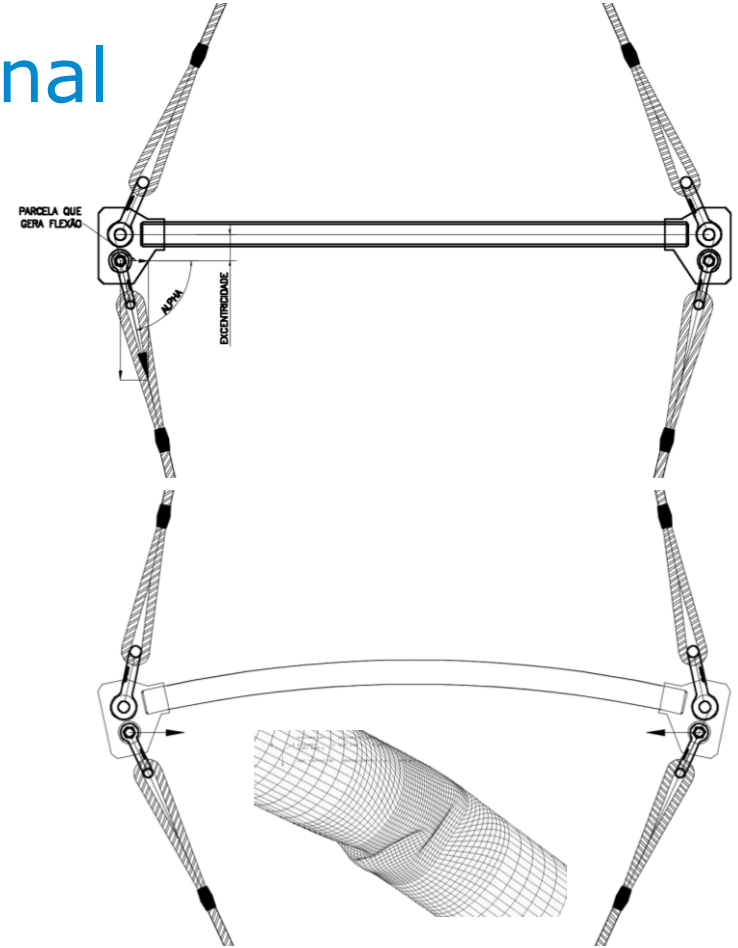
Sling Arrangement

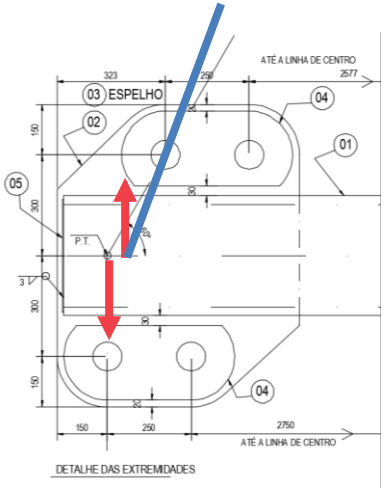
Compression Capacity

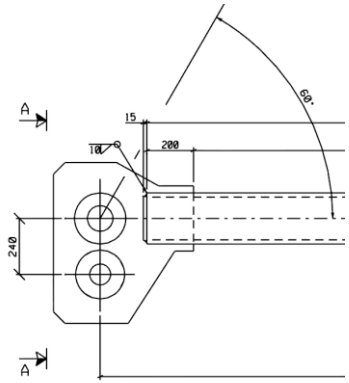
Point of Support

Source: Versabar

Spreader Bar - Traditional







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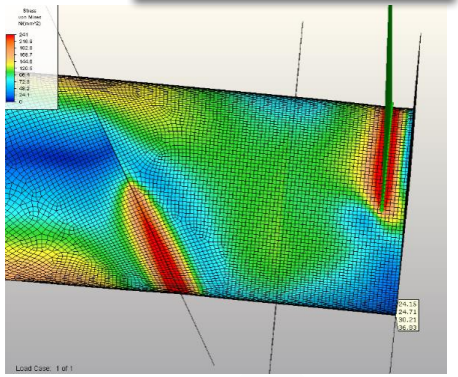
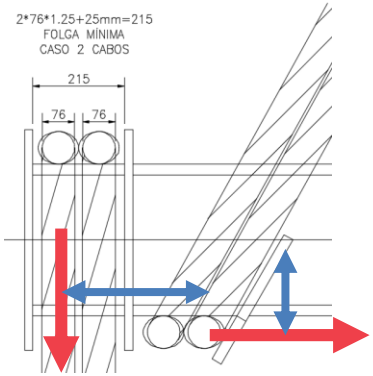
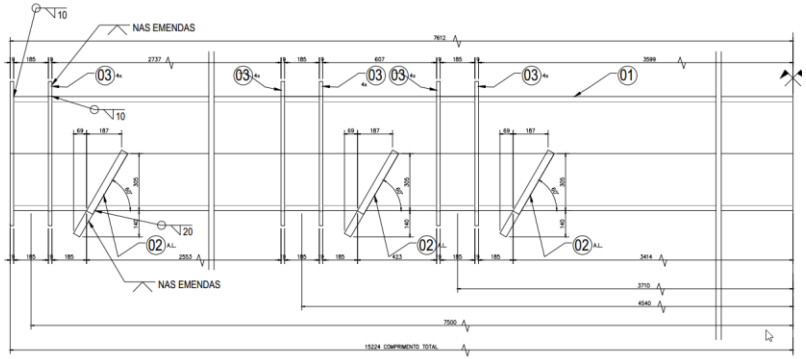
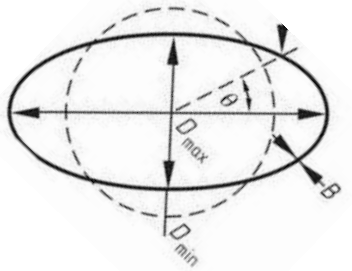
Spreader Bar – Pipe With Guides









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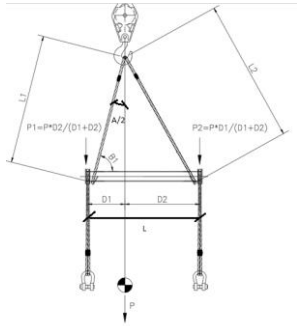
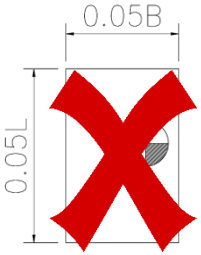
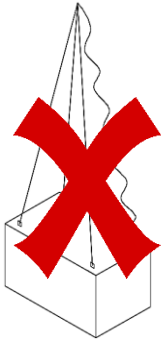
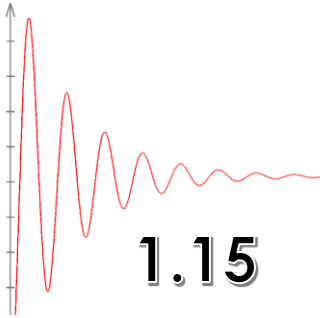
Spreader Bar – ISO Factors



Design Load (1.73 Factor)







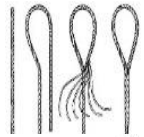
Design Strength $\emptyset . R_N$

ASME: 1.8 Factor

NASCC: THE STEEL CONFERENCE

Wire Ropes

Termination

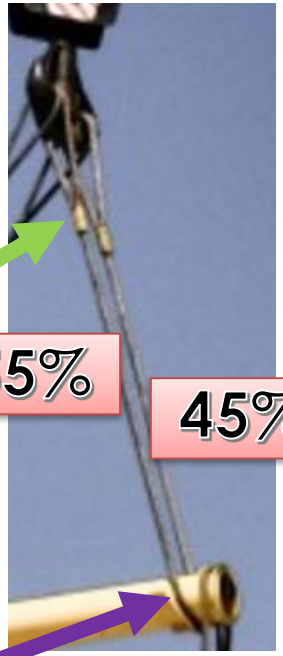


0.75

0.75

0.90

1.00



55%

45%

Bending

$$1 - \frac{0.5}{\sqrt{D/d}}$$

D/d	1.5	2.0	3.0	4.0	5.0
Factor	0.59	0.65	0.71	0.75	0.78

Additional
Safety Factor

2.31 $d \geq 2"$

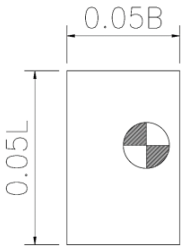
3.85 $d < 2"$

Other kind of slings have different factors!

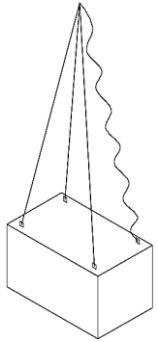
$D/d \geq 1$

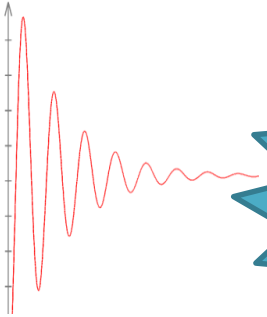
Wire Ropes- ISO Factors

Design Load
(3.3 ~ 9.32 Factor)



Bend | | Term
* MBL

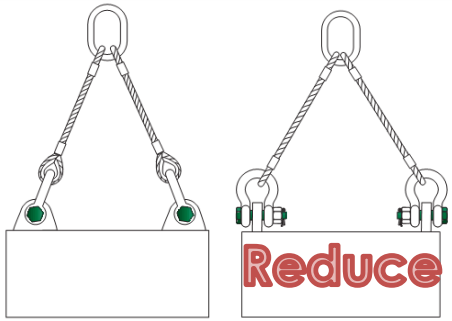


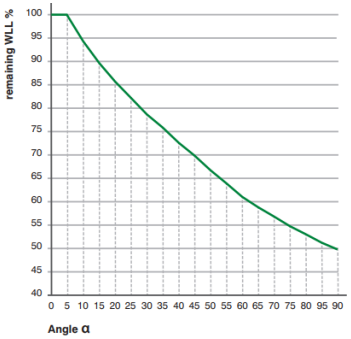


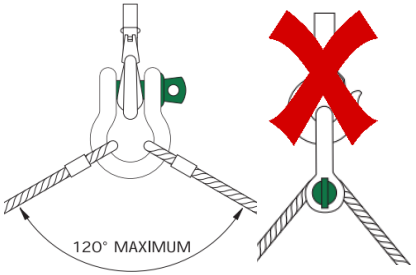
55%
45%

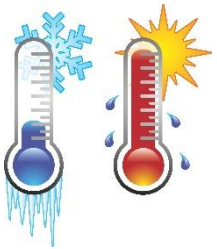
Shackles

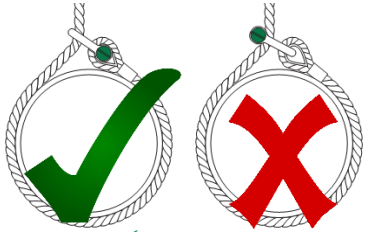
Side Loads



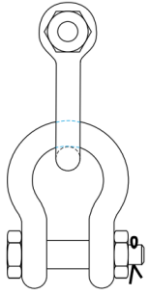


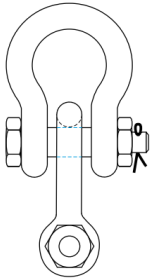


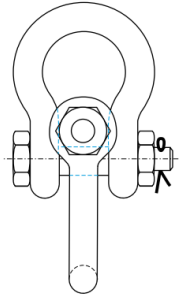


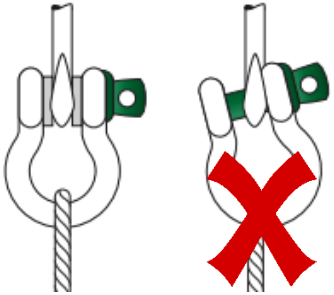


Point Loads









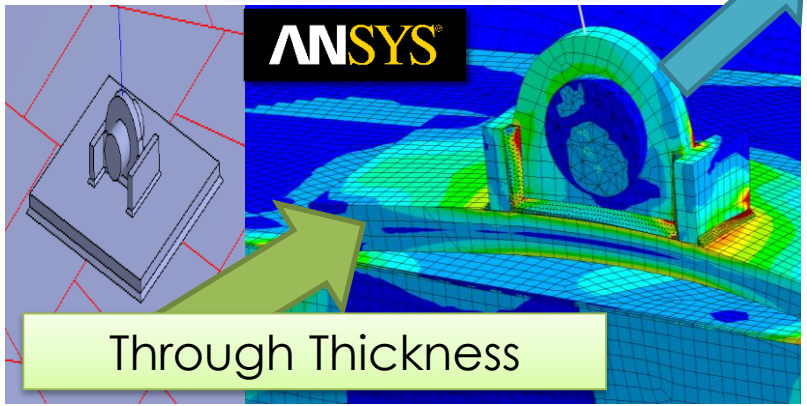
Use Manufacturer's Recommendations

Sources: Van Beest & Crosby Catalogues

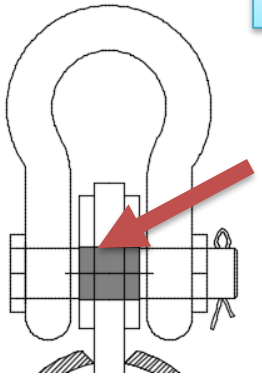
NASCC: THE STEEL CONFERENCE

Lifting Lugs

Lateral Load 5%

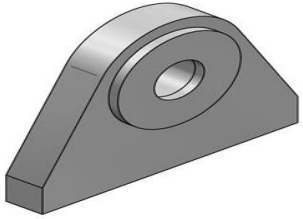


Shackle Interface

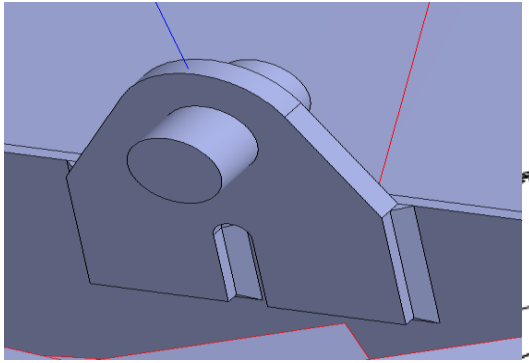


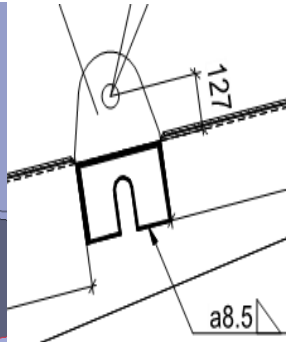
Contact
Lug 75% Space
Allow Cables
Free Rotation

Cheek Plates



Weld → Ream





Hole

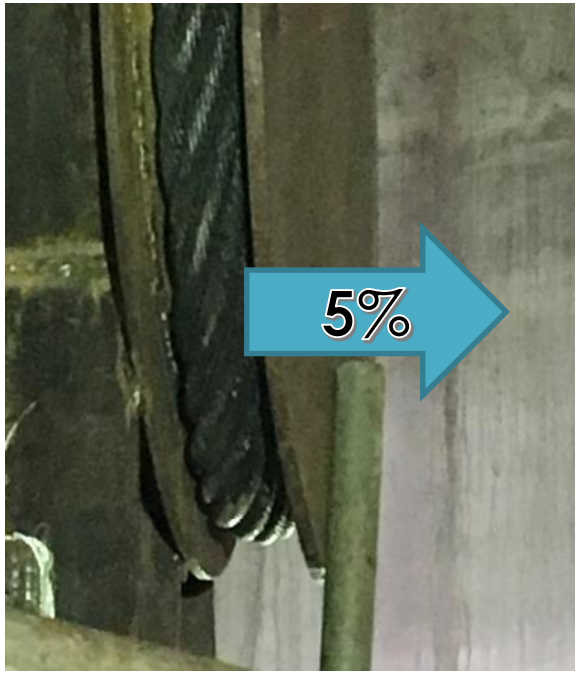
$$d_h = d_p + 1/8"$$

Hertz Stress

Trunnions

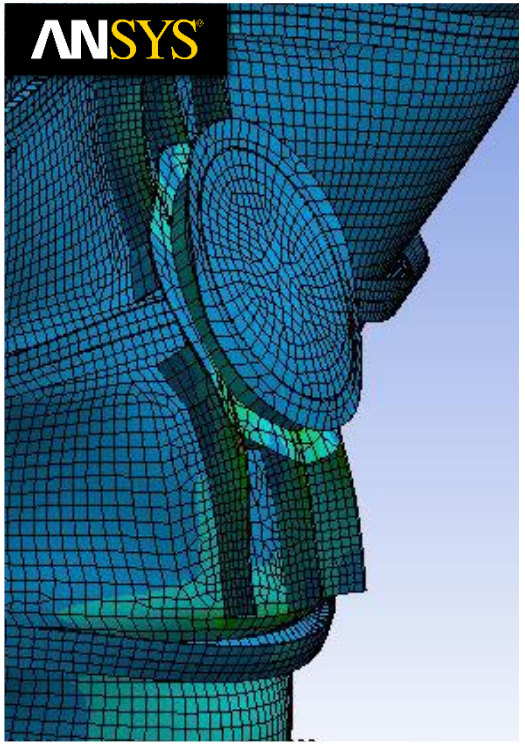
Attachment

Lateral Load



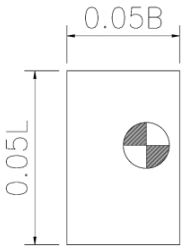
Cable Ovalization $1.25d + 1"$

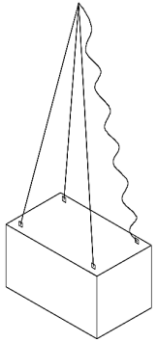
FEA Recommended

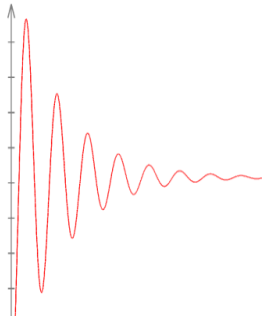


Lifting Lugs / Trunnions- ISO Factors

Design Load
(1.43 ~ 2.2 Factor)





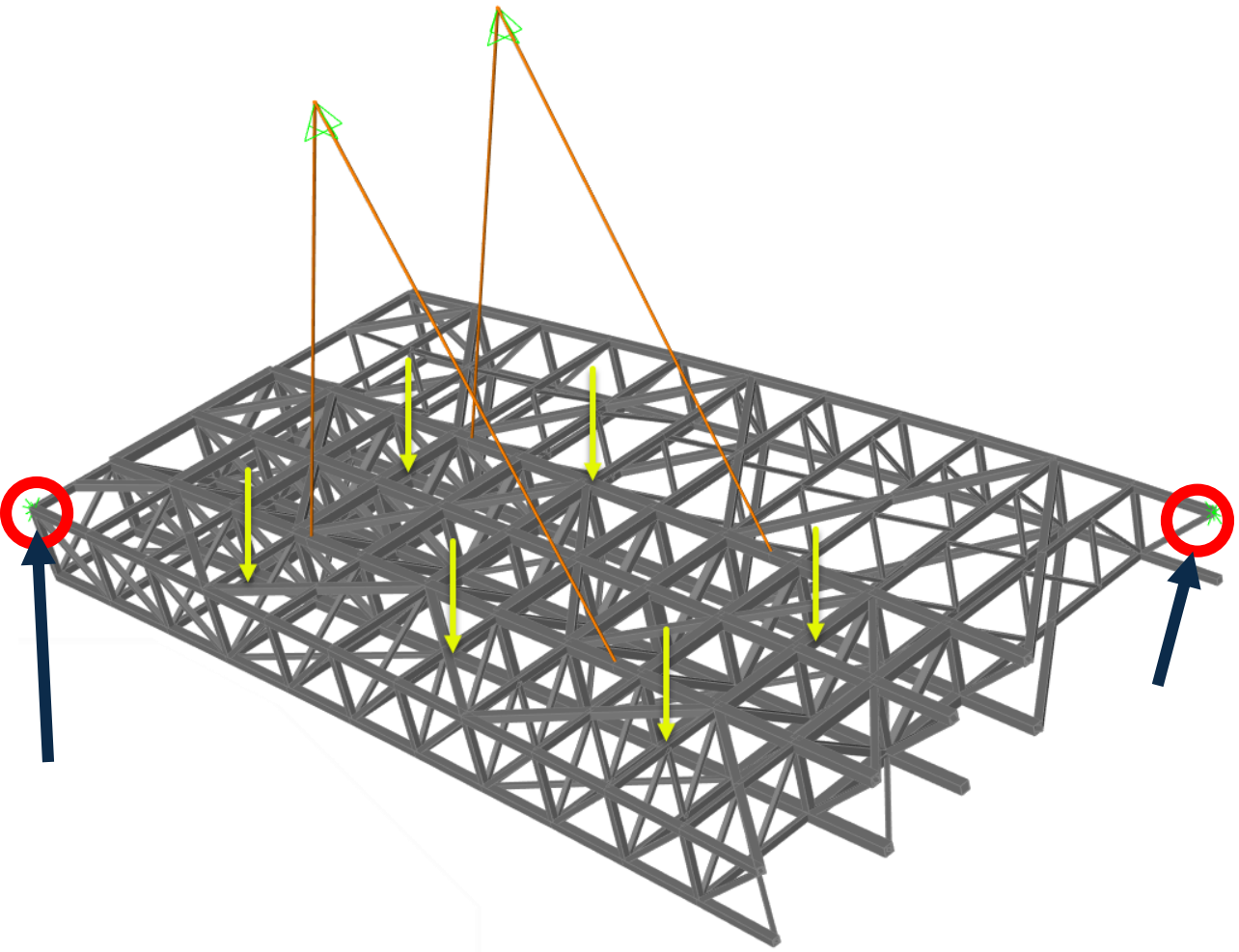


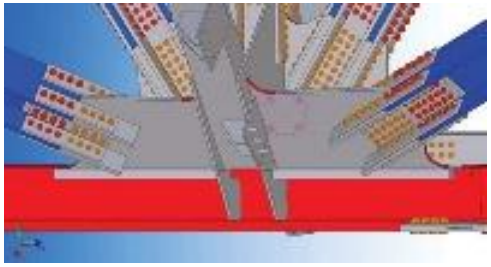
1.3

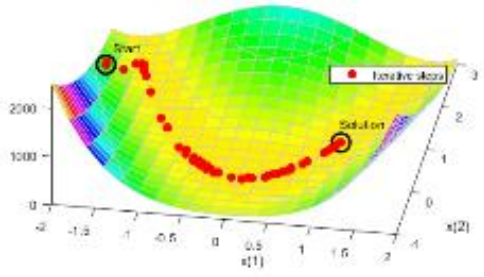
$<$

Design Strength
$\emptyset . R_N$

ASME:
1.8 Factor



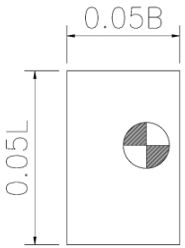


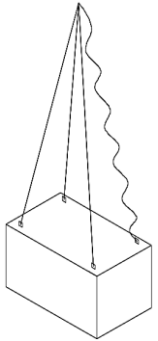


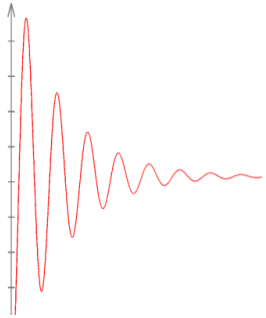
NASCC: THE STEEL CONFERENCE

Overall Structure – ISO Factors

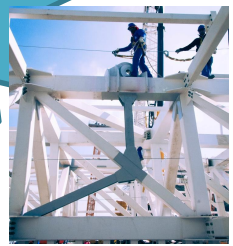
Design Load
(1.10 ~ 1.94 Factor)







1.15
1.00



<

Design Strength
$\emptyset . R_N$

Buckling

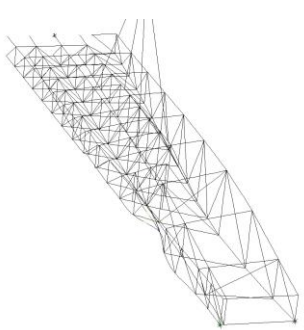
Complex Geometry

K Factor?
Buckling Length?

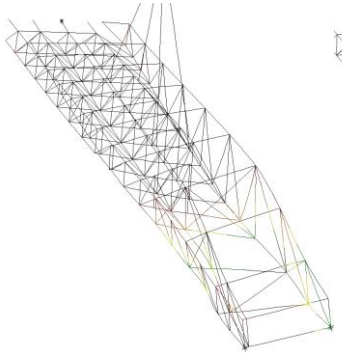
Direct Method (AISC)

Eigenvalue buckling Analysis

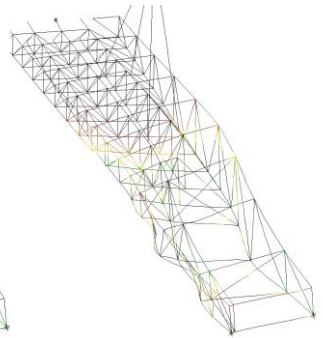
Buckling Eigenmodes



Local



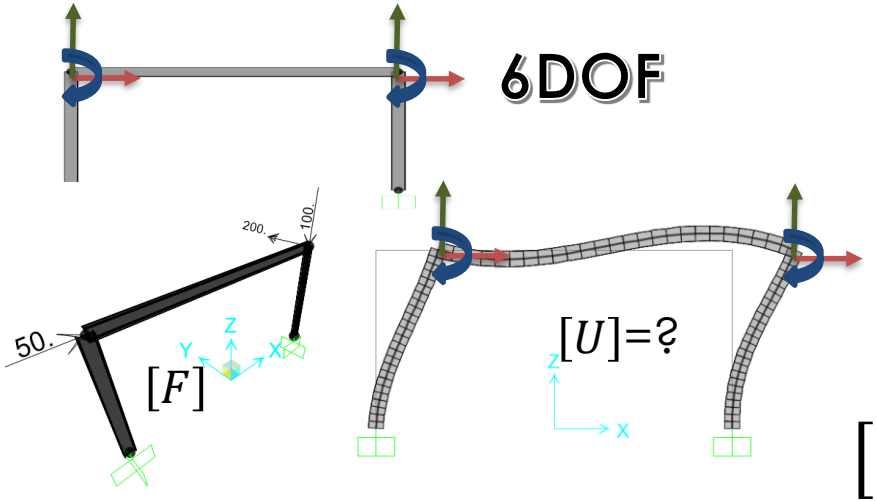
Global



Hybrid

Buckling Eigenmodes

1st Order Planar Frame

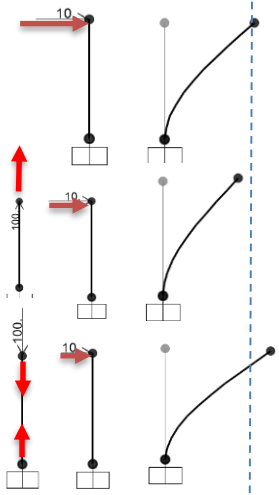


$$[K].[U] = [F]$$

$$\begin{bmatrix} 6\text{x}6 \end{bmatrix} \begin{bmatrix} ? \\ ? \\ ? \\ ? \\ ? \\ ? \end{bmatrix} = \begin{bmatrix} * \\ * \\ * \\ * \\ * \\ * \end{bmatrix} \Leftrightarrow [K].\lambda_i[U] = \lambda_i[F]$$

2nd order contribution

Influence of allocated forces



$[K_G(\lambda_i F)]$

Geometric Stiffness

$$\left[[K] + \lambda_i[K_G]\right].[U_{tot}] = [\lambda_i[F]]$$

2nd Order Stiff. Matrix

NASCC: THE STEEL CONFERENCE

Buckling Eigenmodes

On verge of buckling

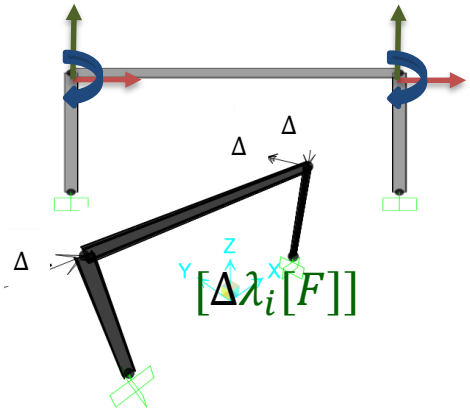
$$[[K] + \lambda_i[K_G]] \cdot [\Delta U_{tot}] = [\sim 0]$$

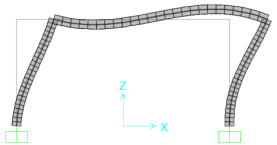
Incremental 2nd Order System

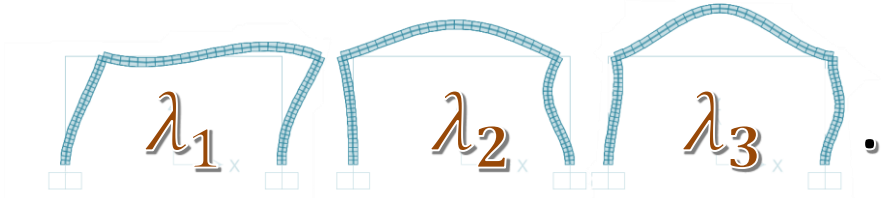
$$[[K] + \lambda_i[K_G]] . [\Delta U_{tot}] = [\Delta \lambda_i [F]]$$

$$\begin{bmatrix} 6x6 \end{bmatrix} + \lambda_i . \begin{bmatrix} 6x6 \end{bmatrix} \cdot \begin{bmatrix} ? \\ ? \\ ? \\ ? \\ ? \\ ? \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Singular







Eigenvalues $\xrightarrow{\infty}$ Eigenvectors

SHAPES

Non-Conservative

NASCC: THE STEEL CONFERENCE

Buckling Direct Method – AISC

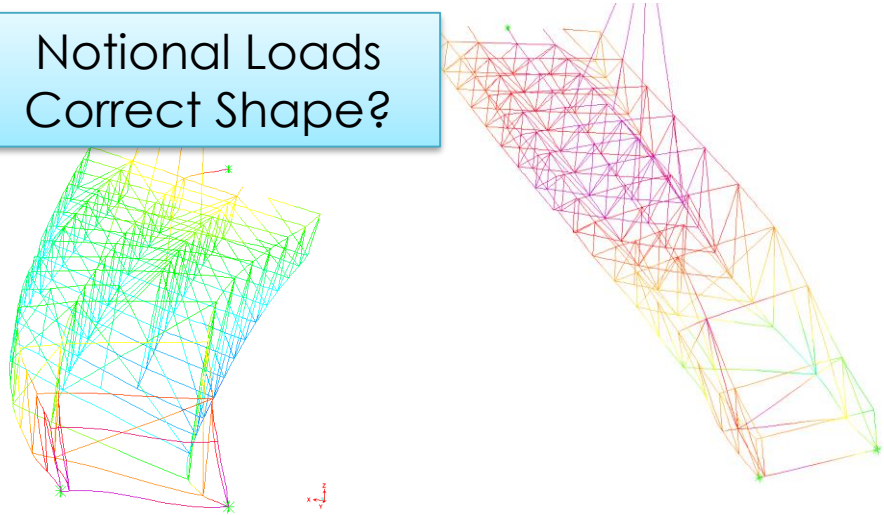
Design Guide 28

E=0.8*E

All k=1

Imperfect Global Shapes

Notional Loads Correct Shape?



Scale to 1.5 COSP

Turn-on Geometrical Nonlinearities

Include Inner Nodes

Include Load Factors On Load To Be Incrementally Applied

No Need to Include Local Shapes

Only one?

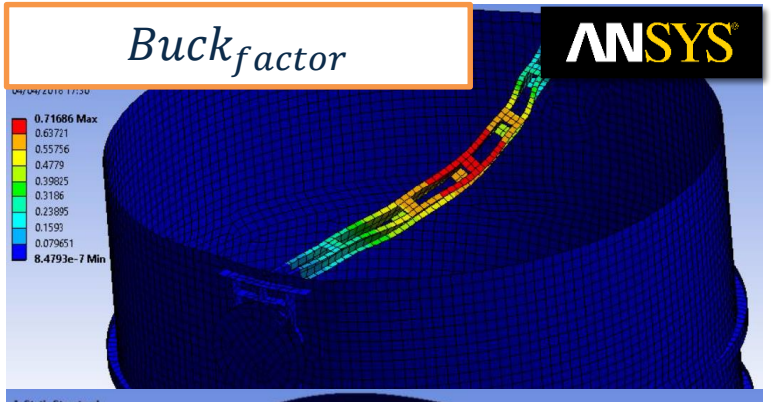
Engineering Judgement

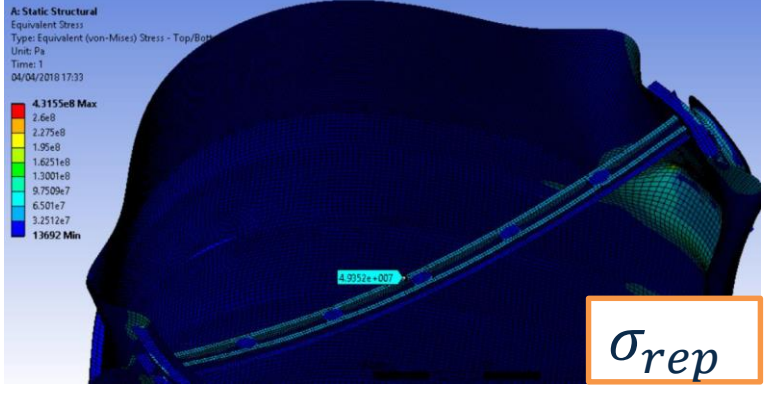
NASCC: THE STEEL CONFERENCE

Linearized Buckling - DNV

Eigenmode

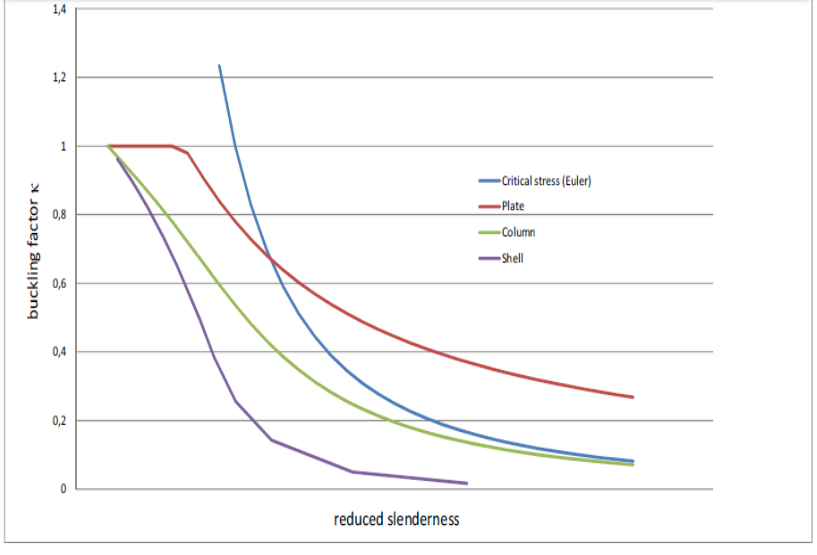
$Buck_{factor}$





σ_{rep}

$slen_{red}(Buck_{factor}, \sigma_{rep})$

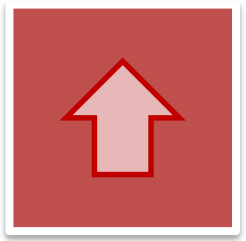


Reduced Available Capacity
(Imperfections, Residual Stresses)

Assessment Question

Select the Level of Uncertainty

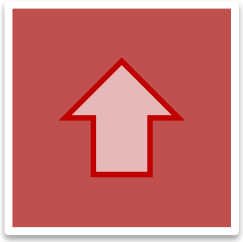
Environmental Loads During
On-Shore Lifting Operations

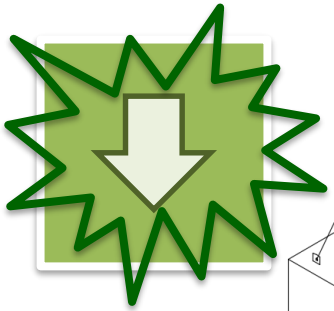


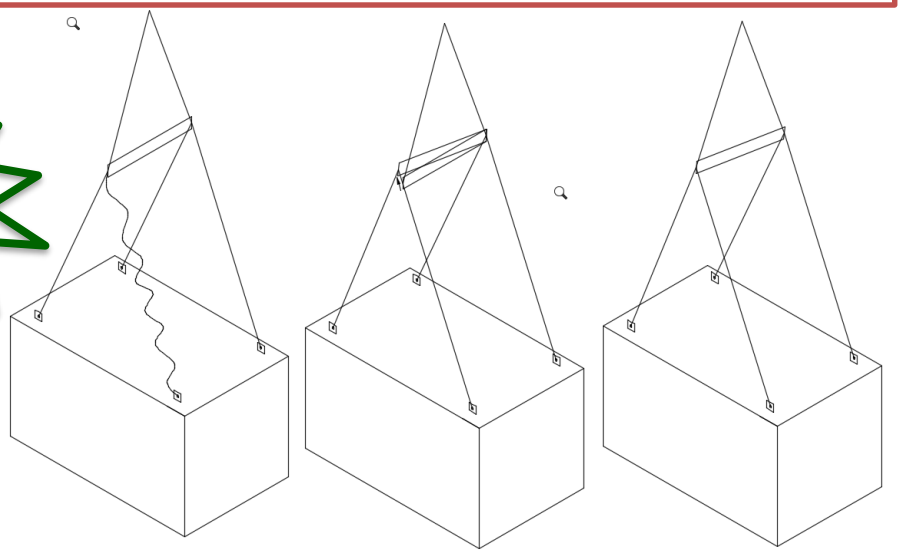
Assessment Question

Select the Level of Uncertainty

Load Distribution On The Slings For
A System With One Spreader Bar







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