MASTER THESIS PRESENTATION

Feasibility and benefit of different lashing arrangements for sea transport of containers on weather deck

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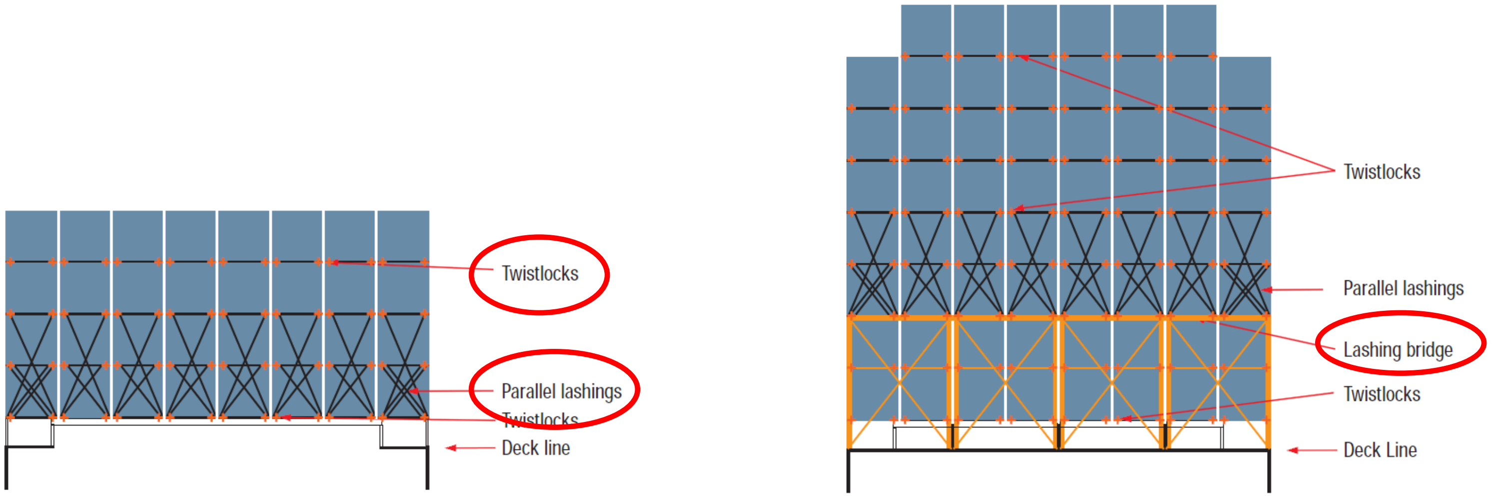
Introduction

- Containers stowed on weather deck
  - Twist locks have to ensure the stack integrity
  - Lashing increases stack stiffness
  - Larger ships → higher stacks
  - Lashing bridge arises the lashing point



Introduction

- Container stacks on the weather deck are exposed to dynamic forces caused by:
  - gravity
  - ship motions
  - green water
  - wind

- In severe seas or improper stowing, forces can become excessive

- Failure of locks / containers

Introduction

- Containers lost overboard are more than an economic issue

- Environmental problem

According WSC, 650 containers are lost overboard every year.

- Danger for other crafts

Problem Description

- Classification societies and shipping industry try to minimize container losses at sea

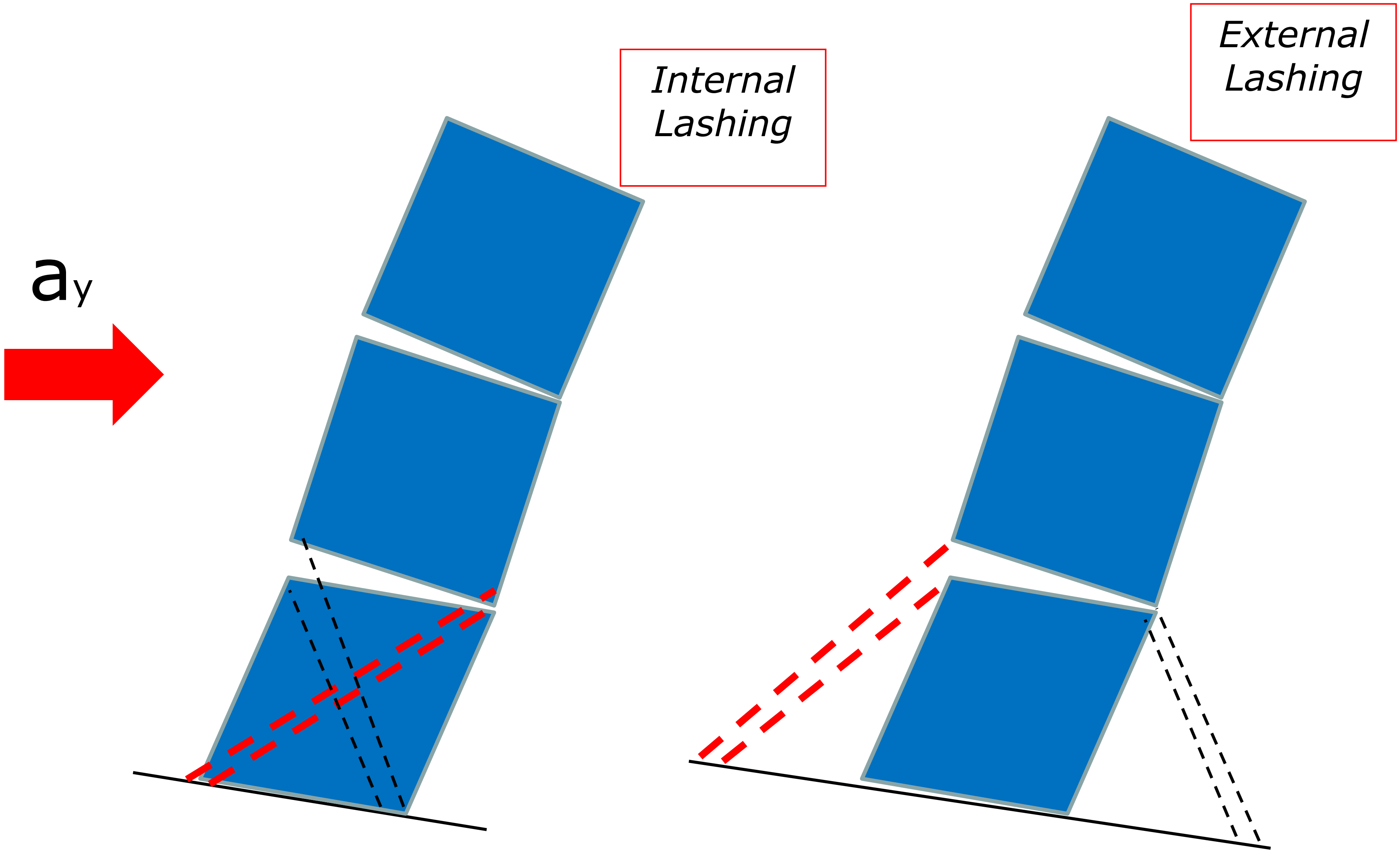
- On the other hand, shipping companies want to optimize the utilization of their fleet

- Alternative method for cargo securing:

    - External Lashing

Not covered by GL rules

Problem Description



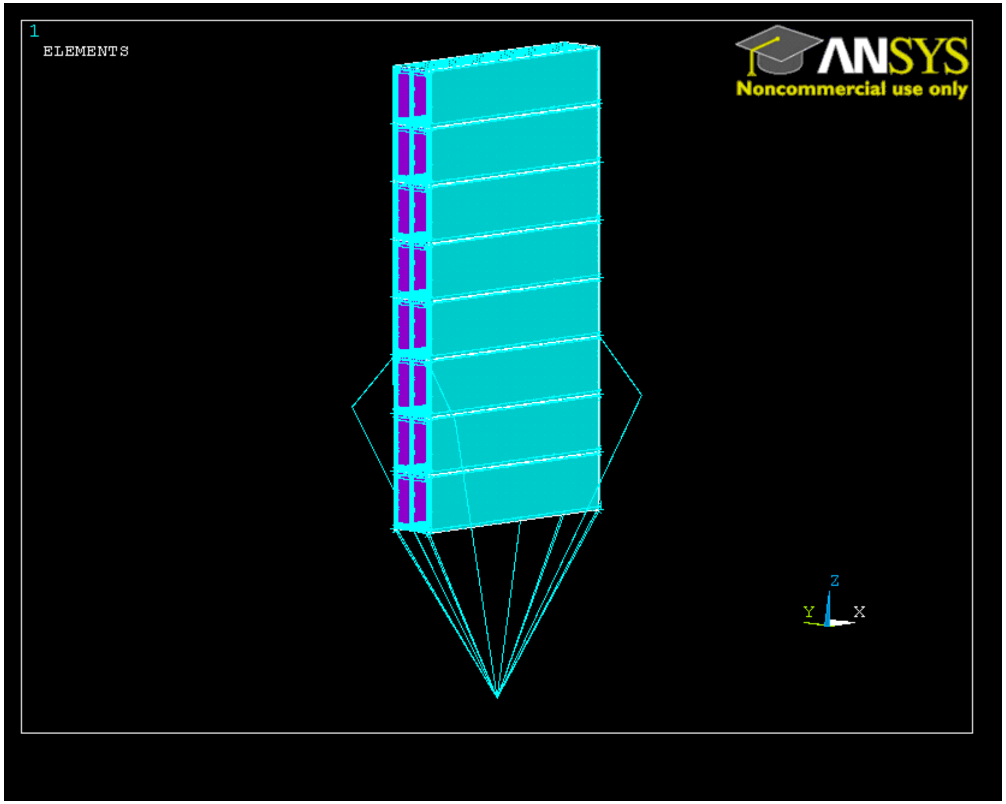
Tasks

- Identify the significant stack parameters affecting the loads acting on container frames and lashing components

- Derive a simplified approach for external lashing evaluation, using the results from the previous step, for rule based design

- Compare the cargo capacity of internal and external lashing arrangements

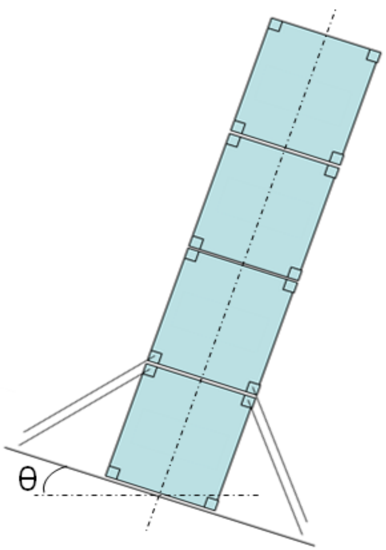
Method

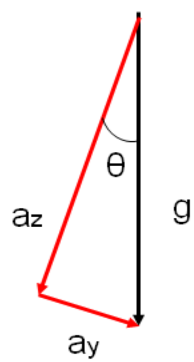


- Superelements to model the containers using substructuring techniques
- Spring elements to represent the twist locks with gap function
- Frictional contact
- Lashing elements with tensile-only stiffness
- Rigid elements linking the base of the stack to the ship's rolling axis
- Possibility to work with multi-stack models
- Several parameters can be changed on the input file (APDL)

Method

- Loading
  - Transverse loading is basically due to ship's inclination during roalling



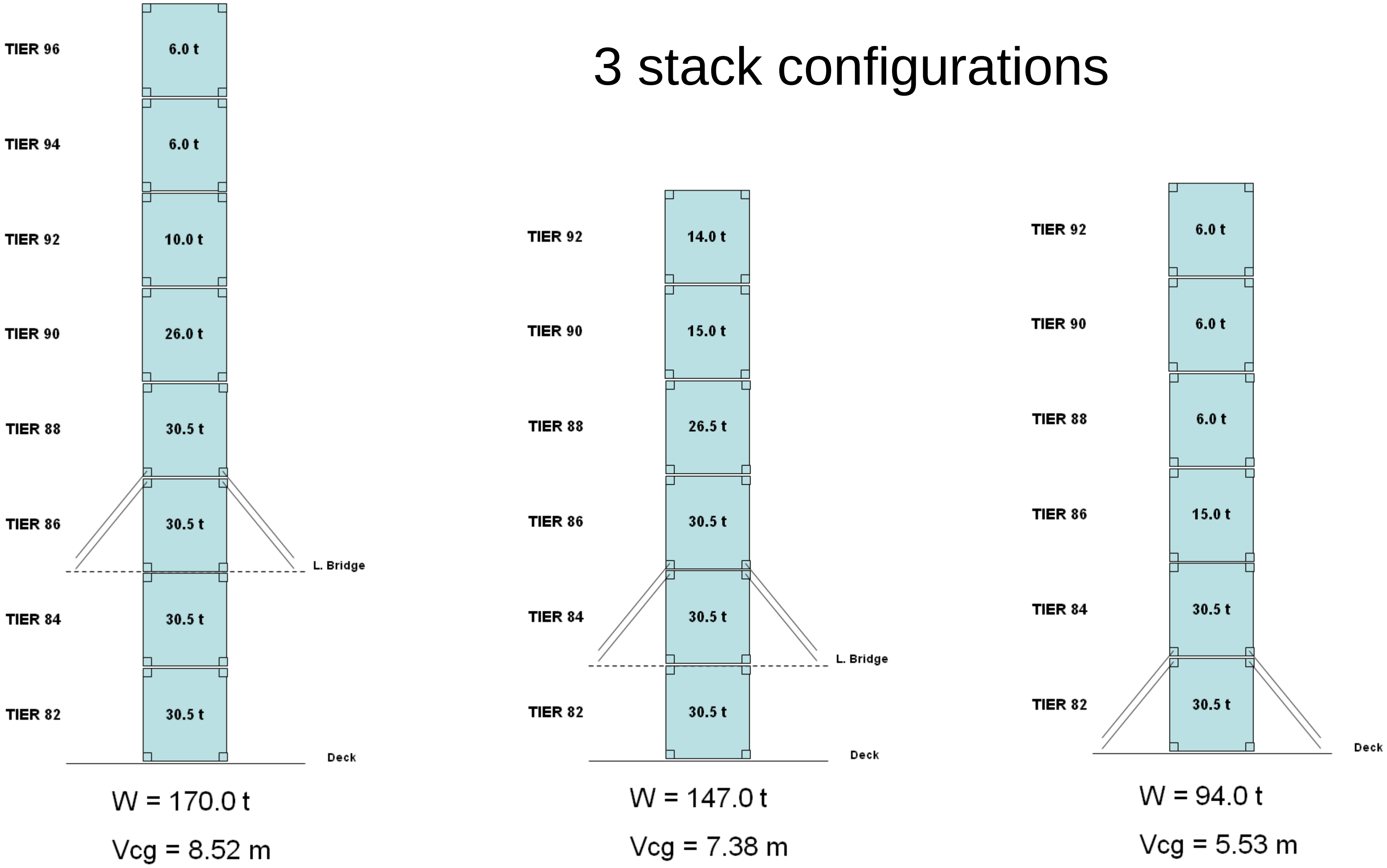


$$a_y = g.\sin\theta$$

$$a_z = g.\cos\theta$$

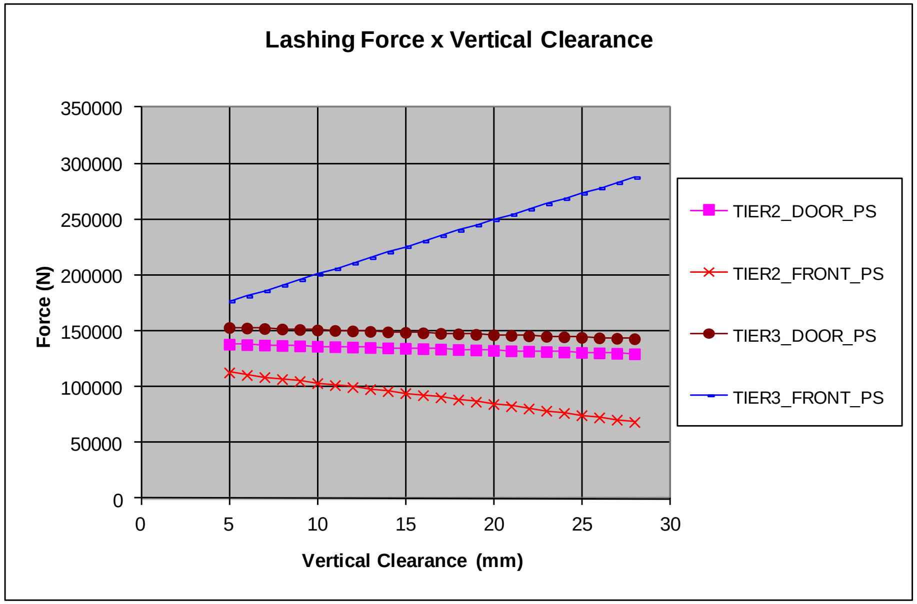
Parametric Studies External Lashing

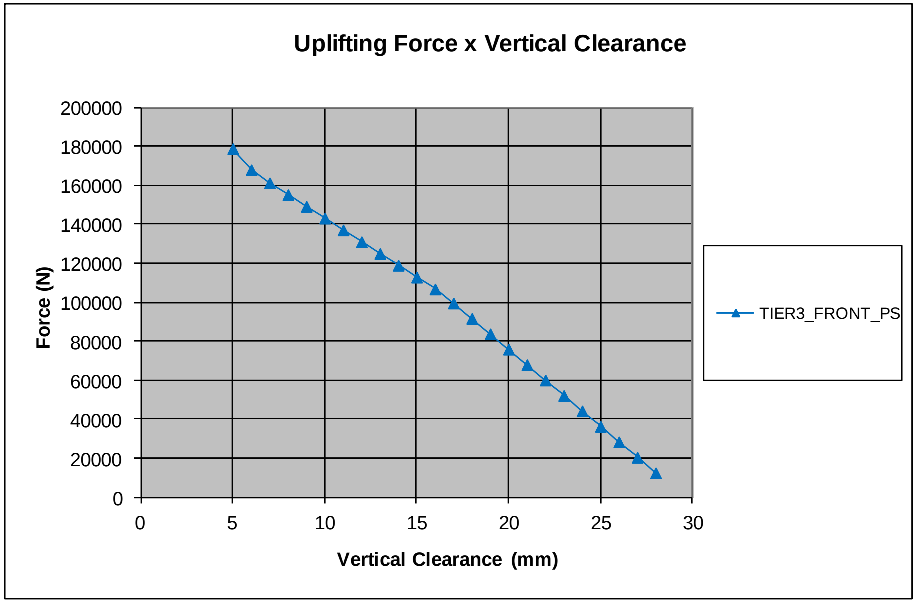
3 stack configurations



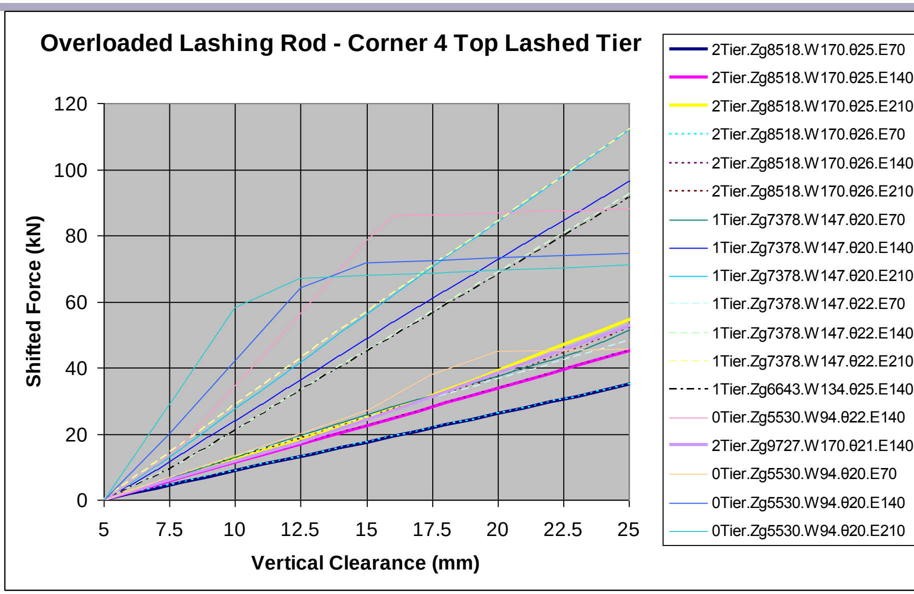
Parametric Studies
External Lashing

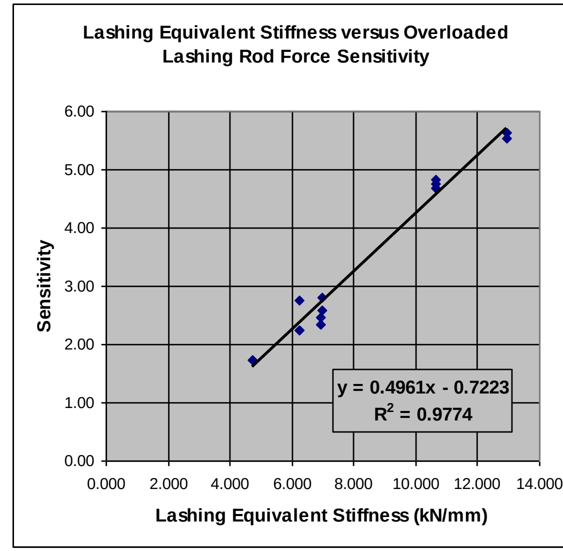
- Force sharing by lashing and twist locks depends on:
  - Lashing stiffness
  - Vertical clearance of locks
- Cargo capacity is limited by the lashing force on the lifted corner

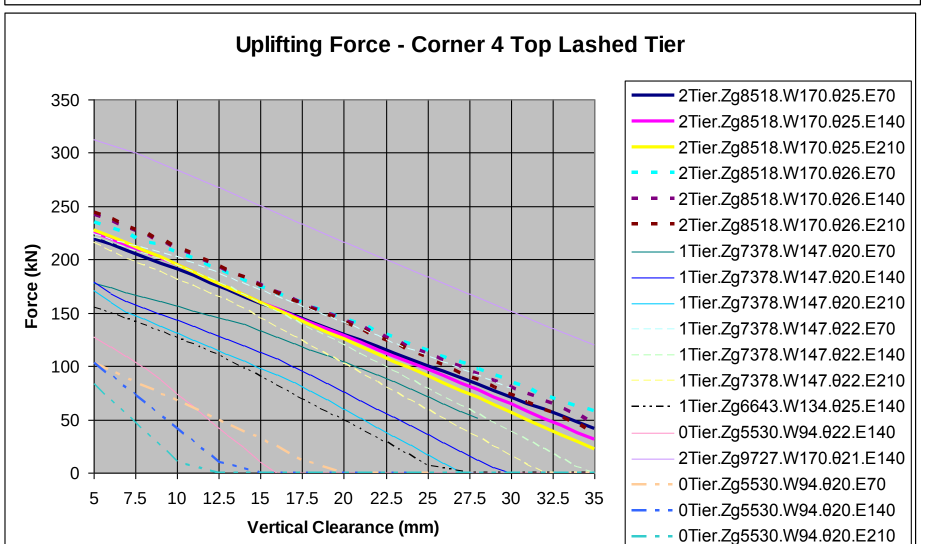


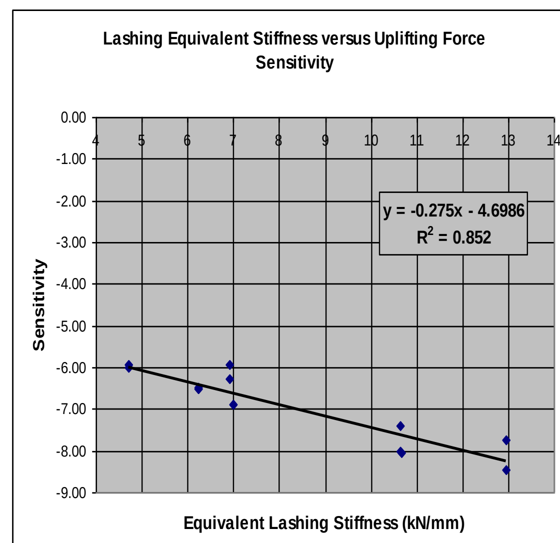


Simplified Calculation Method Assumptions



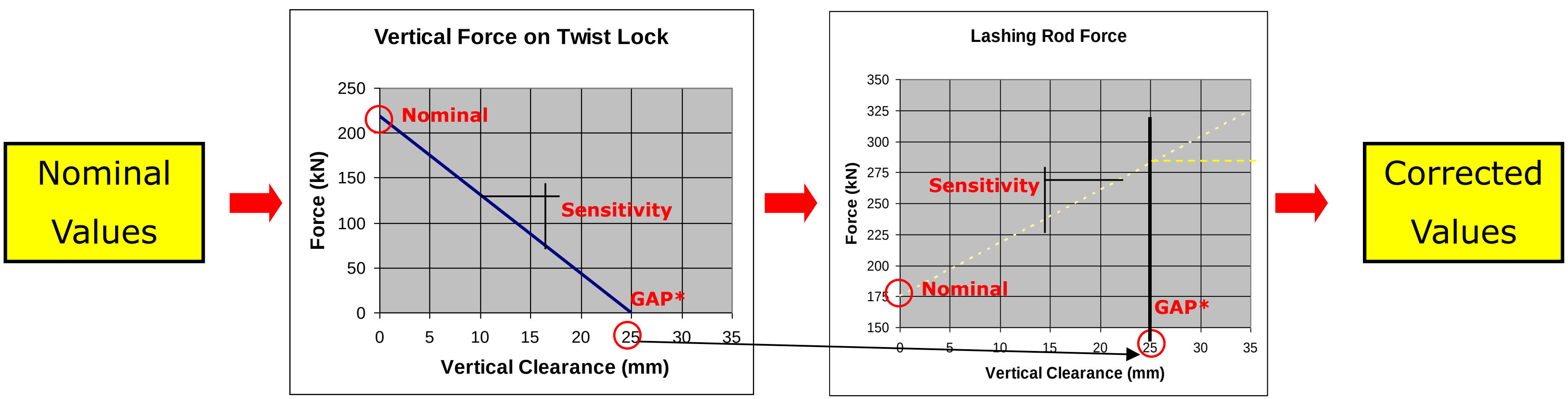




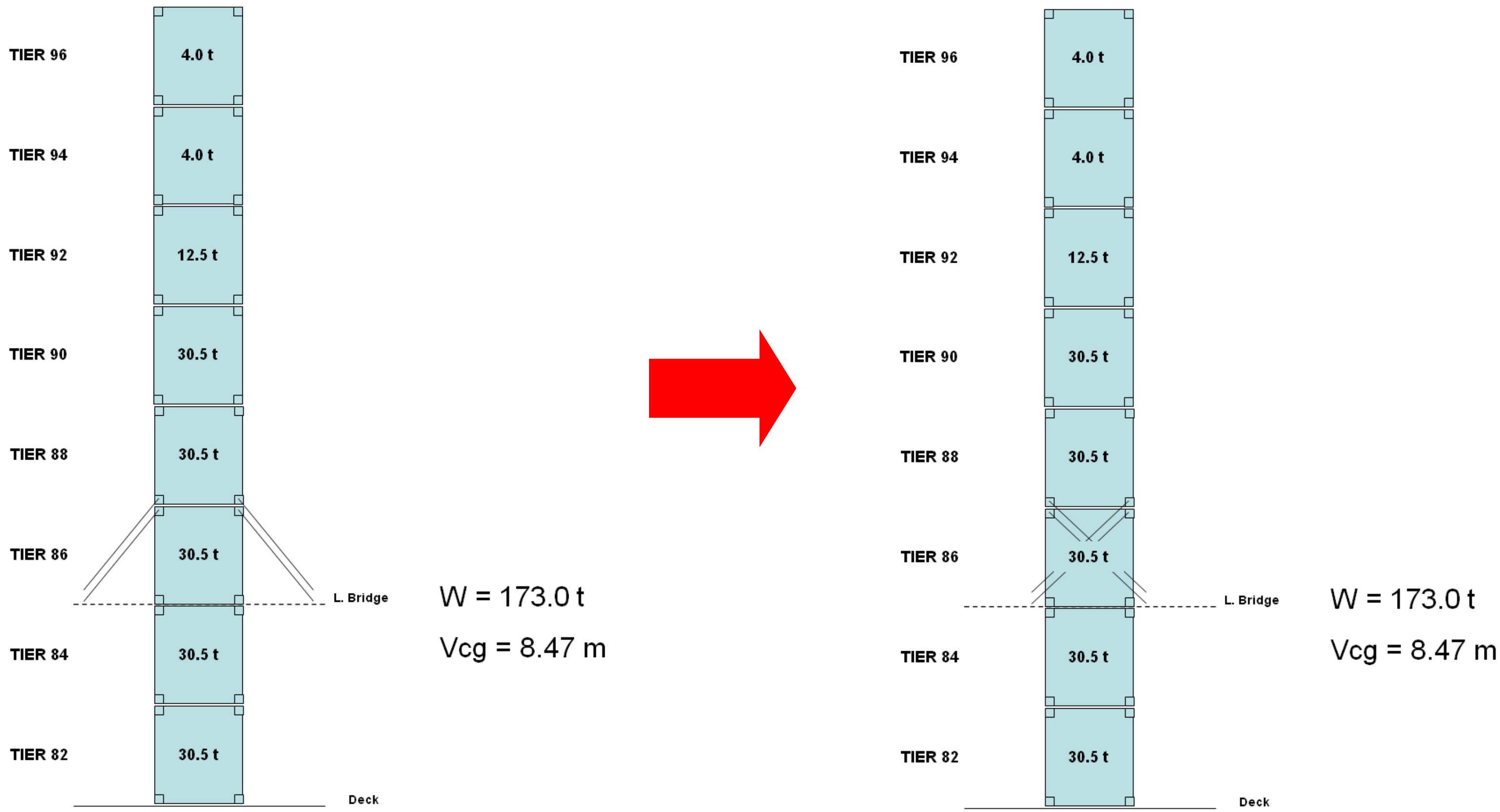


Simplified Calculation Method Procedure

- Lashing elements and container forces are determined by simplified approach based on the rules
- (GAP*) is determined based on the uplifting forces (vertical force on the twist locks)
- Overloading on lashing rod is based on sensitivity of the equivalent lashing stiffness



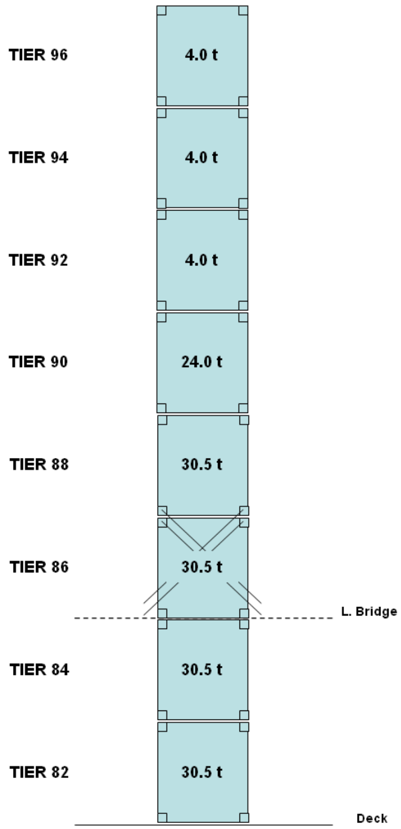
External x Internal Lashing
Maximum Cargo Capacity



FLASH_TIER4_FRONT_PS = 229 kN

Several load limits extrapolated !!!!!!

External x Internal Lashing Maximum Cargo Capacity



W = 158.0 t

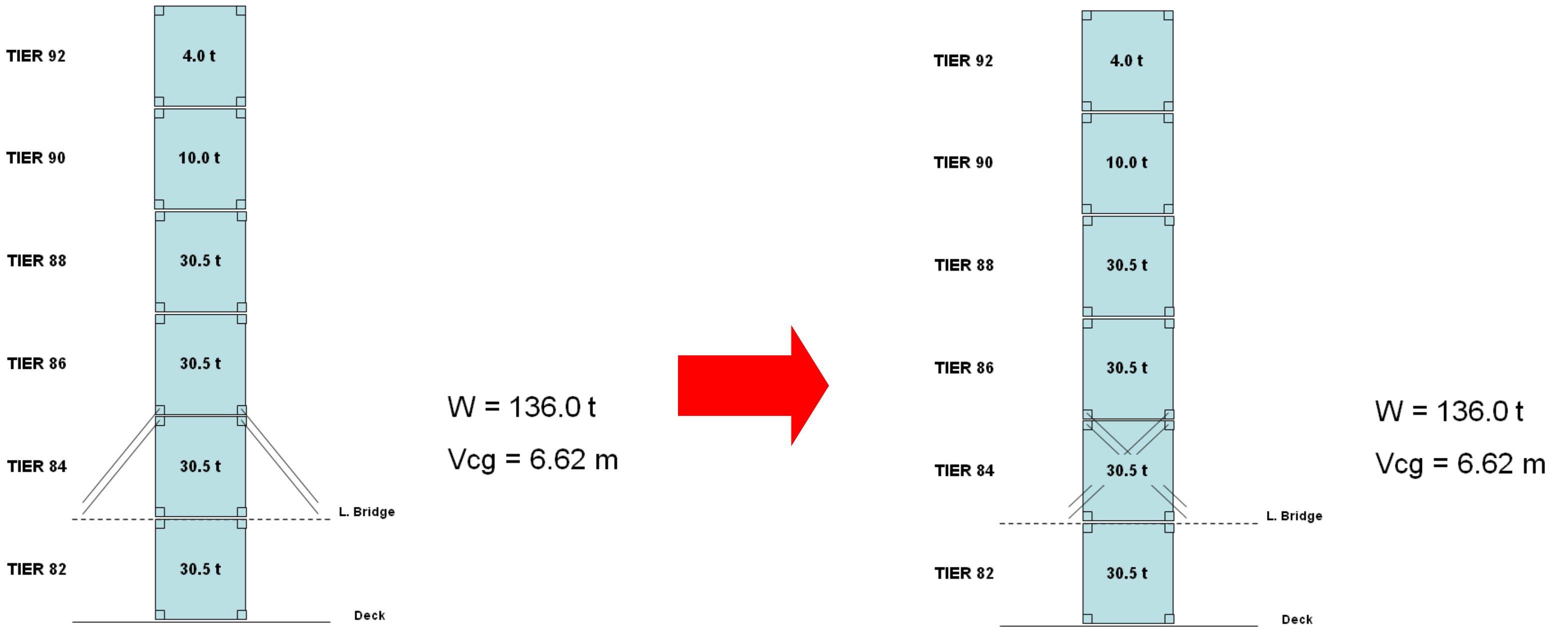
Vcg = 7.88 m

Remarks:

- Nominal values of stiffness for the lashing bridge and lashing rod
- Heeling angle of 25° (ay = 0.42*G)
- No influence of the vertical clearance for internal lashing
- Changing from internal to external lashing, the maximum cargo capacity is increased in 9.5%
- Considering 16 rows on a bay and 11 bays with the same configuration, the capacity using external lashing can be increased in 2640 MT

FPOST_TIER1_DOOR_SB = 843 kN (GAP = 15mm) / 845 kN (GAP = 25mm)

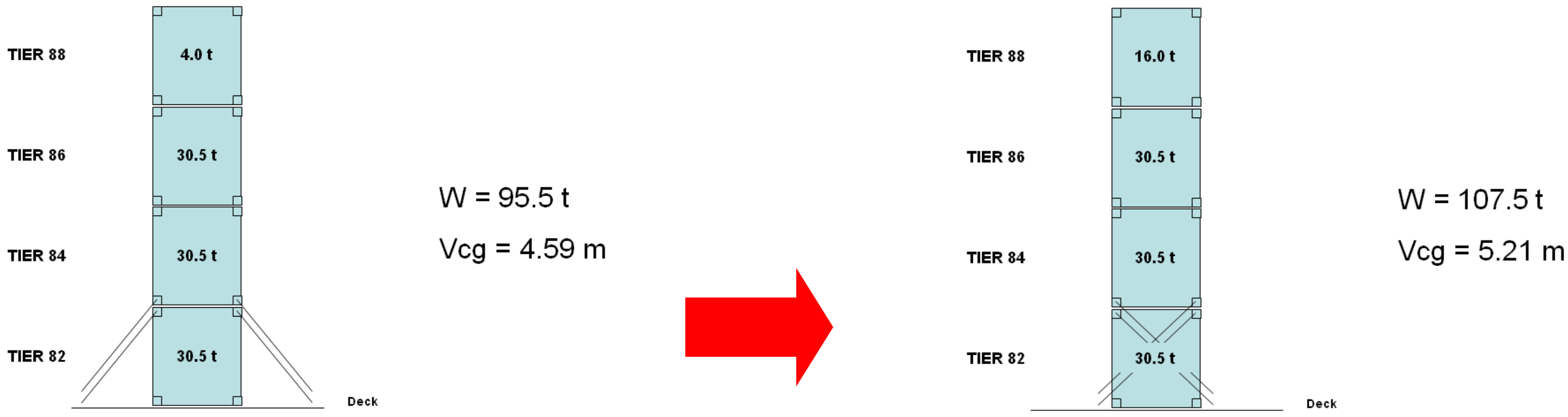
External x Internal Lashing Maximum Cargo Capacity



Remarks:

- Nominal values of stiffness for the lashing bridge and lashing rod
- Heeling angle of 25° (ay = 0.42*G)
- No influence of the vertical clearance for internal lashing
- Both lashing configurations are able to carry the same cargo, using the distribution above. External lashing is limited by the lashing force and internal lashing by the container post load.

External x Internal Lashing Maximum Cargo Capacity



Remarks:

- Nominal values of stiffness for the lashing rod
- Heeling angle of 25° (ay = 0.42*G)
- No influence of the vertical clearance for internal lashing
- Changing from internal to external lashing, the maximum cargo capacity is reduced in 11.2%, respecting the cargo distribution above
- External lashing is not interesting for this case

Additional Studies
Lashing Bridge Stiffness

- According to GL rules, 10 mm deformation (on the direction of the lashing force) for 1 tier high lashing bridge and 25 mm for 2 tier high lashing bridge shall not be exceeded

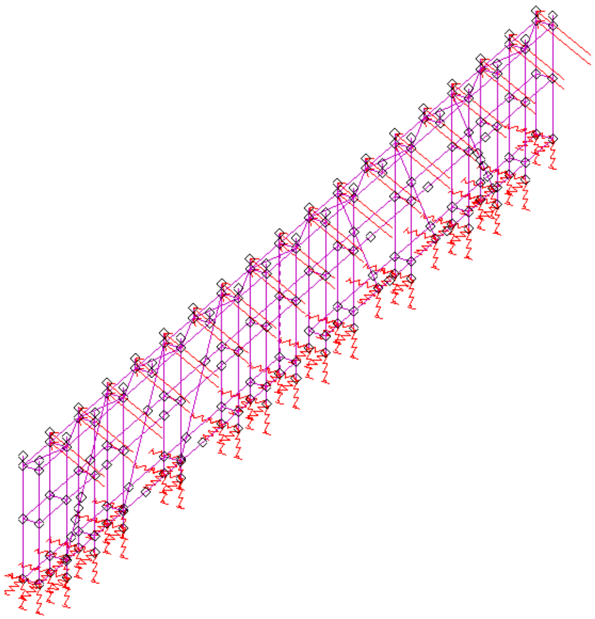
- The lashing force considered is 230 kN (SWL)

- These values give a lashing bridge stiffness of 23.0 kN/mm for 1 tier high and 9.2 kN/mm for 2 tier high

- Do the lashing bridges in operation have stiffness values similar to those presented above ?

Additional Studies Lashing Bridge Stiffness

- 1 tier and 2 tier high lashing bridges from the studied ship were analyzed using beam elements
- According GL rules, 61% of the SWL (230 kN) was applied on each lashing node and the deformation in the load direction was measured



Additional Studies
Lashing Bridge Stiffness

- The lashing bridge stiffness was calculated at each loaded node, dividing the SWL by the nodal displacement on the load direction
- An average was made between all loaded nodes

$$k_{bridge} = \frac{1}{N} \sum_{i=1}^{N} \frac{SWL}{u_F^i}$$

L.B.	K average	K stdev	K nominal	Difference
1 Tier	31.00	7.09	23.00	**+ 35%**
2 Tier	19.65	4.97	9.20	**+ 114%**

Additional Studies
Lashing Rod Stiffness

- According to GL rules, the lashing rod stiffness can be determined using the following formula:

$$c_Z = \frac{E_Z . A}{l}$$

- Where c_Z is the lashing rod stiffness, E_Z is the equivalent modulus of elasticity, A is the effective cross-sectional area of lashing and l is the overall length of the lashing assembly

- For the studied type of lashing, the equivalent modulus of elasticity according to the rules is E_Z = 140 GPa

Additional Studies
Lashing Rod Stiffness

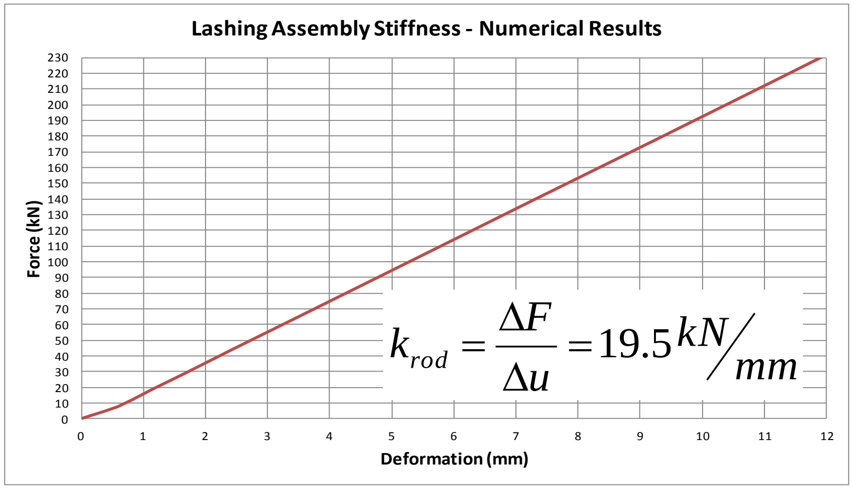
- The assembly lashing bar + turnbuckle used on the studied ship was modeled using finite elements

- The contact region between the rod head and the corner casting was modeled with constraint equations (coupling of normal and tangential relative displacements)

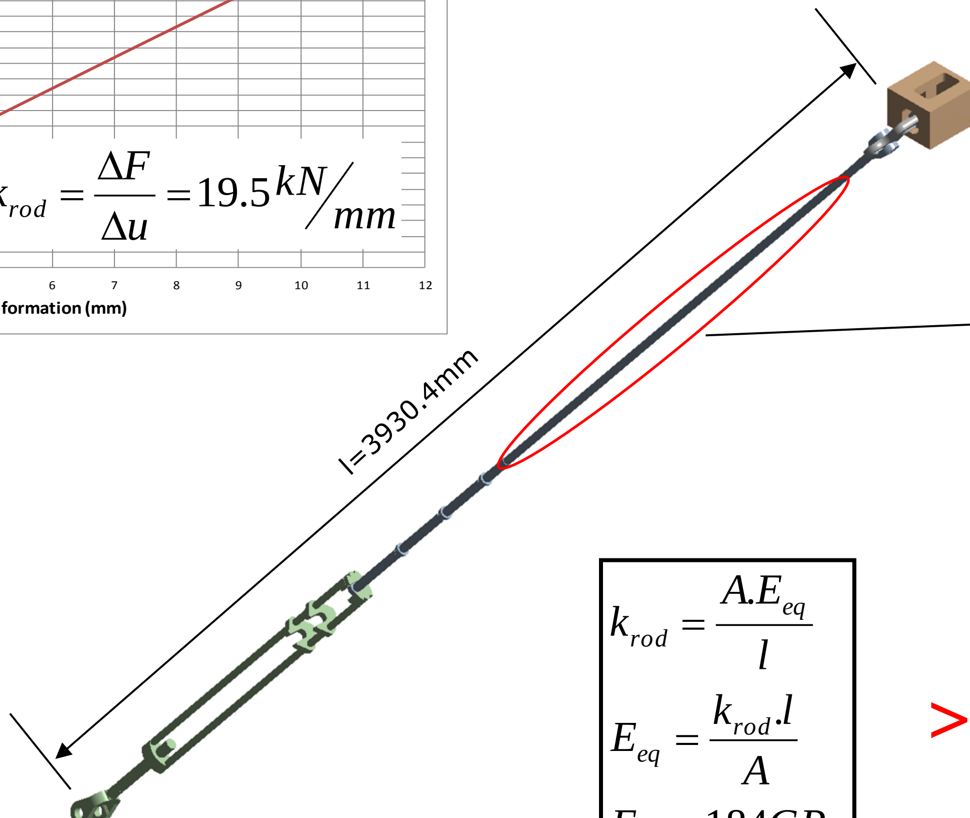
- The corner casting was assumed as elasto-plastic with a yield stress of 235 MPa and a hardening of 0.1E

- An axial displacement was applied on the lashing rod and the reaction force was measured

Additional Studies
Lashing Rod Stiffness



$$k_{rod} = \frac{\Delta F}{\Delta u} = 19.5\, {}^{kN}\!/_{mm}$$



d=23.0 mm

A=415.5 mm²

$$k_{rod} = \frac{A.E_{eq}}{l}$$

$$E_{eq} = \frac{k_{rod}.l}{A}$$

$$E_{eq} = 184GPa$$

>> 140 GPa

Main Conclusions

- For the external lashing system, the main parameters which have influence on the forces acting on lashing elements and container frames are the vertical clearance (twist lock type) and the lashing stiffness
- External lashing system, in comparison with internal lashing, allows carrying more cargo on a container stack, decreasing the uplifting forces and the container post loads. In the other hand, it overloads the lashing rod connected to the uplifted corner
- For some cases, as 8 tier high stacks with 2 tier high lashing bridge, using external lashing system allows carrying 9.5% more cargo than using internal lashing system
- For other cases, as 4 tier high stacks without lashing bridge and with the 2 first tiers lashed, external lashing is not interesting

Main Conclusions

- Rule based approach to estimate the forces acting on lashing elements and container frames has to be updated for external lashing system
- It can be done using the proposed design apporoach or inserting a new methodology (analytical or numerical procedure)
- The rule based values used to calculate the lashing rod and lashing bridge stiffness must be reviewed

Future Work

- Validate the simplified design method proposed
- Cargo capacity comparison must be repeated using actual values for the lashing stiffness
- Possible interference of lashing rods connected to adjacent stacks must be evaluated to determine the maximum relative longitudinal displacement

Thank You!