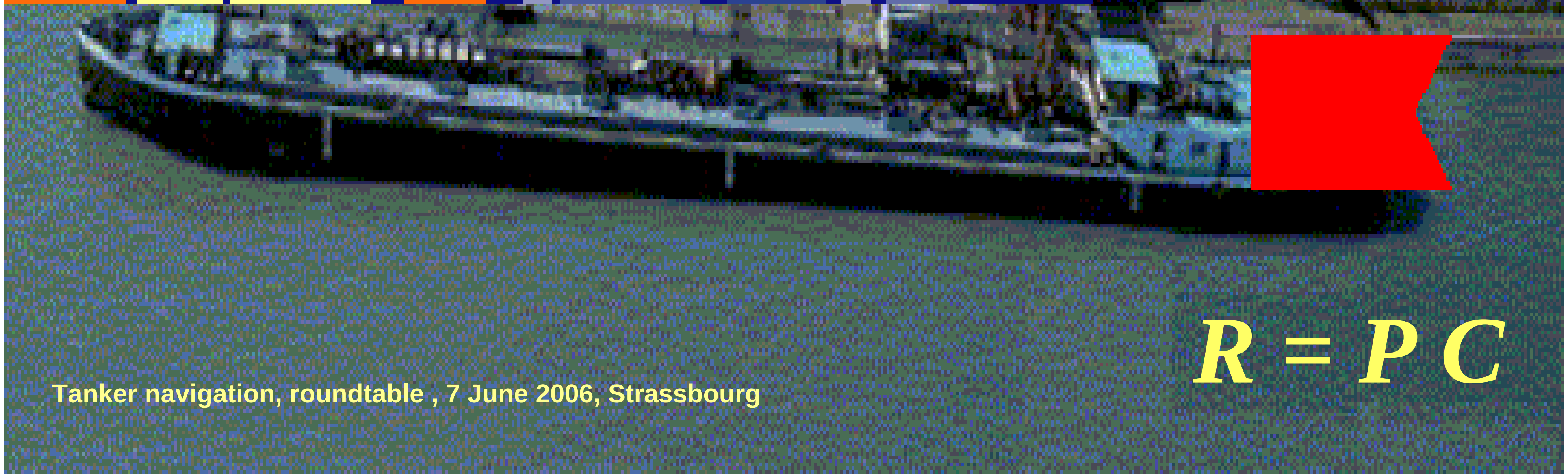
Double Hull Technology

Design and application of crashworthy ship structures

Alex W. Vredeveldt

TNO | Knowledge our business

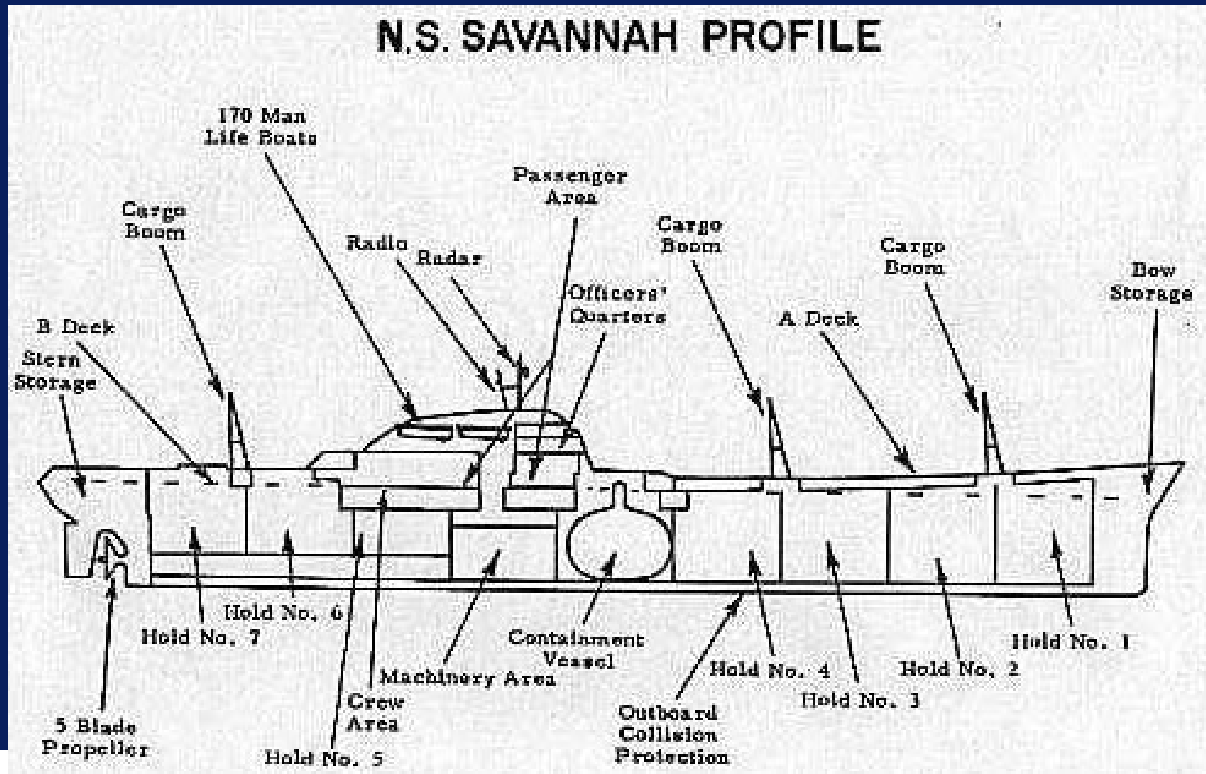


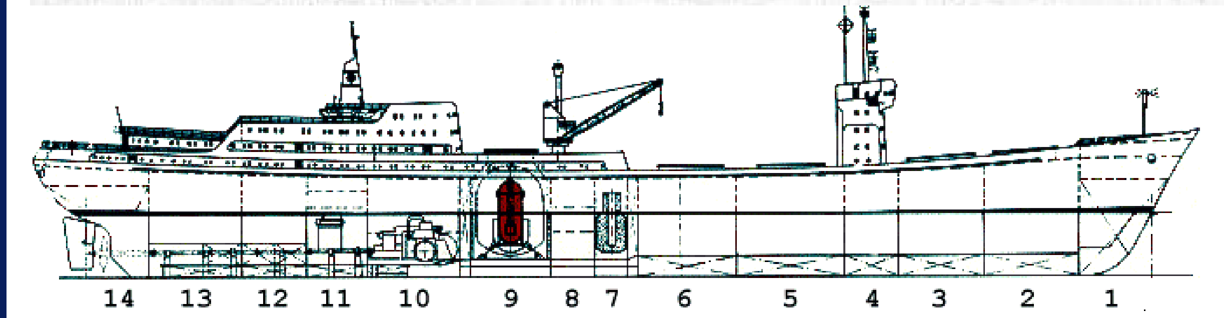
$$R = P\,C$$

Tanker navigation, roundtable , 7 June 2006, Strassbourg

Contents

Nothing new





V.U. Minorsky

Preamble

- Goal based standards, only through risk based assessments
- Class rules based on risk concept
- Implicit Risk must become explicit
- Transparency of design
- Mandatory in offshore
- Mandatory in (petro-) chemical industry
- Design and operational responsibility where it belongs
- Make money

Risk / reliability concept

$$R = p\,E$$

R risk

p probability of occurrence of a calamity

E effect of the calamity

Safety = 1 - Risk

Risk / reliability concept

R =p E

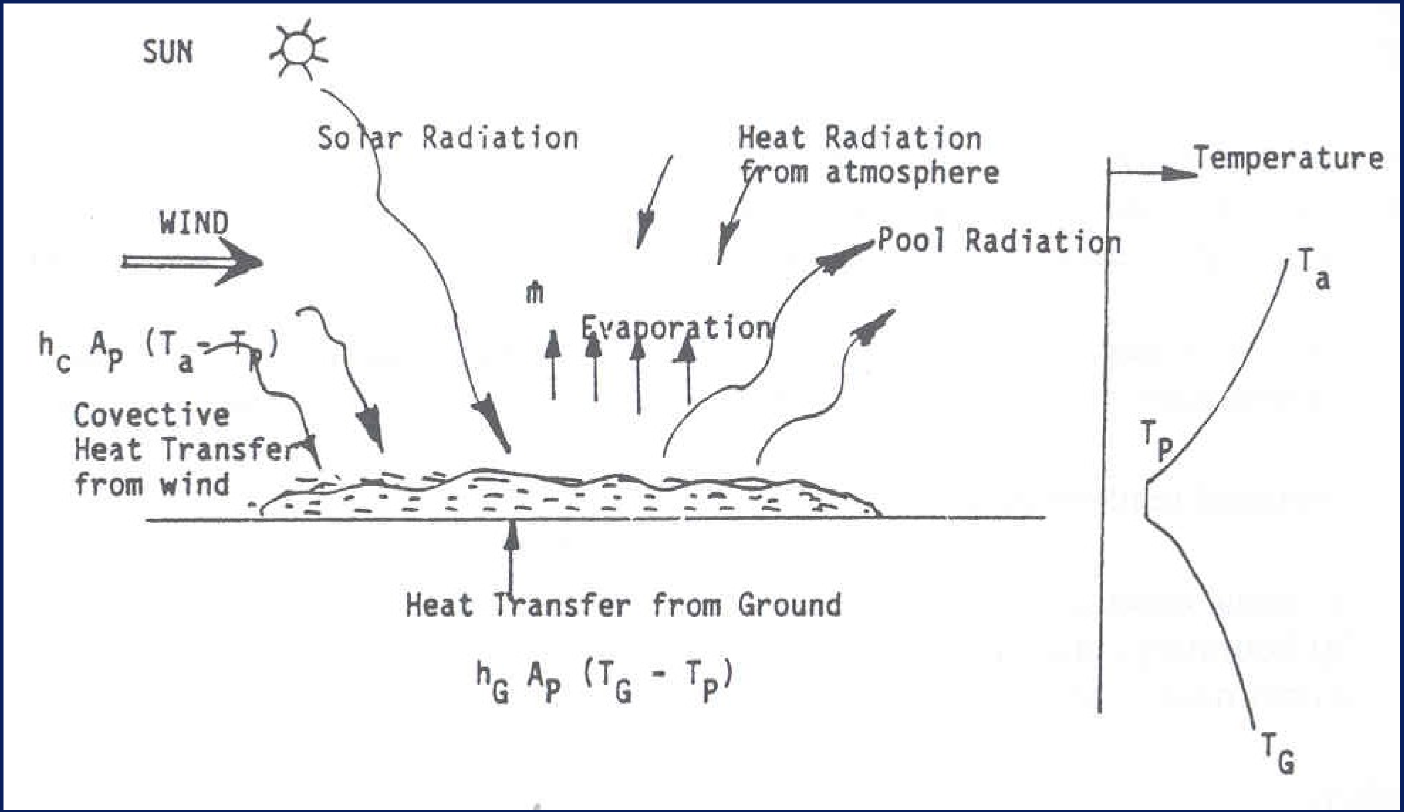
		Damage stability	Hazardoes cargo
Probability	p	*flooding*	tank rupture
Effect	E	*capsize/sinking (loss of life)*	affected area (loss of life)
Example		*Crashcoaster*	Gas barges CCR

Inland waterway tanker

R =p E

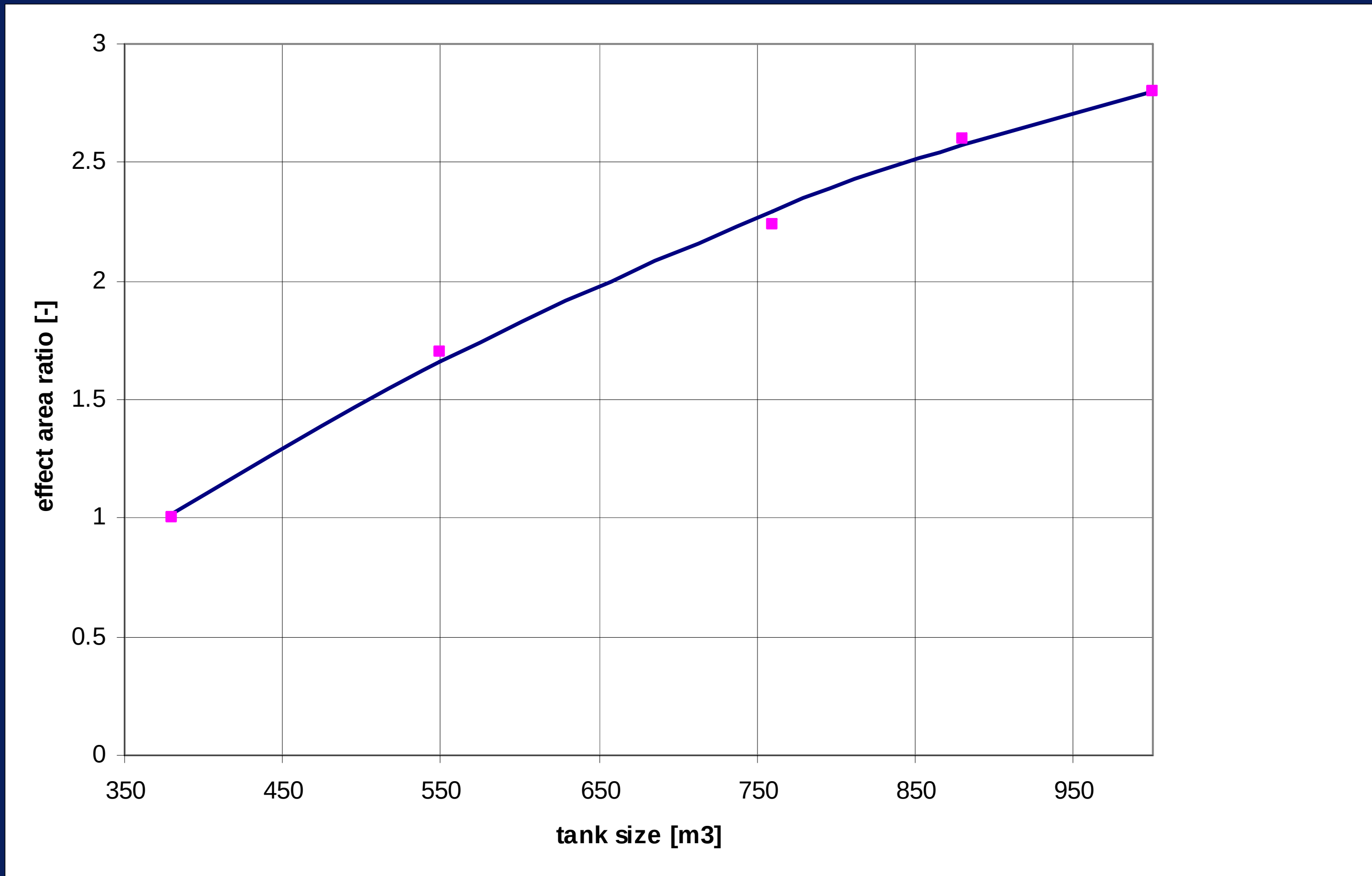
Inland waterway tanker

R =p E



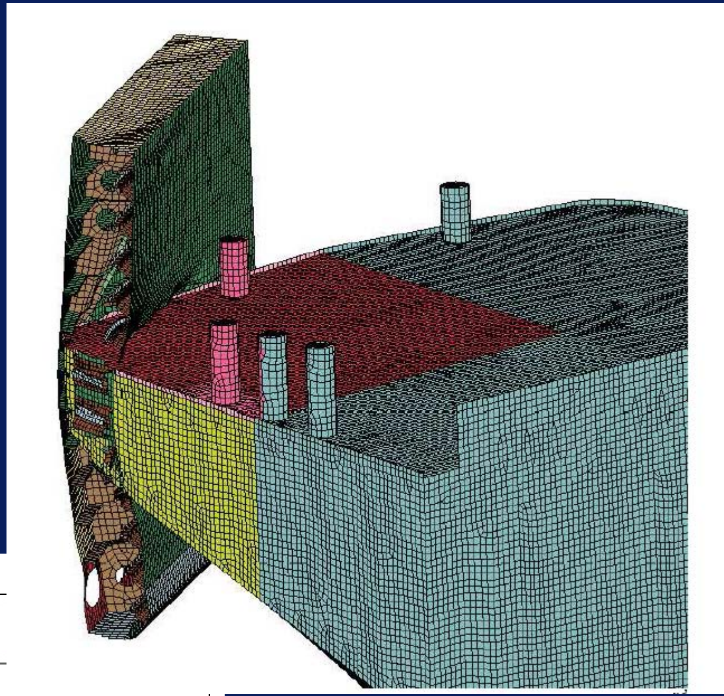
Inland waterway tanker

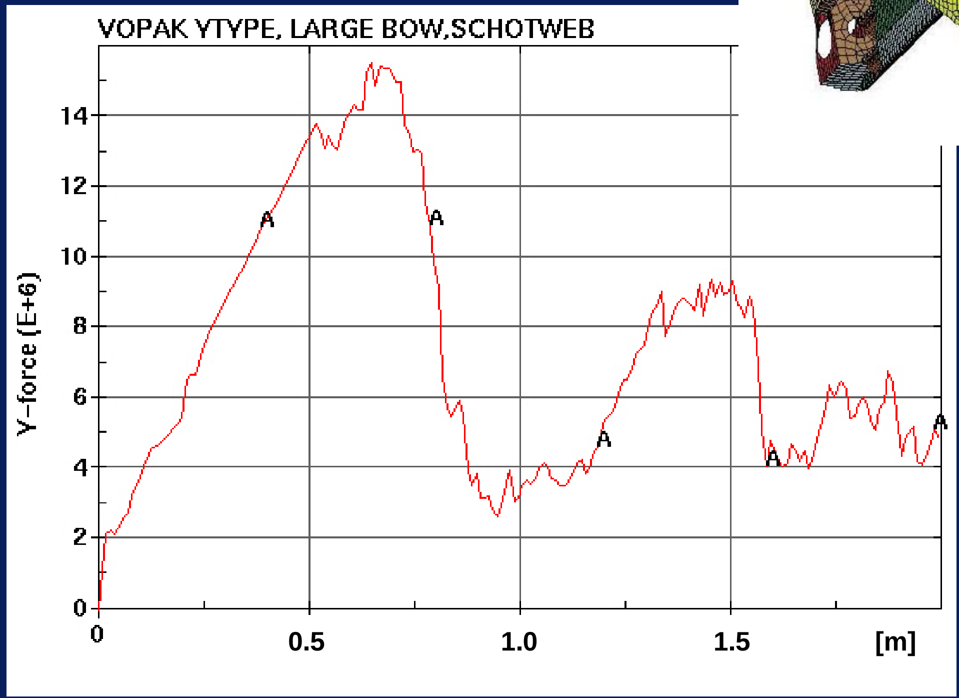
R =p E



Inland waterway tanker

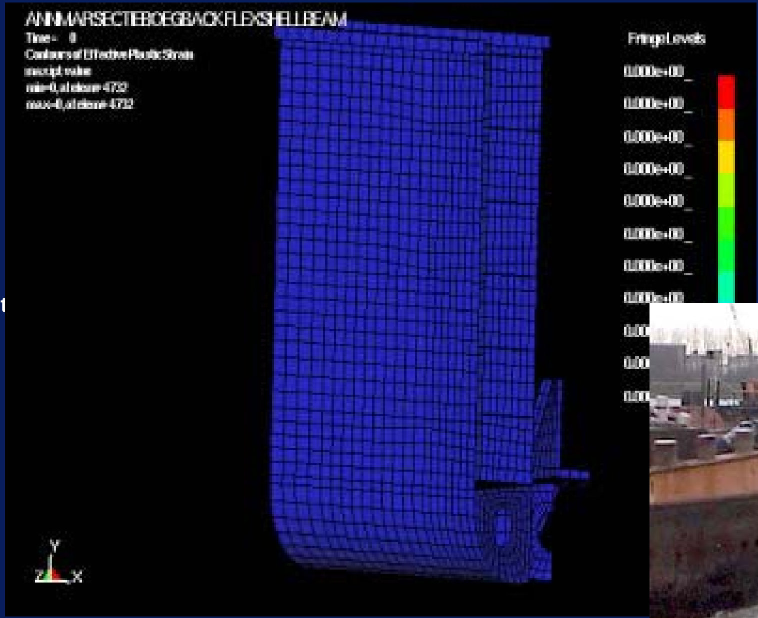
$$R = p\ E$$





Inland waterway tanker

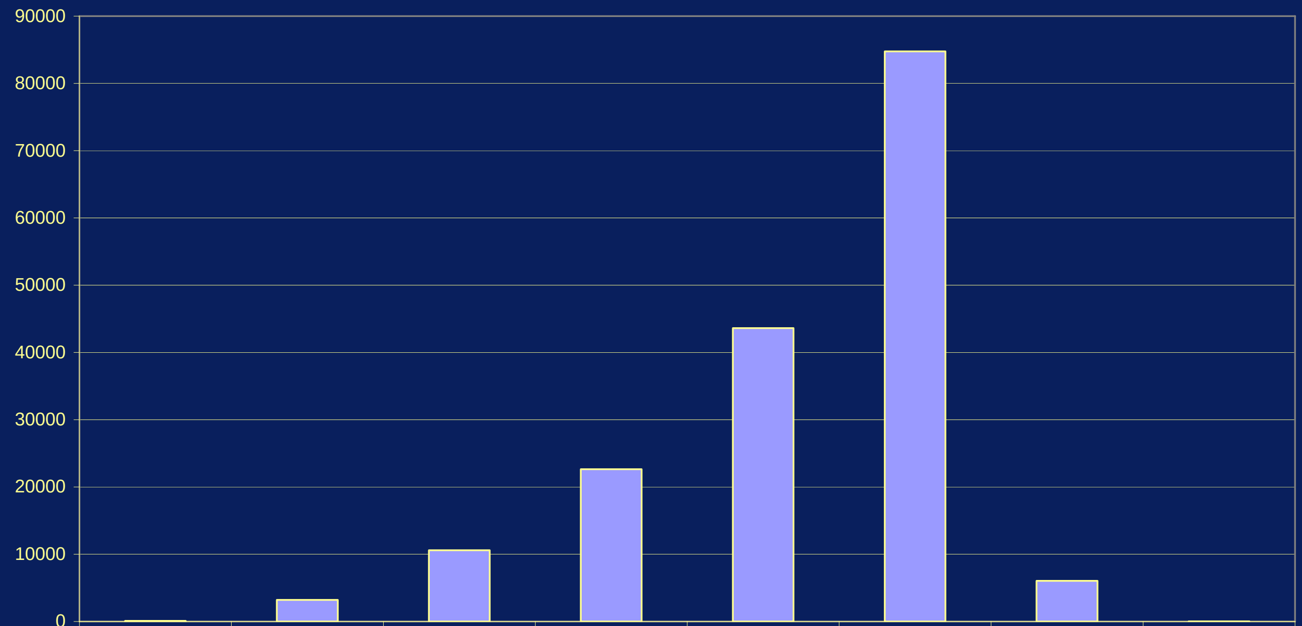
R = p E



Inland waterway tanker

R = p E

Number of ship passages Lobith, upstream + downstream, per displacement range, 1999



	21-250 tonne	250-400 tonne	400-650 tonne	640-1000 tonne	1000-1500 tonne	1500-3000 tonne	3000-6000 tonne	6000 and over tonne
Series1	101	3220	10588	22640	43618	84779	6043	10

Inland waterway tanker

R = p E

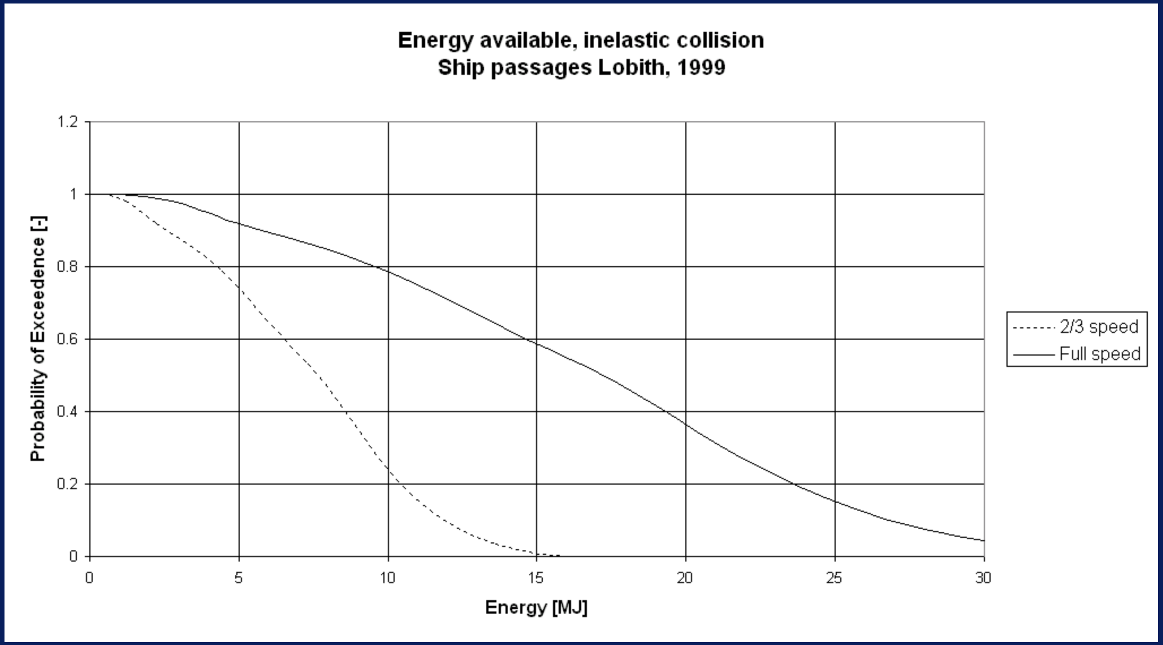


Table 7 Calculated failure probabilities, scenario I, CPDF 66 %

Bow type	Failure probability reference	Failure probability new
Scenario I Push barge	0.56	0.08

Inland waterway tanker

R =p E

Consequence increase

760 m^3 $C_n/C_r = 2.24$

Probability decrease

0.08/0.56=0.14

0.14 x 2.24 < 1

Damage stability

R =p E

Attained subdivision index

$$A = \sum p_i \cdot s_i$$

A	attained subdivision index
	looks like R
p_i	probability of flooding of compartment(s)
	looks like p
s_i	vessel stays afloat and does not capsize
	mostly either 1.0 or 0.0, i.e. digital
	looks like effect E

Damage stability

p_i probability of flooding of compartment(s)

in SOLAS regulations based on statistics

designer does not control this parameter

s_i vessel stays afloat and does not capsize

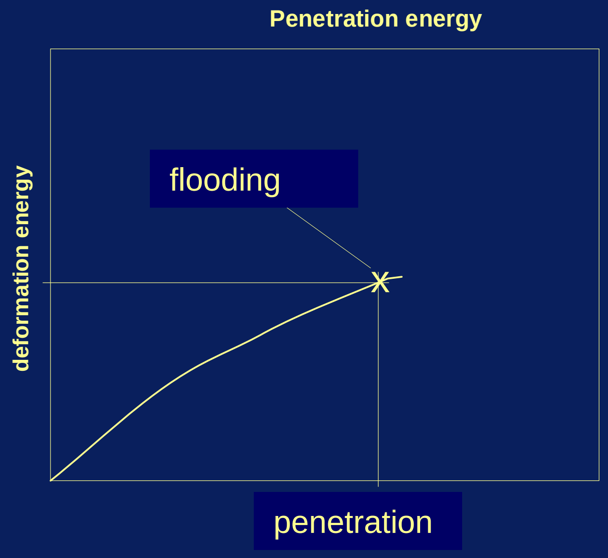
the usual design variable:

- smaller compartments
- permanent buoyancy (sometimes)
- cross flooding
- …

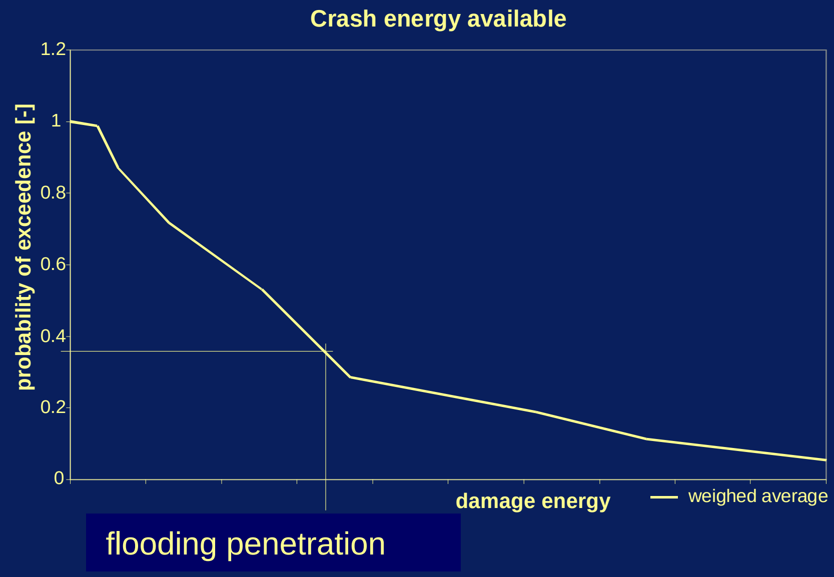
Damage stability

p_i probability of flooding of compartment(s)

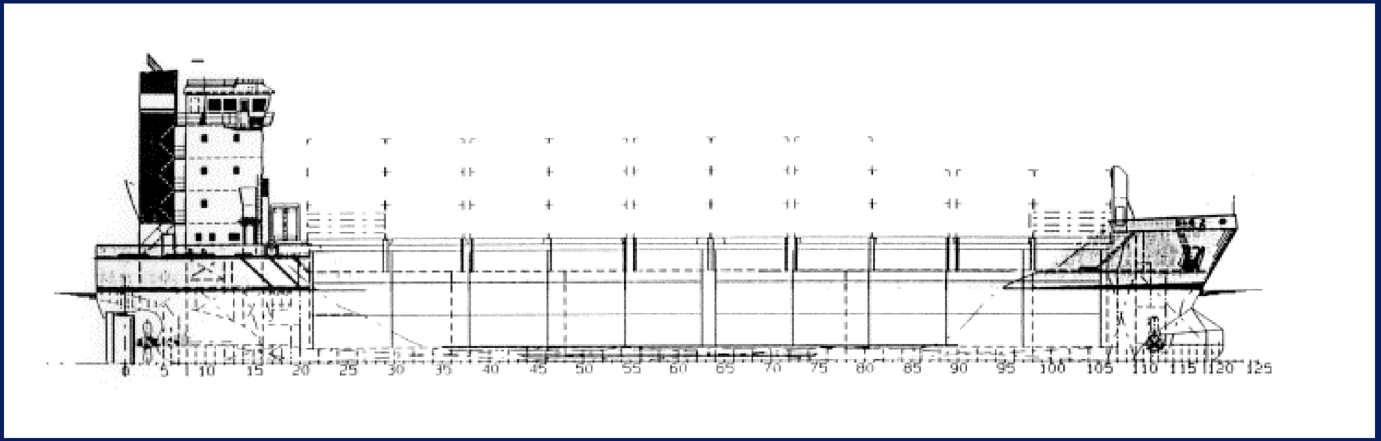
can be reduced by protection against penetration

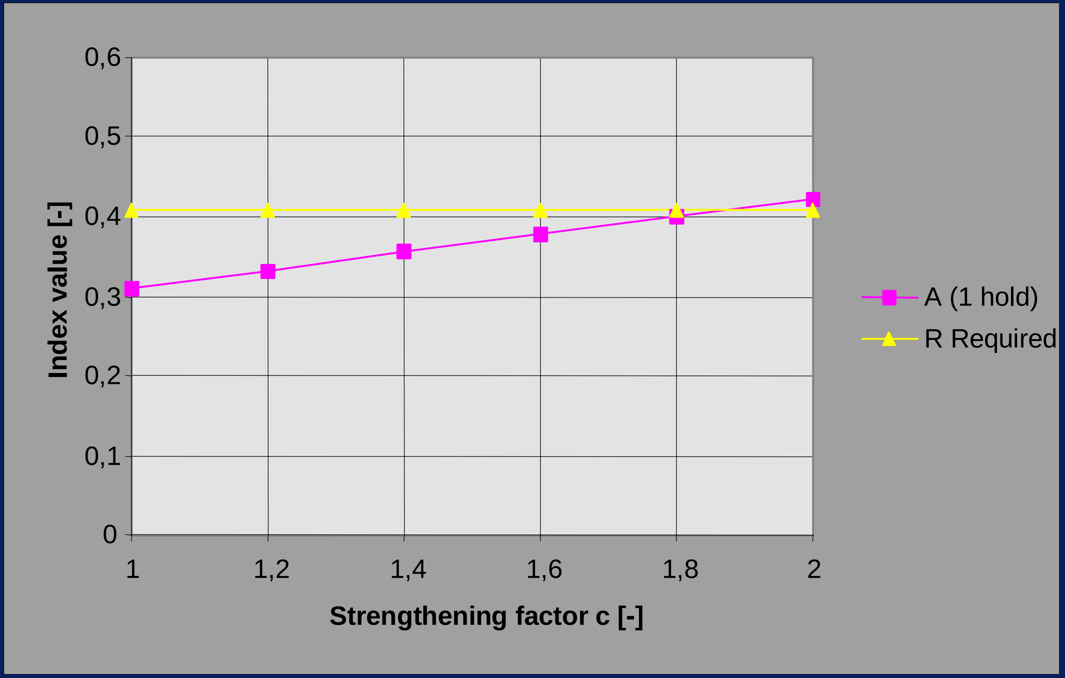


Crash capacity

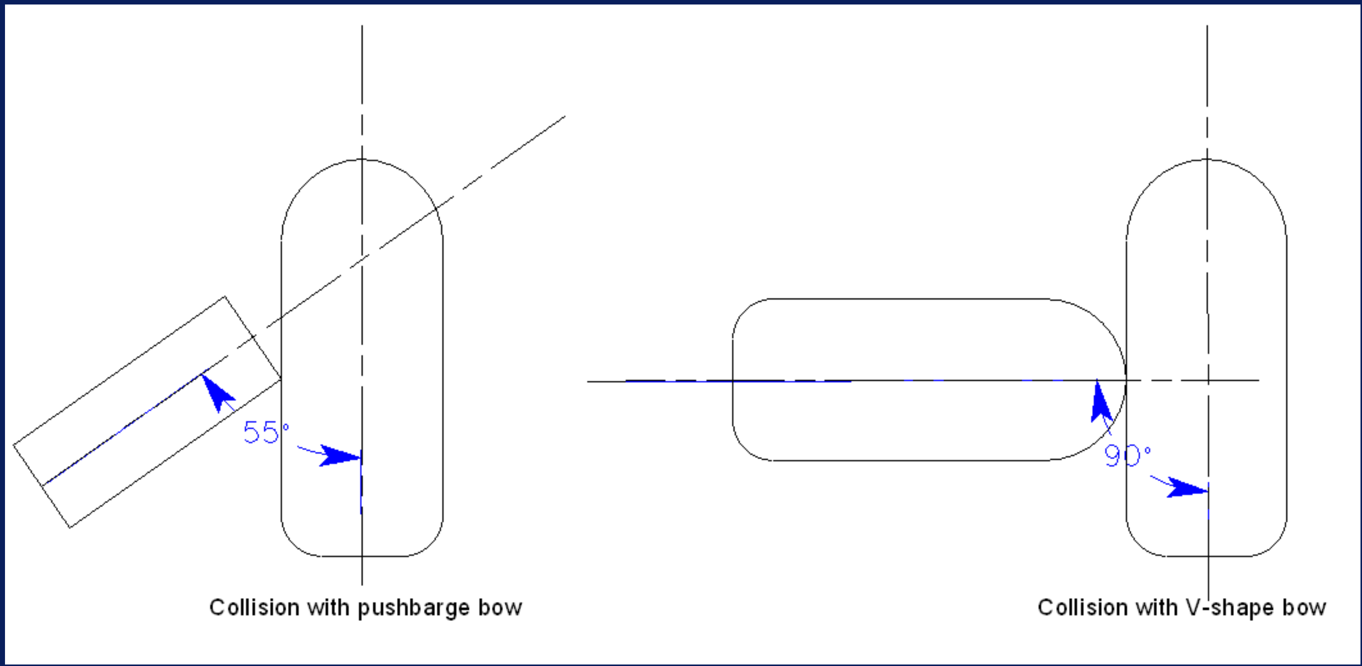


Collision energy at sea

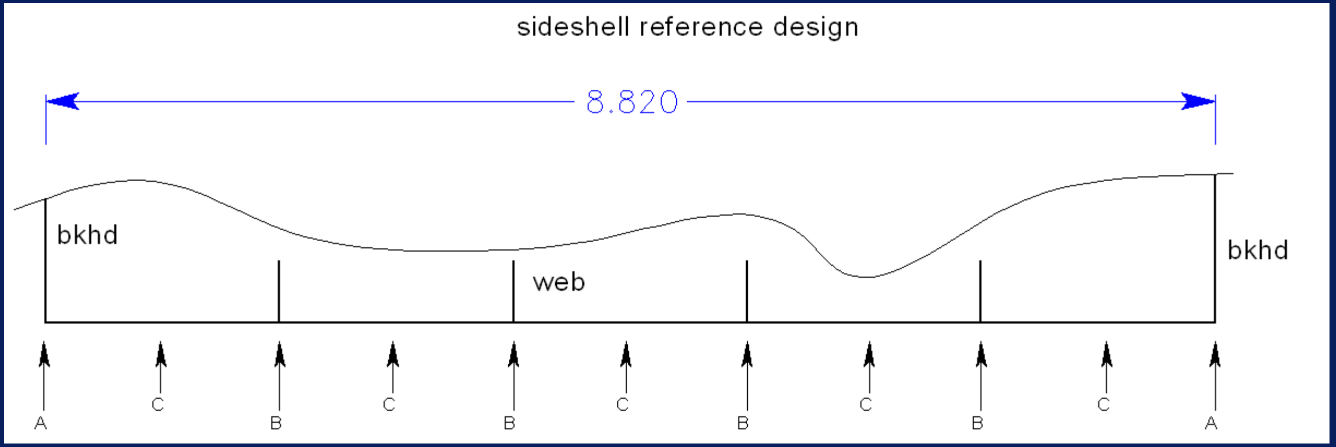



0,6
0,5
0,4
0,3
0,2
0,1
0
Index value [-]
1
1,2
1,4
1,6
1,8
2
Strengthening factor c [-]
A (1 hold)
R Required

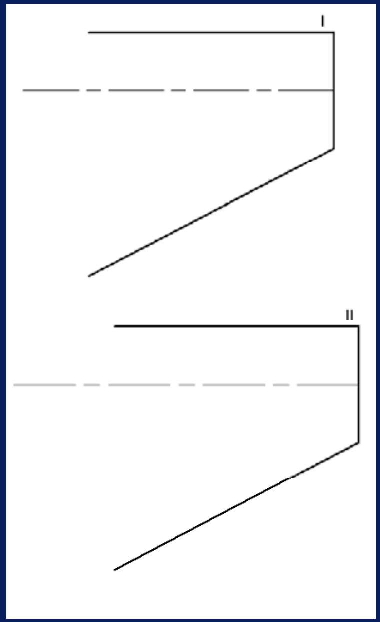
Guideline

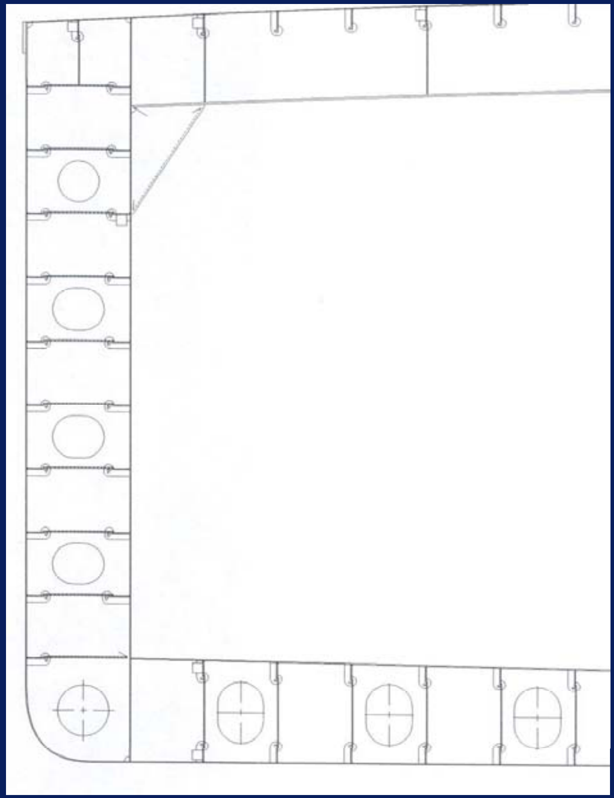

55°
90°
Collision with pushbarge bow
Collision with V-shape bow

Guideline


sideshell reference design
8.820
bkhd
web
bkhd
A
C
B
C
B
C
B
C
B
C
A

Guideline





Methods for Estimating the Damage due to Collision

Complex and highly non-linear phenomenon

- External dynamics
  - Global ship motion and water interaction
- Internal mechanics
  - Large plastic deformations
  - Buckling
  - Fracture and crack propagation
  - Contact/Friction

Impact energy is mainly absorbed by large plastic deformations.

Substantial loss in energy absorbing capability after fracture.

Crucial that fracture and crack propagation are correctly determined.

. Determines if a compartment will be flooded and if oil leakage will occur.

. Influences the global deformation modes.

Methods for Estimating the Damage due to Collision

External dynamics

$$E_{dis} = \frac{1}{2} \frac{m_1 m_2}{m_1 + m_2} v^2$$

E_{dis}	energy to be dissipated	[kJ]
m_1	mass striking ship	[tonnes]
m_2	mass struck ship	[tonnes]
v	collision speed	[m/s2]

Methods for Estimating the Damage due to Collision

Internal mechanics

Partial differential equations

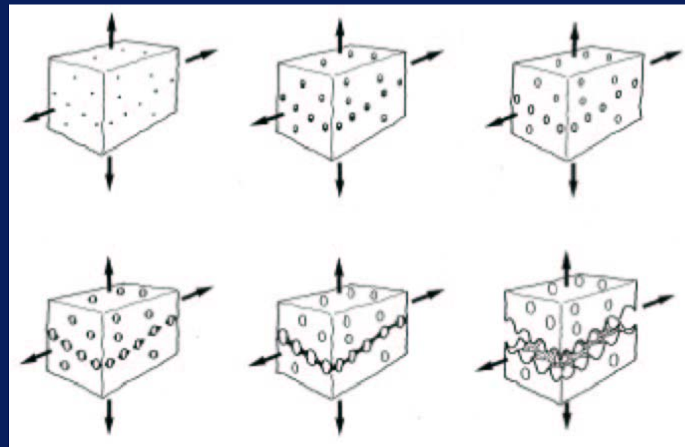
$$x'' = \frac{(F_{ex}^{(n)} - F_{\mathrm{int}}^{(n)})}{M}$$

M	is the diagonal mass matrix,
$\mathbf{F}_{ex}$	the applied load vector at time $t^{(n)}$,
$\mathbf{F}_{int}$	the stress divergence or internal load vector at time $t^{(n)}$,
$\mathbf{x}''$	the vector of nodal accelerations in a global co-ordinate system

Methods for Estimating the Damage due to Collision

ØThe Ductile Damage Process

- Nucleation of voids from inclusions
- Void growth
- Void coalescence

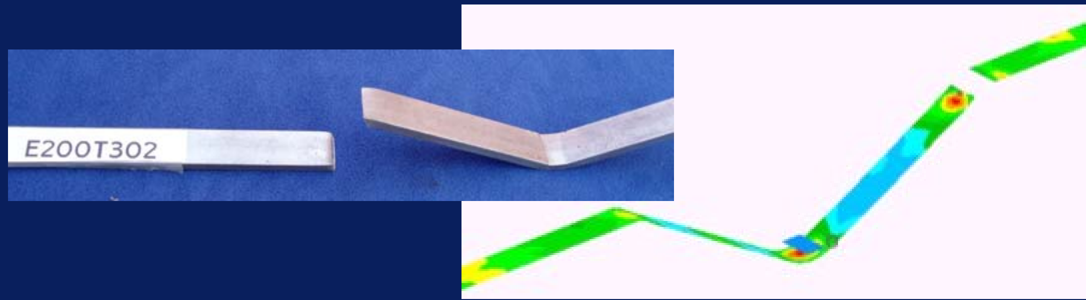


ØThe governing damage process is dependent of:

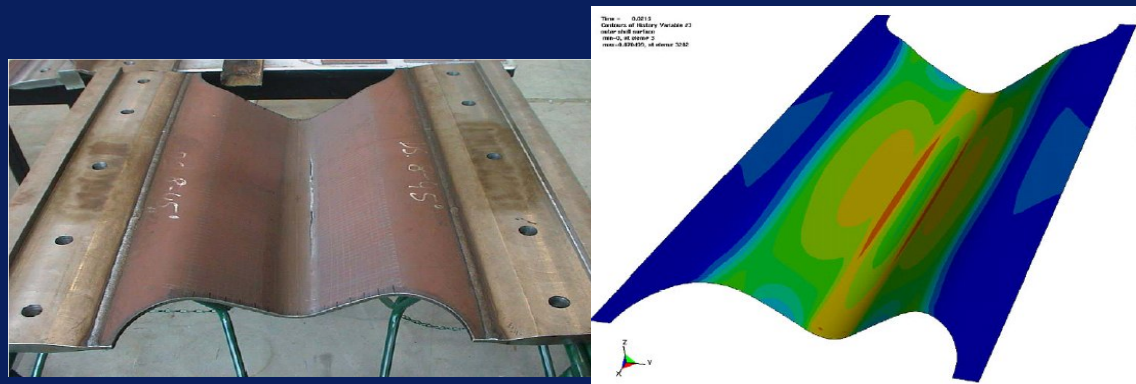
- The stress triaxiality (s_H / s_{eq})
- The plastic strain (e_p)
- Void shape, void density and material

Methods for Estimating the Damage due to Collision

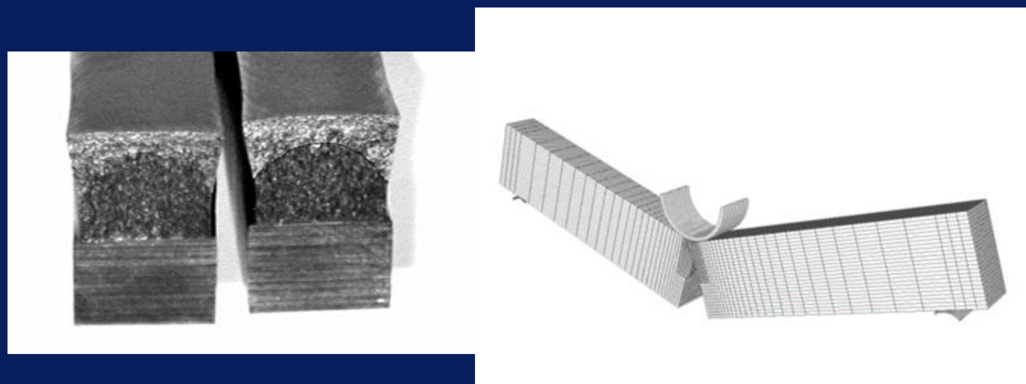
Uni axial



Bi axial



Tri axial



Methods for Estimating the Damage due to Collision

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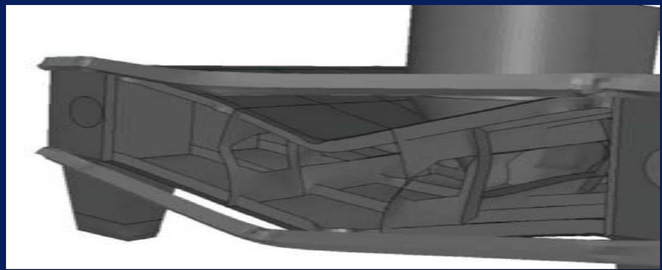
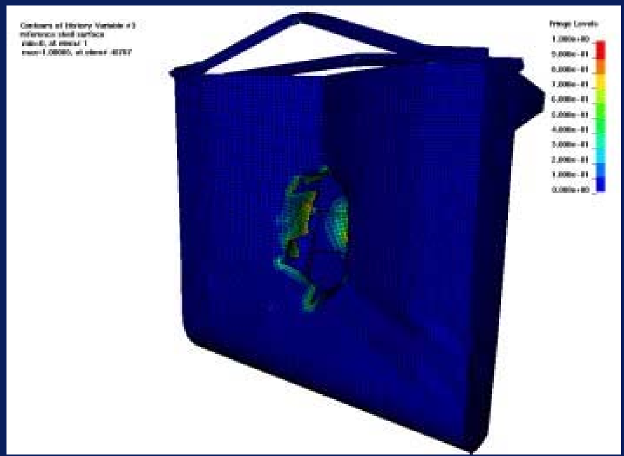
Methods for Estimating the Damage due to Collision

1. Preamble
2. Crashworthiness and risk
3. Application examples
4. Pragmatic use in ADNR
5. Crashworthiness assessments
6. Concepts crashworthiness
7. Conclusion
8. Acknowledgements





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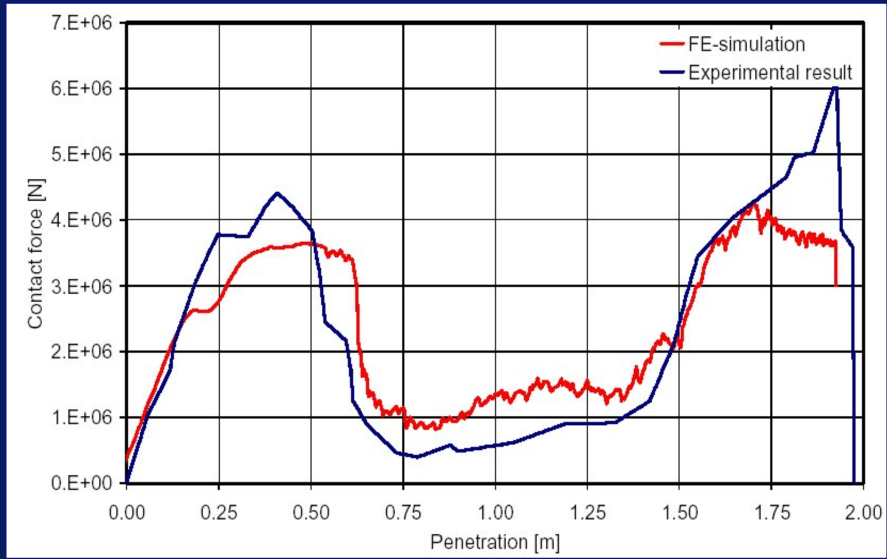
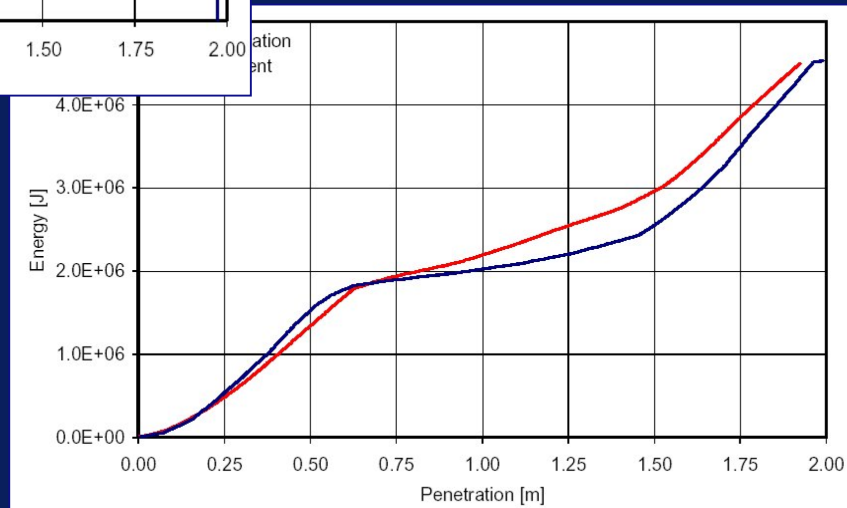
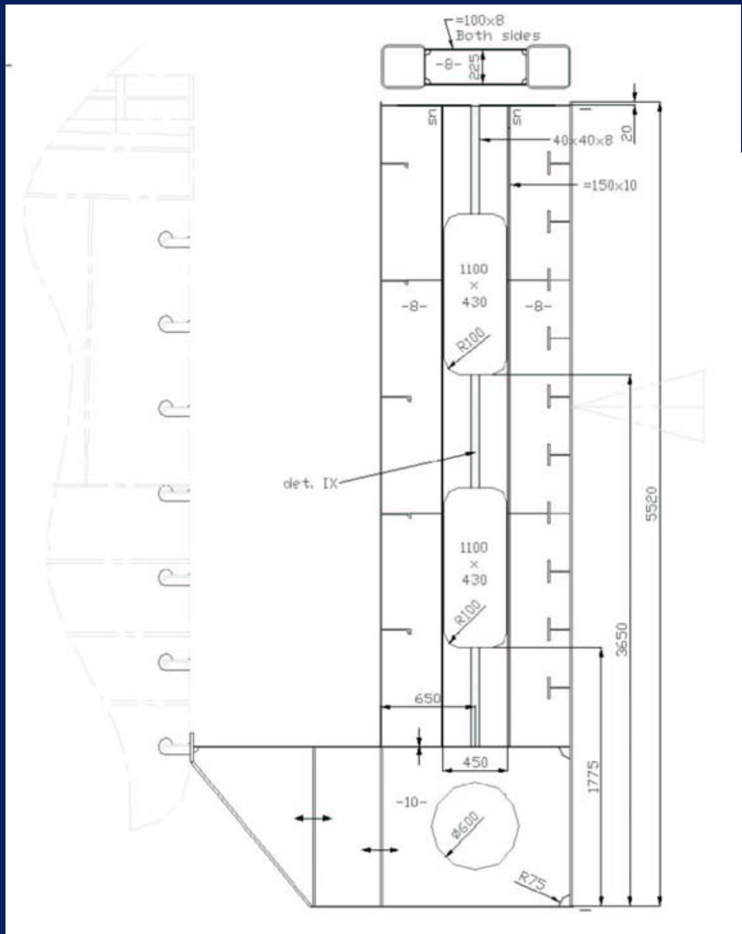
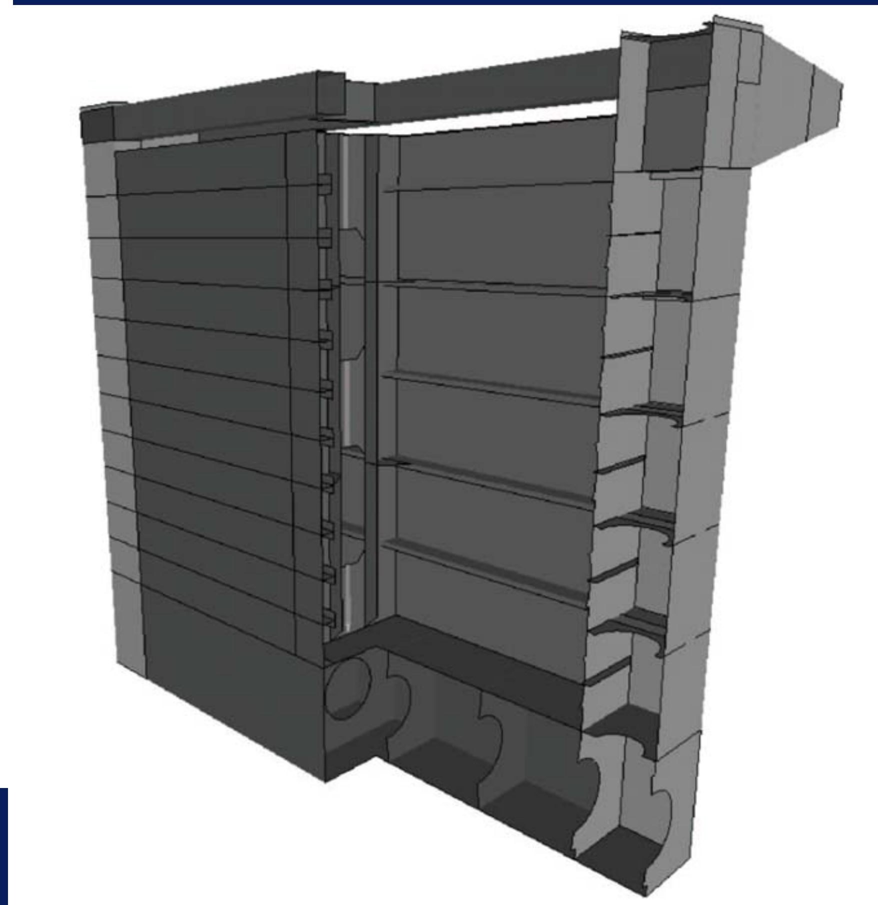




“Ice” strengthening





X - core

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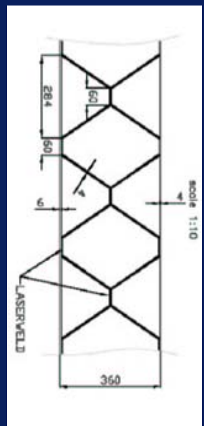

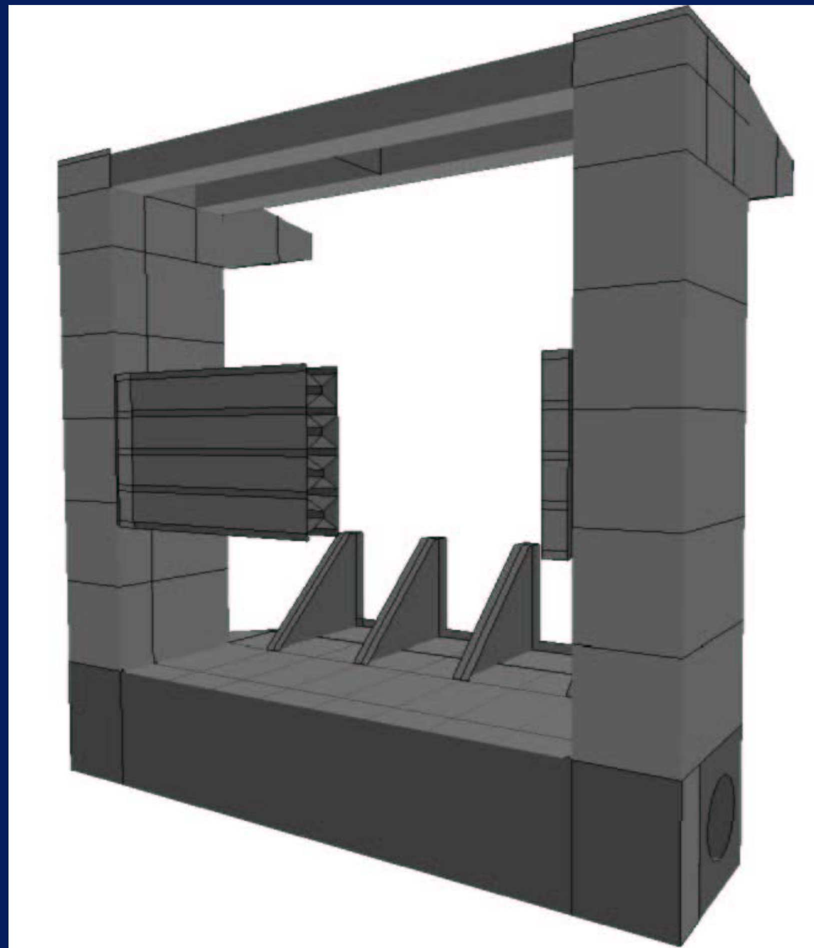

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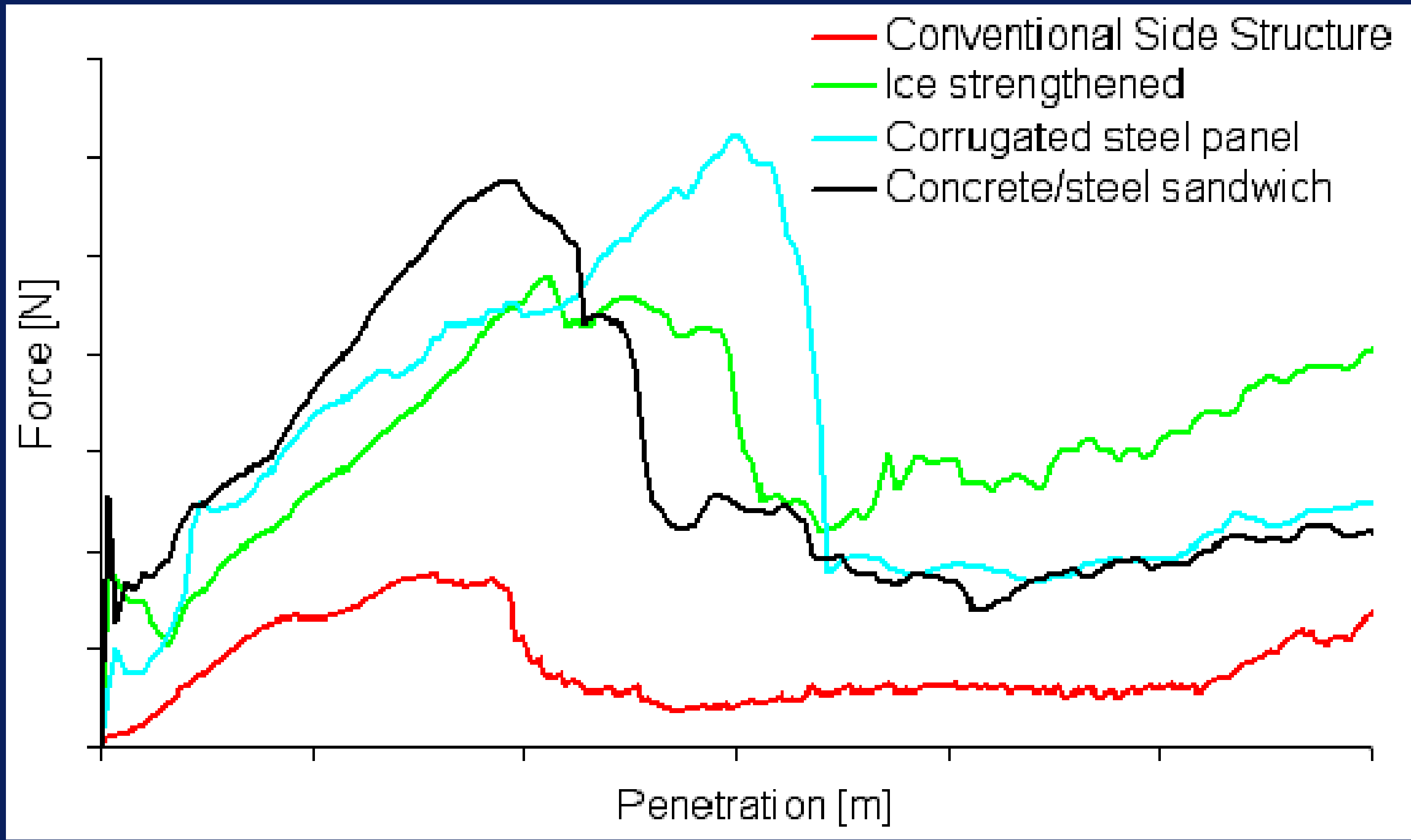
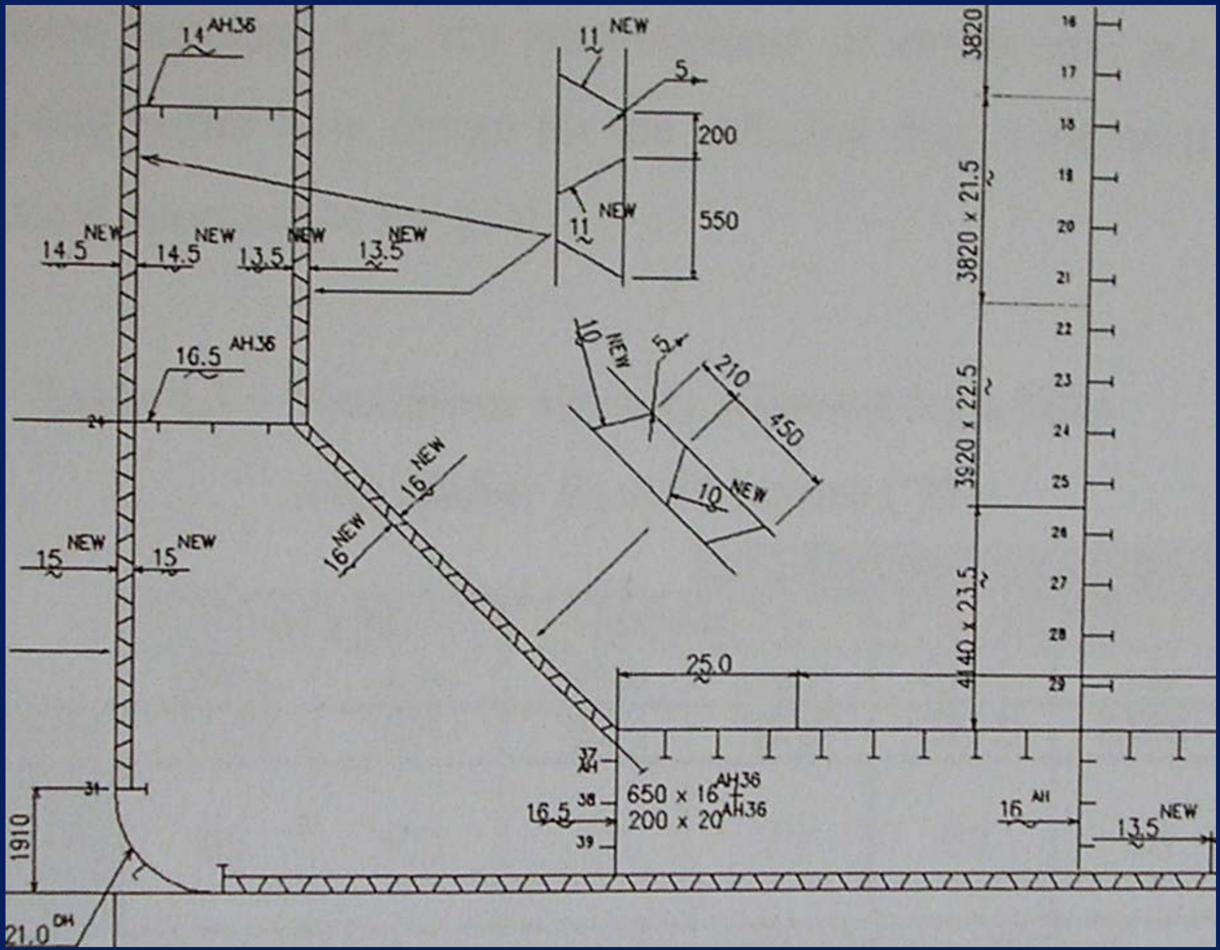
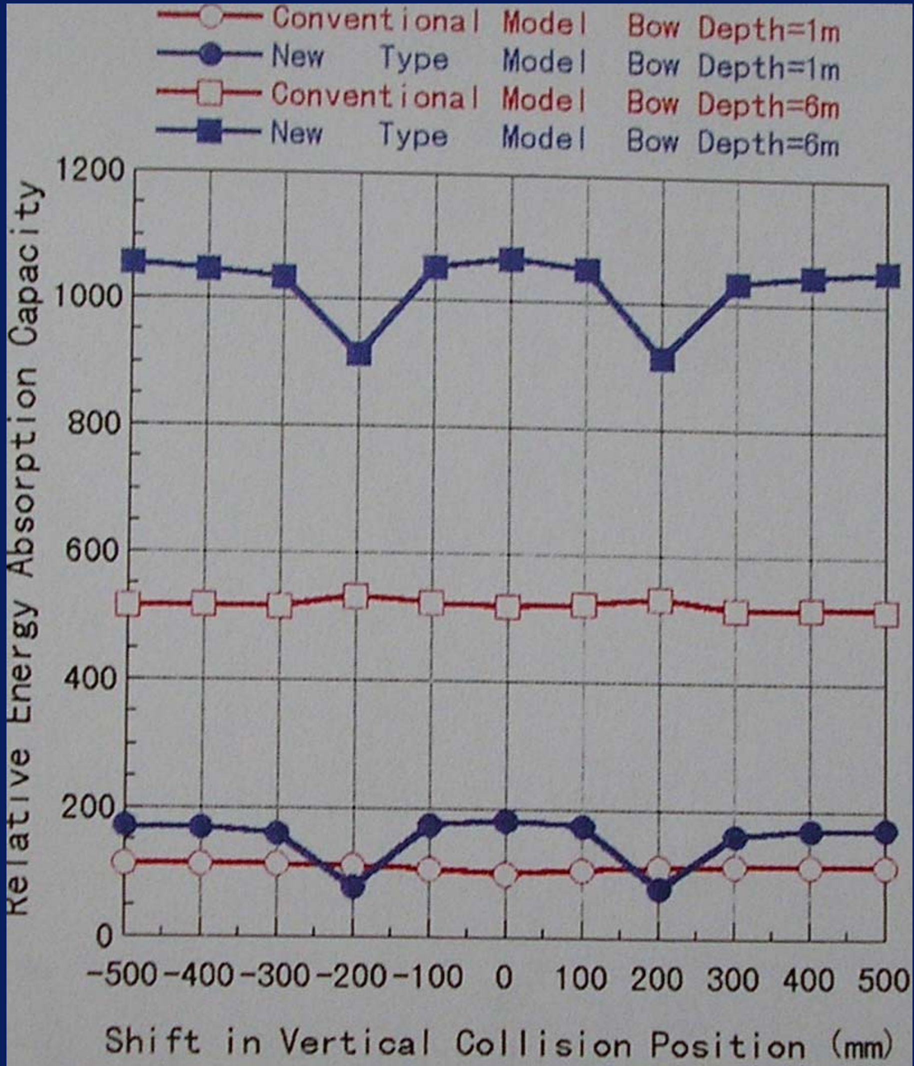


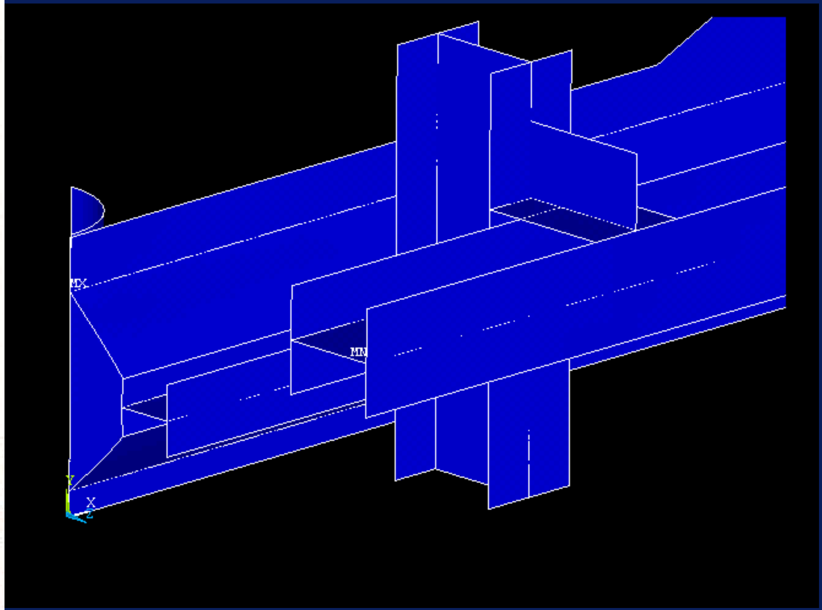
inclined I-core



inclined I-core



Y-type side structure



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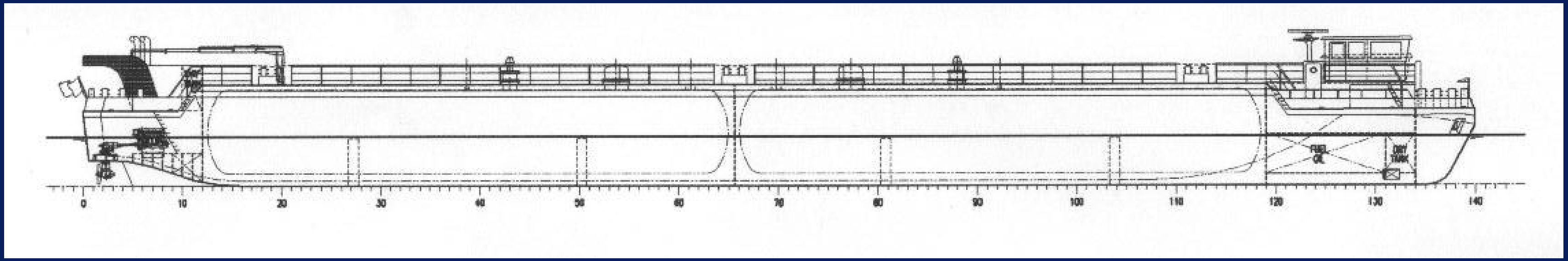
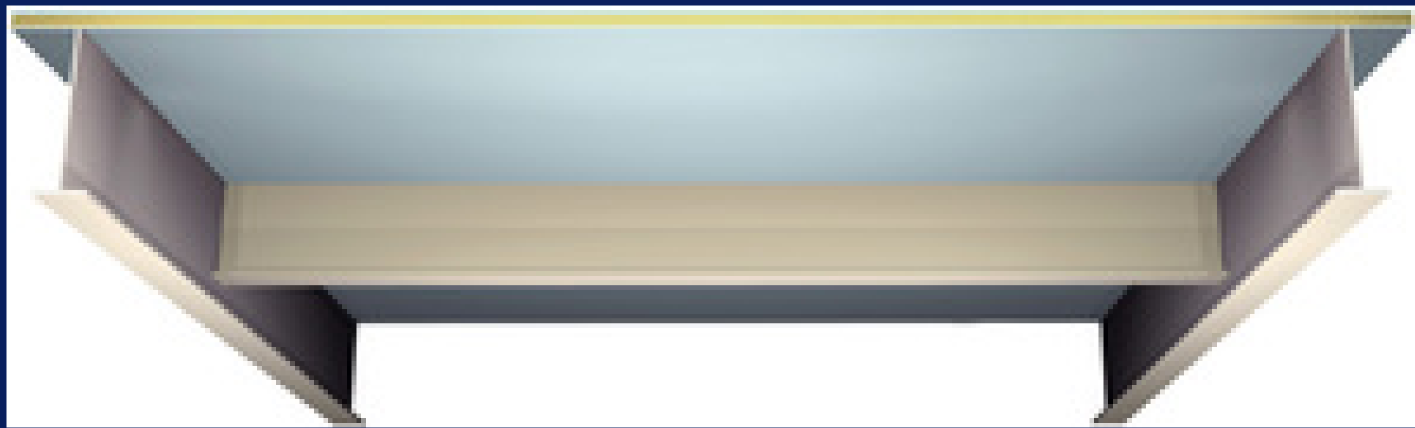
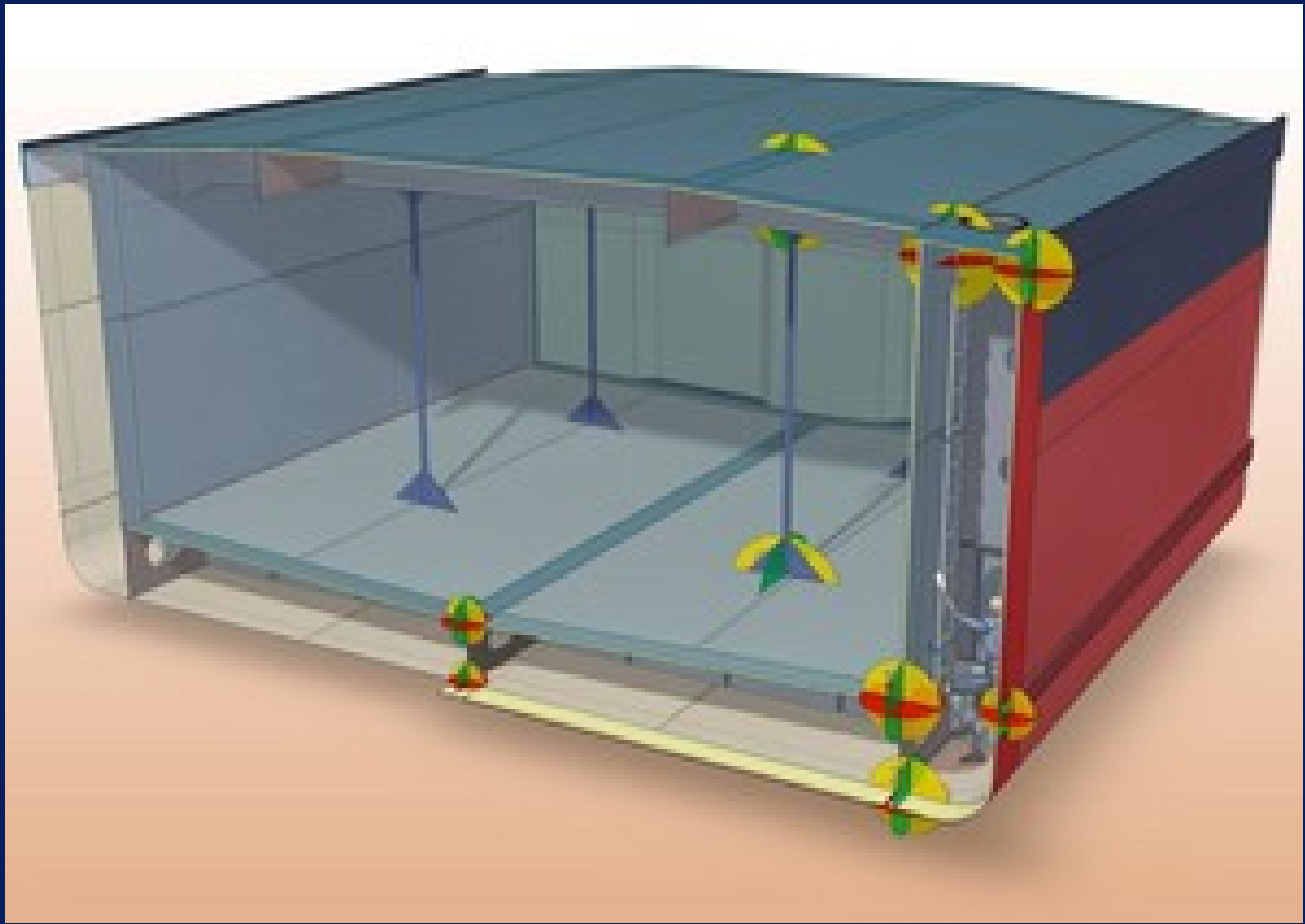


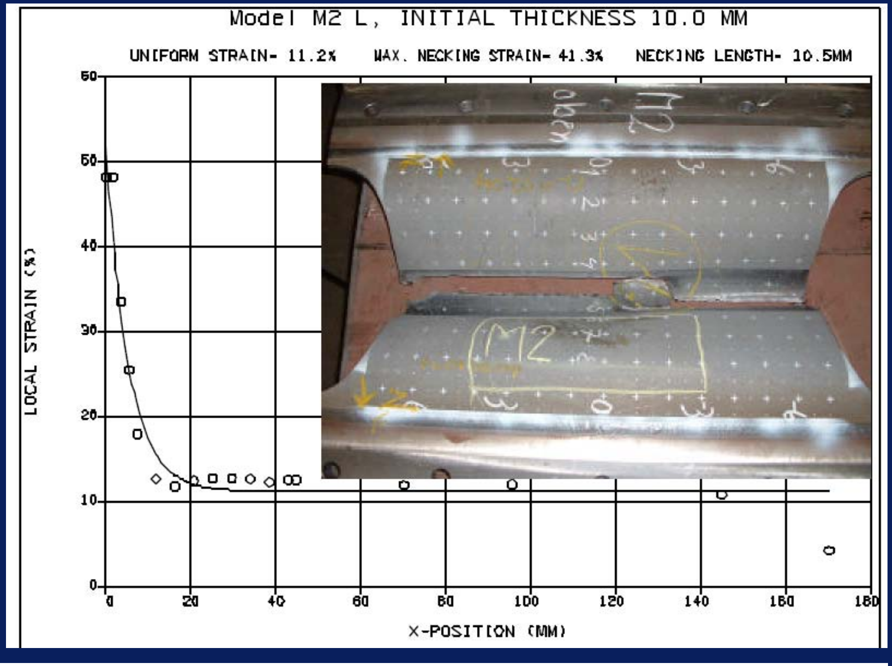
SPS structure

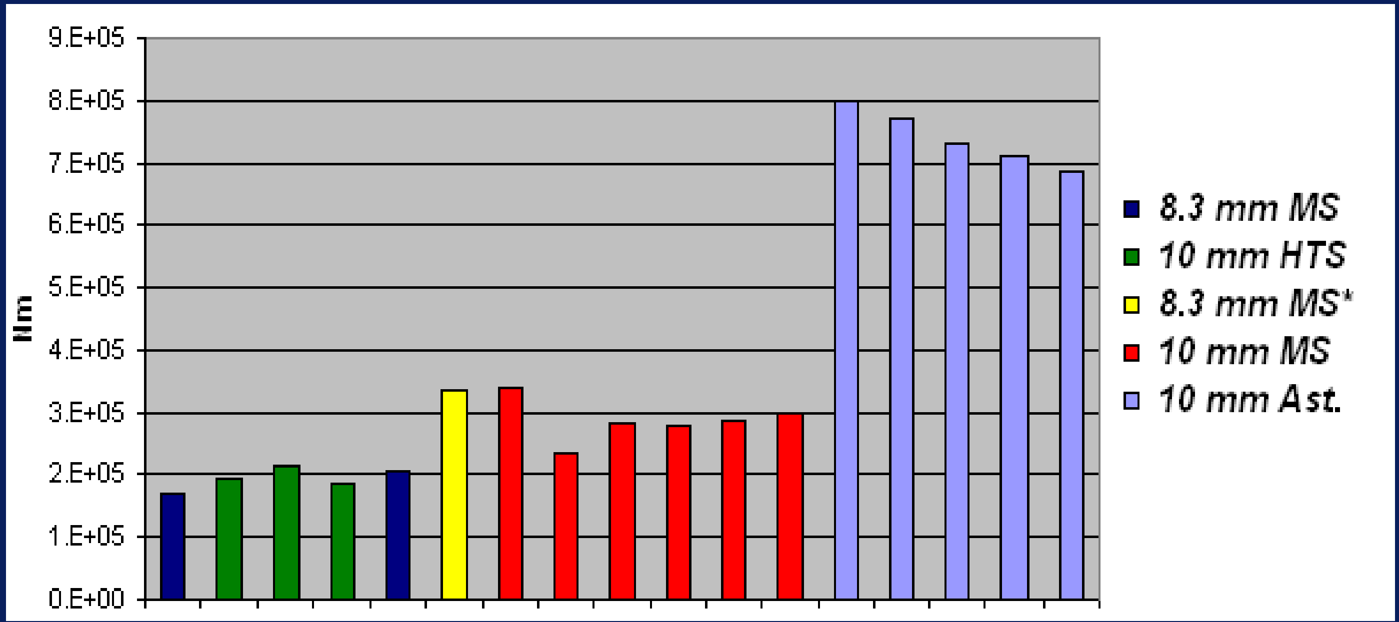


SPS structure



Other steel qualities





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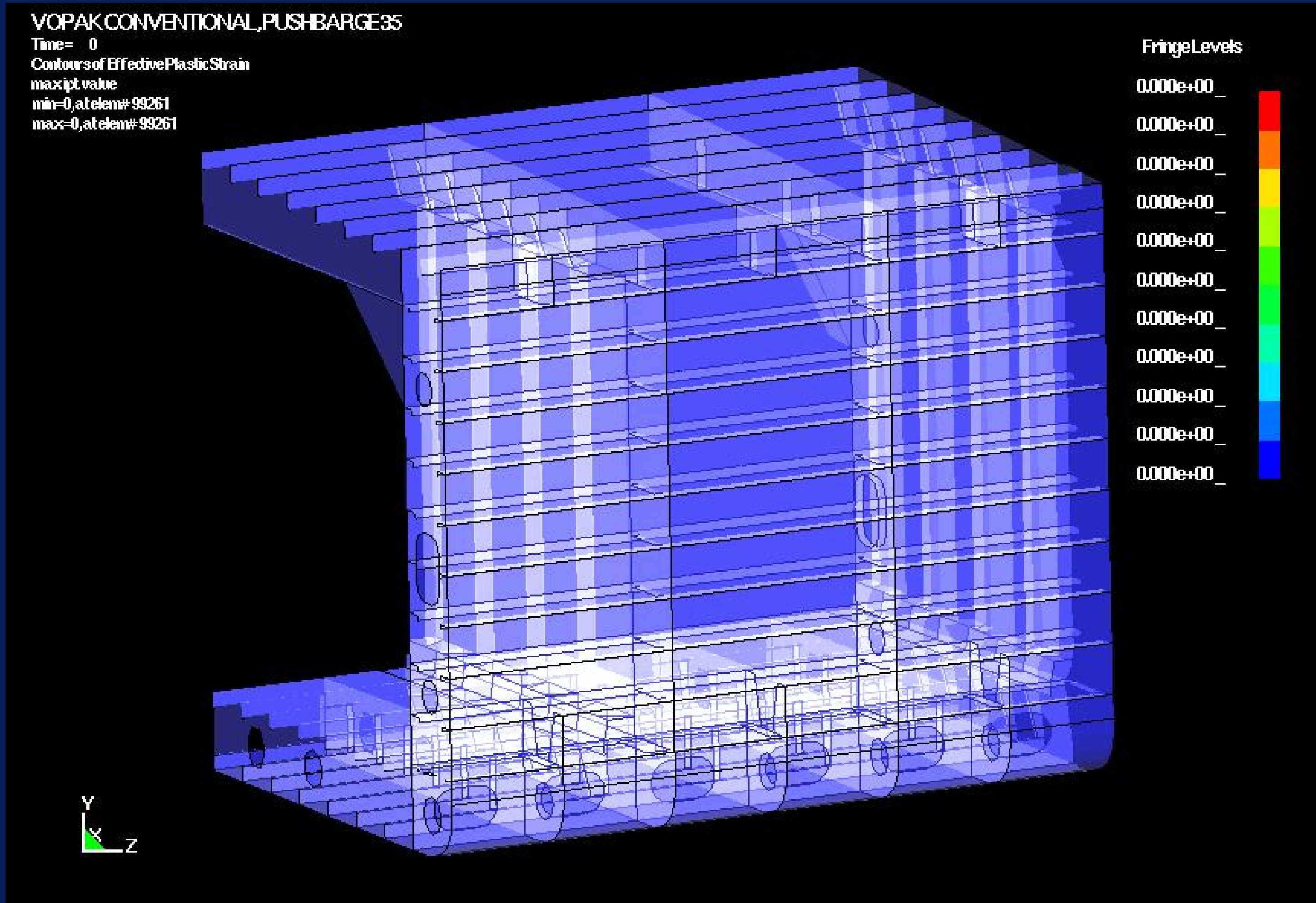

Overview crashworthy concepts

Crashworthy Concept	Technical evidence	Operational
"Ice" strengthening	desk top and full scale test	no
inclined I - core	desk top and full scale test	no
X - core	desk top and full scale test	no
Y - Type, Royal Schelde	desk top and full scale test	yes
SPS	desk top and lab tests	no
austenitic steel	desk top and lab tests	no

Conclusion

1. Risk/Reliability is a viable concept in ship design
2. Risk/Reliability is the ***only*** concept outside the conventional design space
3. Crashworthiness can be treated as a design parameter through applying risk based design
4. Crashworthiness can save money
5. Authorities are willing to consider
6. Further education is crucial

Acknowledgements

Class

PTB

BAM

CCNR

MD/G