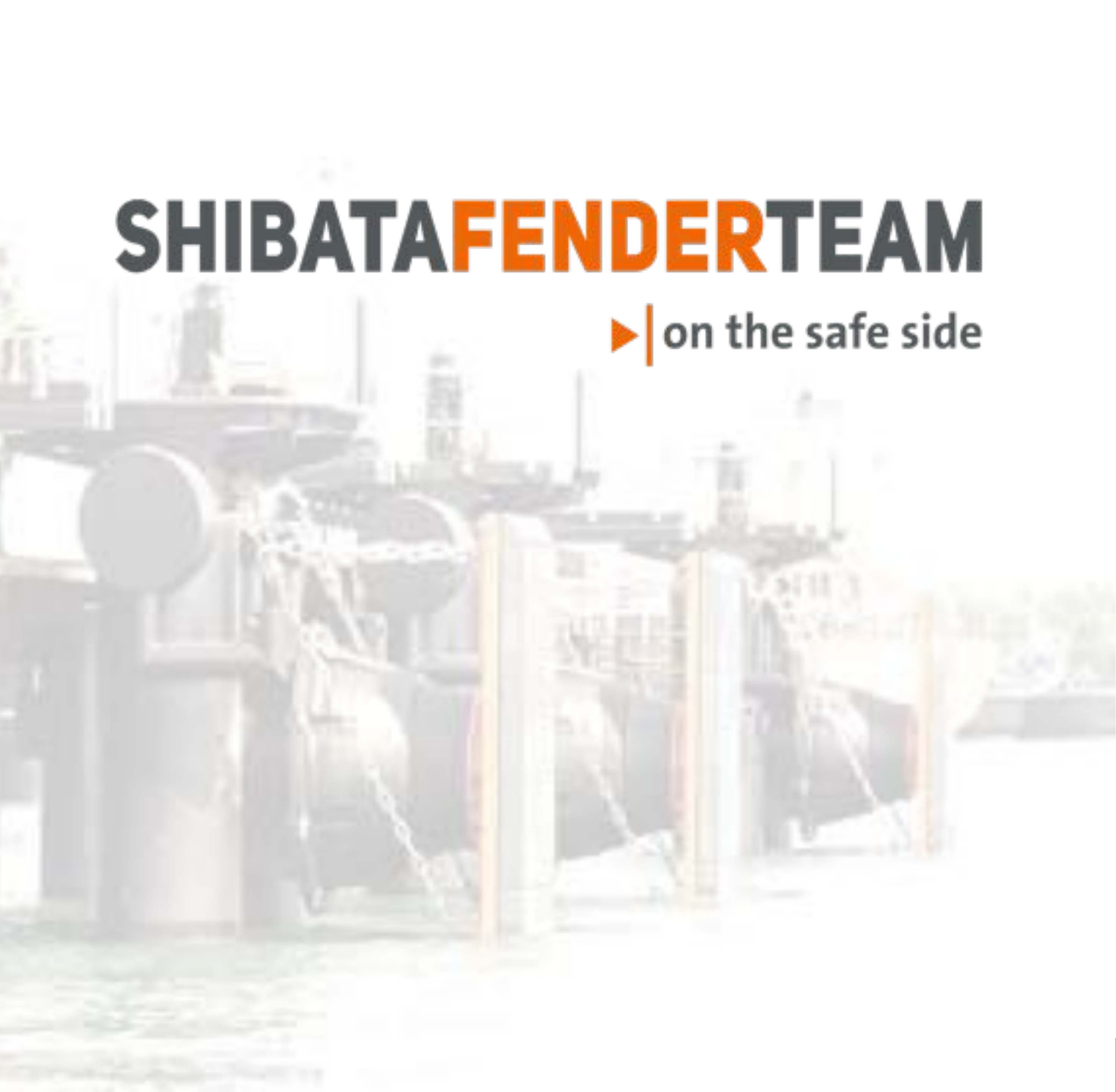


SHIBATAFENDERTEAM GROUP

EUROPE | AMERICAS | ASIA

FENDER SYSTEM DESIGN – HOLISTIC APPROACH

Port and Terminal 2019 – Savannah, GA – USA

Technical Presentation
by Dominique Polte

TABLE OF CONTENTS.

SHIBATAFENDERTEAM
on the safe side

SHIBATAFENDERTEAM GROUP.

HEADQUARTERS: Hamburg, Germany

TURNOVER: ~ 50 Million USD annually

DELIVERED PROJECTS: > 5,000 worldwide since 2006 | Group track record since 1961
GPA has about 1,000 fenders in service, out of 100,000 worldwide

SELECTED REFERENCES – USA (OF > 350)

- Point Thompson, AK
- Dutch Harbor, AK
- Kodiak, AL
- Juneau, AK
- Tacoma, WA
- Kitsap - Bremerton, WA
- Astoria, OR
- Newport, OR
- San Francisco, CA
- Oakland, CA
- Redwood City, CA
- LA/Long Beach, CA
- San Diego, CA – Pier 12
- San Diego, CA – 10th Ave.

- Milwaukee, WI
- Portland, ME
- Quonset, RI
- New York/New Jersey
- Phildephia, PA
- Norfolk, VA
- Houston TX
- Galveston, TX
- Corpus Christi, TX
- Savannah, GA
- Mobile, AL
- Canaveral, FL
- Tampa, FL
- Miami, FL

TABLE OF CONTENTS.

BERTHING ENERGY CALCULATION.

BERTHING ENERGY CALCULATION.

ENERGY DEFINED

Energy is the capacity of a physical system to do work

Specifically we are dealing with:

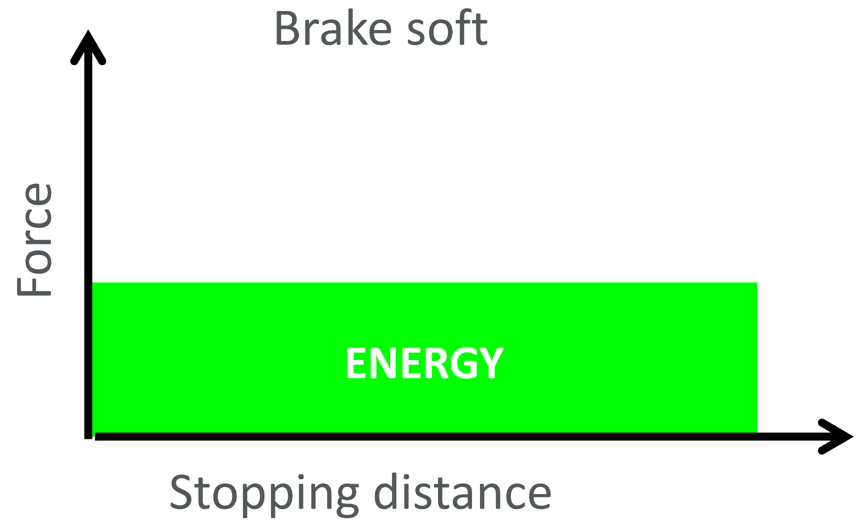
- Kinetic energy – vessel ½ * mass * velocity^2
- Potential energy – fender force * distance

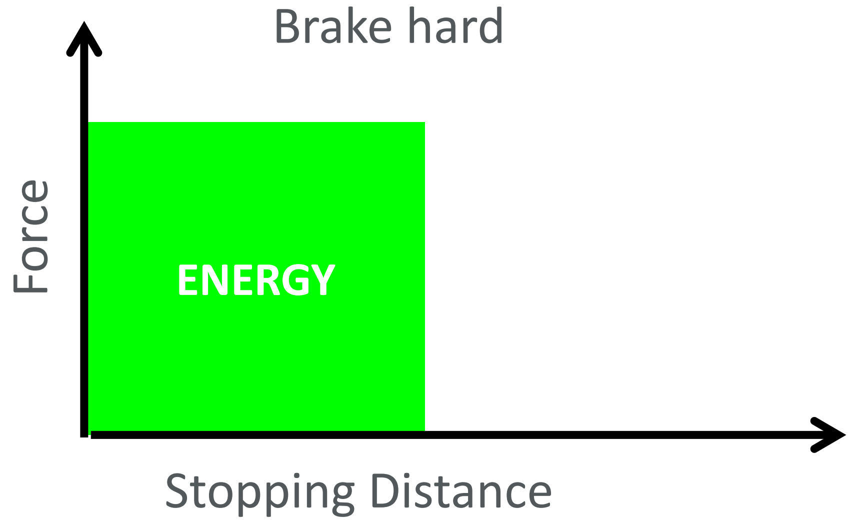
Capacity of fender system to absorb energy needs to be more than the kinetic energy of vessel

BERTHING ENERGY CALCULATION.

ENERGY

Vehicle in motion: $\text{Energy} = \frac{1}{2} * m * v^2$





Energy is the same for each case!

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BERTHING ENERGY CALCULATION.

COLLECTION OF DATA

- Design Vessels (type, size, dimension)
- Location (Exposed / Sheltered)
- Berth Structure (Quay Wall / Piled)
- Environmental Conditions (Tidal Range, Winds, Currents)
- Support Structure (Dimensions / Load Capacity)
- Design Life

The more information available, the more suitable the fender design will be.

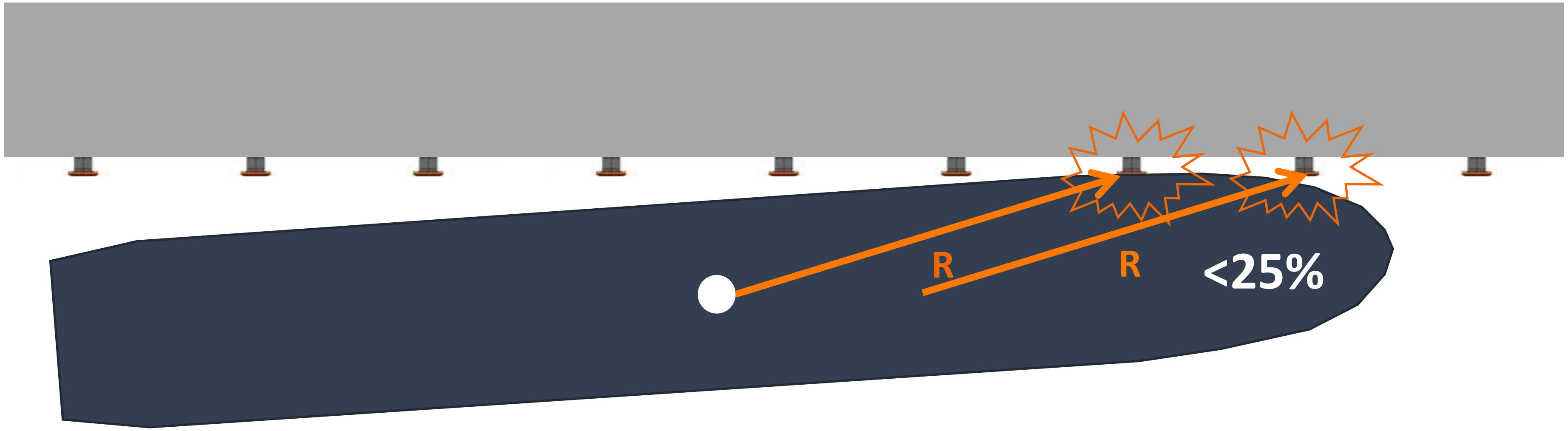
BERTHING ENERGY CALCULATION.

$$E = 0.5 * M_D * \boxed{v_B^{\,2}} * C_E * C_M * C_C * C_S$$

Berthing energy sensitive to berthing velocity

BERTHING MODE.

BERTHING MODE - CONTINUOUS JETTY.



- Contact point assumed to be within 1/4 length from end
- Typically container, cargo, multi-use berths
- Low impact on energy if vessel berths out of position (impact distance R unchanged)

BERTHING MODE - DOLPHINS.

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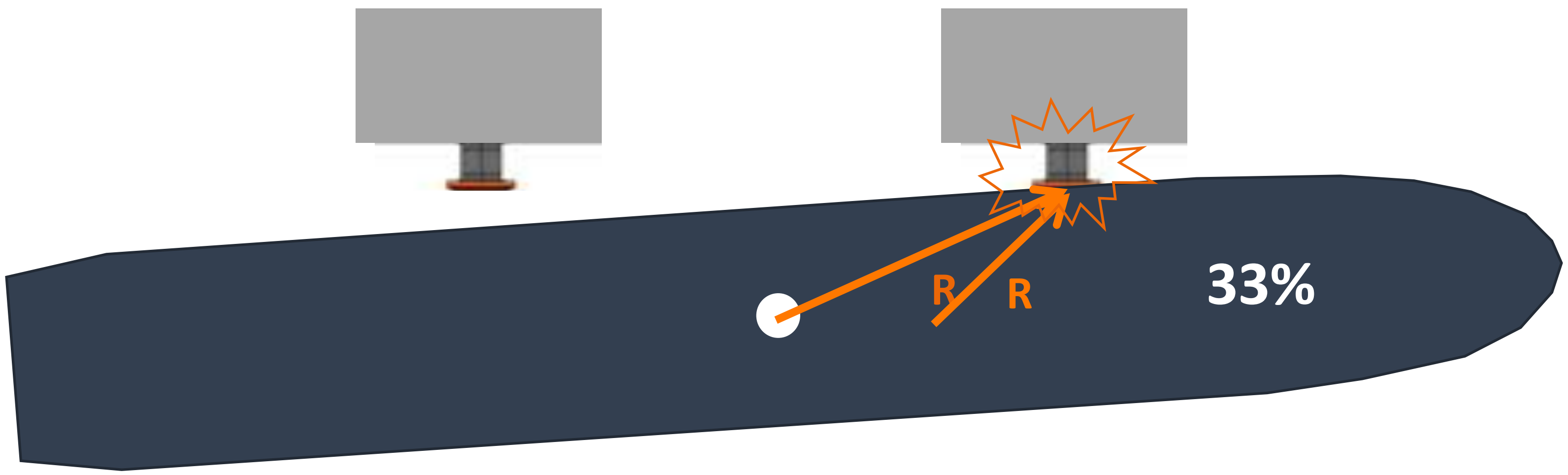

- Contact point assumed to be within 1/3 length from end (distance should be confirmed)
- Typically oil, gas and bulk liquids berths
- High impact on energy if vessel berths out of position (R reduced, C_E higher, Energy higher)
- PIANC recommends +/- 5% of L_{OA}

SAFETY FACTOR.

SAFETY FACTOR.

A Factor of Safety should be applied to the calculated berthing energy such that the fender system will be capable of absorbing ***reasonable abnormal impacts***, which may be caused by mishandling, malfunction, adverse wind and current or a combination of all. Consideration should be given to:

- Consequence of failure (high cost / lost revenue)
- Frequency of use of berth / design life
- Load sensitive structures
- Range of vessels using the berth
- Hazardous cargoes (environmental damage)

SAFETY FACTOR GUIDELINES.

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SAFETY FACTOR (ABNORMAL IMPACT)

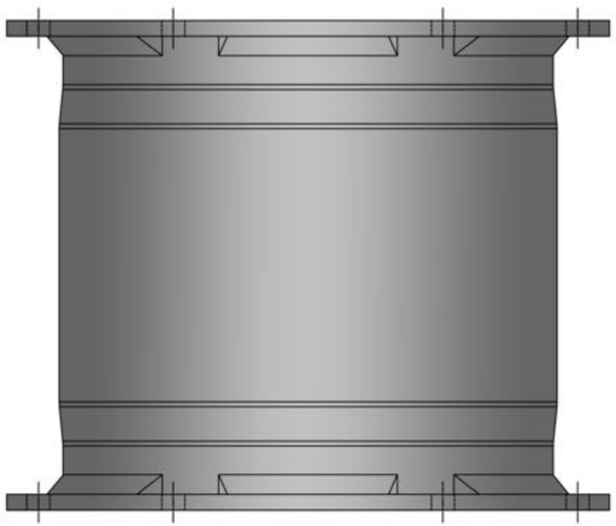
PIANC 2002		
Vessel class	Largest	Smallest
Tankers & Bulk carriers	1.25	1.75
Gas carriers	1.50 – 2.00	
Container ships	1.50	2.00
General cargo	1.75	
RO-RO, Ferries	≥ 2.00	
Tugs, Workboats	2.00	

BS6349 – PART 4 (2014)	
Vessel class	FOS
Continuous Structures	1.50
Ferries	2.00
LPG / LNG	2.00
Island Berths (Dolphins)	2.00

FENDER ENERGY.

FENDER ENERGY.

CSS Cell Fender
Uncompressed



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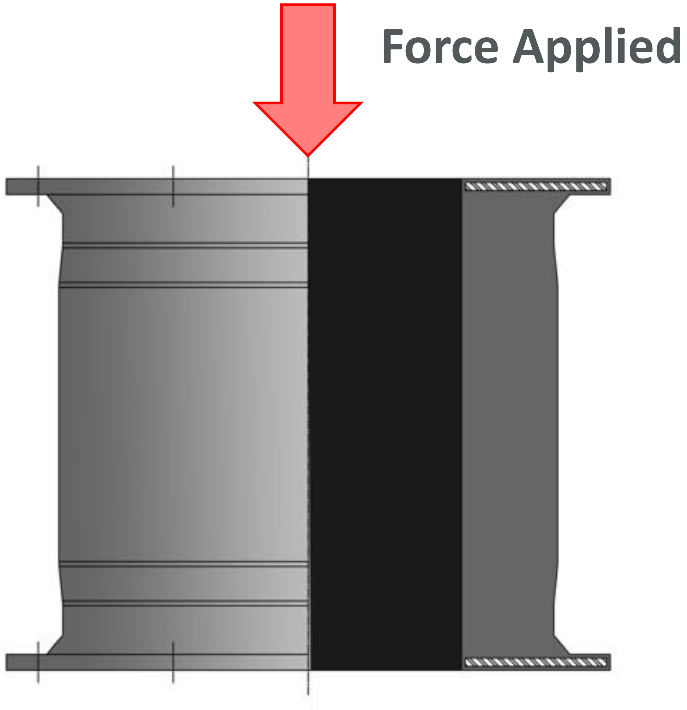
FENDER ENERGY.



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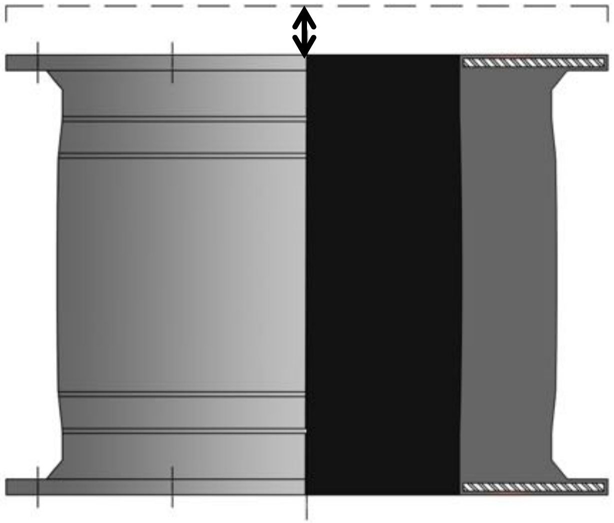
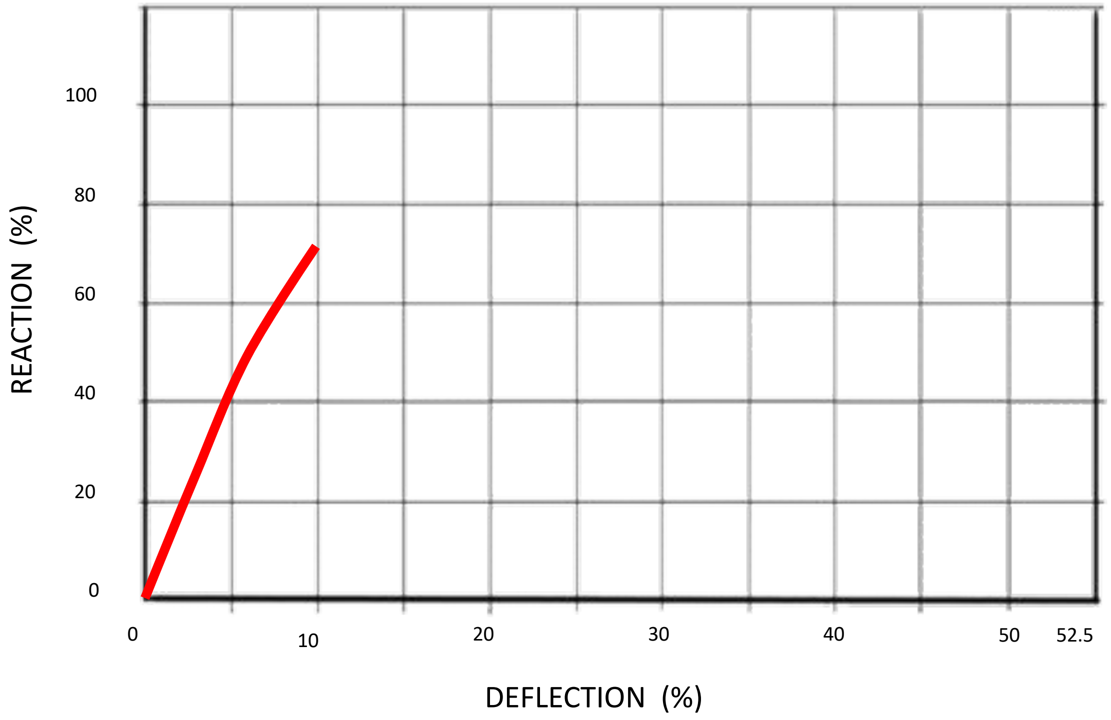
FENDER ENERGY.

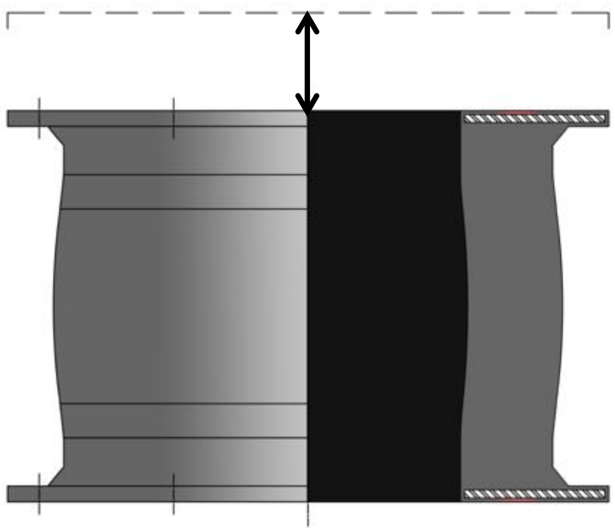
10% Deflection

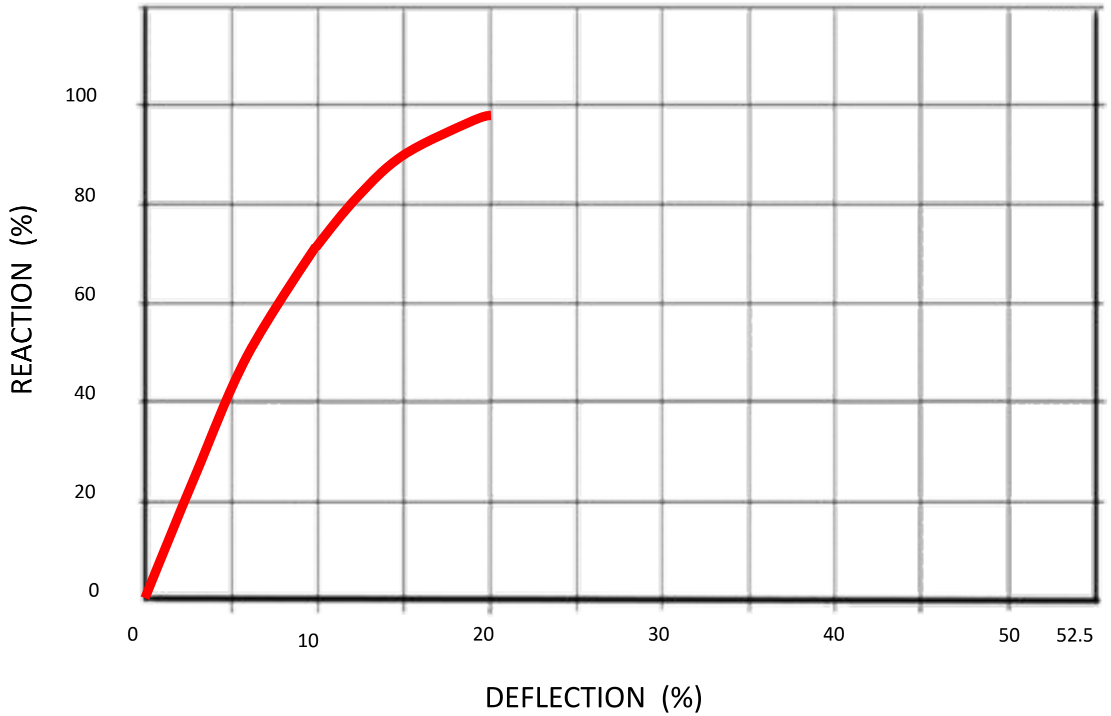




FENDER ENERGY.

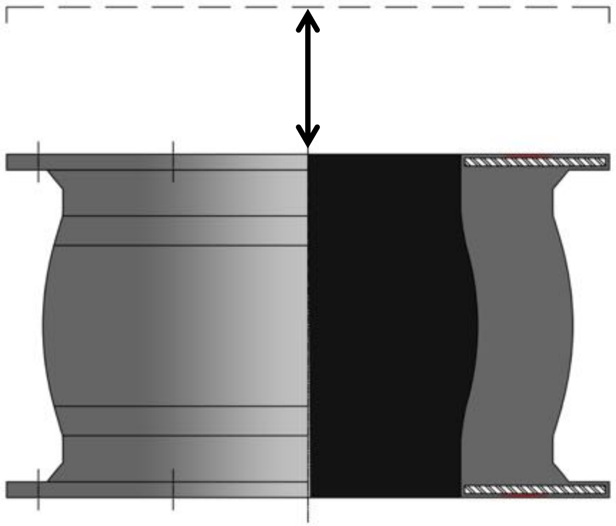
20% Deflection

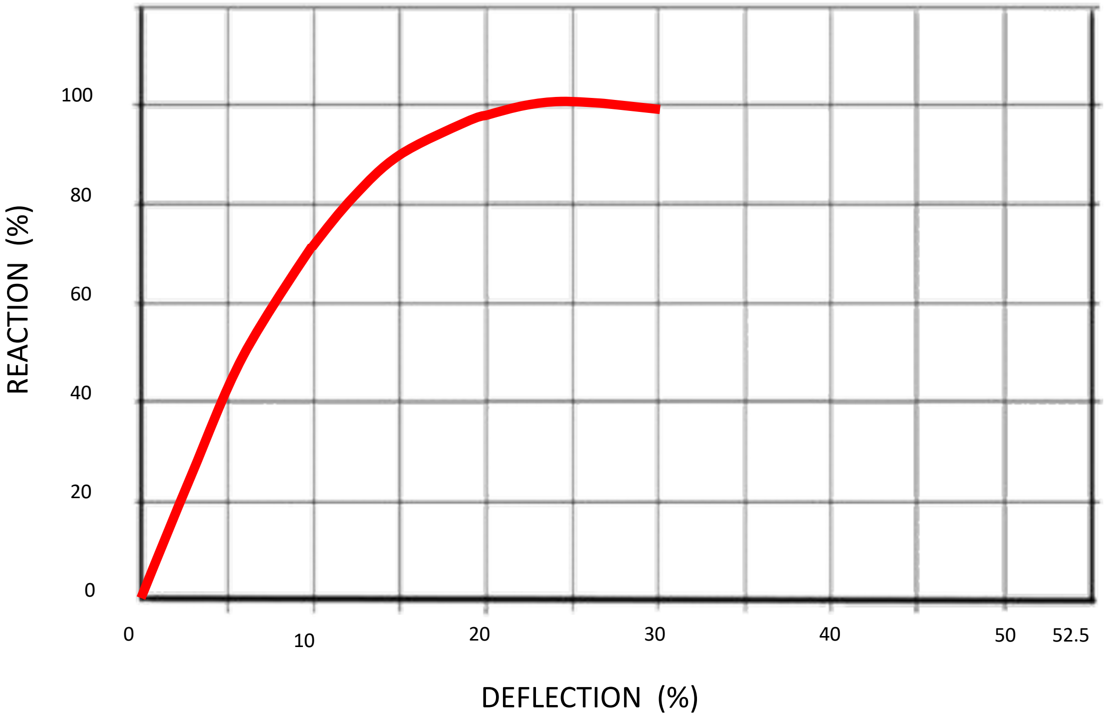




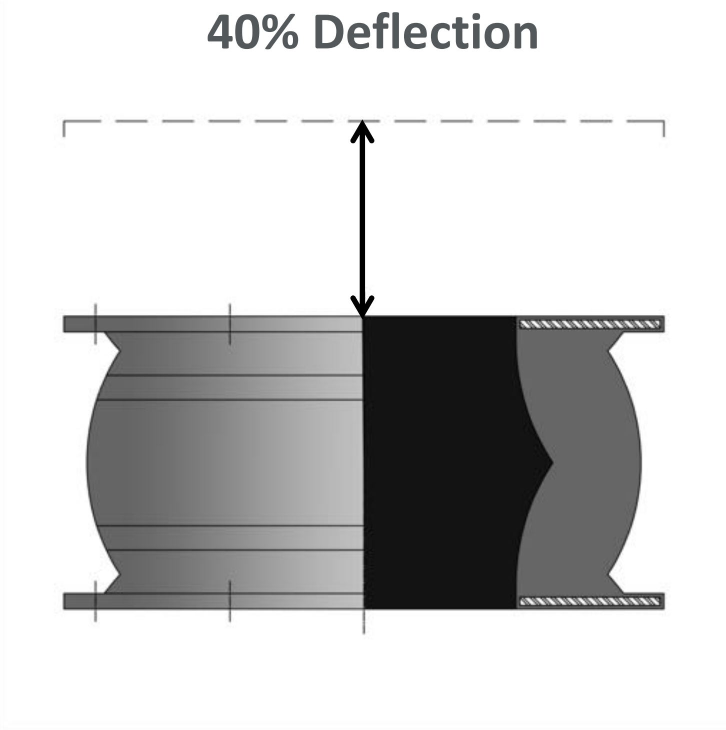
FENDER ENERGY.

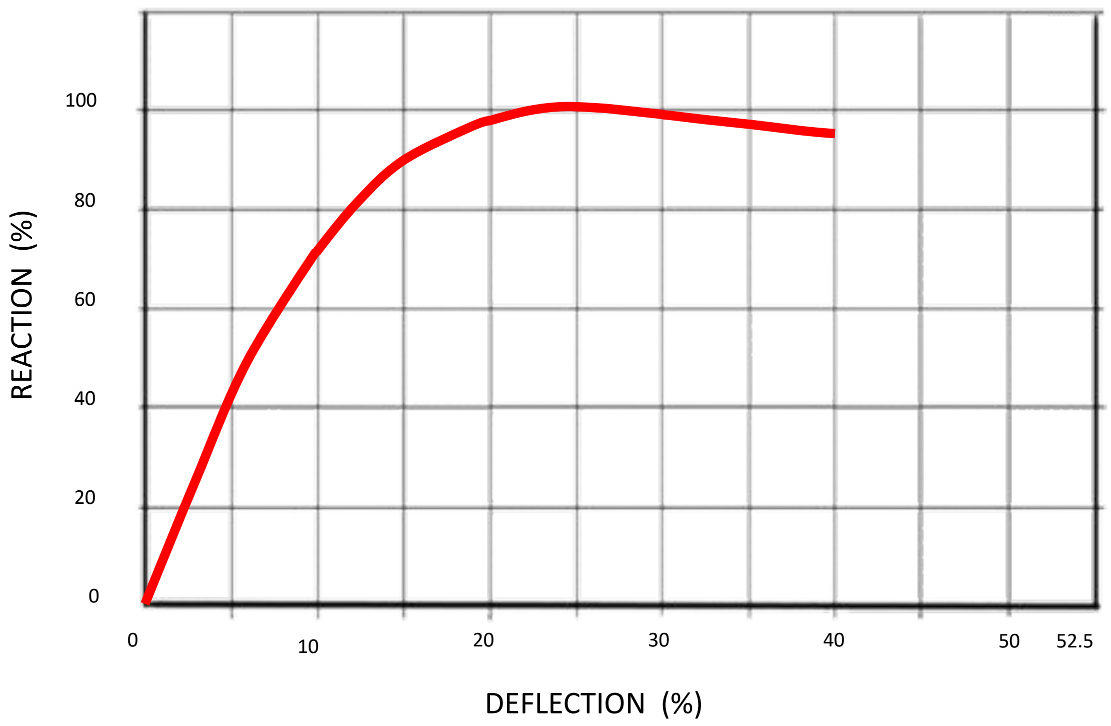
30% Deflection



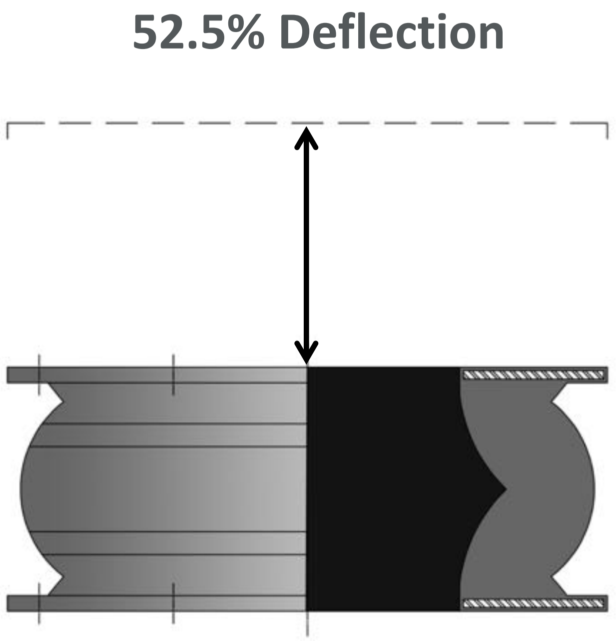


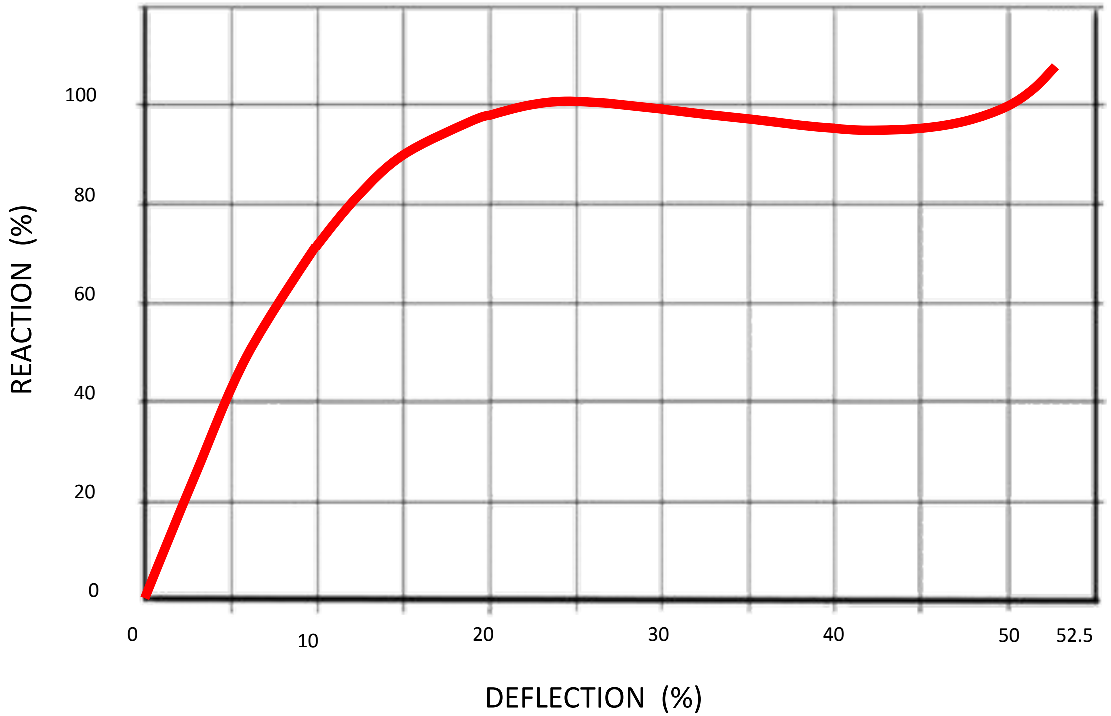
FENDER ENERGY.



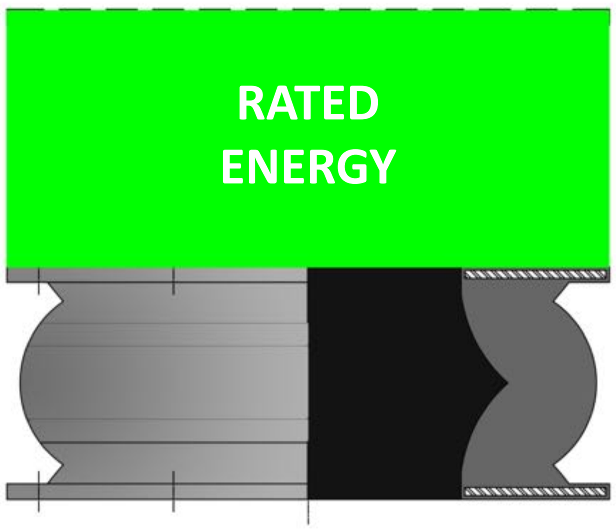


FENDER ENERGY.

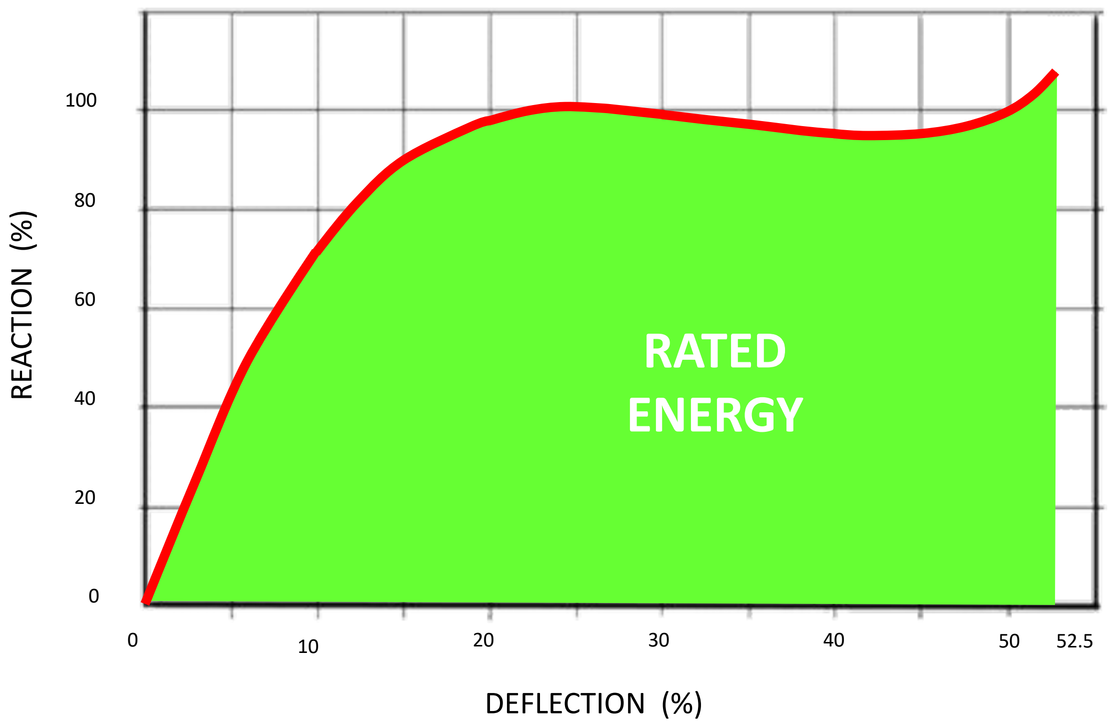




FENDER ENERGY.

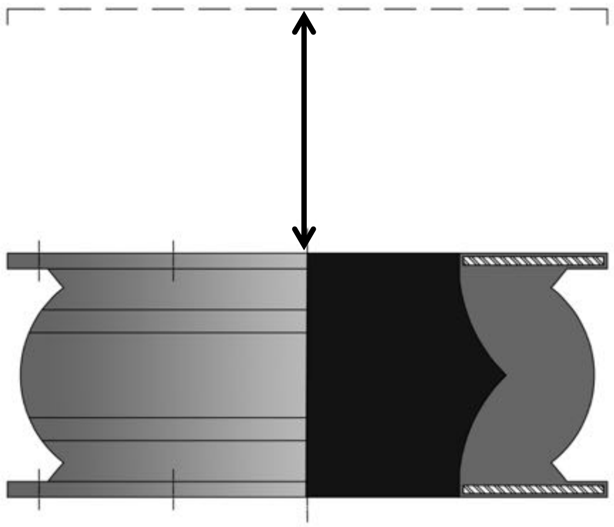


Energy = Area under Load Deflection Curve

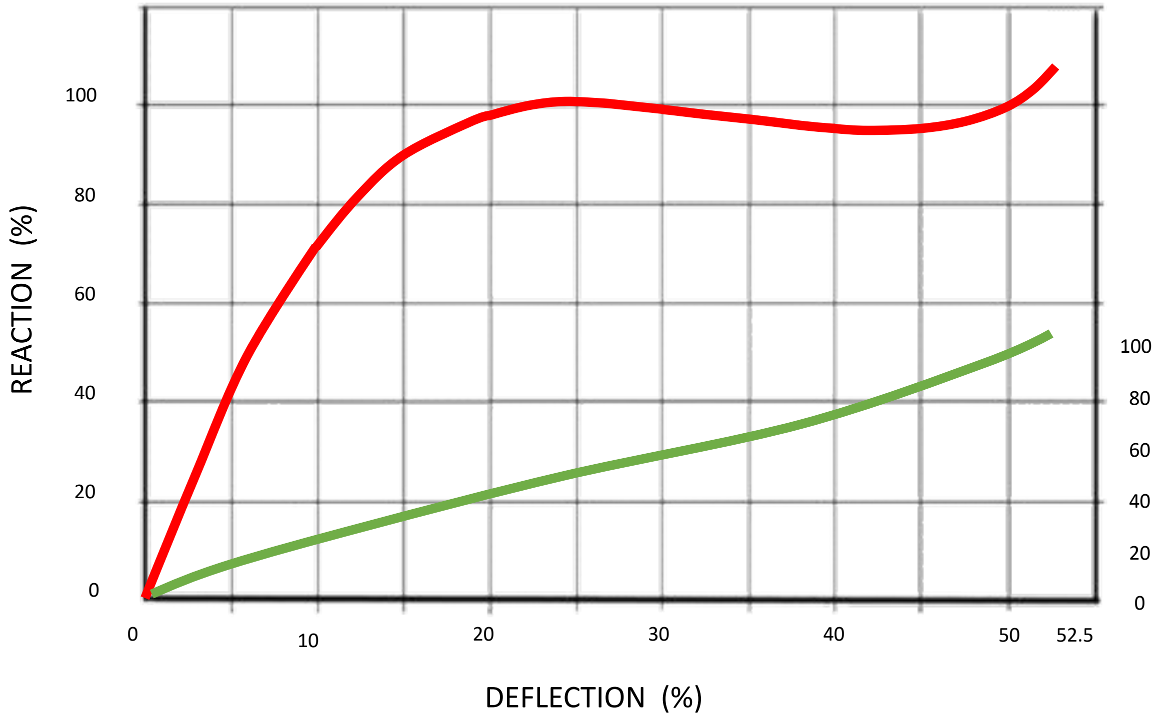


FENDER ENERGY.

52.5% Deflection

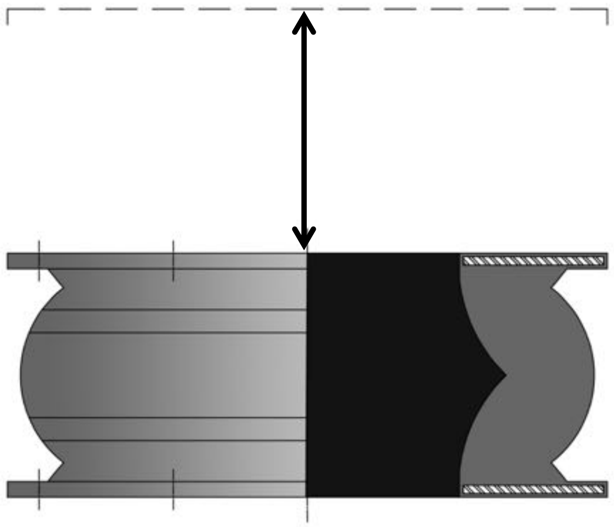


Expressed as a curve on 2nd y-axis

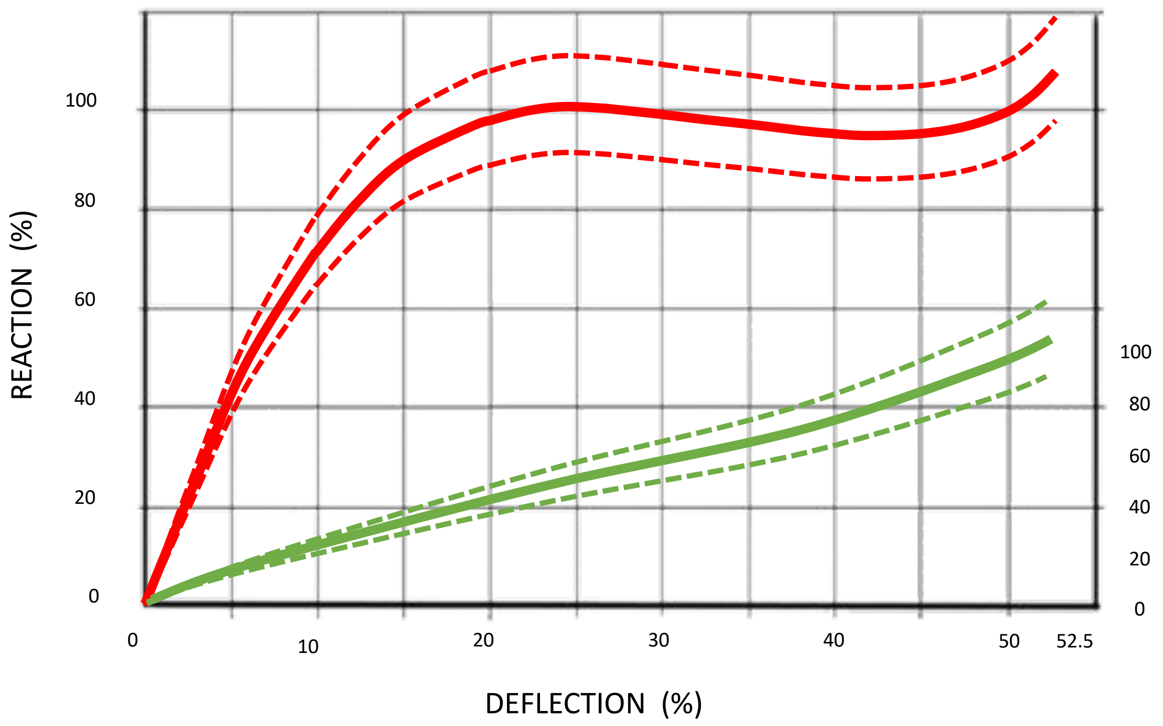


FENDER ENERGY.

52.5% Deflection

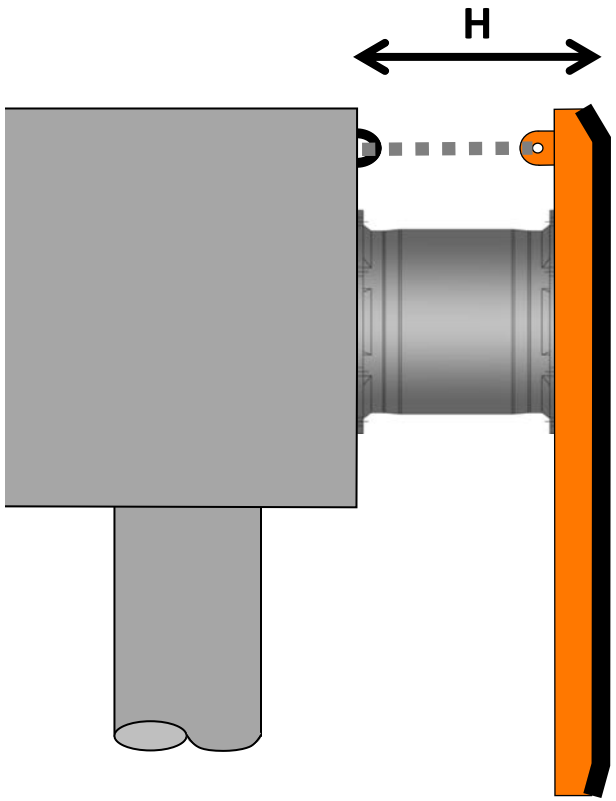


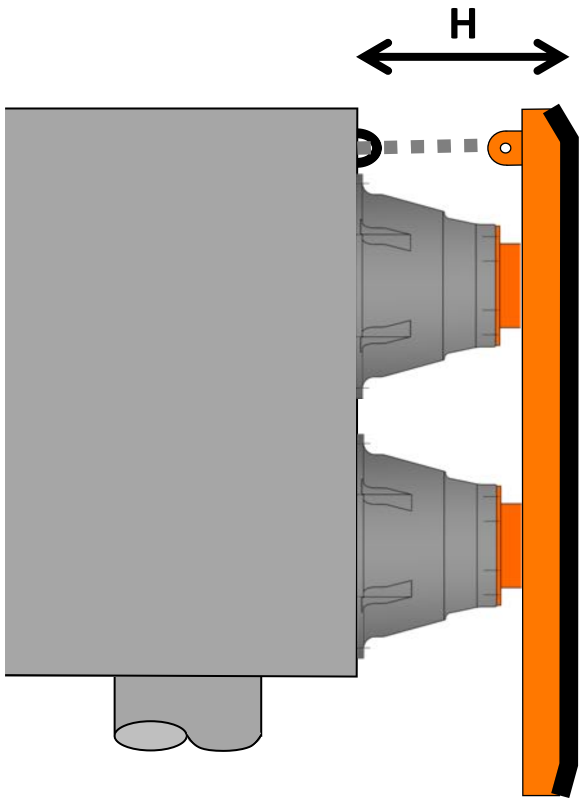
Performance subject to +/-10% tolerance



WORKED EXAMPLE – ALTERNATIVE.

WORKED EXAMPLE – ALTERNATIVE.





WORKED EXAMPLE - ALTERNATIVE COMPARISON.

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DESIGN BERTHING ENERGY EA = 457.2 kN.m

1 x CSS 1250 (G2.5)

Energy Capacity

E_{RPD} = 575 kNm [424 kip-ft]

Reaction Force

R_{RPD} = 1,045 kN [235 kip]

R_{MAX} = 1188.6 kN [267.2 kip]

2 x SPC 800 (G2.4)

Energy Capacity

E_{RPD} = 280 kNm [206 kip-ft] **x2 = 560 kNm [412 kip-ft]**

Reaction Force

R_{RPD} = 667 kN [150 kip]

R_{MAX} = 758.6 kN [170.5 kip] x2 = 1,517.2 kN [341 kip]

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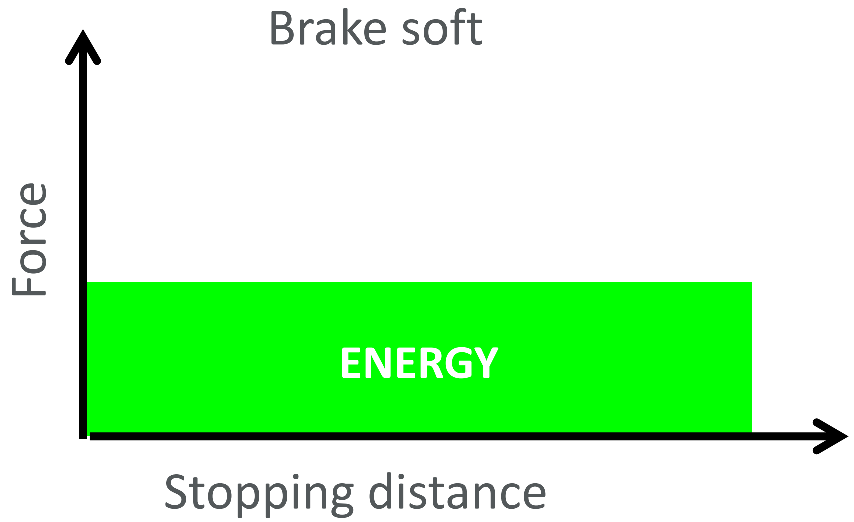
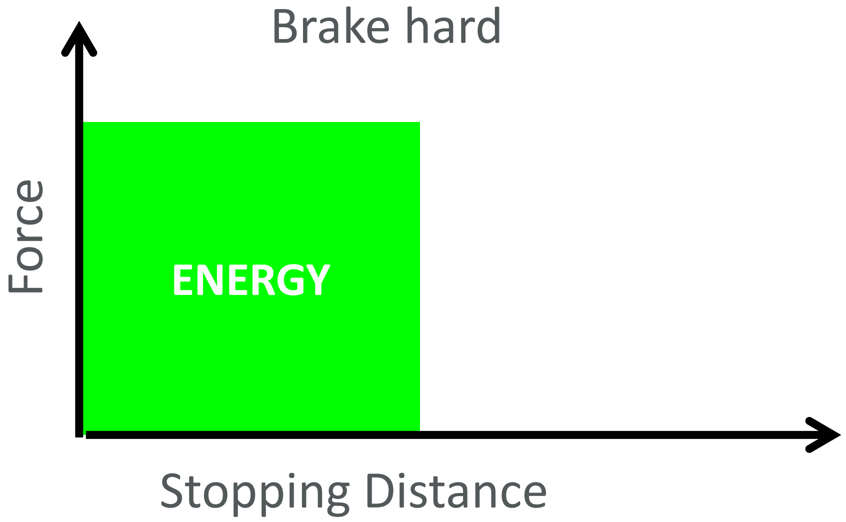
BERTHING ENERGY CALCULATION.

ENERGY



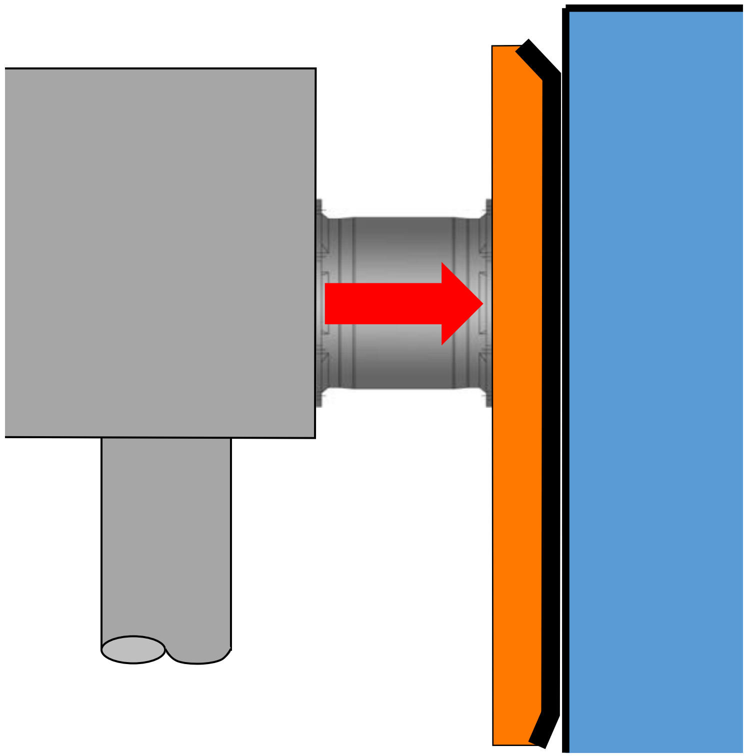


Energy is the same for each case!

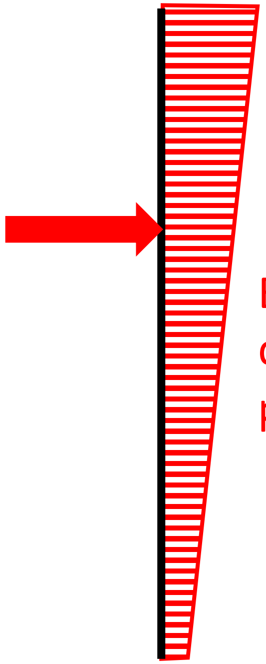
STRUCTURAL DESIGN OF PANELS.

STRUCTURAL DESIGN OF PANELS - LOAD CASES.

LOAD CASE 1 – HULL PRESSURE

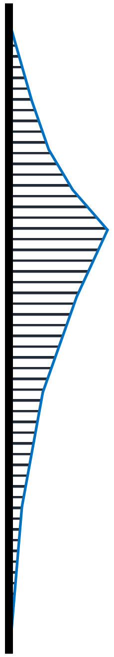


Force Diagram



Evenly distributed pressure

Moment Diagram



Low bending moments

STRUCTURAL DESIGN OF PANELS - LOAD CASES.

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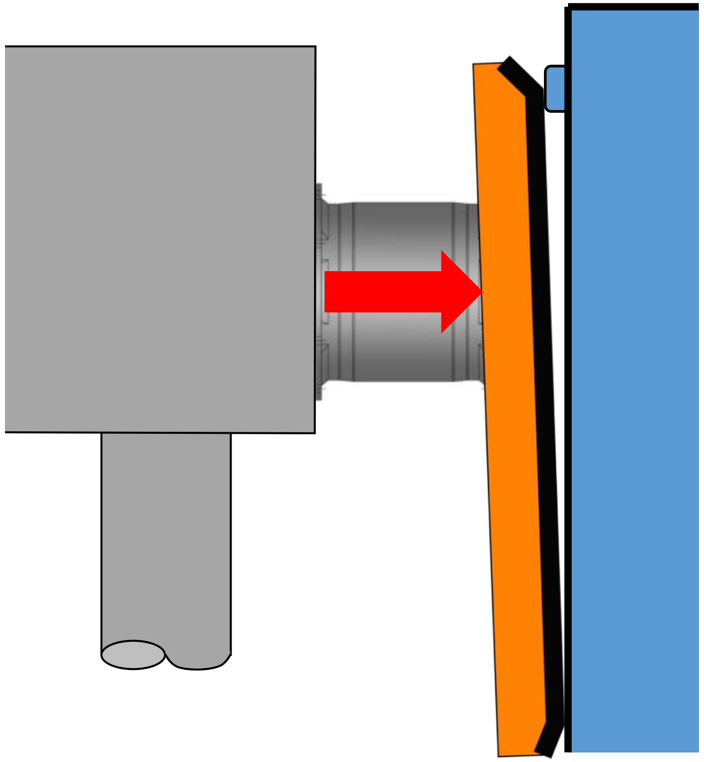
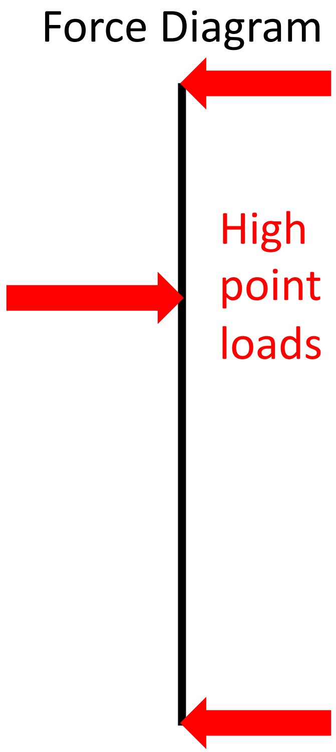
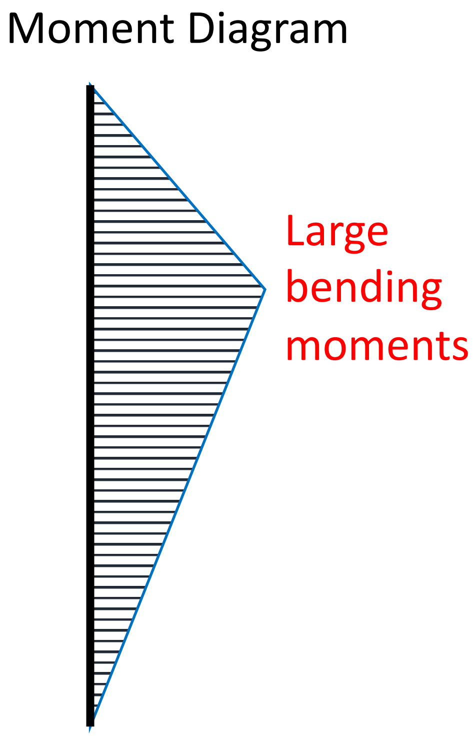
LOAD CASE 2 – BELTING CONTACT

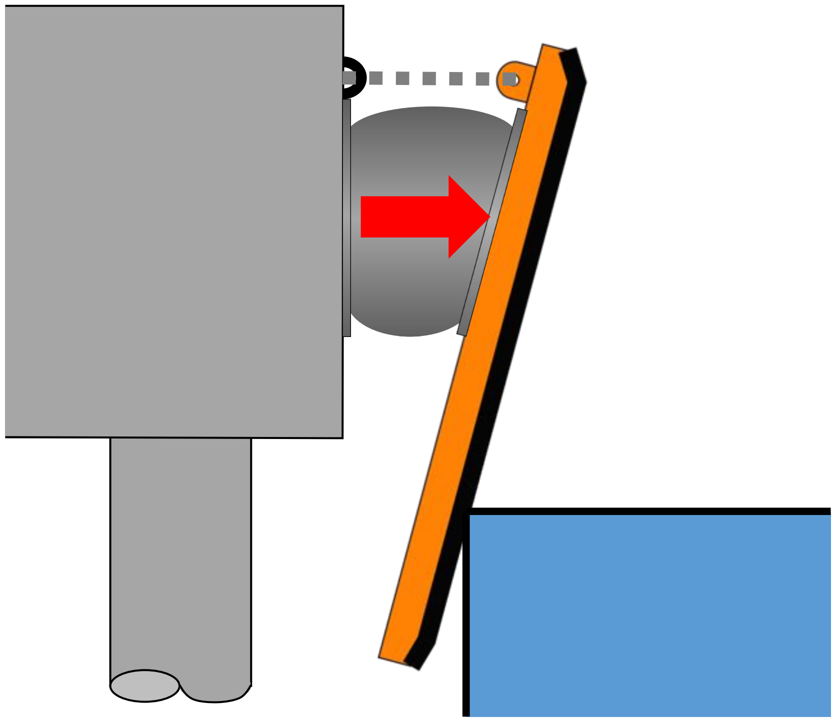




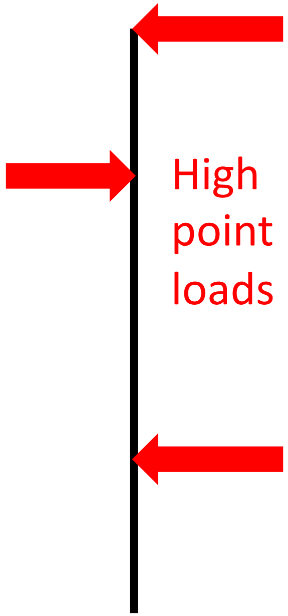


STRUCTURAL DESIGN OF PANELS - LOAD CASES.

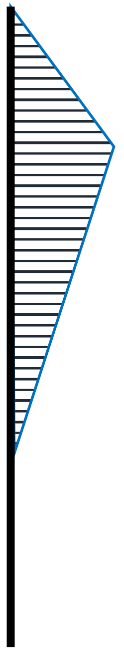
LOAD CASE 3 – LOW CONTACT



Force Diagram

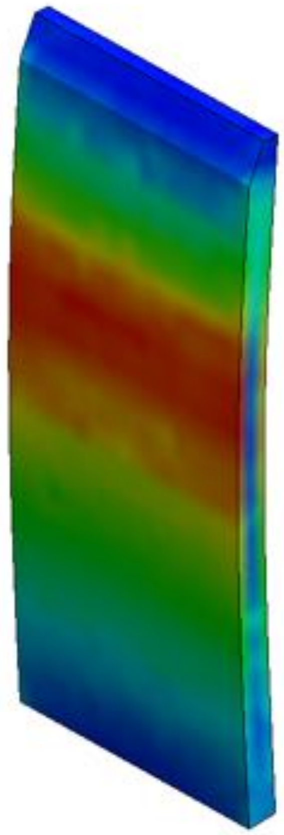


Moment Diagram

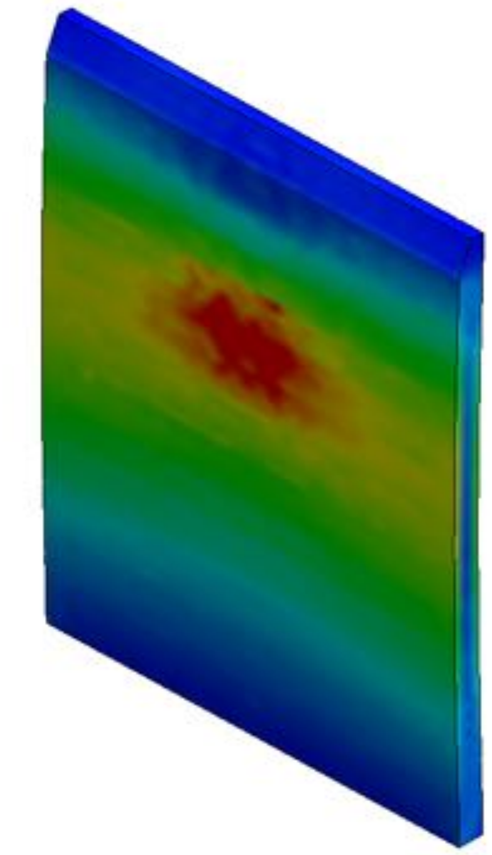


STEEL PANEL DESIGN – EXAMPLE FEA ANALYSIS.

Narrow panel



Wide panel



HULL PRESSURE.

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HULL PRESSURE.

LIMITATIONS

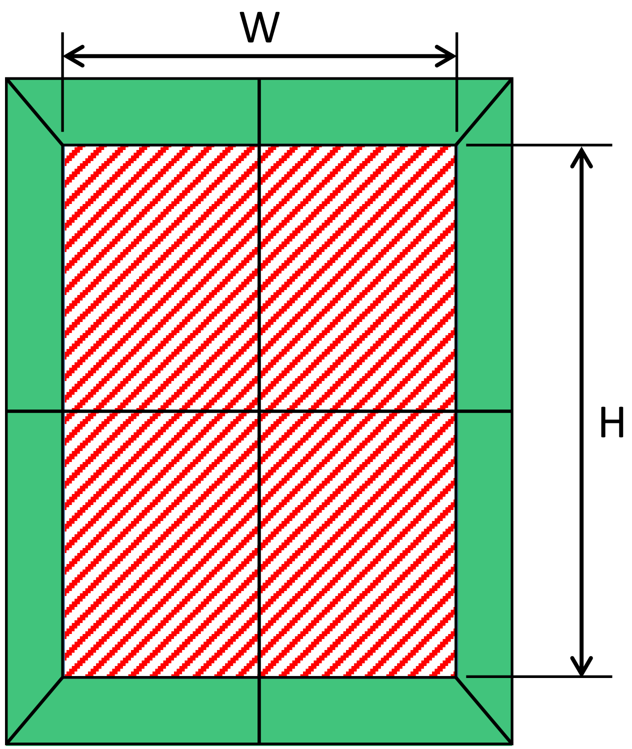
CLASS	SIZE	PRESSURE kN/m² (kPa)
Oil tankers	Handysize Handymax Panamax or bigger VLCC	≤ 300 ≤ 300 ≤ 350 150-200
Bulk carriers	All sizes	≤ 200
Container	Feeder Panamax Post-Panamax ULVC	≤ 400 ≤ 300 ≤ 250 ≤ 200
General Cargo	≤ 20,000DWT >20,000DWT	400–700 ≤ 400
RoRo & Ferries	Not applicable – usually belted	

Typical hull pressure limitations:

- Recommended limits based on vessel type and class
- Hull pressure limits based on panel contact area and reaction force
- To prevent damage to vessel hull

HULL PRESSURE.

AVERAGE HULL PRESSURE



Hull pressure based on panel contact area

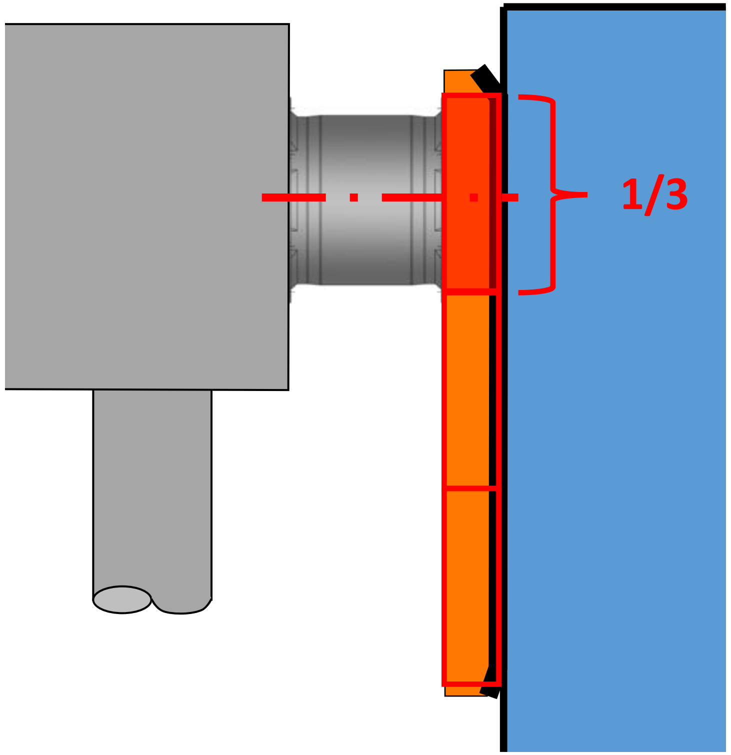
$$\overline{HP} = \frac{\sum R}{W * H}$$

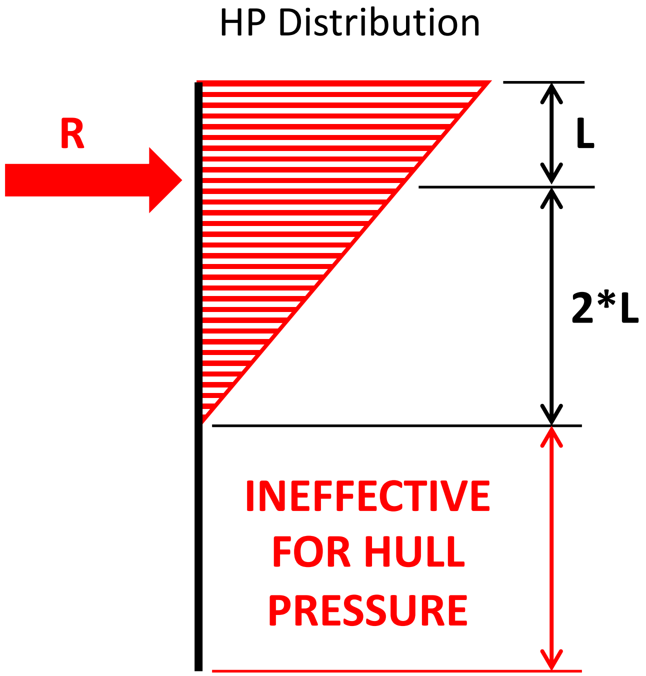
HP = Average hull pressure

SR = Sum of all fender Reaction Forces

HULL PRESSURE – DISTRIBUTION.

FENDER WITHIN TOP 1/3 OF PANEL

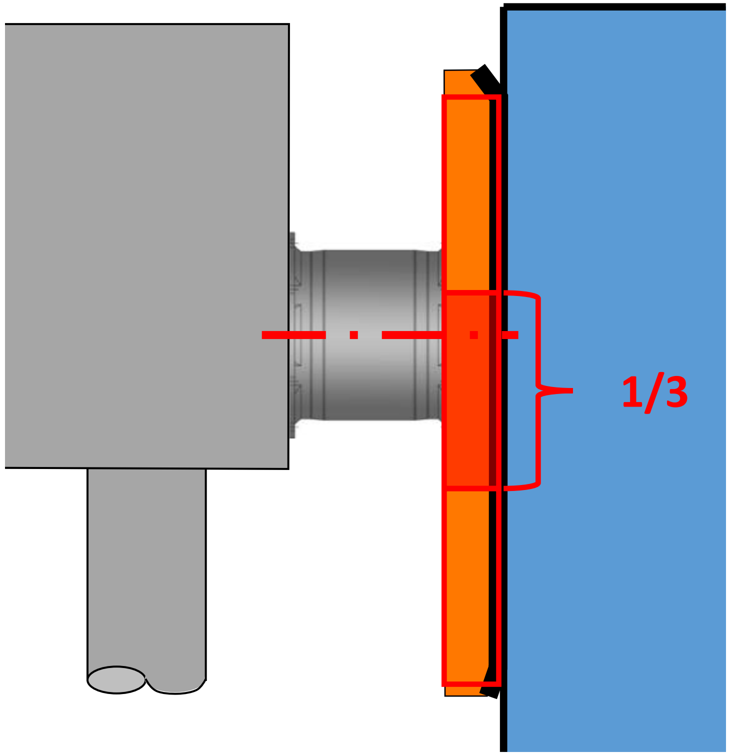


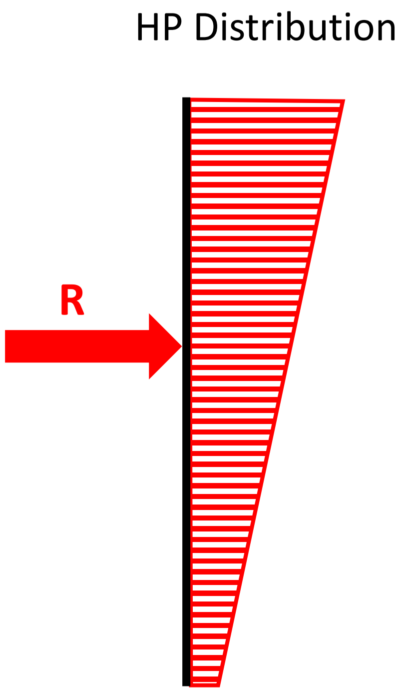


- High “Peak” Pressure

HULL PRESSURE – DISTRIBUTION.

FENDER WITHIN MIDDLE 1/3 OF PANEL

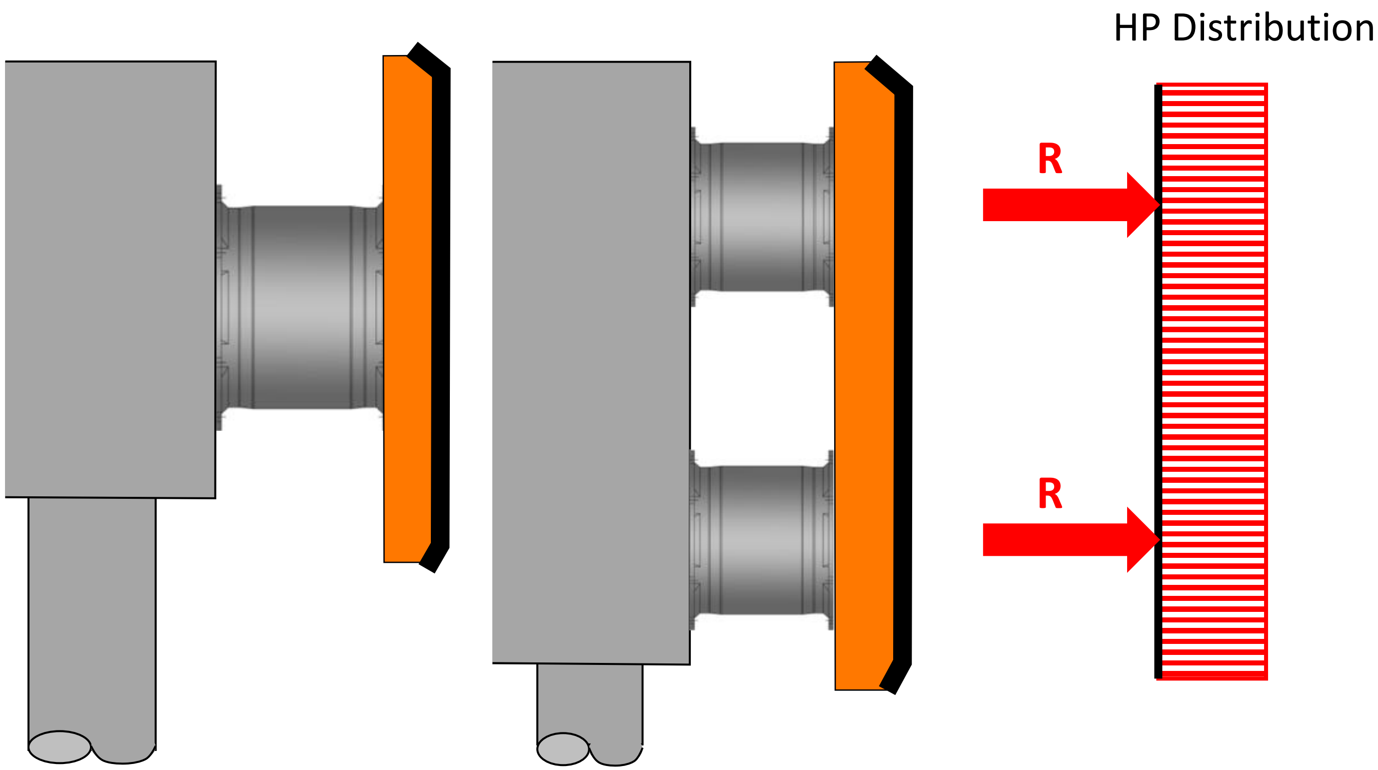




- Reduced “Peak” Pressure
- Improved layout for Hull Pressure Distribution

HULL PRESSURE – DISTRIBUTION.

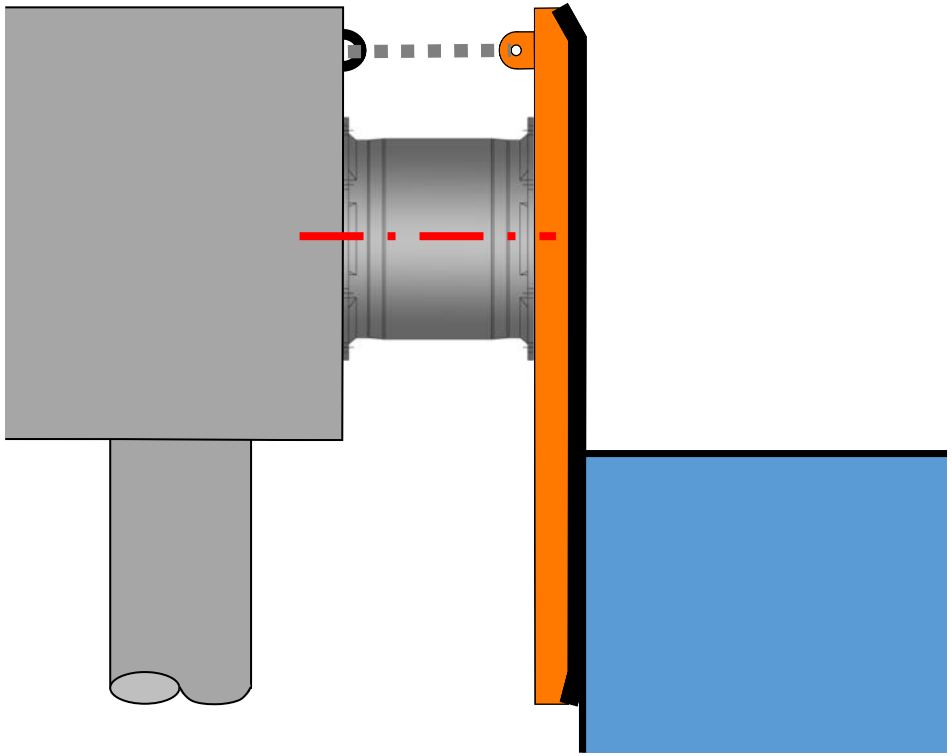
SYMMETRICAL SYSTEMS



- Even hull pressure distribution
- More common layout for LNG, oil & gas projects

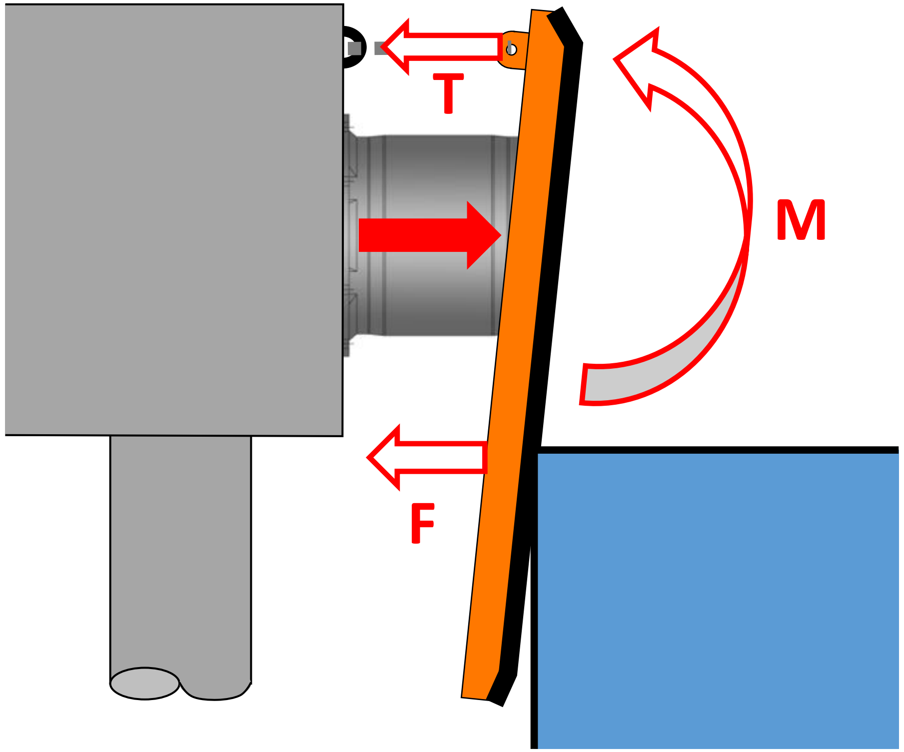
HULL PRESSURE – DISTRIBUTION.

LOW LEVEL CONTACT

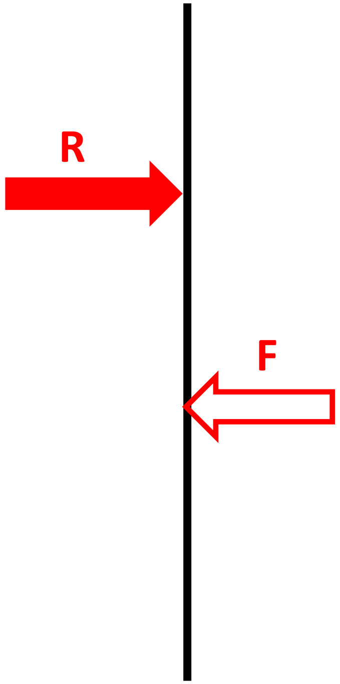


HULL PRESSURE – DISTRIBUTION.

LOW LEVEL CONTACT



HP Distribution



- Panel will rotate
- Force translated to vessel by tension chain force and panel bending moment
- Panel Line load only
- Expressed as Force / metre
- Vessel should be checked for line load generated

EFFECTS OF VESSEL BELTINGS.

EFFECTS OF VESSEL BELTINGS.

VESSEL PROTECTION

Beltings (or "steel fenders") are protection for the vessel

- Installed at or just above waterline
- Common on ferries, cruise ships, barges
- Also used on smaller feeder vessels (general cargo, container, bulk liquids)

EFFECTS OF VESSEL BELTINGS CHAMFERS.

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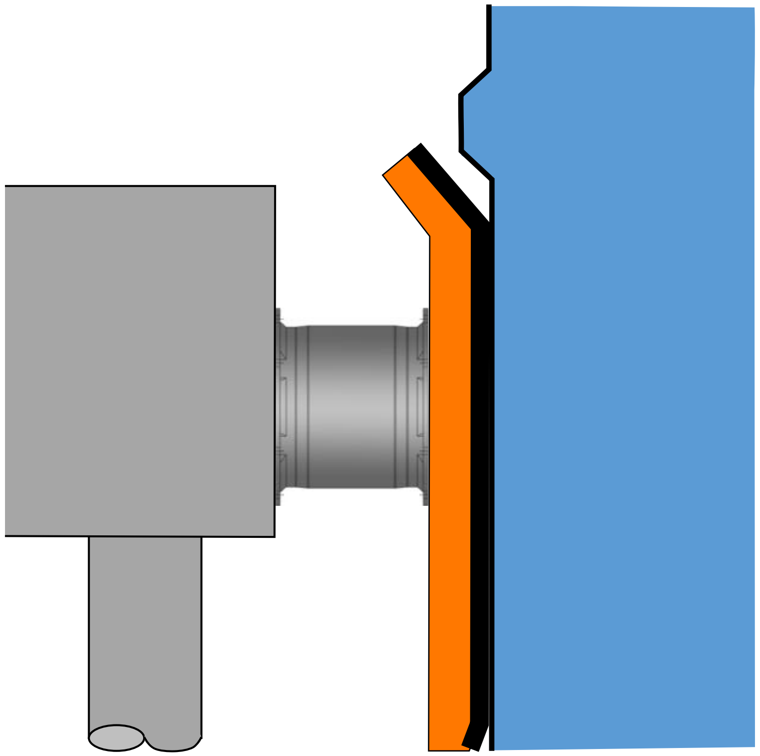
on the safe side

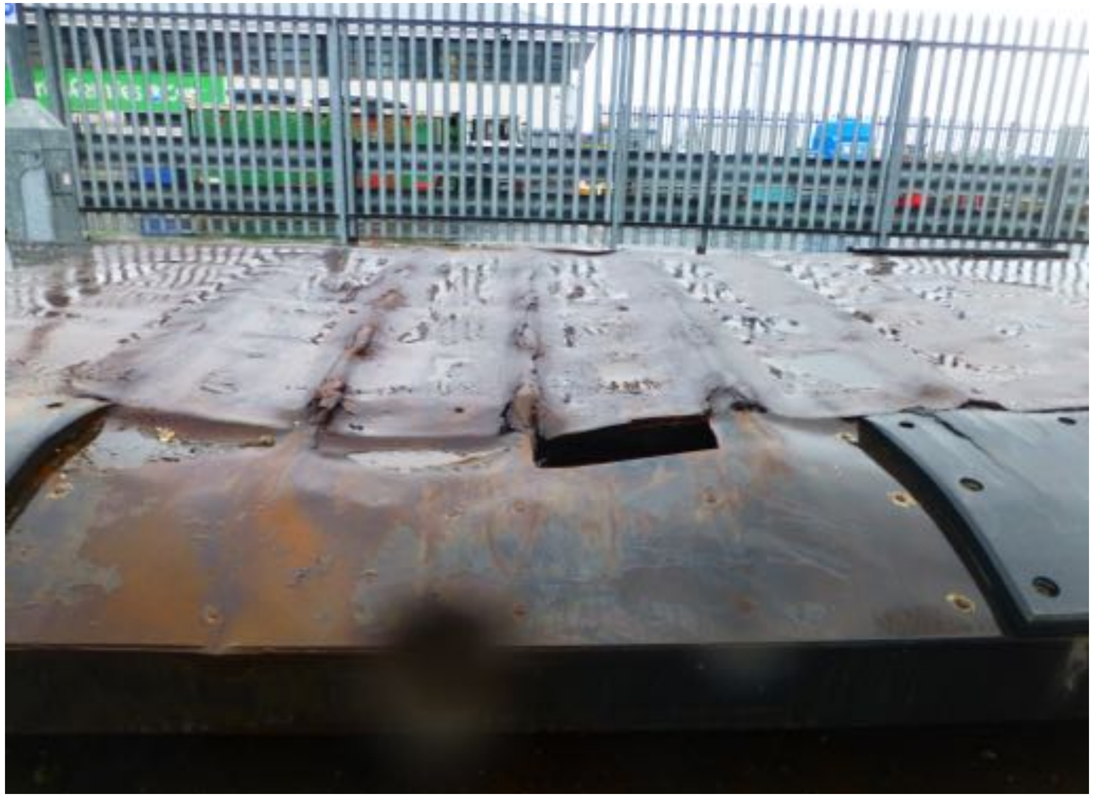
PANEL CHAMFERS



- Chamfers needed to prevent beltings getting caught on panels during tidal variations, loading etc.

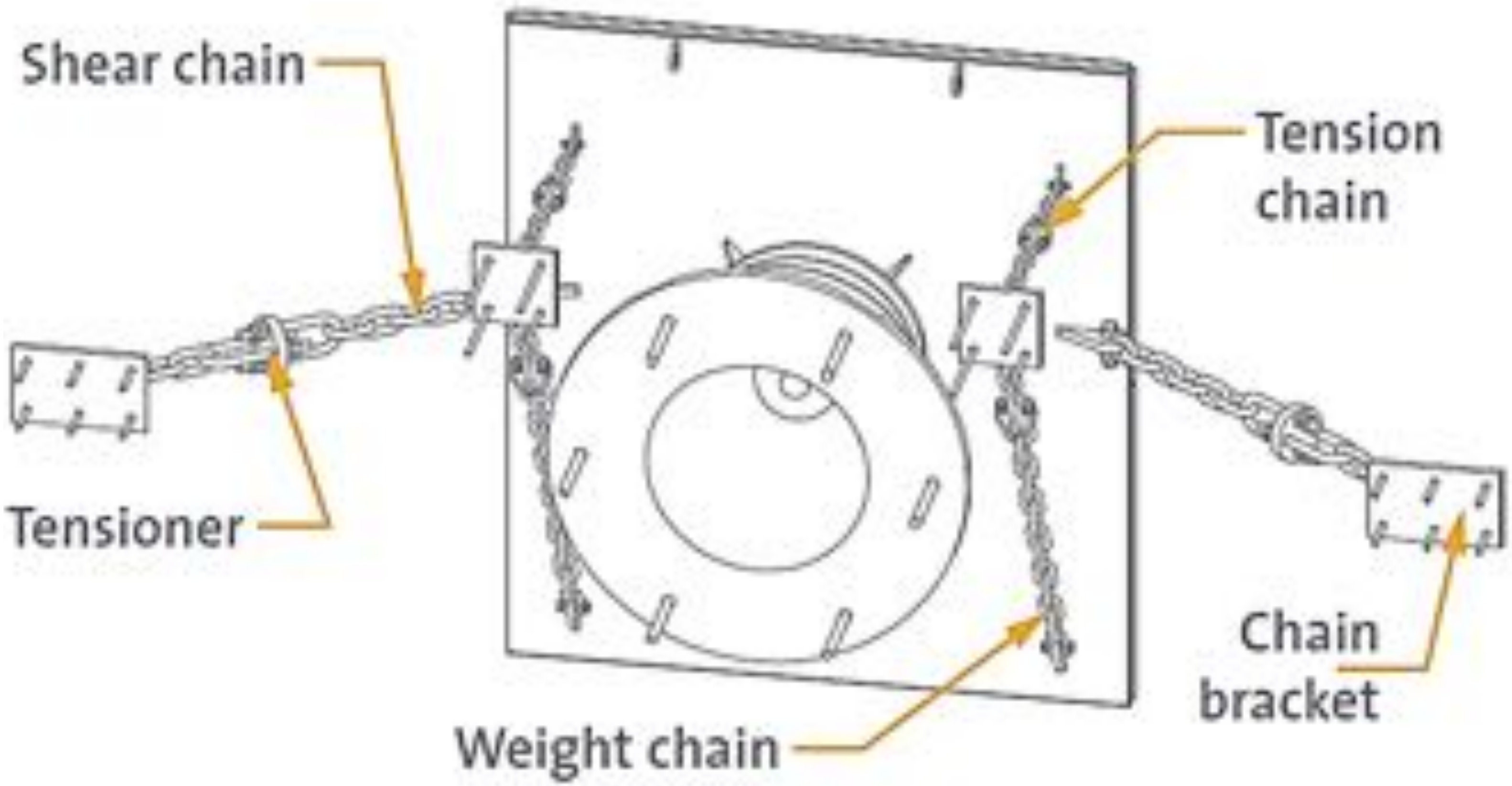
EFFECTS OF VESSEL BELTINGS CHAMFERS.

▶ RESULTS OF INCORRECT CHAMFER/PANEL DESIGNS



ACCESSORIES.

ACCESSORIES – CHAINS.



ACCESSORIES - ANCHORS.

ACI 318M – APPENDIX D / EUROCODE 2 – CCD METHOD

- Concrete Failure Mechanisms

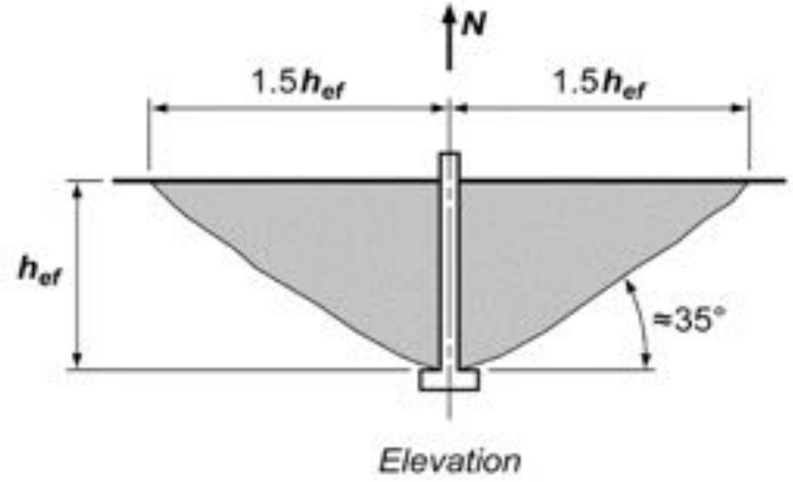
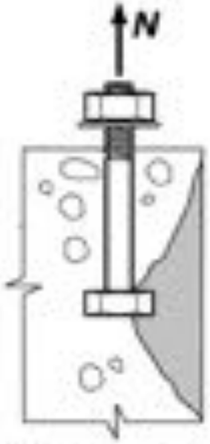
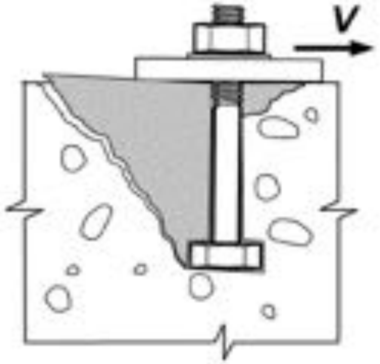


Fig. RD.4.2.2(a)—Breakout cone for tension.



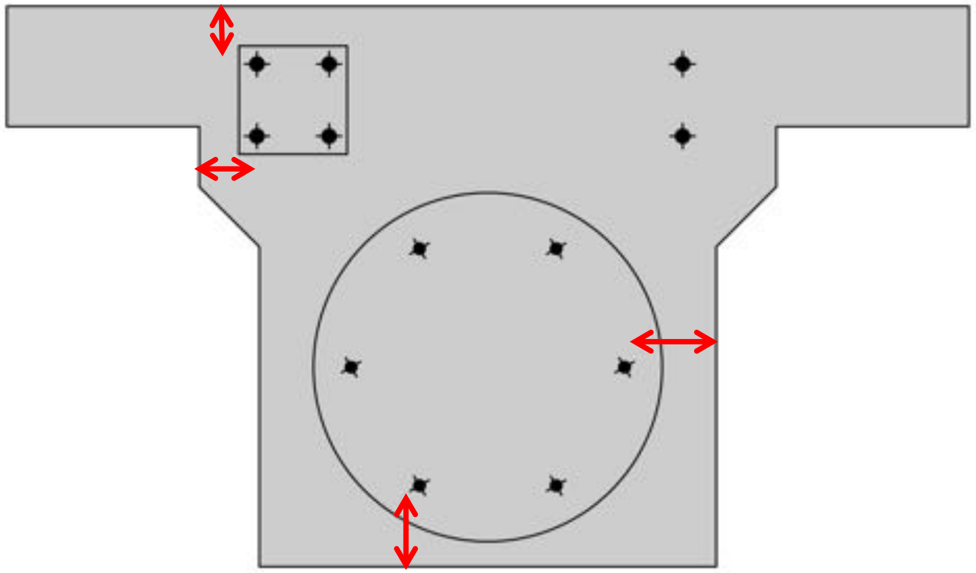
v) Side-face blowout



(ii) Concrete pryout for anchors far from a free edge

ACCESSORIES - ANCHORS.

EDGE DISTANCE



Concrete pull-out capacity needs to be checked wherever anchors are close to the concrete edge

If pull-out capacity is insufficient, entire load should be tied into structure using reinforcing bar

FENDER TESTING - MATERIAL TESTS.

FENDER TESTING - COMPOUNDS.

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RUBBER COMPOUNDS

Elastomer

- Natural Rubber (NR) / Styrene-Butadiene (SBR)

Reinforcing Agent

- Carbon Black

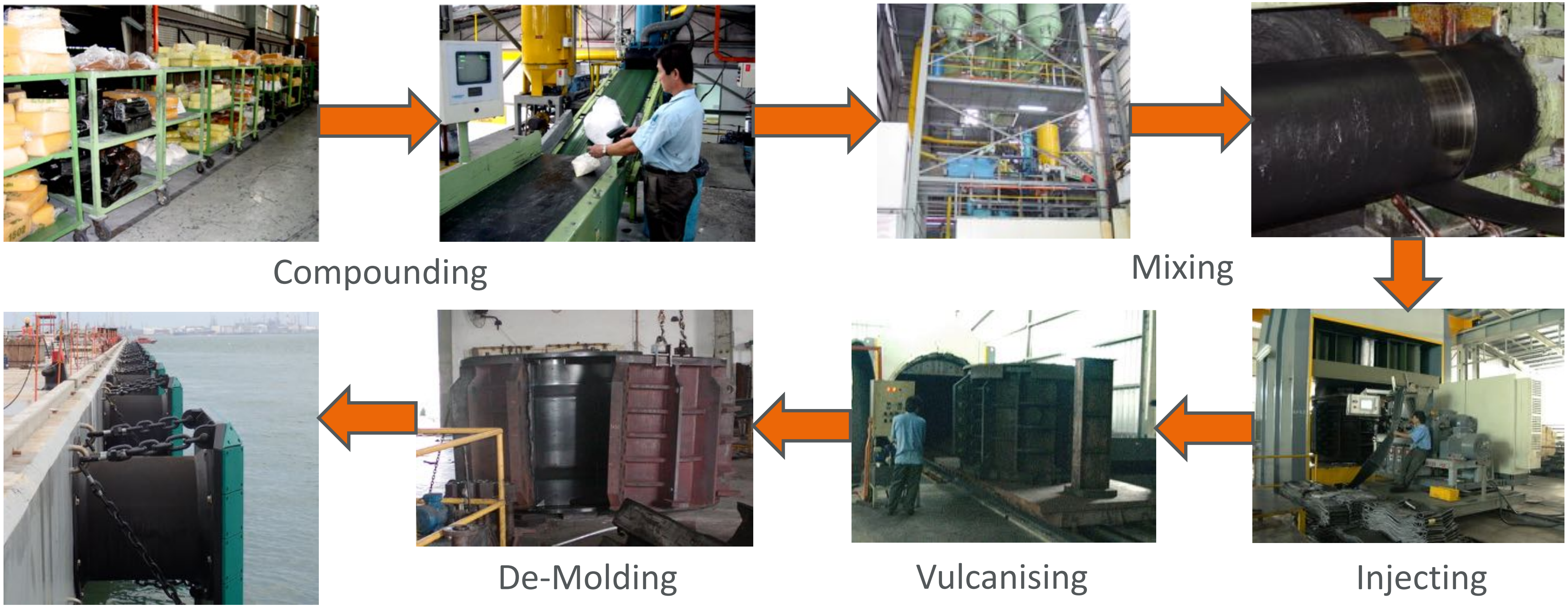
Curing Agent

- Sulphur (for vulcanisation)
- Retardants (slow curing – thick sections)

Other Additives

- UV Stabilisation / Procesability (CaCO3)

FENDER TESTING - PRODUCTION.



SFT WHITE PAPER SERIES.

SFT WHITE PAPER SERIES.

SFT Whitepaper Series:
#1 Compounding | #2 Mixing | #3 Curing | #4 Testing

CARBON BLACK – ESSENTIAL IN MEASURES.

THE PARTICLE SIZE.

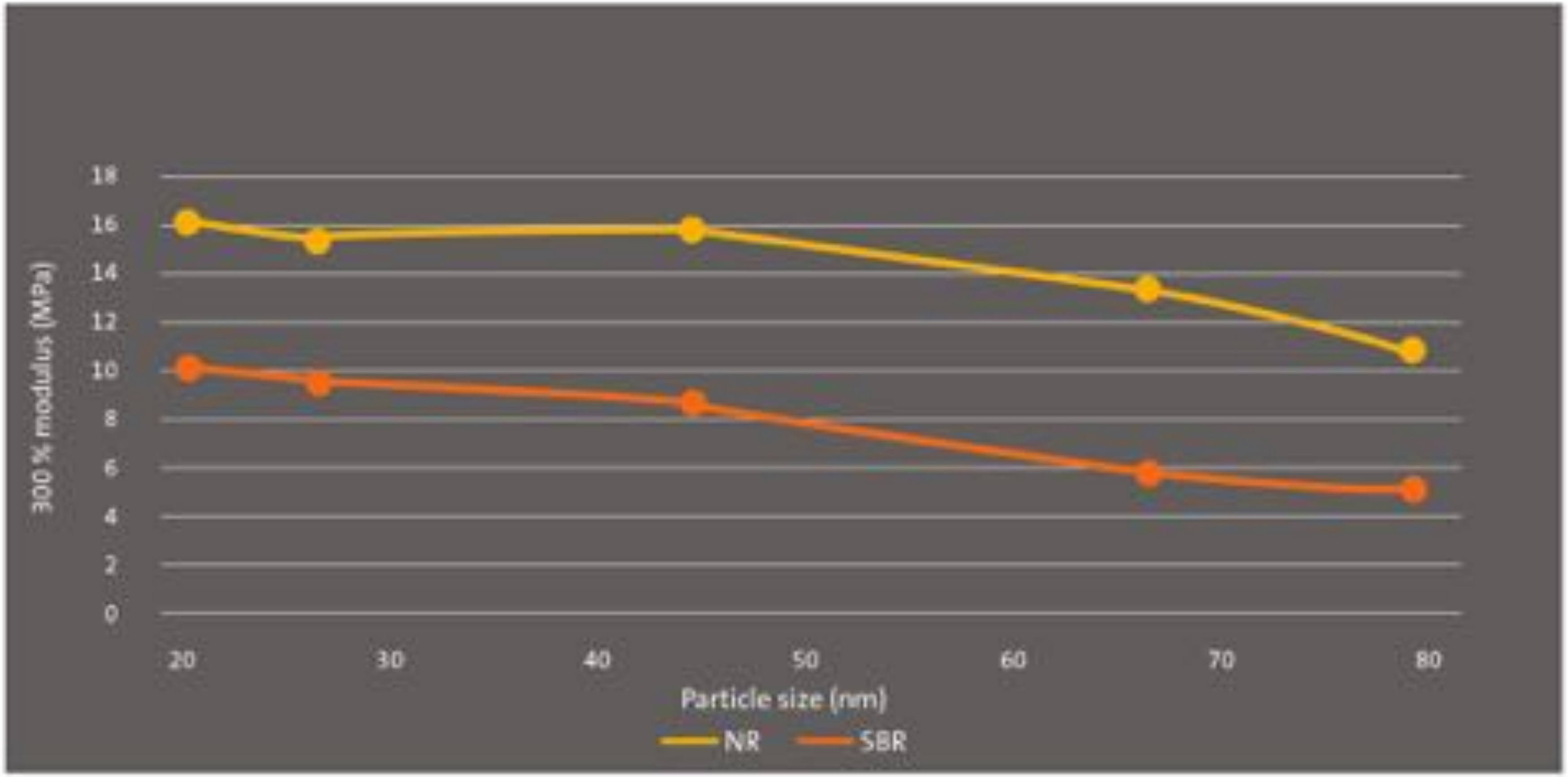


Figure 2: Modulus vs. particle size of CB (CB 33 %)

INFLUENCE OF CARBON BLACK ON TENSILE STRENGTH.

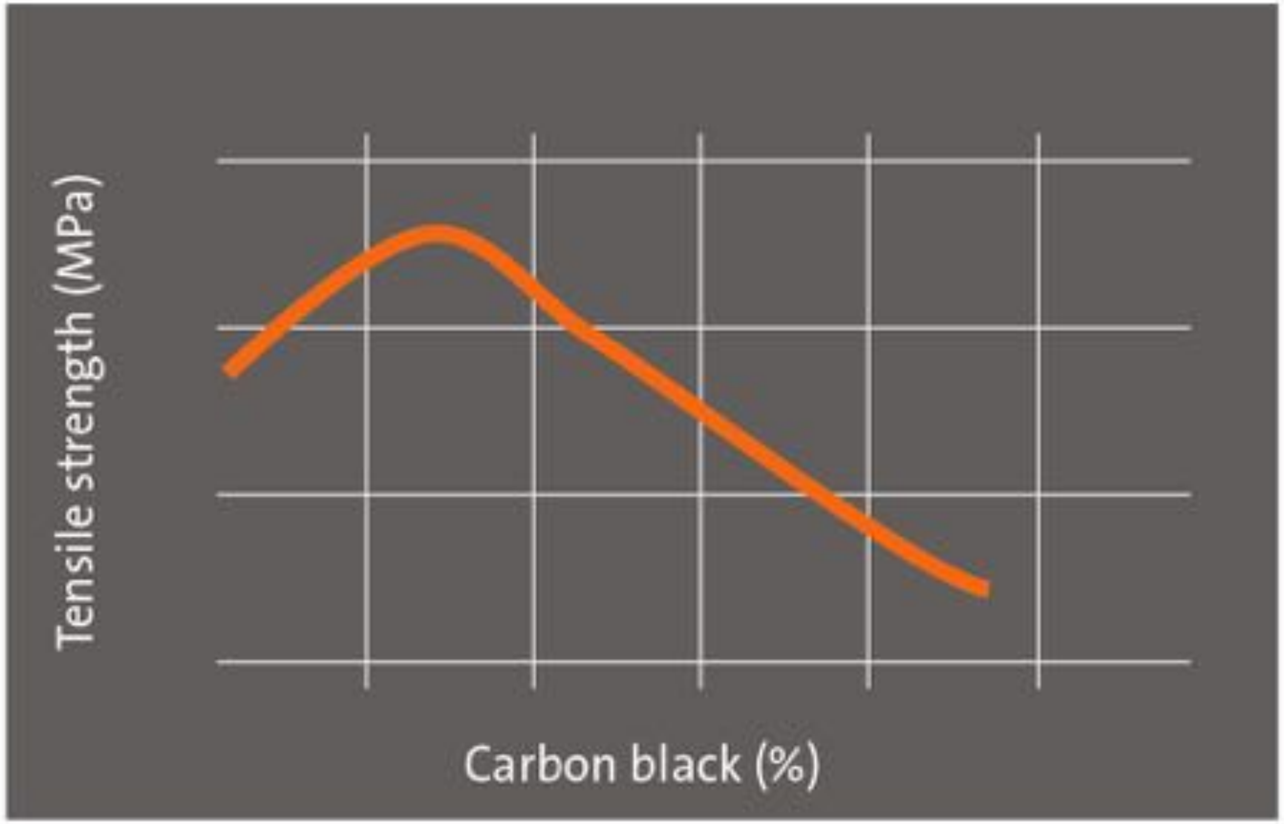


Figure 1: Typical influence of CB on tensile strength in NR compounds

CALCIUM CARBONATE – BETTER THAN ITS REPUTATION.

CALCIUM CARBONATE – BETTER THAN ITS REPUTATION.

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- Enhances processability
- Improves behavior during vulcanization
- Improves compression set result
- Right amount in small particles has a distinct reinforcing effect

FENDER TESTING - COMPRESSION TEST.

FENDER TESTING - COMPRESSION TEST.

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PIANC 2002 COMPRESSION TEST PROCEDURE

- Fender temperature to be stabilised at 23C+/- 5 degrees prior to test (or adjust results for temperature)
- Fender to be pre-compressed a minimum of three times to break-in the fender
- Fender to be rested for a minimum of 1 hour before final test
- Fender compressed at a constant velocity of between 2-8 cm/min
- Reaction (+/- 1kN) and Deflection (+/- 1mm) shall be recorded during compression
- Energy calculated from the Load / Deflection curve
- Energy and Reaction should be within the prescribed tolerance (+/- 10%)

PERFORMANCE TEST CRITERIA.

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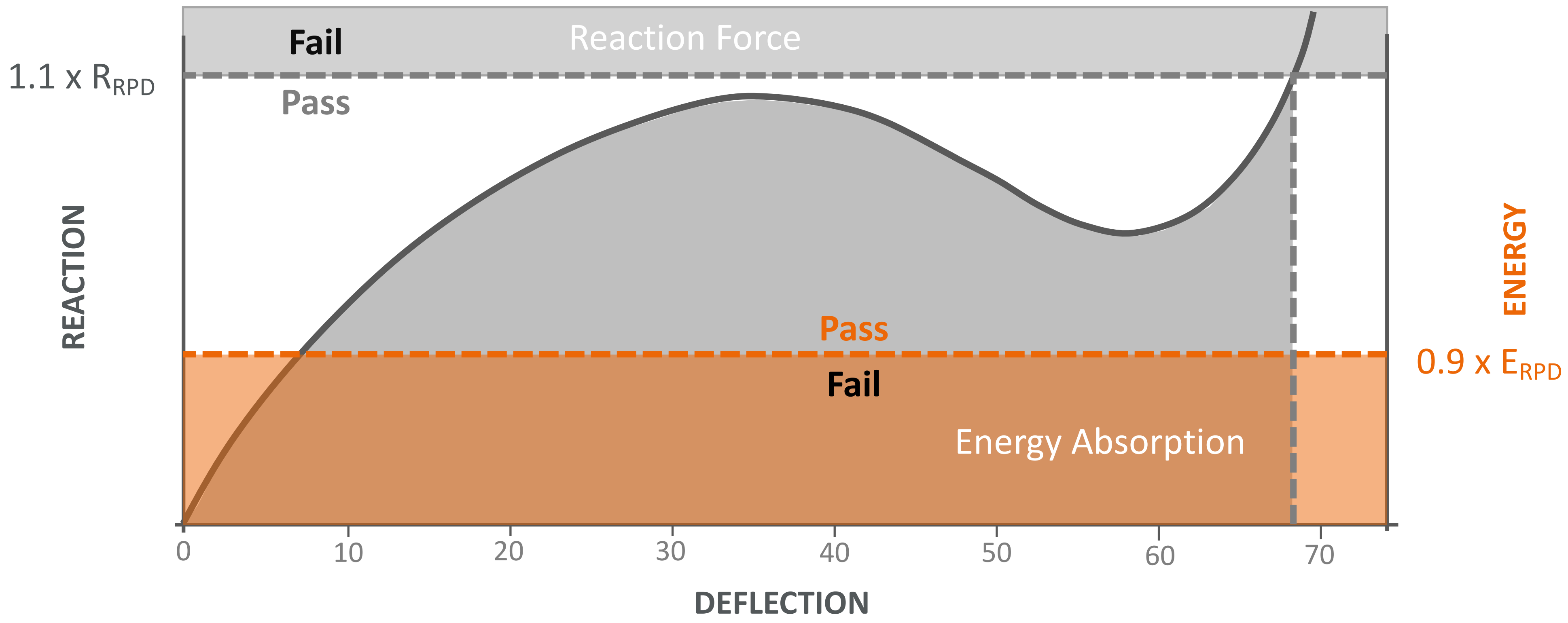
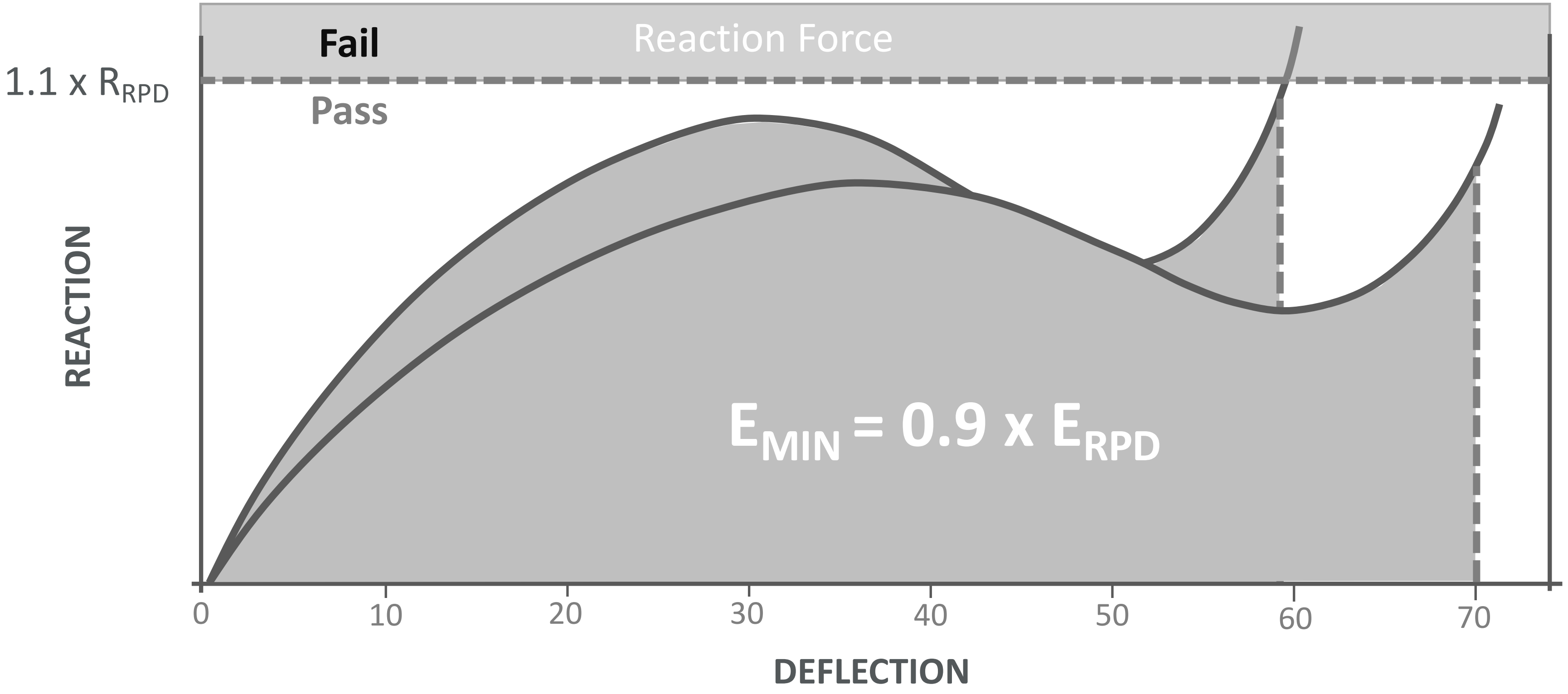
Test Curve



PERFORMANCE TEST CRITERIA.

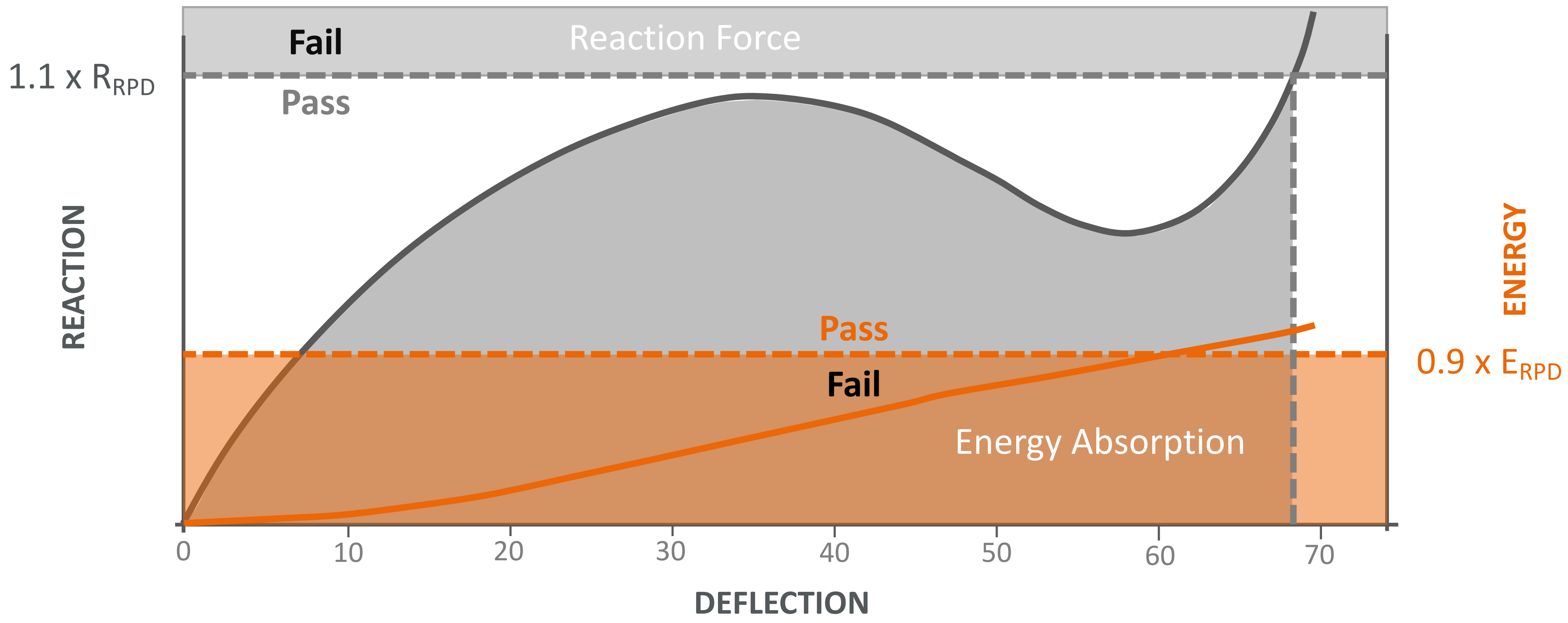
Test Curve



PERFORMANCE TEST CRITERIA.

Test Limits

DEFLECTION IS NOT A PASS / FAIL CRITERIA!
PIANC:2002 Section 6.1.2
ASTM F2192 Item 7.1.2



PERFORMANCE TEST
FACTORY ACCEPTANCE TEST.

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BENEFITS OF TESTING AT FACTORY LOCATION?

- Purpose-built and calibrated test-equipment available
- Performance testing can be carried out earlier in the manufacturing schedule
- Tests can we witnessed by third-party inspectors and/or our client
- Selection of fenders can be on-site during testing
- Less cost and time involved should additional testing be required
- Avoid 12+ week project delays in case of issues during testing.

FENDER DESIGN FAILURES.

FENDER/PANEL POSITION & CHAIN LAYOUT.

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Incorrect solution by low cost supplier

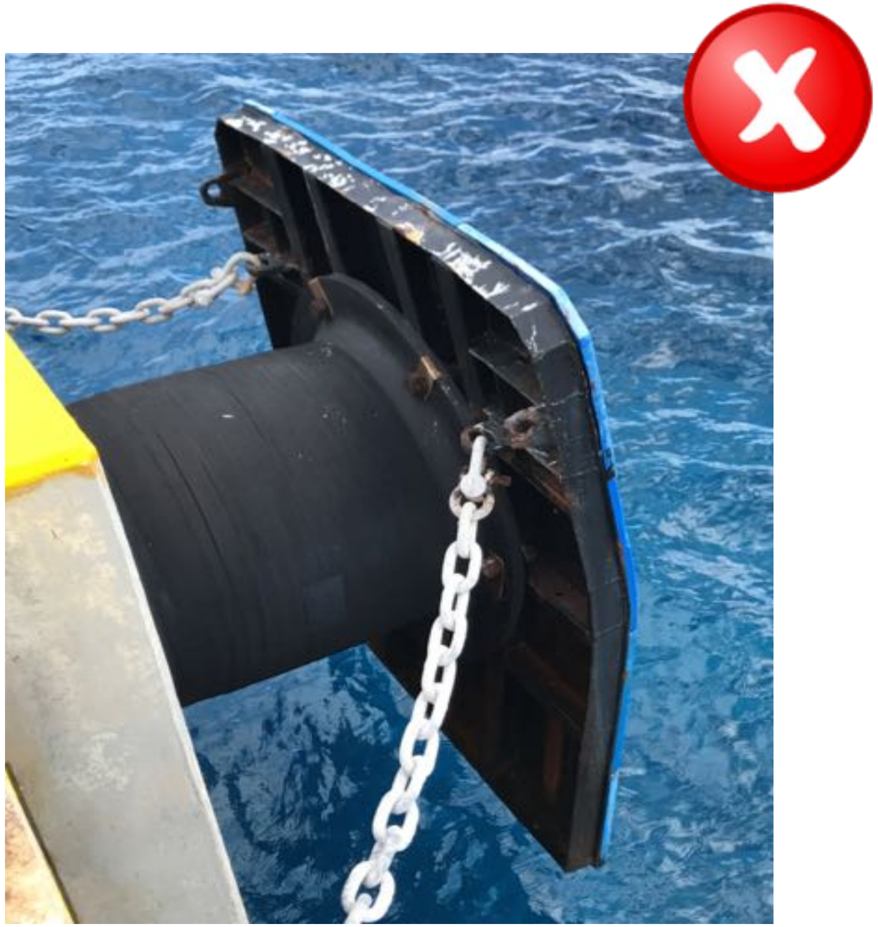
Causes:

- P1 – Unfavorable panel position. Rubber fender installed too close to the top edge of the panel. Deflection by dead weight. “Propeller” Fender System.
- P2 – Chains with the incorrect angle and length not protecting the fender rubber unit, even normal tension/weight/shear loads.
- P3 – Low rubber quality. Incorrect Design. Rubber fender is ¨sagging.

Consequences:

- High peak hull pressure onto vessels’ hull.
- Potential damage to the vessels’ hull.
- Panel self weight supported by rubber instead by the chains.
- Torsion and bending loads damaging the rubber unit
- Cracks and damages in the rubber.
- Lower fender performance
- Reduction of life cycle of the system.
- **Increase in maintenance and replacement costs**
- **Additional losses for stopping operations during replacement/maintenance.**

STEEL PANEL INTERNAL STRUCTURE.



Incorrect solution by low cost supplier

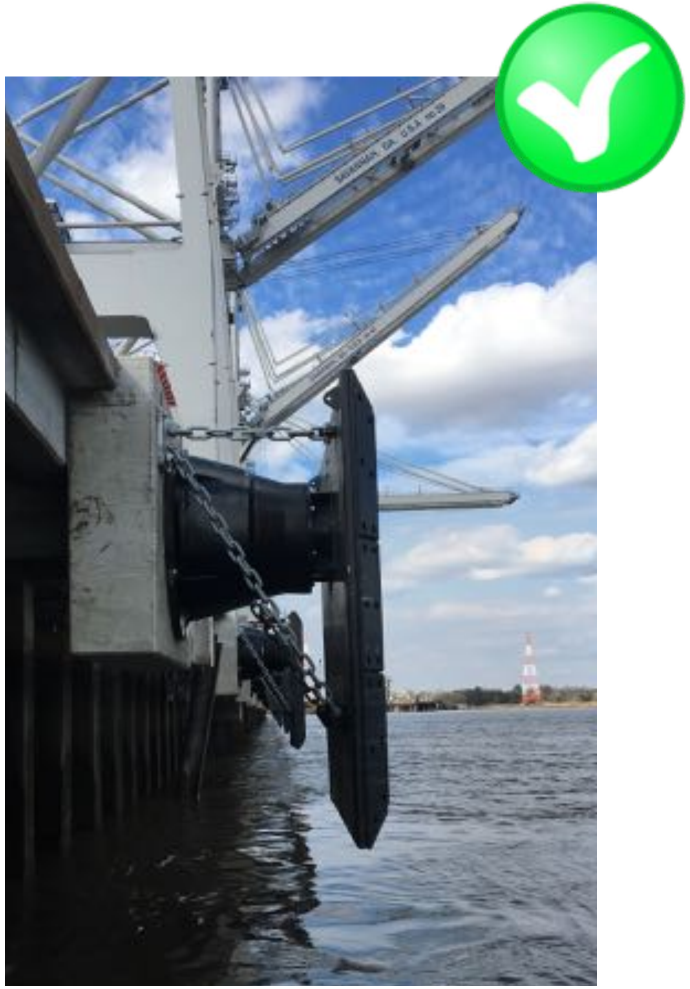
Causes:

- Panel internal structure under sized.
- Wrong structural calculation.
- Thickness of the steel beams is lower than required for the applicable load cases.

Consequences:

- Bent Panel.
- Increase of hull pressure onto vessels.
- Dramatic reduction of the life cycle of the systems.
- **Increase in maintenance and replacement costs.**
- **Additional losses for stopping operations during replacement/maintenance.**

INVERTED FENDER EXAMPLE.



FENDER DESIGN - HOLISTIC APPROACH.

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CONCLUSION

- Work with established manufacturers only
- Gather all vital data for the design
- The most efficient fender, might not be the most suitable fender for your project
- Incorrect information can lead to substantial liability claims
- Understand importance of specifications
- Don’t fall for marketing schemes leading to sole sources
- What might look good on a drawing, might not work in the field

THANK YOU FOR YOUR ATTENTION!

For more information visit us at
booth #33
or
www.shibata-fender.team