CONGRESO INTERNACIONAL DE

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Marzo 15 - 17 de 2017

Equivalent SPS Compact Double Hull (CDH) Bottom Structure Grounding of Inland Waterway Barges

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Inland Waterway Barge and Channel Characteristics

- barge convoy typically operates in different configurations
- 8 barges and push tug, total mass of 10,514 tonnes
- maximum velocity = 16 km/hr (4.44 m/s)
- kinetic energy = 104 MJ
- navigational channel dredged regularly
- river bed conditions well known (sandy soil type with small rocks, maximum diameter of 100 mm)

Inland Waterway Barge: Rules and Regulations

- ABS Rules for Building and Classing Steel Vessels for Service on Rivers & Intracoastal Waterways
  - double hull spacing (between inner and outer hull) of 610 mm (2 ft)
  - minimum clearance of 460 mm (18 in.) for passage between framing (double sides and double bottom)
- ABS rules are prescriptive and not performance based
- double hull barge designed in accordance with MEPC.110(49) (MARPOL Regulations) satisfy requirements
- MARPOL Regulations stipulate that single hull barges must be made of double skin construction or alternate construction with same level of protection
- no definition of the grounding event

Issues with Current Practice: Double Hull Conversion

- conversion to double skin is time consuming (~90 days)
- access and working in confined spaces affects schedule
- problematic to complete weld operations and conduct inspections or maintenance
- increased material and labour costs associated with surface preparation; shop priming and coating
- no existing data on performance of double hull barges during grounding event
- reporting practice not comprehensive and not available in public domain

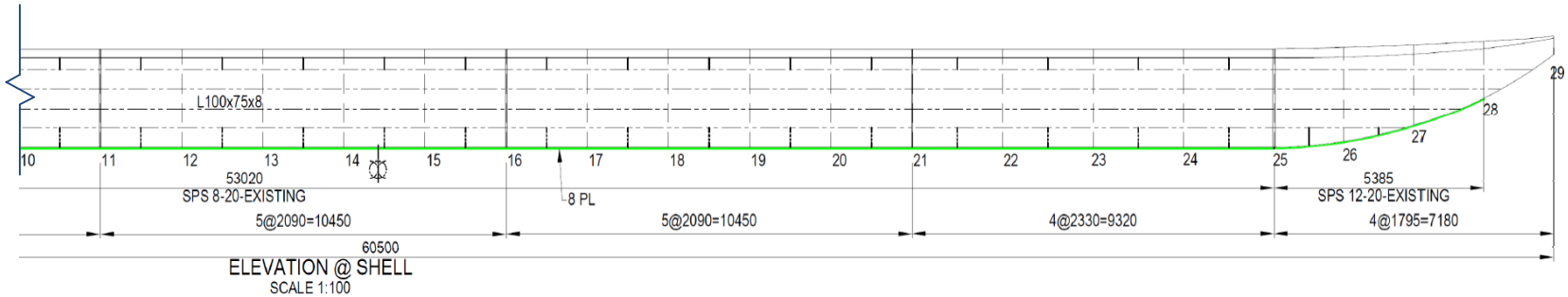
view along length

view across width at stern

Double Hull Conversion

Alternate Solution: SPS Compact Double Hull (CDH)

- Intelligent Engineering and Khalela S.A.S. propose using SPS CDH construction as an alternate solution
- conversion using SPS CDH ~28 days (69% reduction)
- issues with accessibility eliminated as construction is from outside
- reduction in intersecting steel pieces that are prone to crack propagation, fracture and rupture at stress concentrations
- no void space in double bottom reduces inspection and maintenance requirements



SPS Compact Double Hull (CDH) Construction

What is SPS CDH construction?

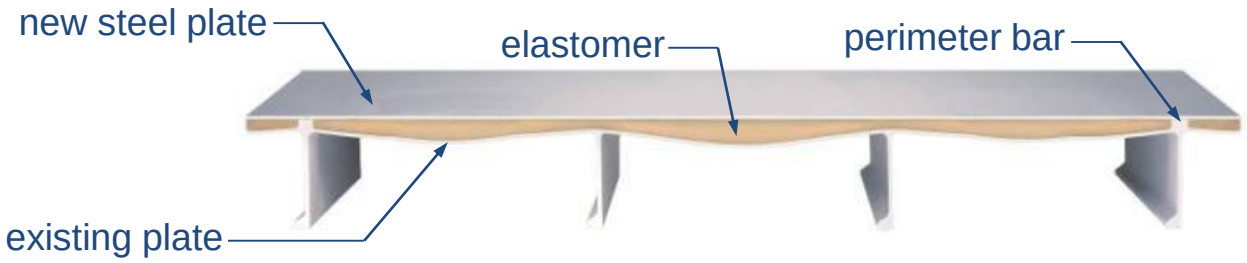
- SPS Overlay uses the existing bottom plating as one side of a steel composite panel formed by a new steel plate and an elastomer core

What are the barge characteristics required to resist a grounding event?

- impact and puncture resistant skin that absorbs energy from initial impact
- does not introduce new details that would make vessel susceptible to rupture and crack propagation

Where is SPS CDH construction applied?

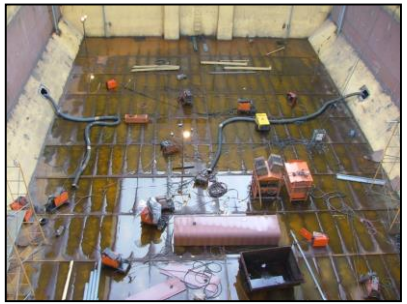
- SPS Overlay (CDH) is applied to the bottom structure (bow and cargo tanks)



SPS Overlay – Proven Technology

- approved by major classification societies
- better than new structural performance
- thin construction has no void space between outer and inner hull and provides the required impact and puncture resistance due to grounding events
- extremely fast process, no structural removal
- non-disruptive and safe
- minimises labour content and downtime

Bulk Carrier Tank Tops



Before

After

SPS CDH Application - FPSO Side Shell Protection

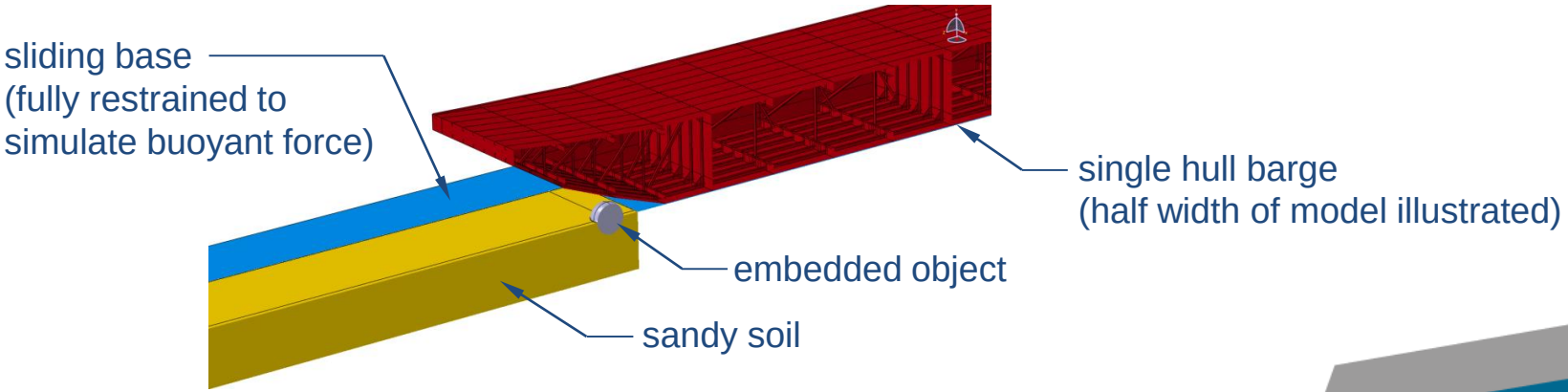
- requires side shell protection in way of boat landing area to prevent oil outflow
- meets IMO MEPC 139(53) and is approved by classification societies LR, ABS, and DNV-GL
- SPS eliminates need to install cofferdams or sponsons (double hulls)
- withstands collision with OSVs (11 MJ); capacity of 100 MJ
- hull rupture is prevented and absorbs collision energy
- side shell protection applied to 13 FPSO vessels (19,162 m^2)

"SPS Overlay provides the ideal side shell protection for our FPSOs. It is applied quickly, delivers improved impact resistance and reduces our operational costs."

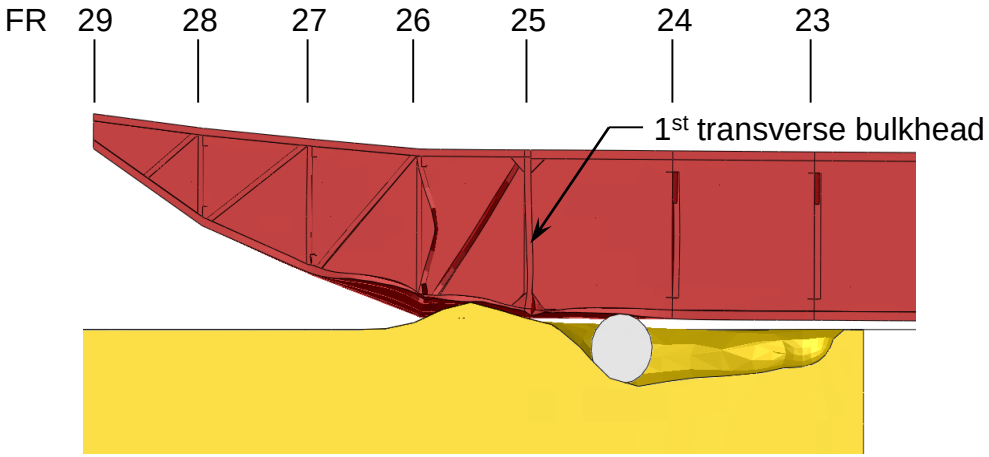
Andy Lau, Conversion / Construction Manager, MOPS

Simulation of Grounding Event: Single Hull Barge

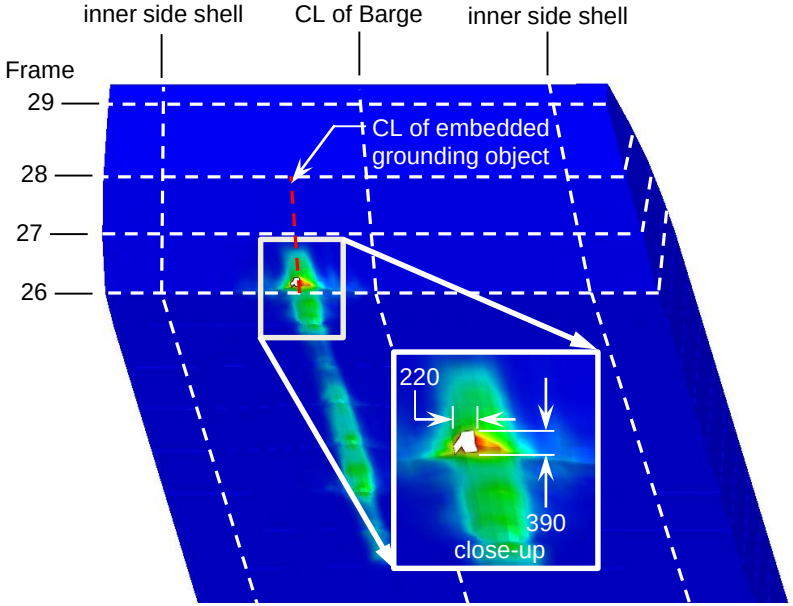
- single hull model constructed to:
  - ensure the simulation is a reasonable representation of actual conditions (mass, vertical and horizontal energy)
  - verify soil characteristics and behaviour are accurately modeled
  - evaluate the effect of different embedded object shapes
  - naturally occurring rocks in the dredged channel were not critical (maximum rock diameter modeled without causing rupture was 250 mm)



Simulation of Grounding Event: Single Hull Barge



Hull Rupture, t = 1.88 s



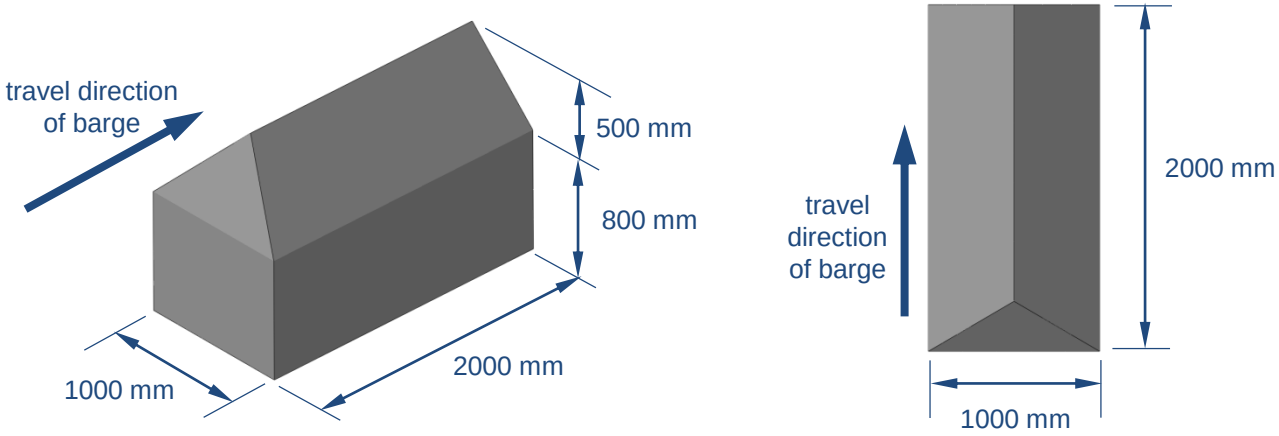
longitudinal frame spacing is 550 mm

Hull Rupture, t = 4.86 s

SINGLE HULL BARGE VIDEO

Definition of Grounding Event

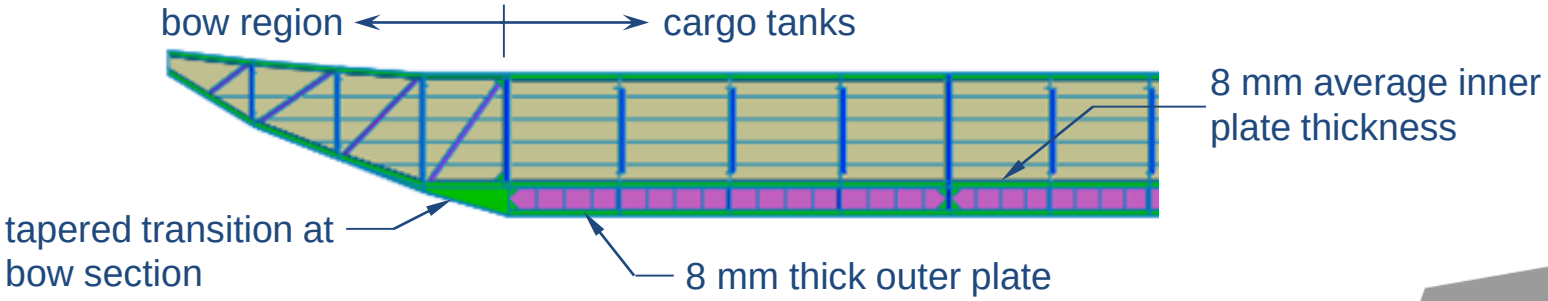
- deterministic load definition used to define the grounding event is a single embedded object which causes rupture of both the outer and inner hull (man-made object of irregular shape, ex. spud)



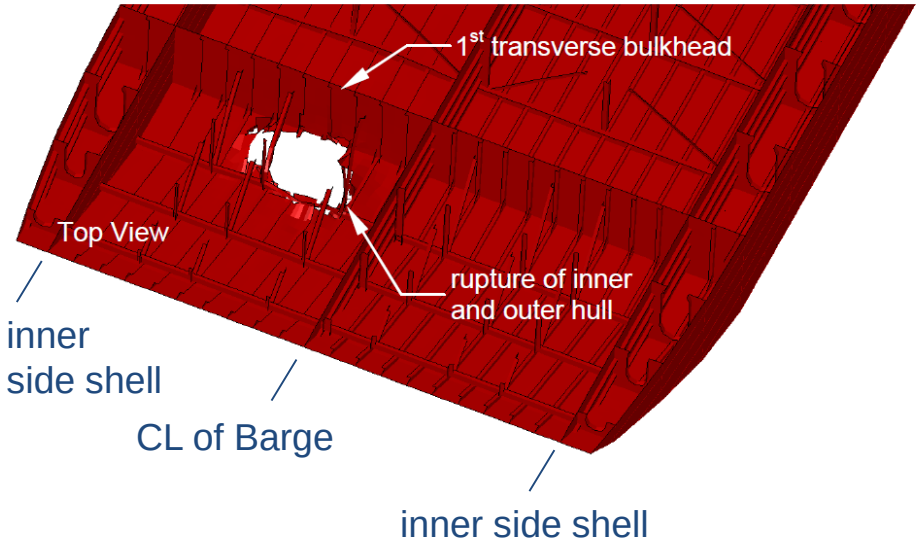
prism-block shaped object selected for simulation
represents man-made object of irregular shape

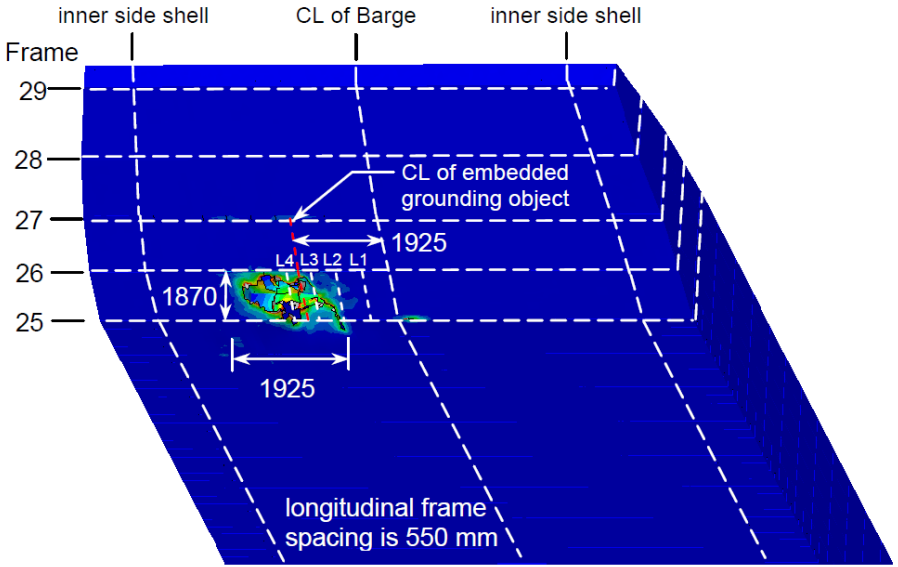
Simulation of Grounding Event: Double Hull Barge

- double hull construction based on outer bottom plating thickness of 8 mm and additional internal framing structure matching existing structure
- tapered transition applied at bow section:
  - assembly, inspection and maintenance is difficult in this area (no access)
  - completed with slotted welds from one side (subject to poor weld quality)
  - suffers from localized damage to coatings (accelerated corrosion)
- greatest protection is required at bow section where impact occurs (not explicitly addressed by current design rules)



Simulation of Grounding Event: Double Hull Barge

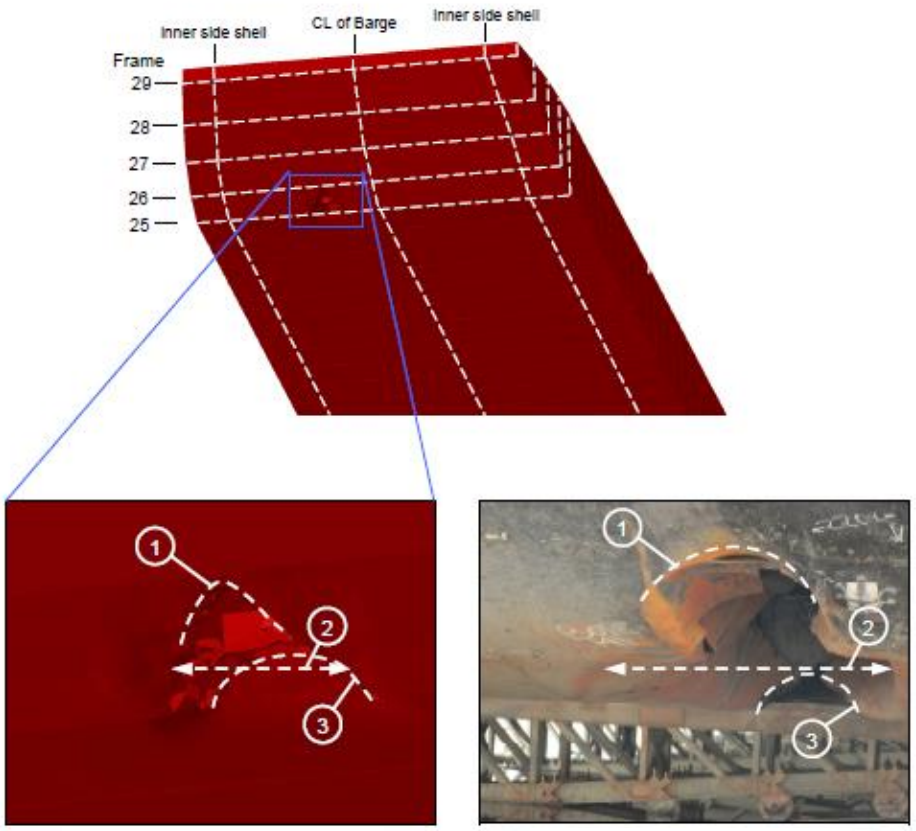




Inner and Outer Hull Rupture at t = 0.87 s

DOUBLE HULL BARGE VIDEO

Double Hull Barge Performance

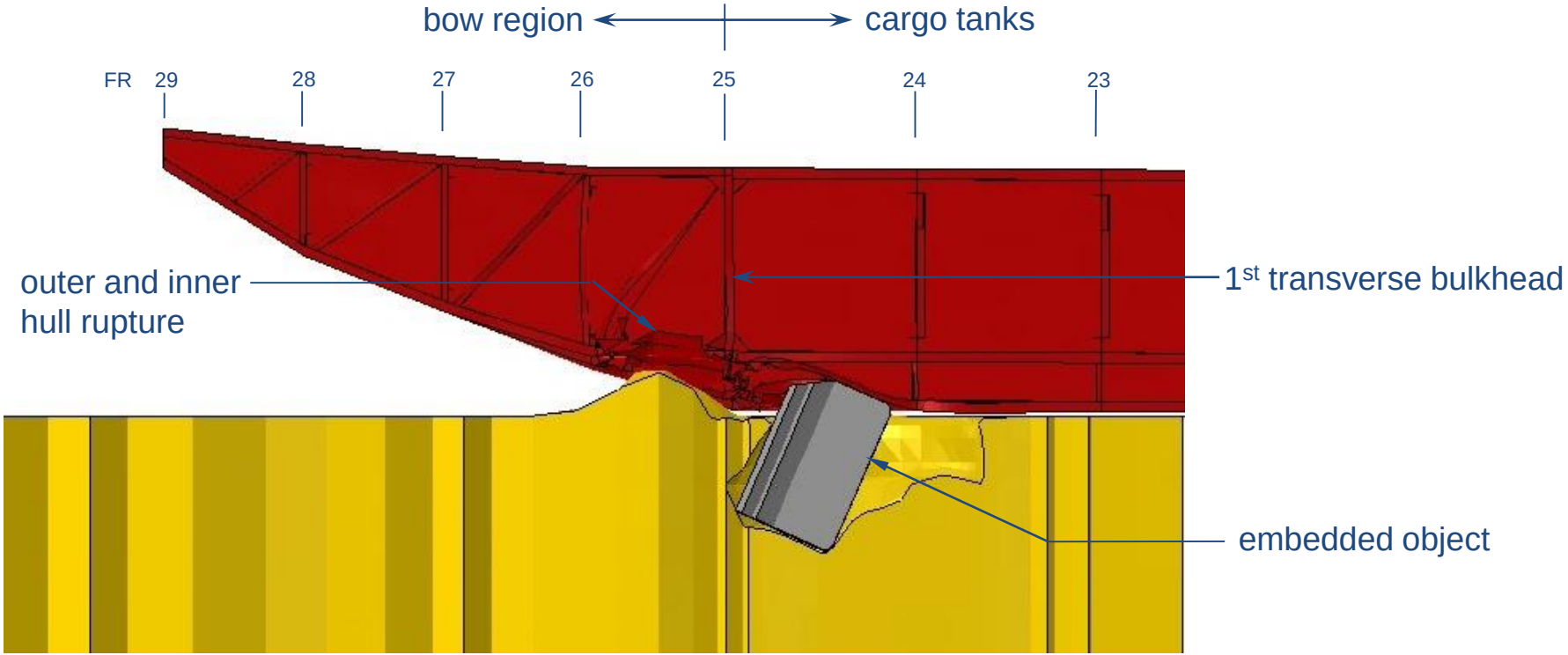


Double Hull Barge

Single Hull Barge

1. initial local rupture of outer hull plate in the bow region
2. lateral extension of rupture
3. propagation of impact object and rupture in cargo tanks
4. tunneling along the cargo tanks
5. model replicates behaviour; shape and depth of penetration is a function of impact object shape

Double Hull Barge Performance

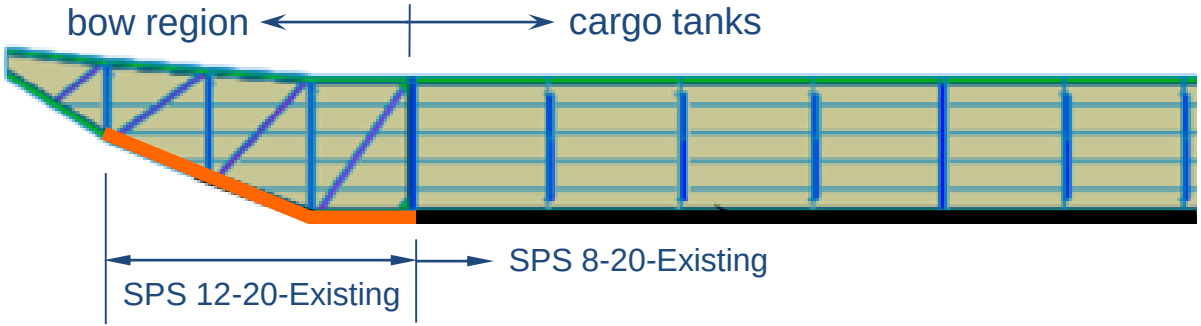


Double Hull Barge Performance

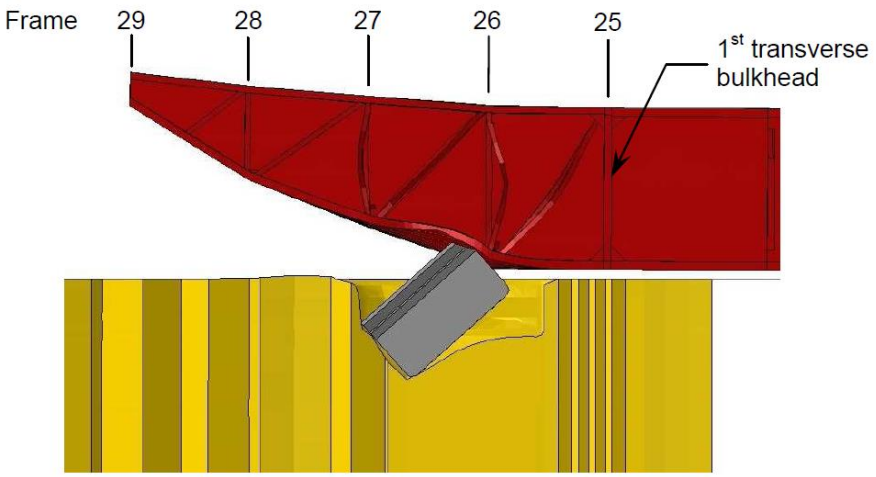
- rupture of outer hull occurs in the bow transition zone upon contact with embedded object
- after rupture of the bottom plate, there is continuing plastification (small amount of energy absorbed)
- inner hull ruptures as embedded object passes the first transverse bulkhead
- embedded object is driven into the soil
- hull structure runs over embedded object and absorbs little energy
- key design driver is prevention of rupture and oil outflow, not the energy absorbed

Simulation of Grounding Event: SPS CDH Barge

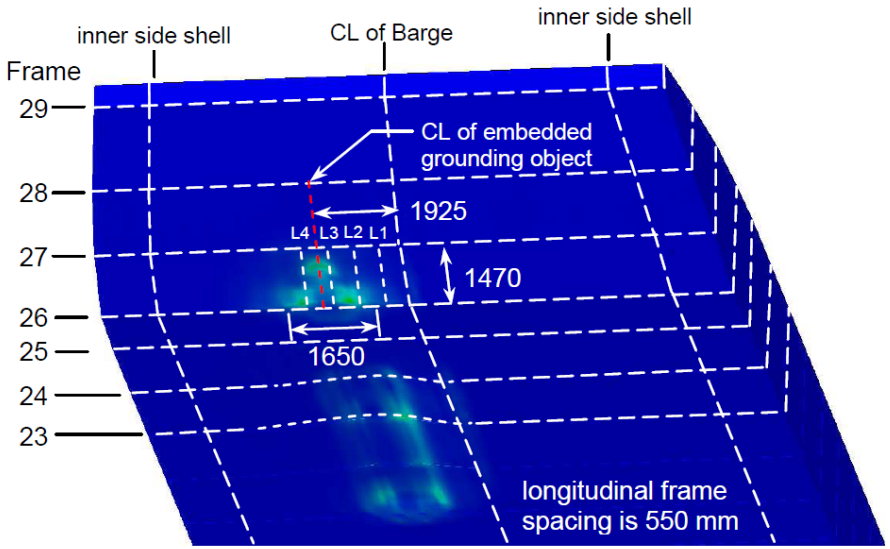
- SPS CDH construction has two different faceplate thicknesses tailored to eliminate rupture and to maximize the energy absorption capability of outer hull
- outer bottom plating thickness 12 mm, 20 mm elastomer core (bow region):
  - tough skin, robust construction for initial impact in bow transition region
  - allows barge to deflect upwards and ride over top of the embedded object
- outer bottom plating thickness 8 mm, 20 mm elastomer core (cargo tanks):
  - resist secondary impacts and continues to move forward



Simulation of Grounding Event: SPS CDH Barge



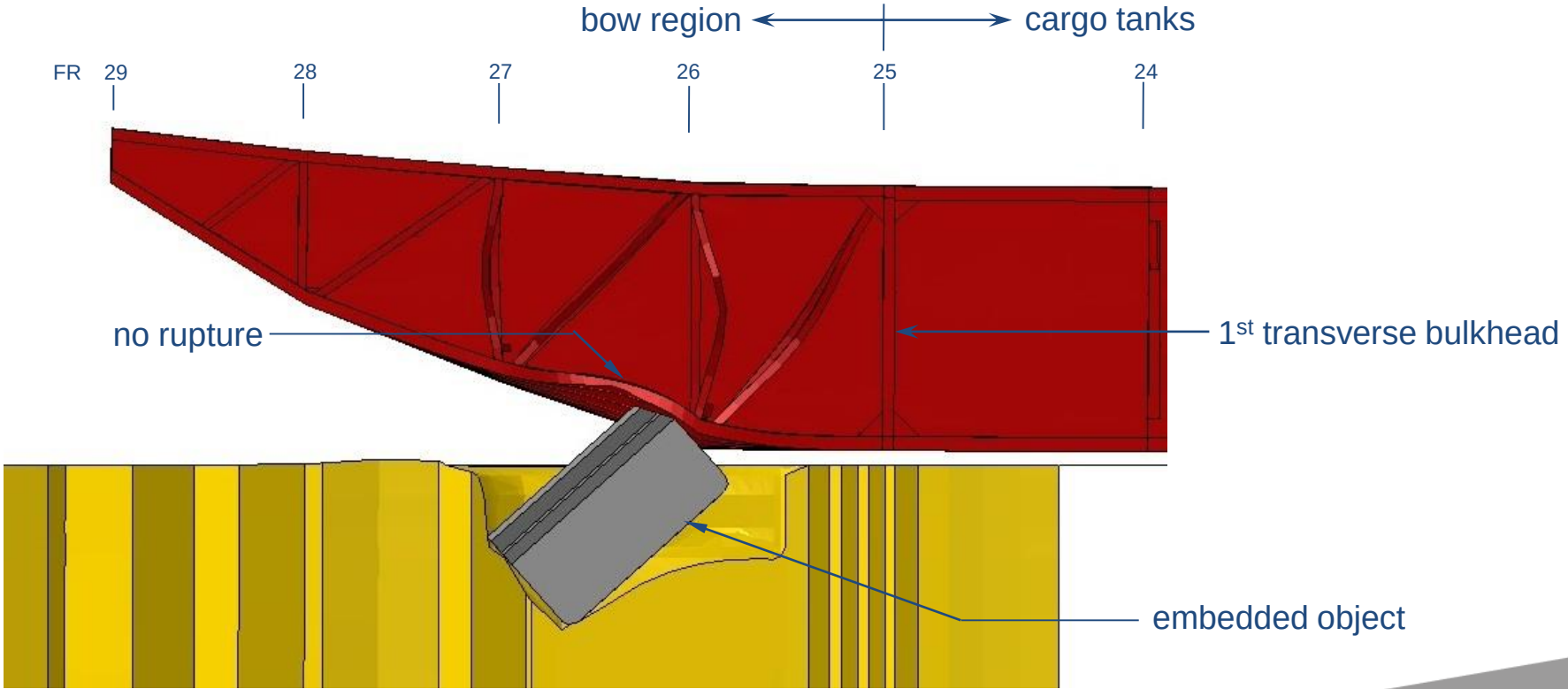
No Rupture, t = 0.48 s



No Rupture, t = 3.56 s

SPS CDH BARGE VIDEO

SPS CDH Barge Performance



SPS CDH Barge Performance

- SPS CDH construction provides better performance than double hull construction:
  - tough skin in bow transition region (no rupture on initial impact)
  - drives the impacted object into the soil and plastifies the steel over an increased area
  - tough skin within cargo tank region to prevent rupture (tunneling effect) and to further absorb energy

- **no rupture, no oil outflow, no oil pollution**

- negative impacts associated with void space in double bottom construction:
  - additional surface area and complex structural arrangement requires coating, inspection and ongoing maintenance
  - problems ventilating and ensuring void space is gas free
  - difficulty accessing confined spaces
  - ballasting required; easier for sediments to become trapped; corrosion of hull plating may go undetected
  - vessel operator must develop maintenance procedures to ensure safety and risk is mitigated; more onerous for double hull construction
- SPS CDH mitigates the negative impacts associated with corrosion, inspection and maintenance as there is no void space between inner and outer hull
- damage stability assessment not required for SPS CDH construction as no rupture and no oil outflow means no flooding of cargo space

Comparison of Benefits:
SPS CDH and Double Hull Construction

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- key commerical drivers that impact cost and schedule include:
  - **reduced installation costs:** reduction in weight of steel; number of steel pieces, weld length, surface area and coatings (~5% cost savings)
  - **reduced installation time:** SPS CDH conversion time is ~28 days compared to ~90 days for double hull conversion (~69% reduction in schedule)
  - **increased revenue opportunity:** based on installation times, 12 conversions per year for SPS CDH compared to 4 conversions per year for double hull conversion; barge rate for converted barges ~20% higher than single barges
  - **reduced inspection/maintenance cycles:** annual maintenance and inspection costs are reduced due to reduced structural complexity

- SPS CDH design provides a **15% overall cost saving** compared to double bottom construction for a typical barge fleet with added cost advantage accrued over the life of the barges

Summary and Conclusions

- MARPOL Regulations require that single hull barges be converted to double skin construction or modified by alternate construction with same level of protection
- grounding simulations conducted for a single hull barge to ensure the simulation is a reasonable representation of actual conditions
- comparative grounding simulations were conducted for double hull and SPS CDH
  - double hull; demonstrates rupture of inner and outer hull for a specified grounding event resulting in oil outflow and oil pollution
  - SPS CDH; demonstrates that initial and secondary impacts are absorbed with ***no rupture, no oil outflow, no oil pollution***
- SPS CDH allows inspection and maintenance procedures to be conducted with less risk and more efficiently; damage stability assessment not required
- SPS CDH provides a ***15% cost saving with equivalent or better performance*** than double hull construction

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