144-Car Ferry

Aluminum vs. Steel Superstructure Study

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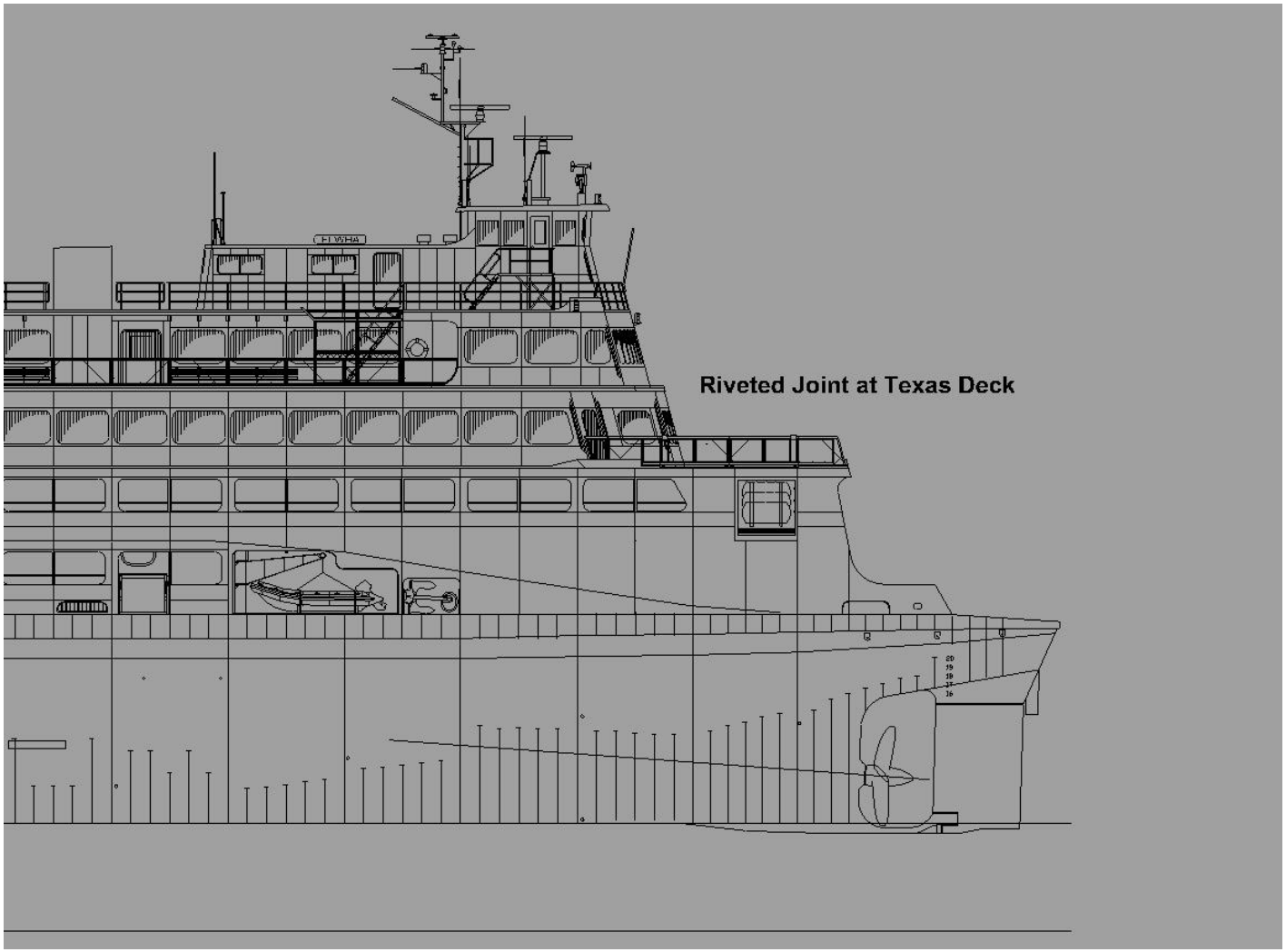
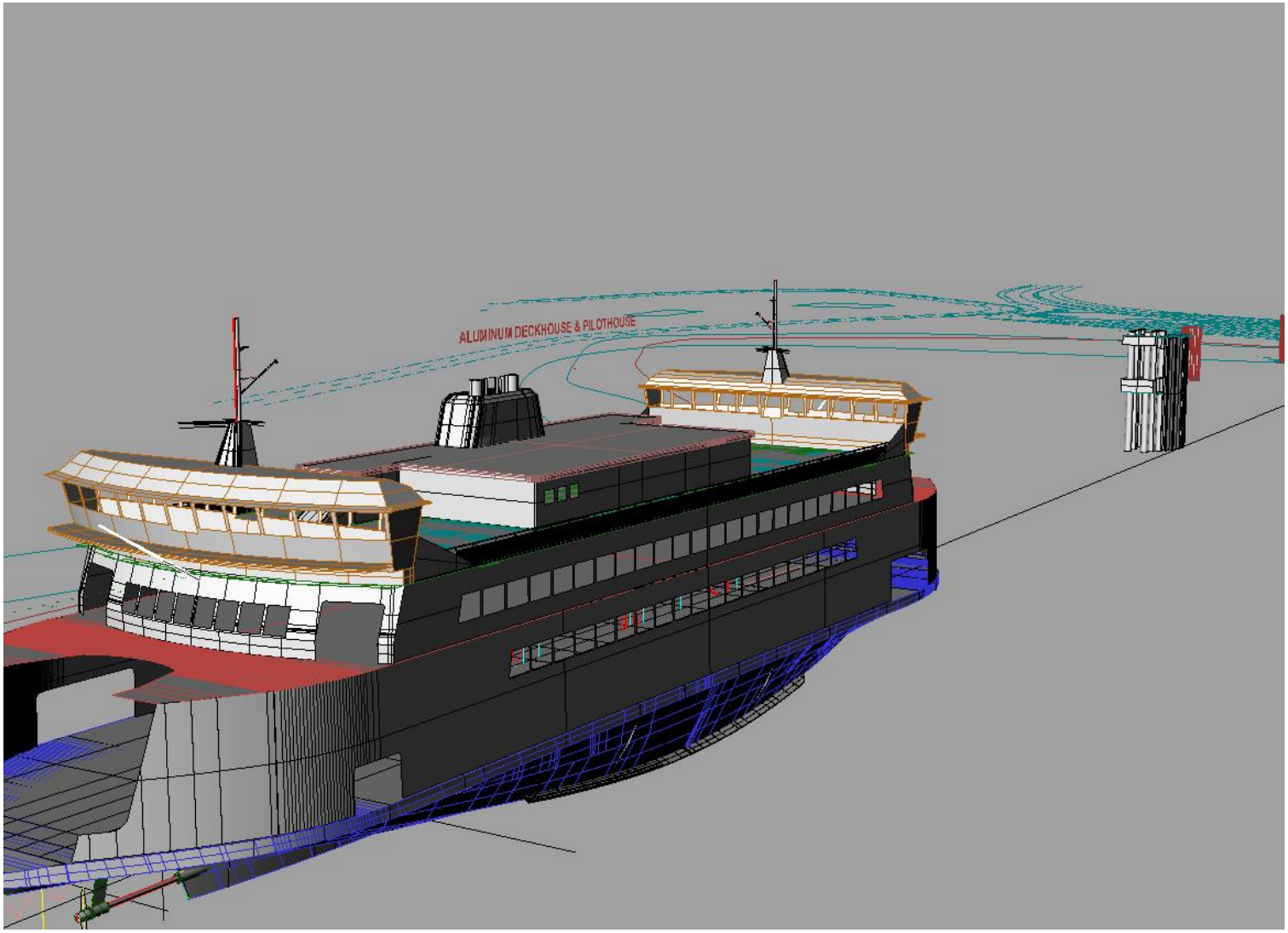
Washington State Department of Transportation

Super Class Aluminum Superstructure



Experience with Aluminum Deckhouses



Impact of Aluminum Deckhouse

Weight of Aluminum vs. Steel

- Aluminum has a higher strength per weight ratio than steel.
- Important with:

  - High speed craft
    - Fast ferries
    - Military vessels
    - Law enforcement vessels

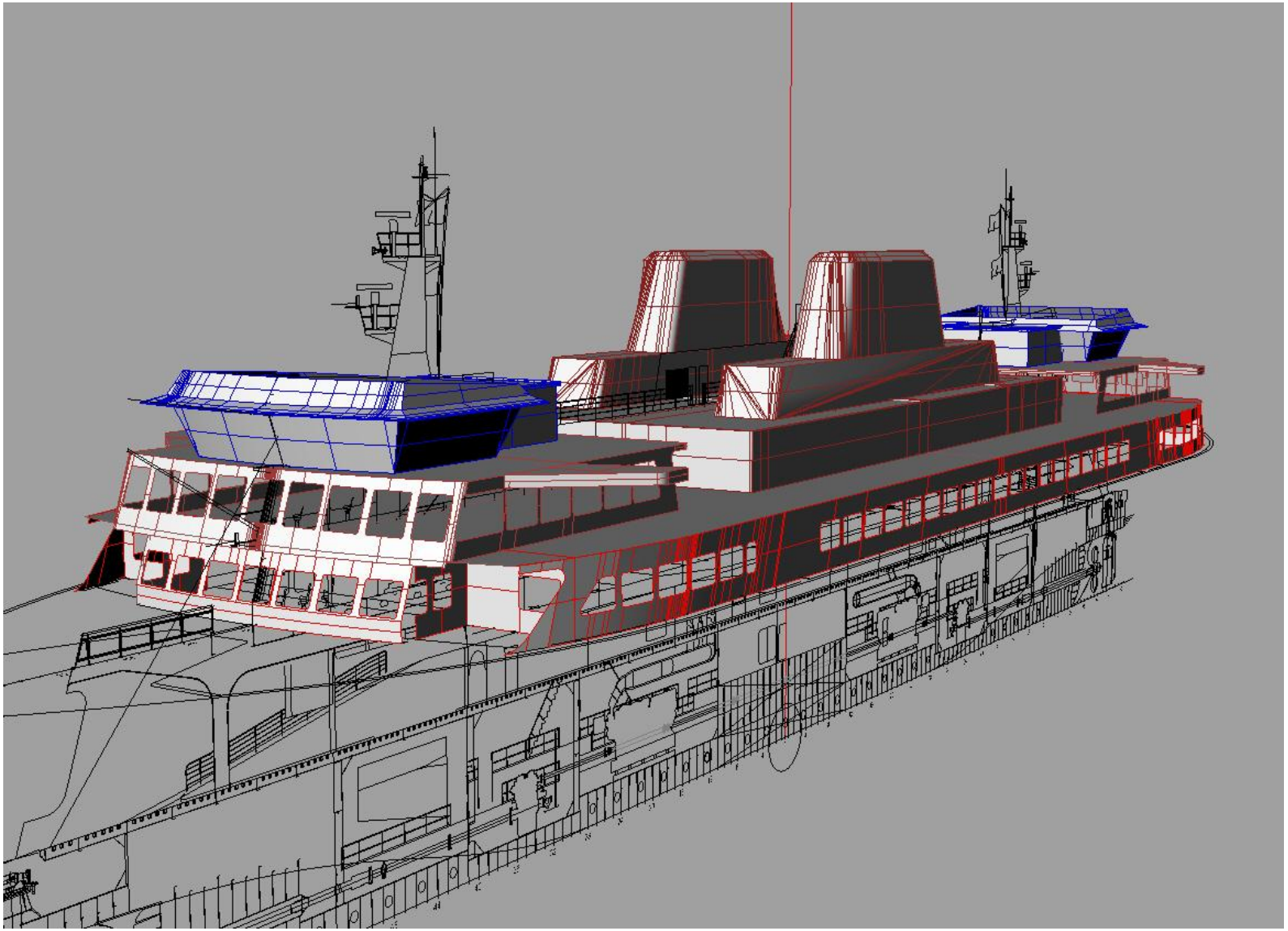
  - Weight critical vessels
    - Vessels requiring shallow draft
    - Self-righting life boats
    - Passenger cruise vessels with many deck levels

Weight of Aluminum vs. Steel: 144 Ferry

	Steel pounds	Aluminum pounds	Increase/decrease
Metal fabrication	914,000	640,000	-274,000
Fire insulation	11,000	31,000	20,000
Enclosing auto deck sides	0	44,000	44,000
Total weight Difference			**-210,000**

This means the vessel would ride about 2.5 inches higher in the water in any operating condition.

144 Car Ferry Aluminum Structure



Weldability

- Aluminum's weldability is different than steel.

  - Requires different equipment and qualifications.

  - Less forgiving than steel when comparing:
    - Weld porosity.
    - Shrinkage.
    - Distortion due to high heat conductivity.
    - Alignment of parts during fabrication.

- Welding aluminum reduces the strength near the weld.

  - Requires more attention in design and fabrication for placement of seams and related structural details.

Fatigue

- Aluminum has a shorter fatigue life than steel.
  - Cracks sooner than steel in high stress areas.
  - Requires more attention to design details to eliminate stress risers.

Strain Rate Sensitivity

- Steel is strain rate sensitive, many aluminum structural grades are not. That is, at the higher rates of strain typically associated with crash events, steel has a higher energy absorption at a given weight.

Vibration

- Aluminum is less stiff than steel.

  - Structural members require strengthening.

  - Requires a modified superstructure design and re-doing vibration analyses of the new structure with several iterations to get it right.

Airborne Noise

- The ability of any material to attenuate airborne noise is directly proportional to its mass.
- Aluminum is one-third the density of steel.
- More mass less noise.
- Steel is quieter for passengers.

Paint

- Painting the superstructure is a preference.

Chetzemoka

- “Aluminum is a very difficult substrate to paint successfully. In professional circles companies go to great lengths to prepare aluminum before painting because paints and coatings do not adhere easily to the surface…” *Paint and Coatings Resource Center (PCRC)*

Fire Protection

- U.S. Coast Guard (USCG) Requirements:

  - More insulation to designate zones to protect the opposite side of the fire location. The goal is to install passive systems to minimize human error on system performance.

  - Aluminum requires more insulation, and on both sides of these boundaries impacting current design and structures.

  - If a fire becomes out of control there is a greater chance for aluminum to lose its structural integrity sooner, allowing for a greater potential of structural collapse. (USCG required a modeled 80 megawatt fire)

Fire Protection

- No “light and air” openings along the sides of the car deck.
  - This is to prevent heat from a vehicle fire from raising the temperature of the deckhouse exterior above allowable limits.
  - There is no practical method of insulating an exterior surface from fire, so any possible source of fire on the exterior side must be eliminated.
  - The 144 auto class is currently designed with openings along the full length of the main and upper car decks. This structure would have to be redesigned, and vessel weight would increase.

Impact of Aluminum Superstructure: Fire Constraints

Standard Layout

Aluminum Deckhouse

Cost Analysis

Costs are brought to present value.

Item	Steel	Aluminum	Change
Metal fabrication	$3,792,000	$10,708,000	$6,916,000
Structural fire protection	$60,000	$175,000	$115,000
Coatings, new construction	$375,000	$145,000	($230,000)
Coatings, 60-year life cycle	$600,000	$448,000	($152,000)
Fuel, 60-year life cycle	$0	($3,120,000)	($3,120,000)
Redesign cost	$0	$885,000	$885,000
Contract delay cost (5 months)	$0	$2,033,000	$2,033,000
WSF program delay costs (5 months)	$0	$143,000	$143,000
Total			**$6,590,000**

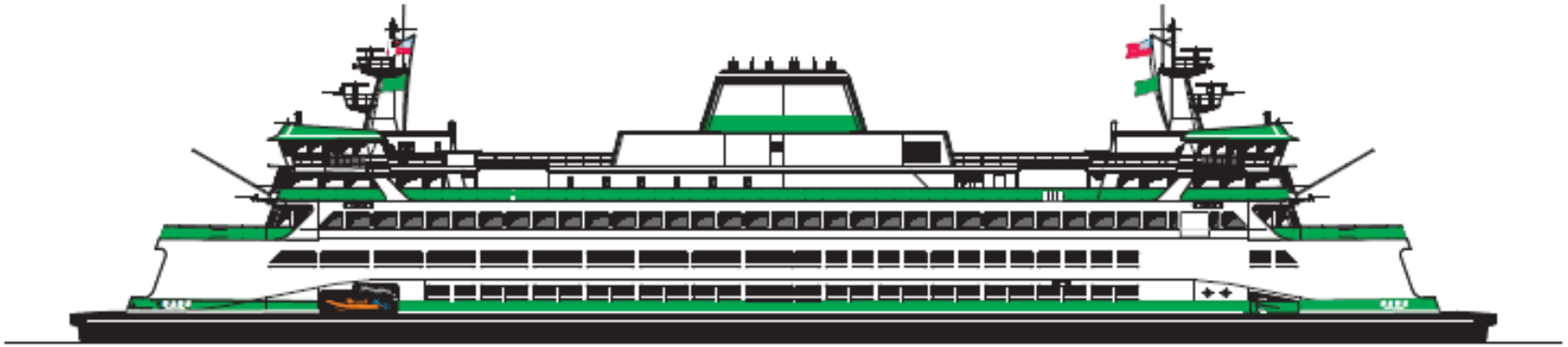
Cost Analysis

Risks we were unable to quantify:

- Regulatory risks such as how the U.S. Coast Guard will treat certain fire protection requirements and vehicle deck ventilation requirements.
- Construction phase risks such as unforeseen design implications and dimensional controls during fabrication.
- Service life risks due to built in stress and fabrication imperfections leading to metal fatigue.

Conclusion

- The costs and uncertainties of changing to aluminum deckhouse construction outweigh potential benefits.
- The increased construction costs are over $6.5 million. The potential life cycle savings after 60 years including fuel savings, are just over $3.5 million.
- **Based on our Cost Benefit Evaluation we strongly recommend against changing the deckhouse design/construction to aluminum.**



Questions?

For further information on the 144-car ferry *Aluminum vs. Steel Superstructure Study* contact, please contact:

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