Seismic Retrofit of Container Cranes

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Historic Seismic Performance

Kobe - Liquefaction

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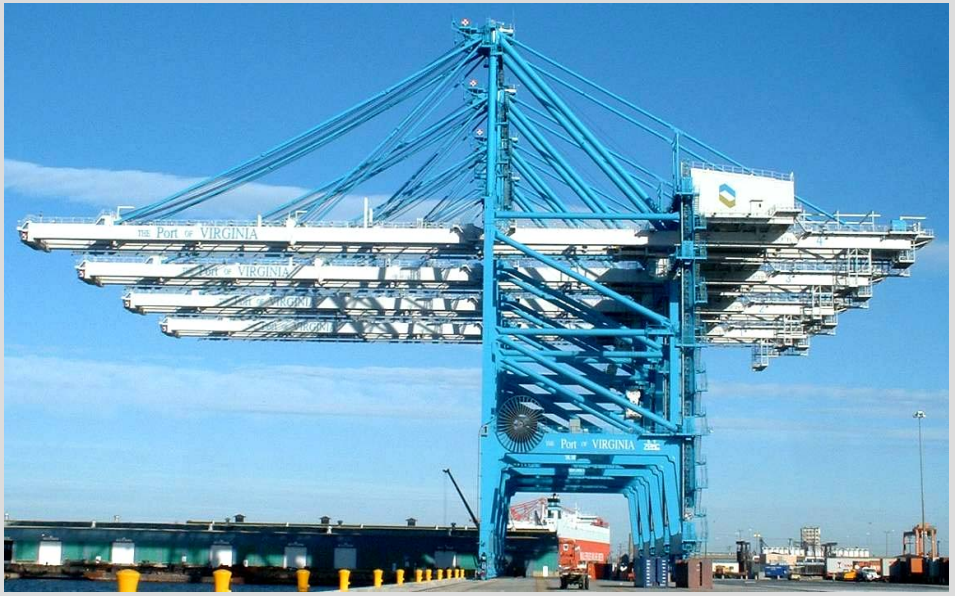
Crane Evolution

Circa 1970



Modern Jumbo

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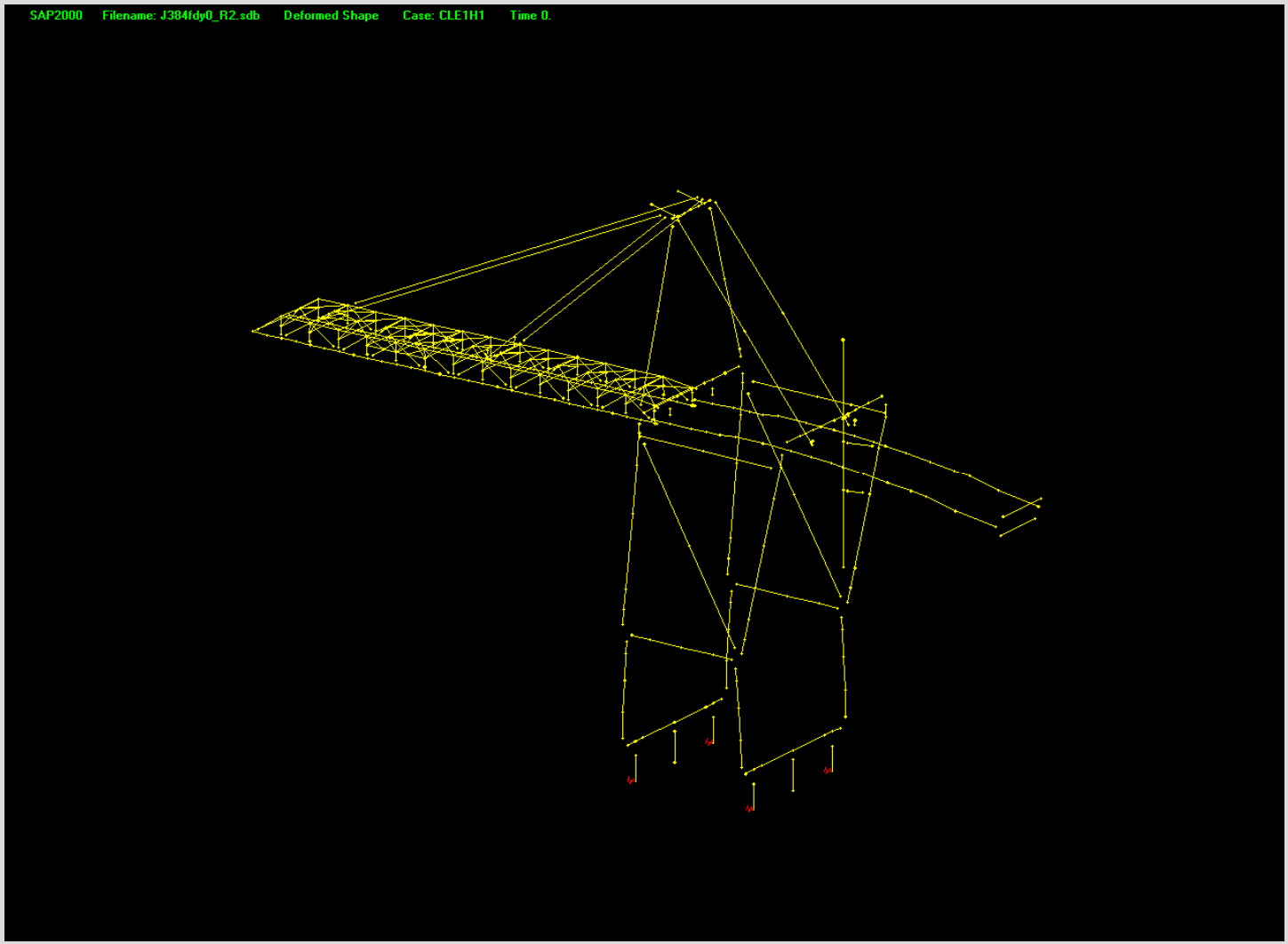
50’ Gage Crane CLE Response



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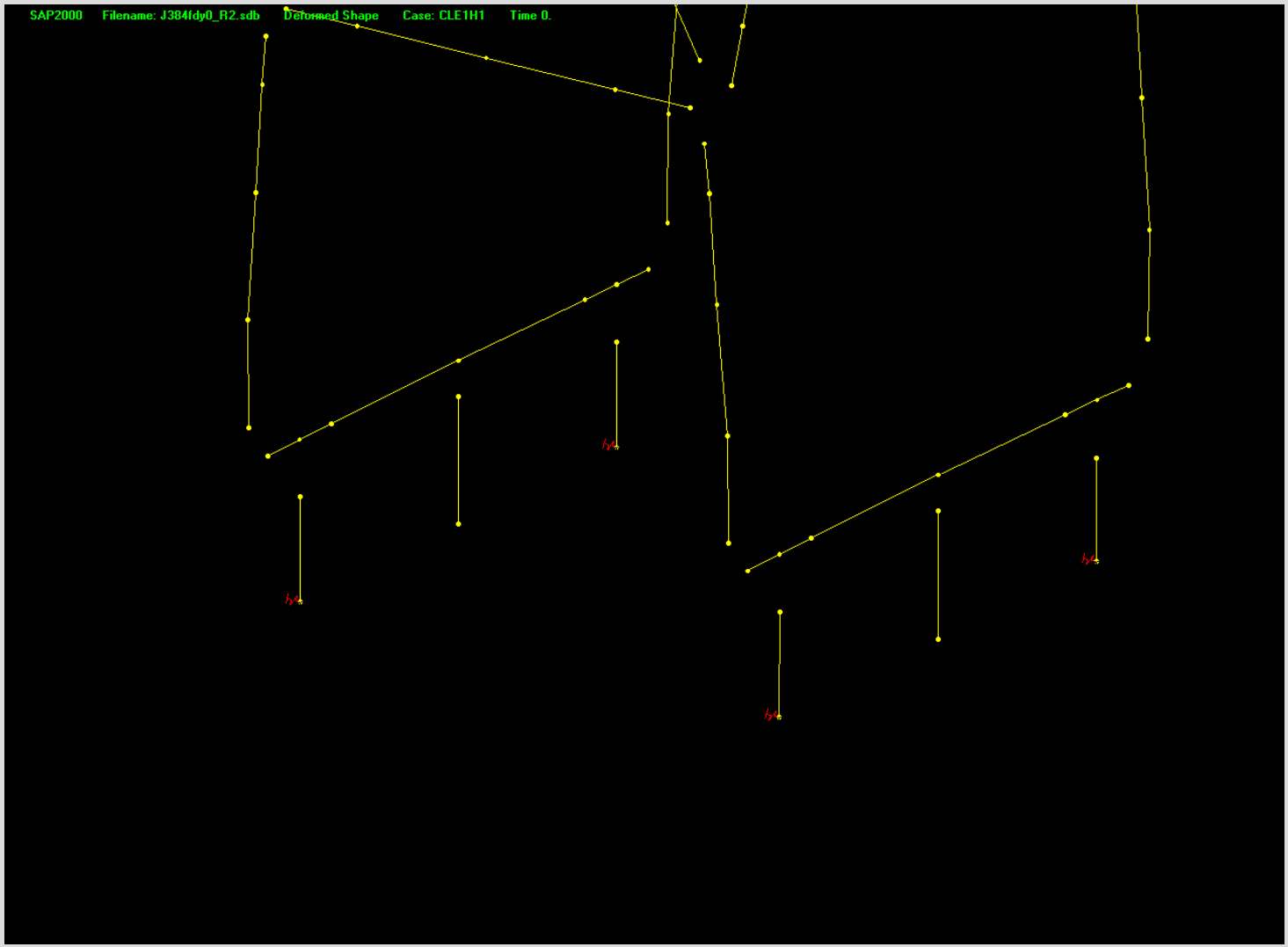
50’ Gage - Close-up



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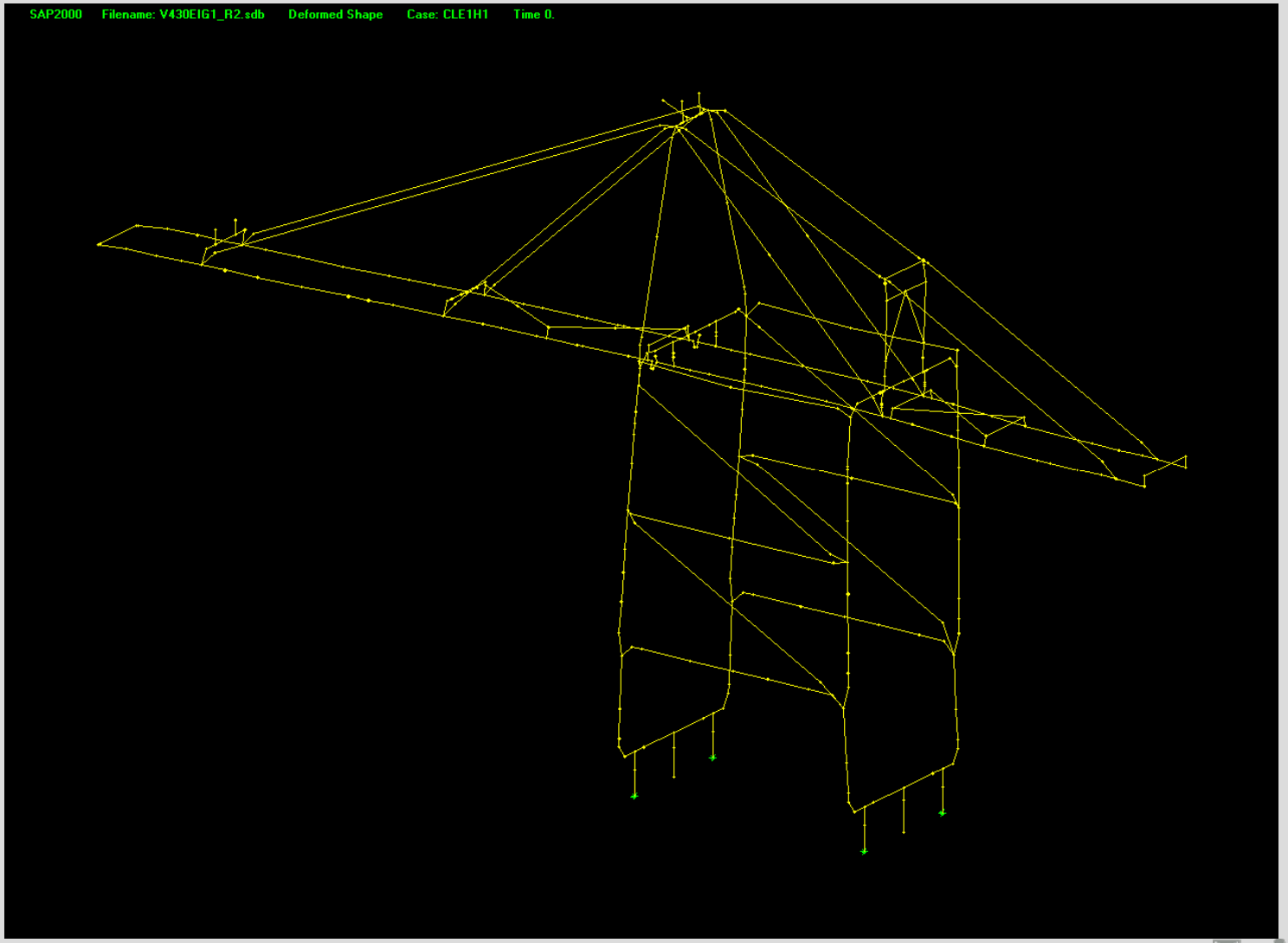
100’ Gage Crane CLE Response



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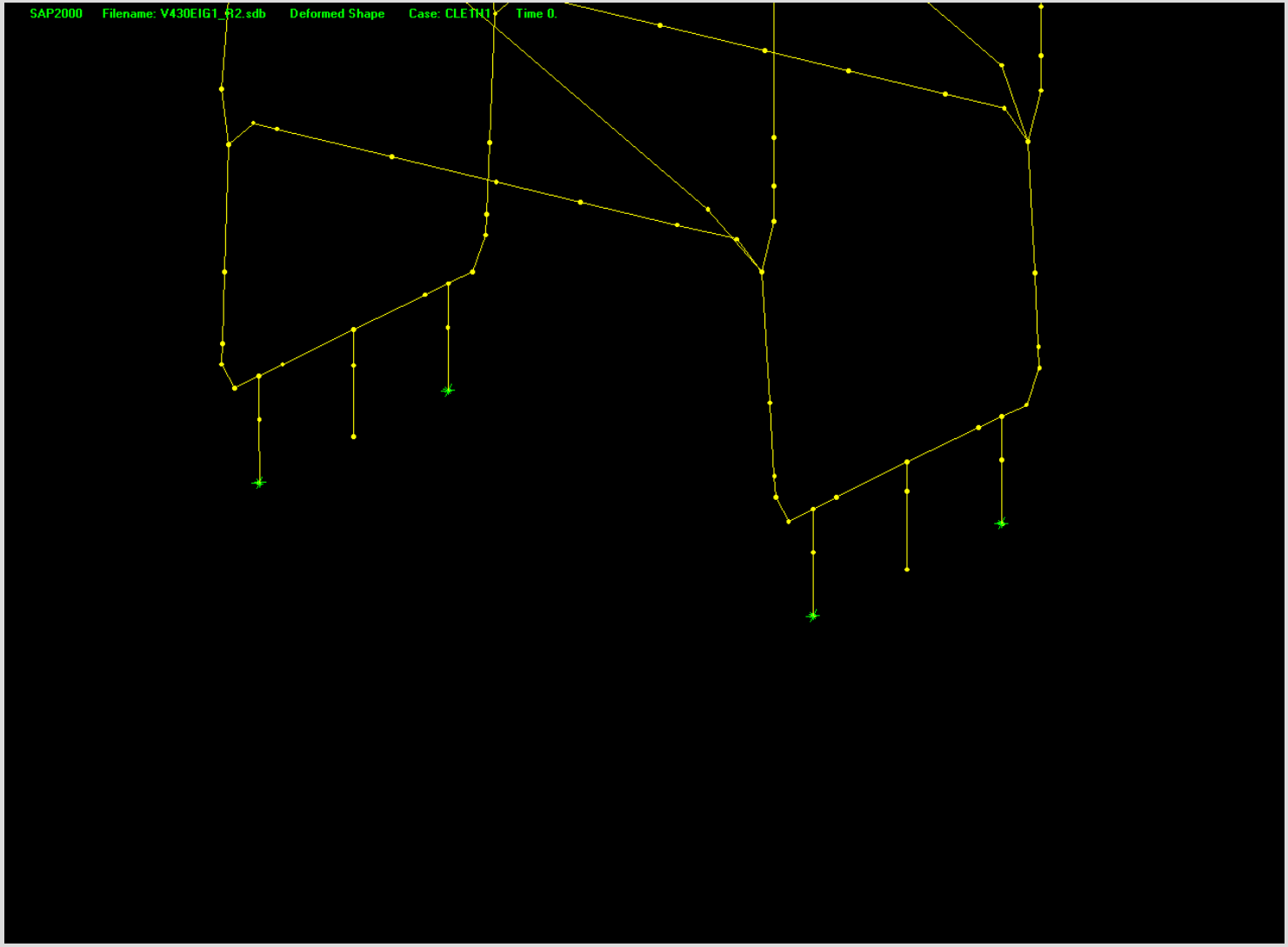
100’ Gage Close-up



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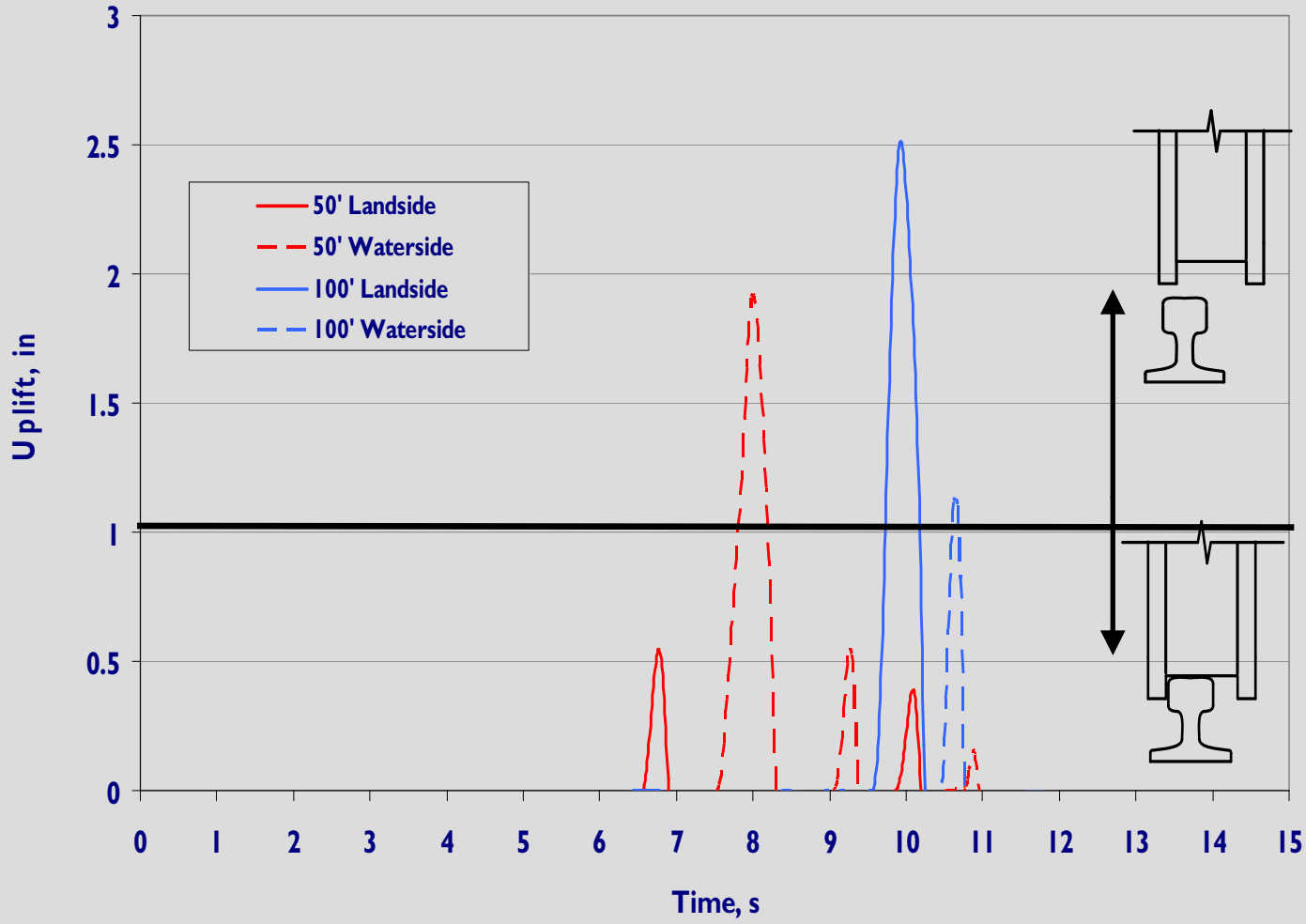
Wheel Uplift



WHEEL DISENGAGES FROM RAIL

WHEEL ENGAGED ON RAIL

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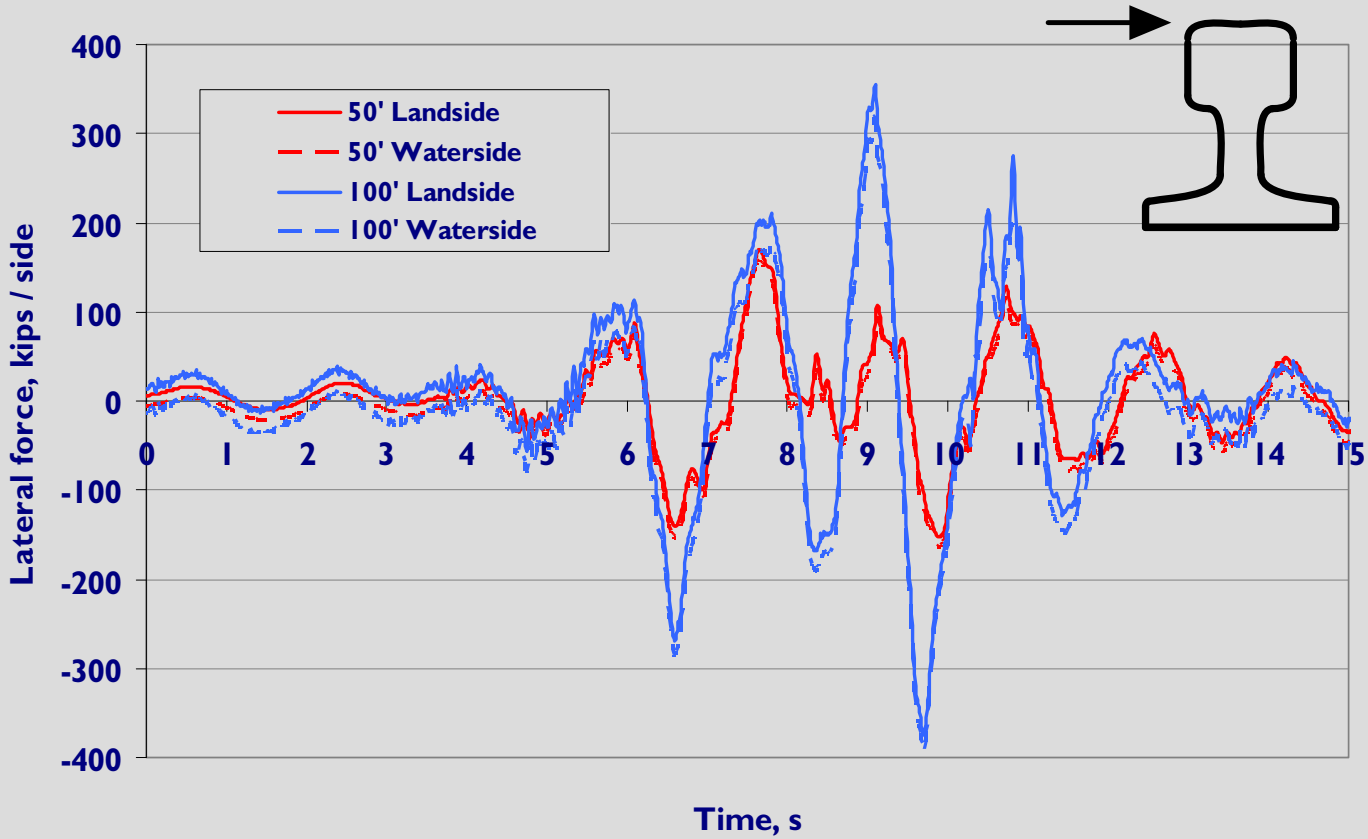
Lateral Force on Rail



Note: Wheels engaged with rail. If one side disengages, the shown forces may be up to double at the engaged wheels.

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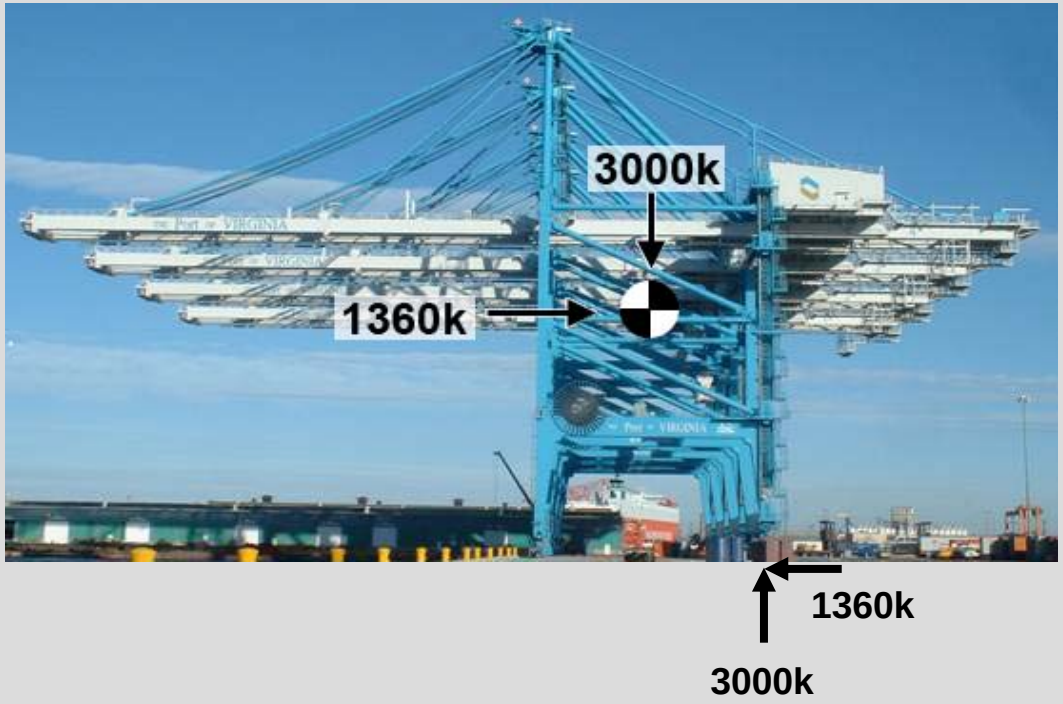
Tipping Forces

Circa 1970



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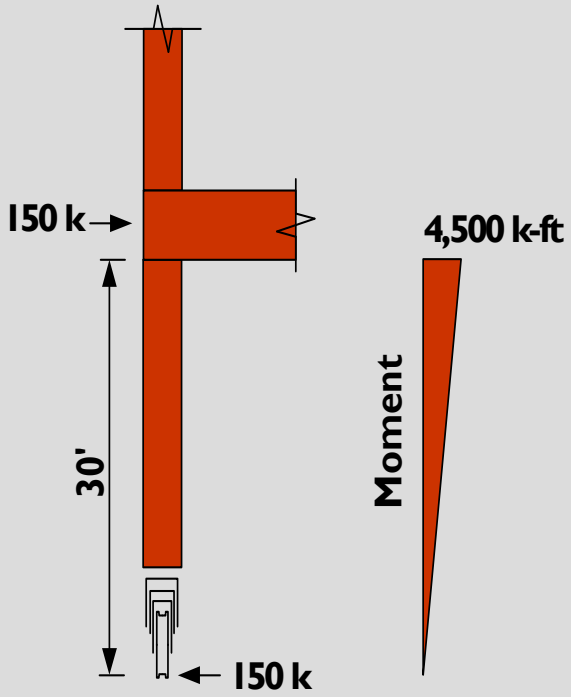
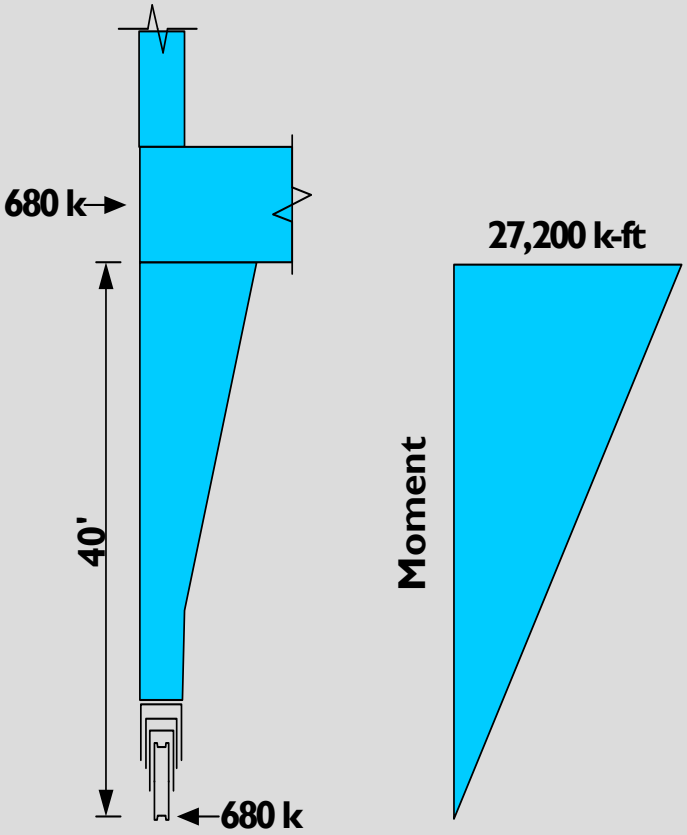
Tipping Leg Moments



Circa 1970



Jumbo

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Recent Liftech Design Criteria Changes

Pre 2006 – Force-based design – elastic response for 0.2g lateral loading

2006 to present – Performance-based design – consistent with current wharf design practices

New Crane Design Criteria

Operating Level Earthquake:

Elastic strains – no damage

Contingency Level Earthquake:

Tipping load – no damage

Ductile yielding – some damage

Isolation – no damage

Reference:

http://www.liftech.net/LiftechDesignNotebook/designcriteria.pdf

Design for Tipping

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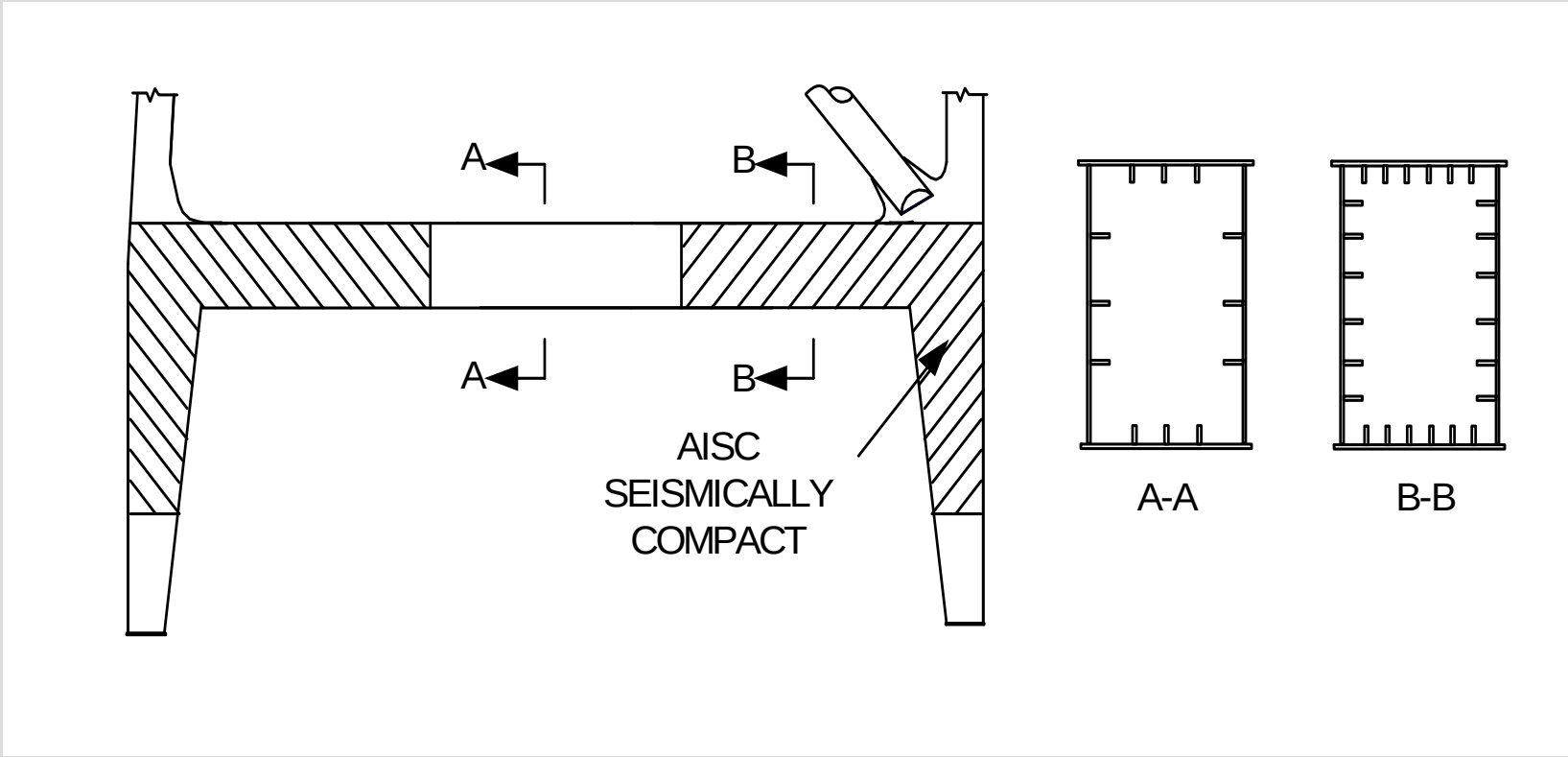
Design for Ductile Yielding



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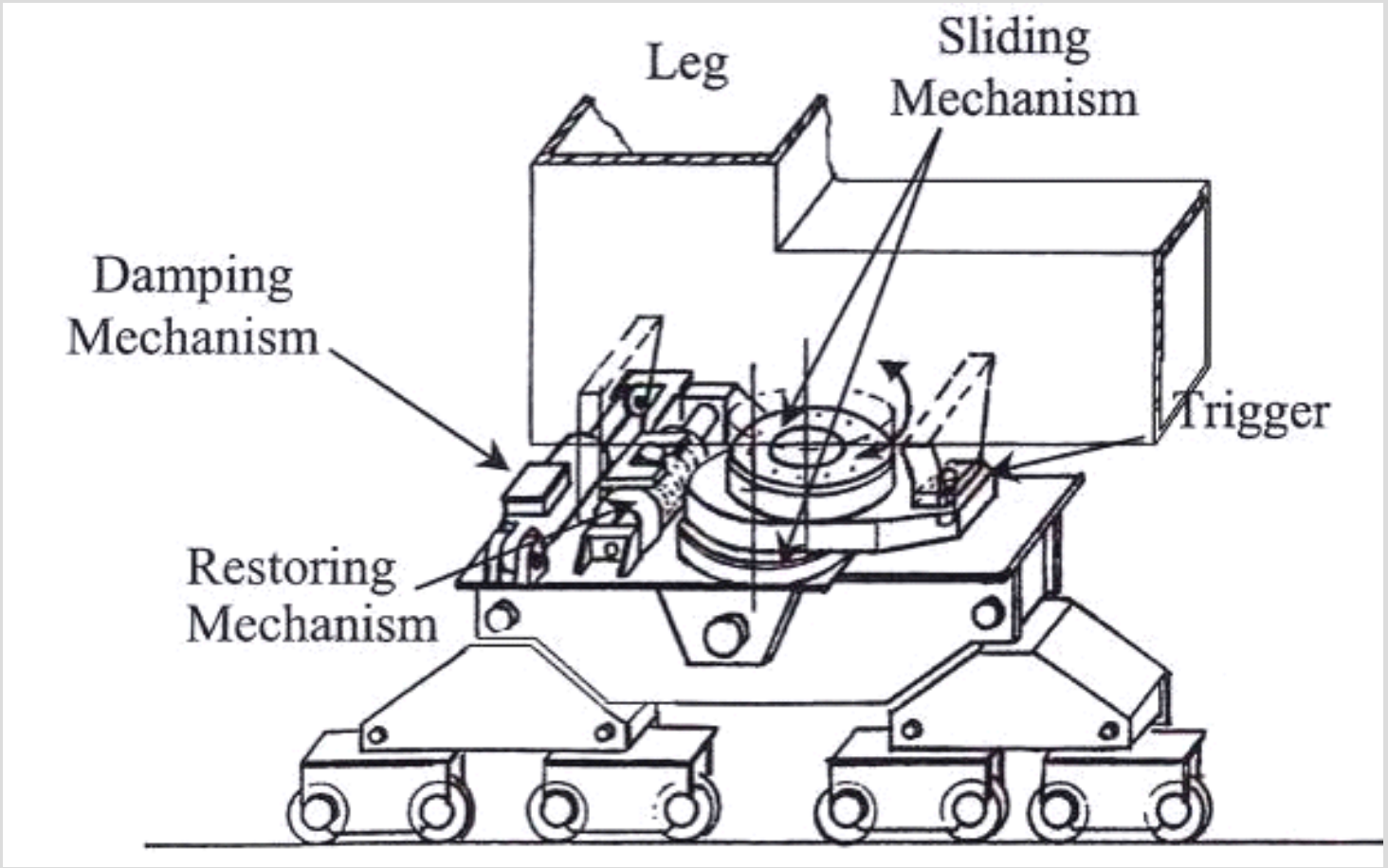
Design For Isolation

Isolation Between Main Equalizer and Sill Beam



Mitsubishi Heavy Industries

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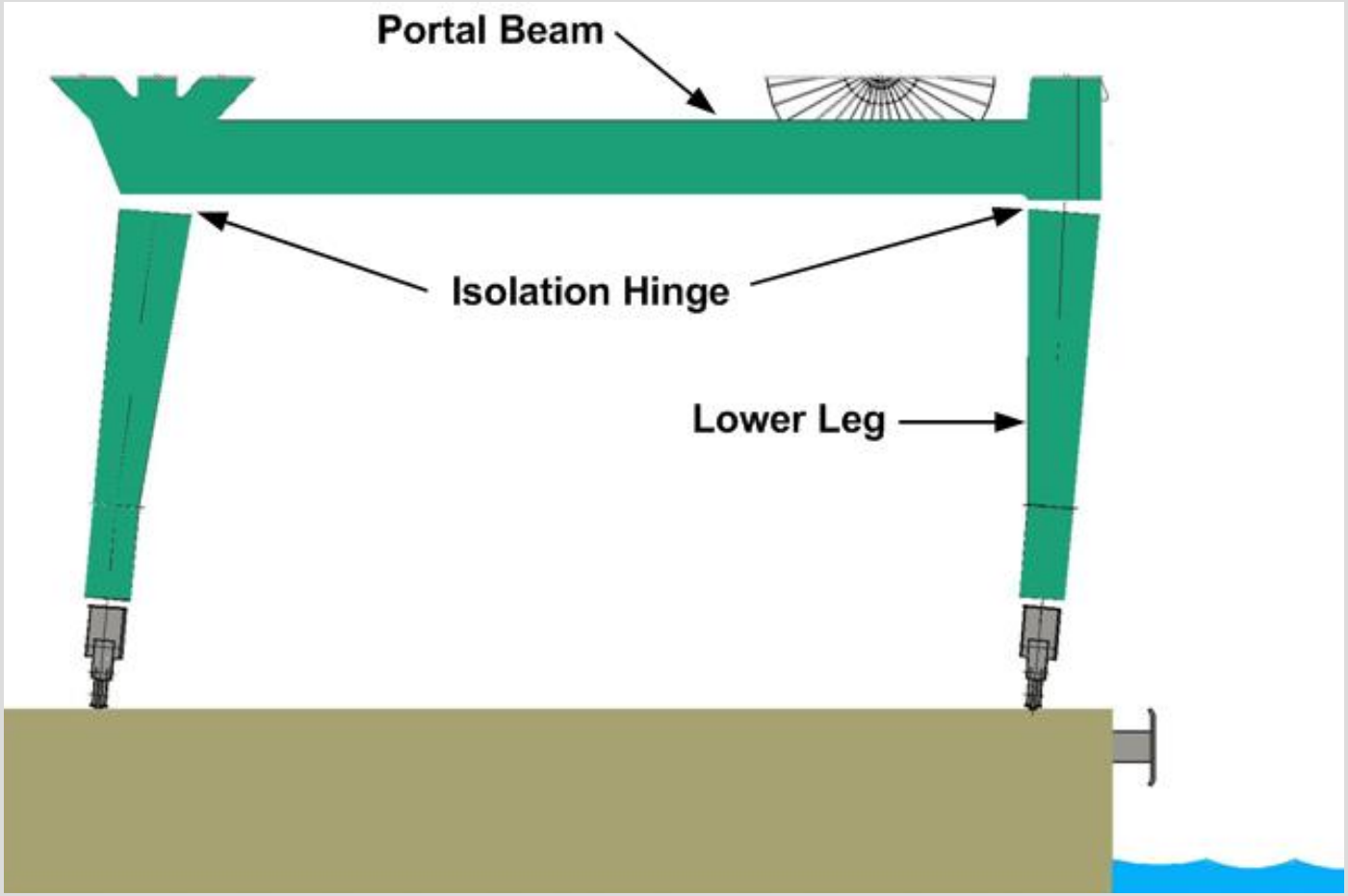
Design For Isolation

Isolation Between Lower Leg and Portal Beam



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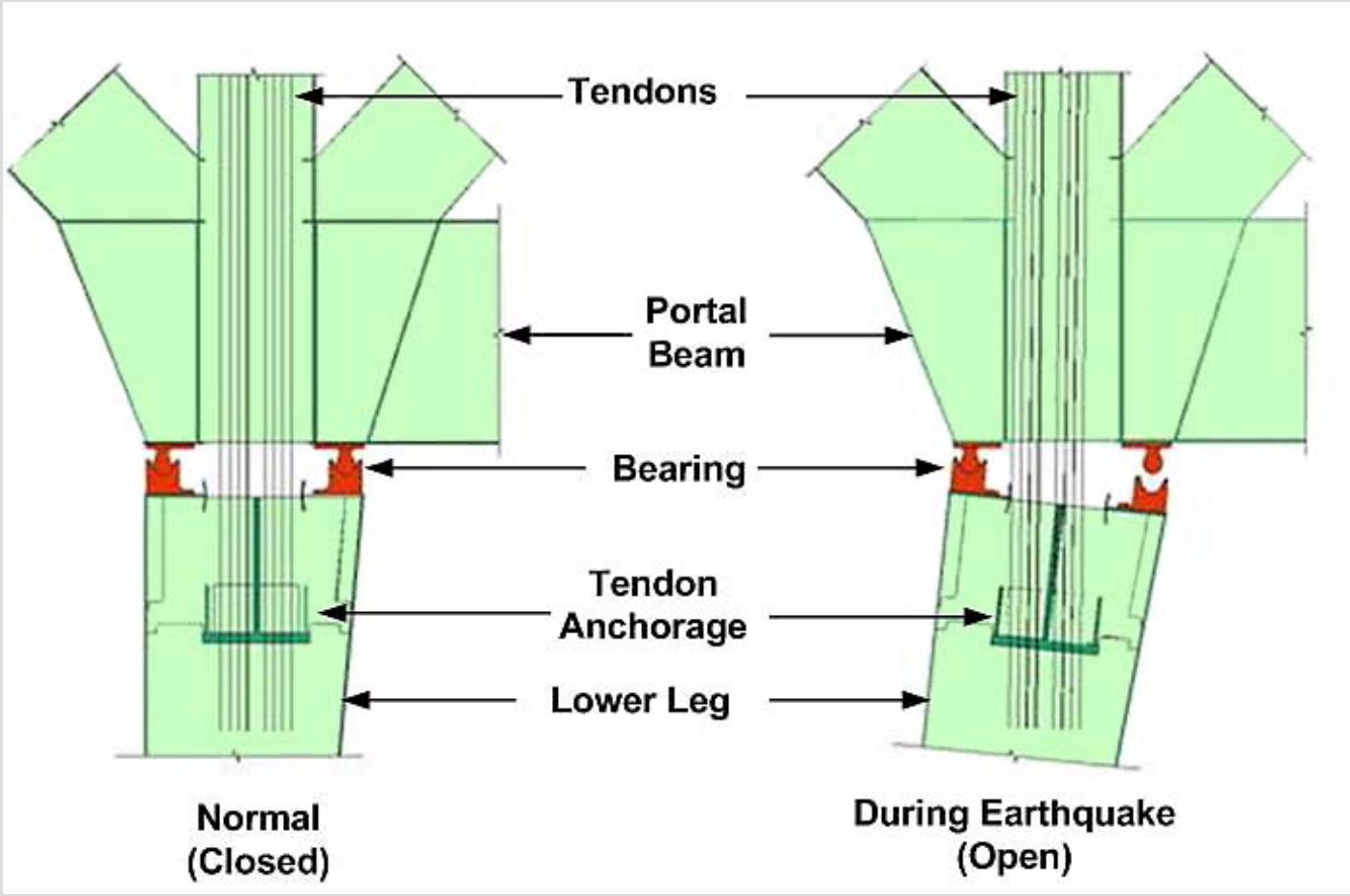
Isolation Detail

Isolation Between Lower Leg and Portal Beam



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What about Existing Cranes?

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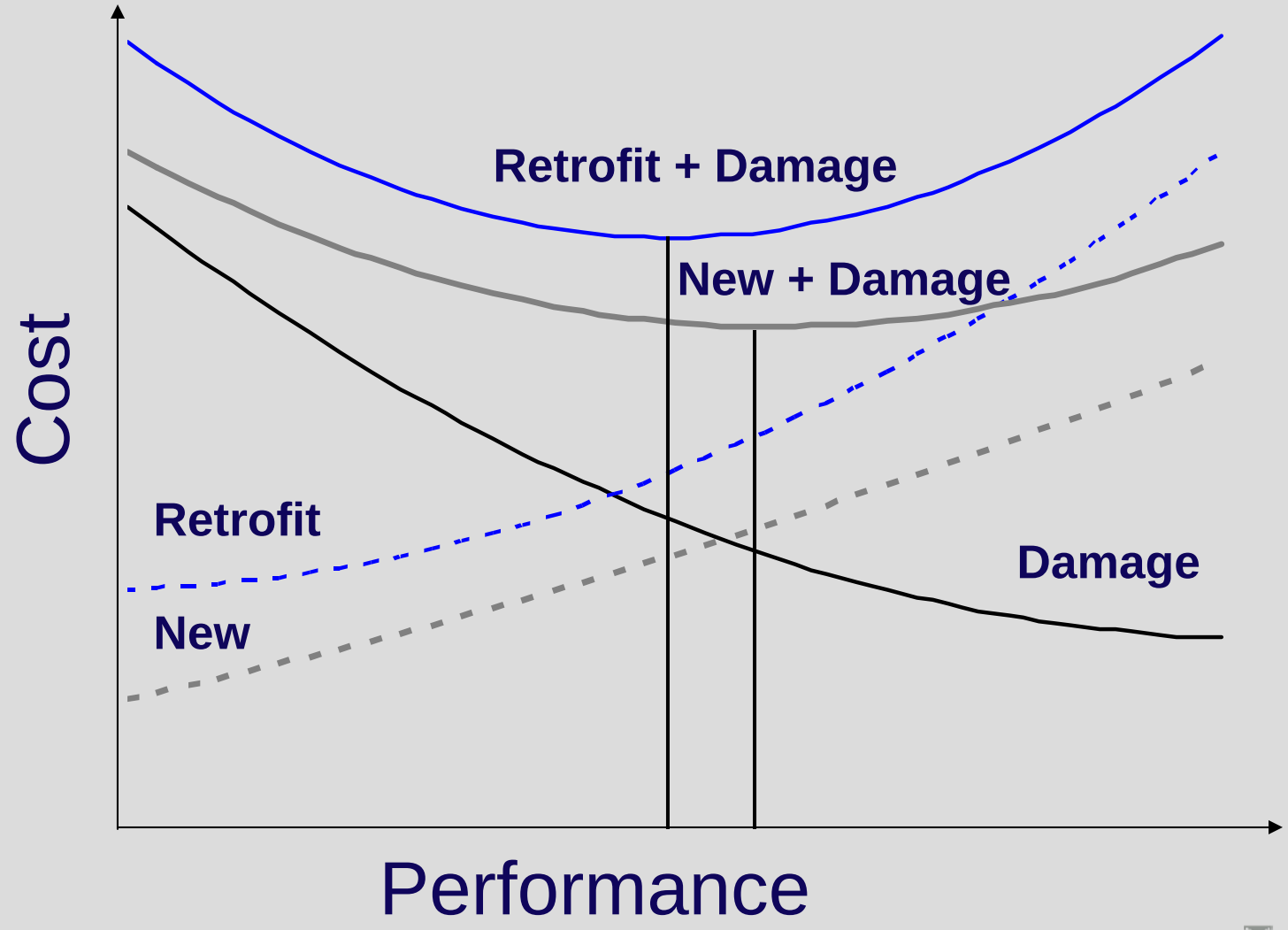
Some Retrofit Questions

1. How will the existing crane perform?
2. Is significant damage acceptable in an operating level earthquake?
3. At what magnitude earthquake is collapse acceptable?
4. Should different criteria be used for different cranes?
5. Should cranes be upgraded when the wharf is upgraded?

Cost vs. Performance
New Construction and Retrofit



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Factors Affecting Seismic Risk

Location – Seismicity

Rail Gage

Ductility of the Portal Frame

Mass

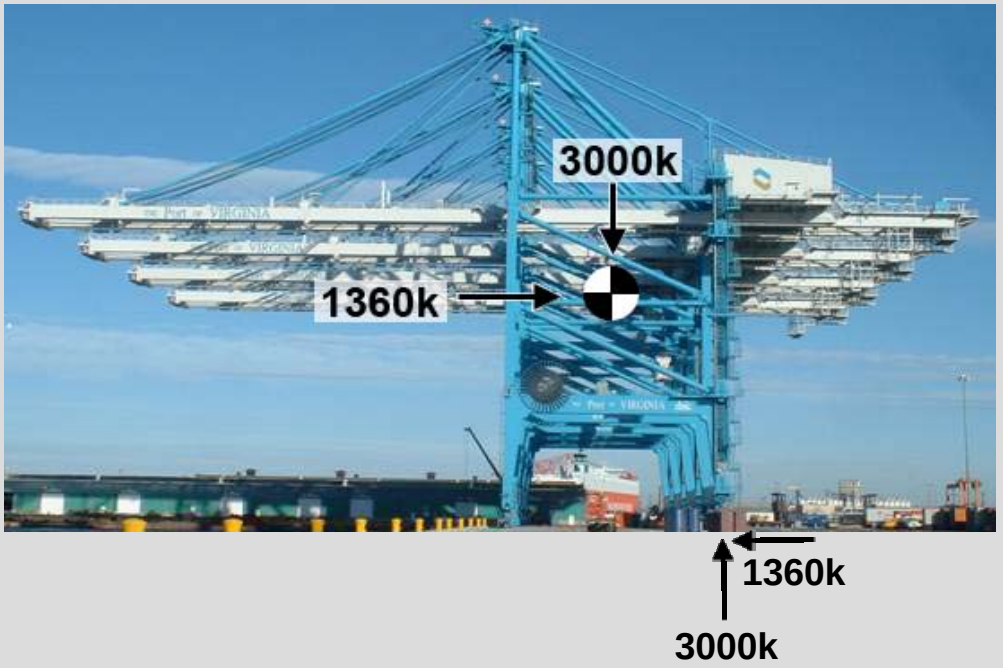
Portal Strength

Portal Stiffness

Trolley Mass

Rail Gage

50’ Gage



100’ Gage or Larger

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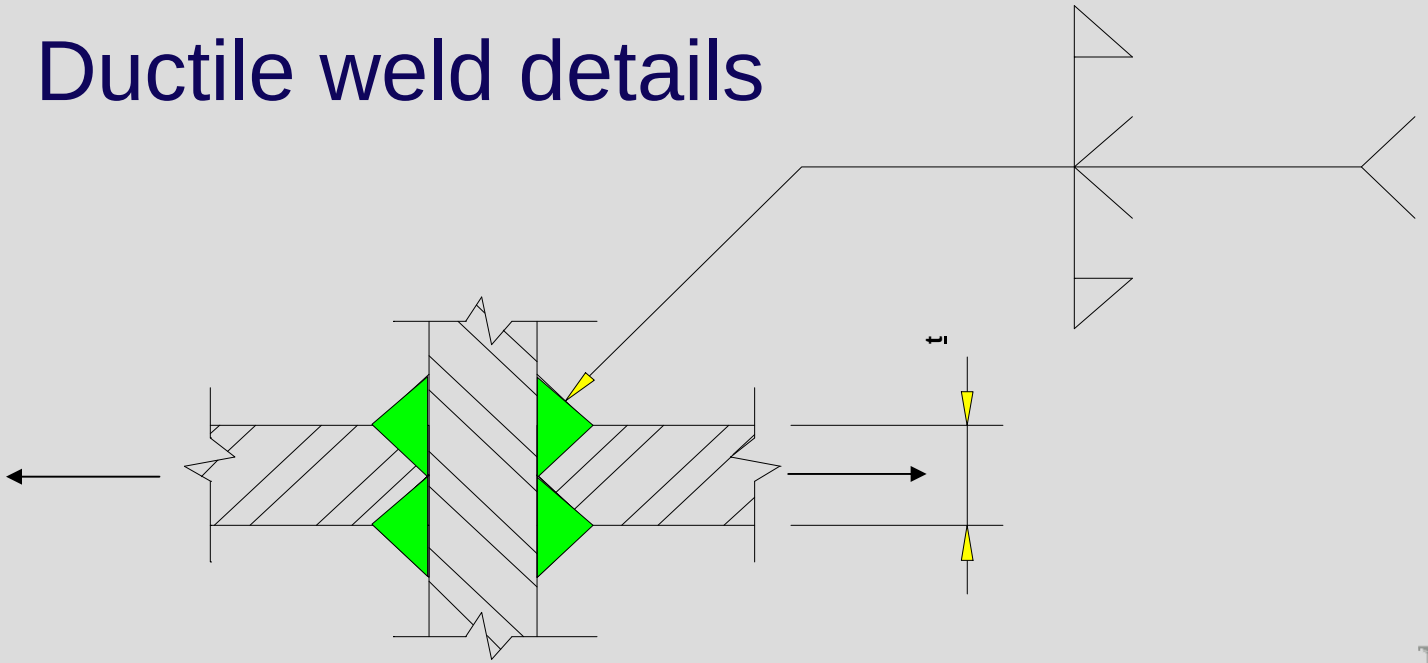
Ductility

Connection strength > member strength

Close stiffener spacing to limit local buckling.

Ductile weld details



FILLET SIZE t/4 BUT AT LEAST AWS MIN.

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Mass, Portal Strength, and Stiffness

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Evaluating Existing Cranes
Suggested Steps

Check if the portal structure can support the tipped crane

Check if the portal structure can deflect laterally 30” without collapse considering secondary effects and multiple load cycles.

Perform time history analysis

Retrofit Options

Option	Pro	Con
Strengthen structure	Reduces probability of damage	May reduce portal clearance or be expensive
Improve ductility and strength by adding stiffeners	Least costly, avoids collapse	Probability of damage unchanged
Add isolation mechanism	No damage	Expensive

Strengthen Portal to Carry Tipped Crane

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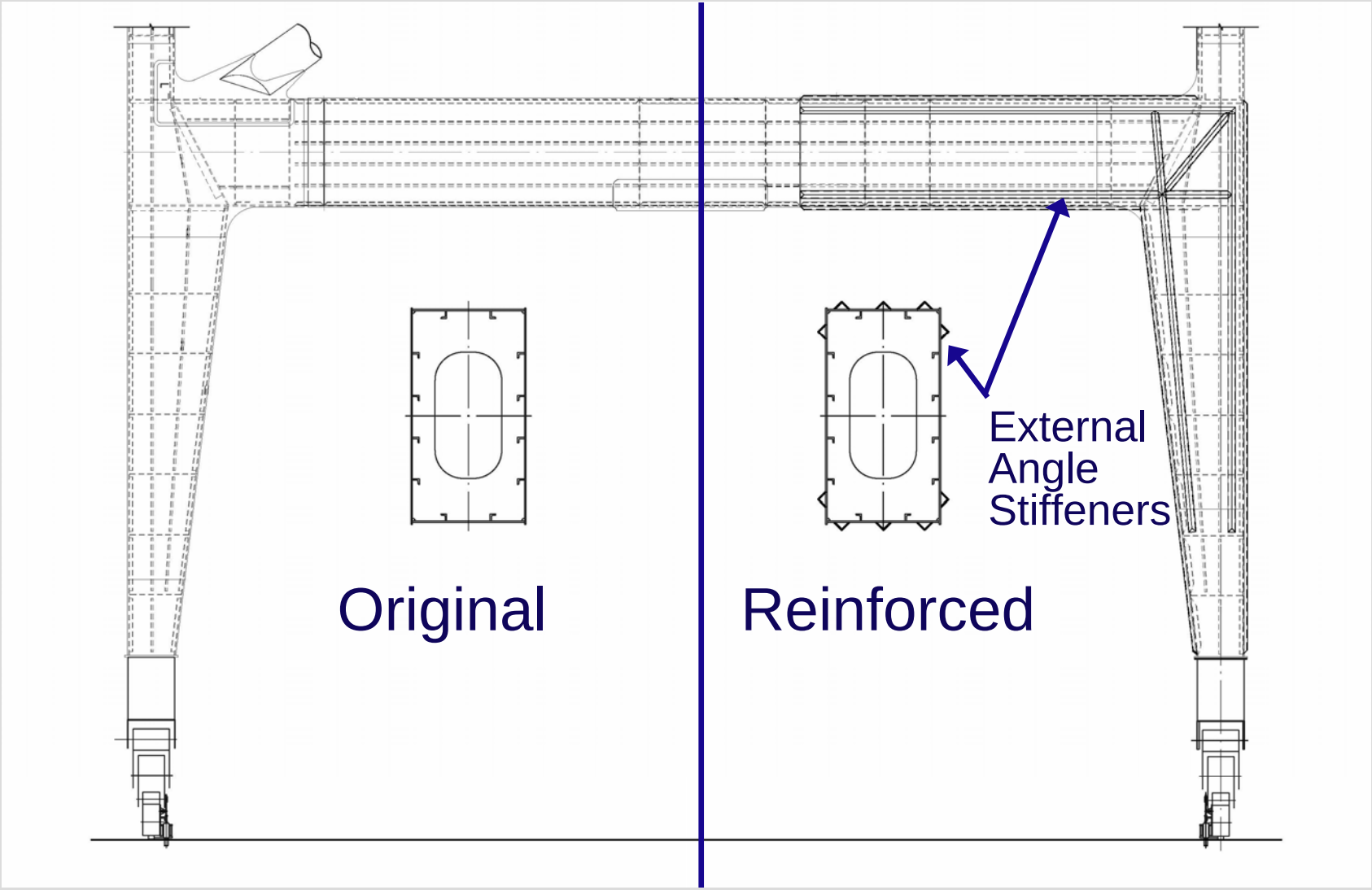
Add Plate Stiffeners to Improve Ductility



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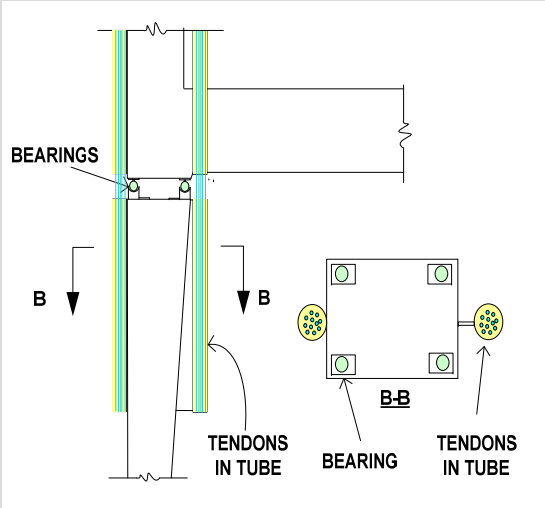
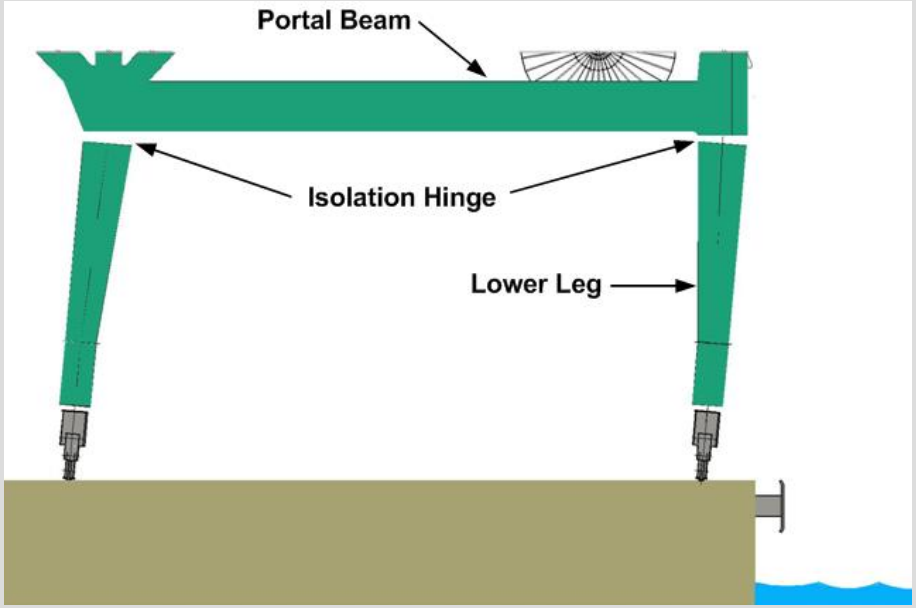
Add Isolation Mechanism

Isolation Between Lower Leg and Portal Beam





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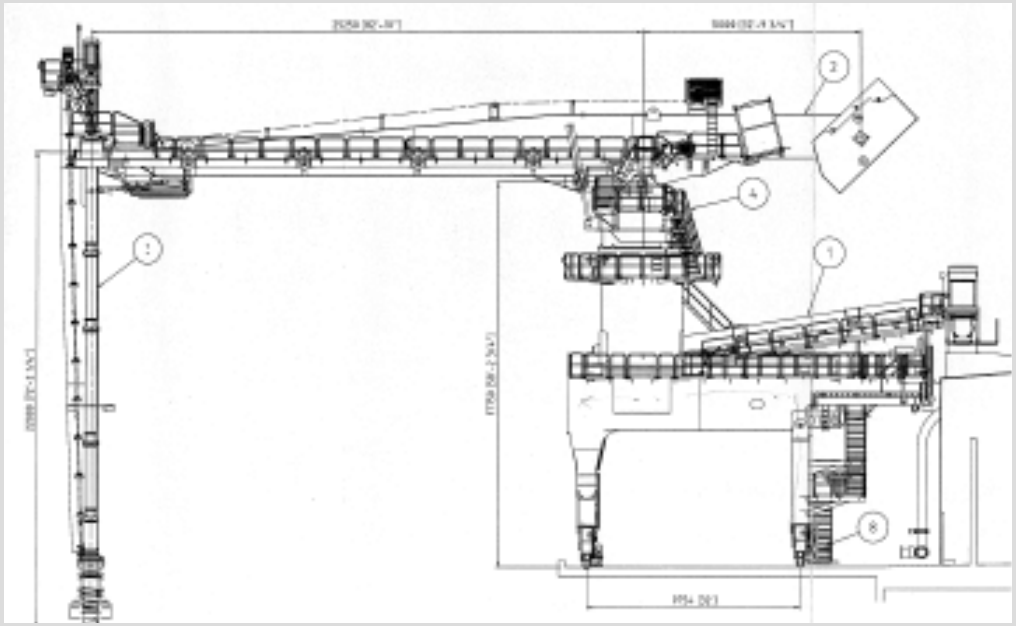
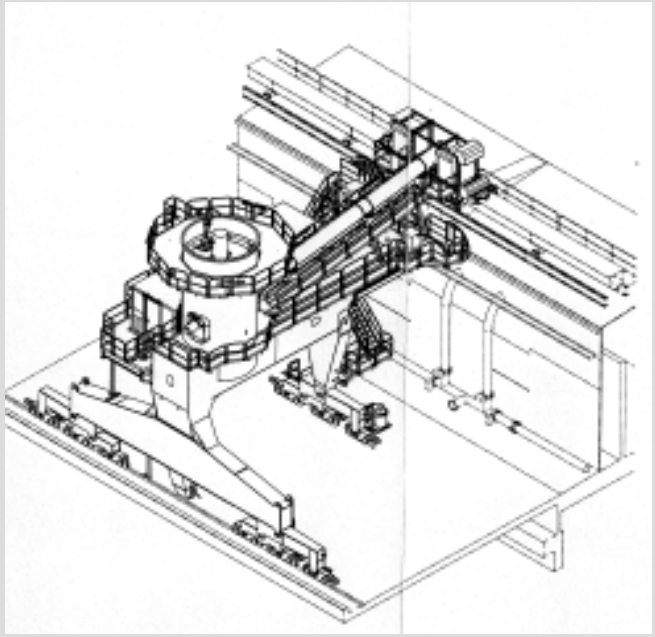
Other Gantry Structures



Bulk Loader



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Loader Damage
Aticu, Peru 2001

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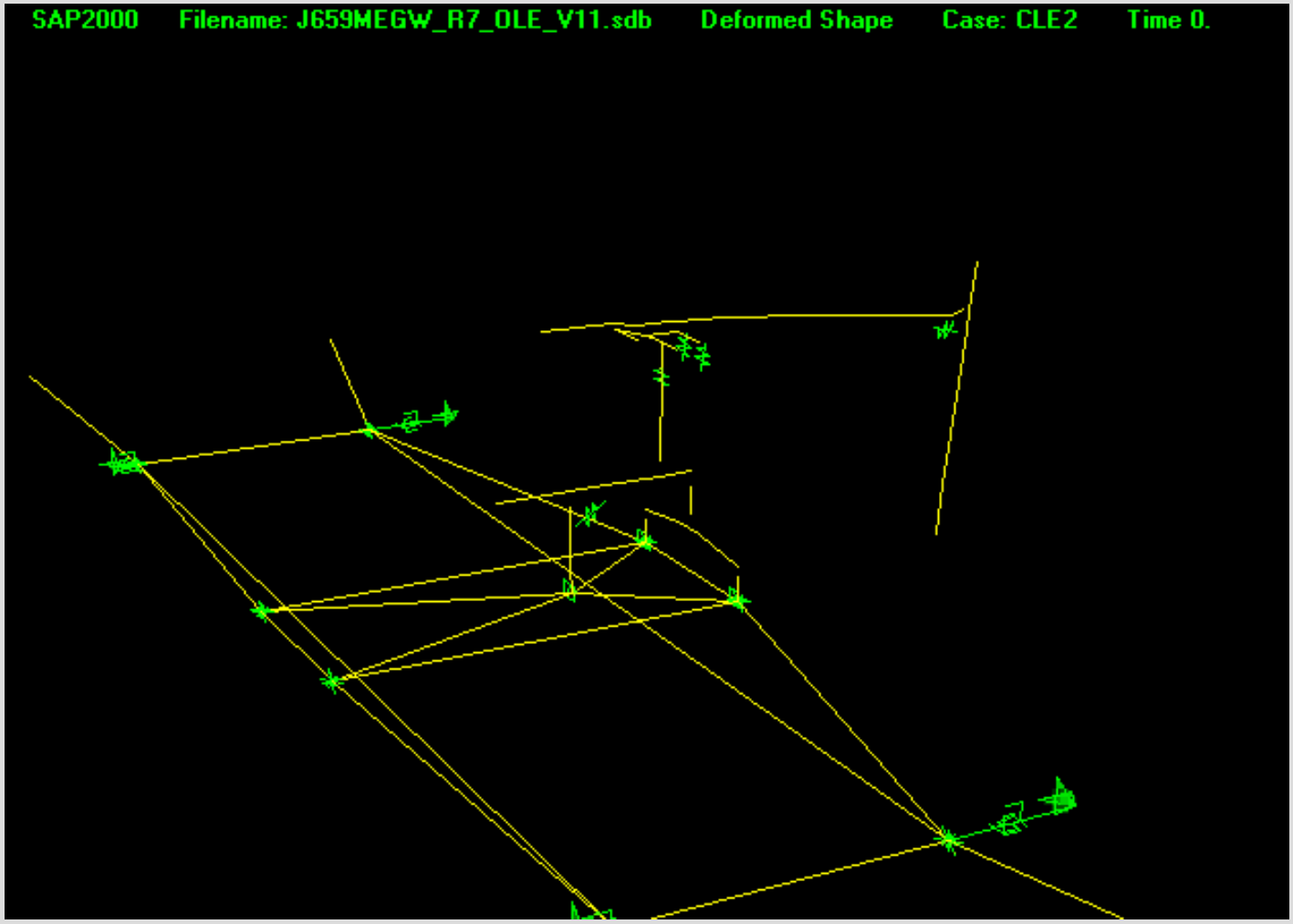
Time History Analysis



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Summary

Be aware of seismic risk.

Use state-of-the-art performance criteria when purchasing new cranes.

It is practical to evaluate seismic risk.

Retrofit is an option and is most practical when making other modifications.

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Thank You

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