# Justify Larger Wheel Load Capacity

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Good afternoon everyone. Thanks for the opportunity to present.

I have been working on the structural engineering of marine structures including wharves and piers for over 26 years.

Have designed about 4 kilometers of pile-supported wharves and over 10 kilometers of STS crane rail girders.

Have reviewed dozens of wharf structures and girder systems.

Have designed and reviewed over 100 STS crane designs including new cranes, modifications, and repair.

Participate in the ASCE 61 committee which is updating a wharf seismic design standard.

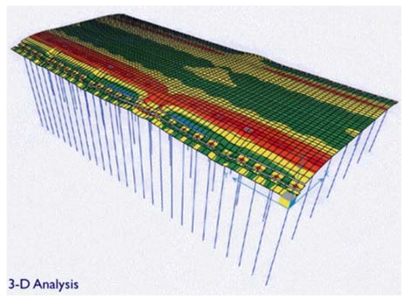
Arun has worked on the structural engineering of marine structures for over 50 years. Arun managed the Felixstowe project that I will talk about later.

# Background

Larger cranes mean larger wheel loads

Upgrading rail girders is expensive

Justifying larger girder capacity without upgrades is often practical



3-D Analysis

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The background for this presentation is the increasing demand on wharves due to the increasing size of cranes.

Modifications to the crane rail girder system can be very expensive.

Existing girder systems often have more capacity than they are rated for due to one or more of the following:

1. how they were designed, for example, conventional analysis;
2. uncertainty in soil capacity and use of conservative criteria;
3. soil strength typically increases with time;
4. overly conservative loading criteria;
5. typically the design is for more than the specified capacity.

# Methods

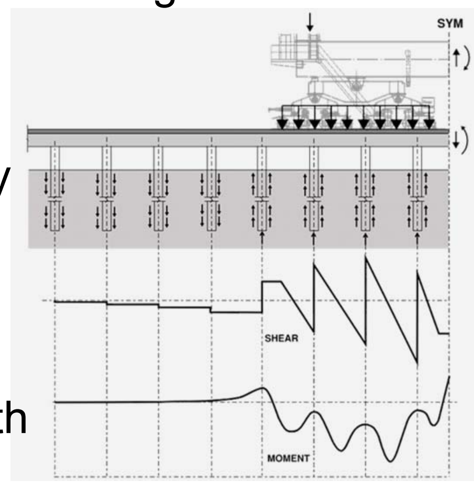
Method(s) depend on controlling factor

Pile structure capacity

Soil capacity

Girder shear strength

Girder flexural strength

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What methods are used to justify increased rail girder capacity depends on what controls its capacity.

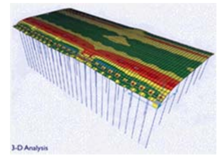
The pile structure may control; however, this is not common. This is more likely with longer unbraced waterside piles.

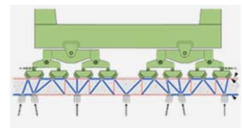
The soil supporting the pile can control; this is common.

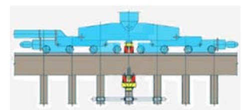
The girder structure can be controlled by shear strength, which is also common or flexural strength.

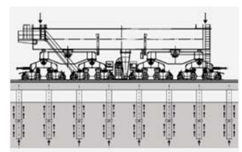
# Methods

- Refined structural analysis
  - 2D or 3D finite element analysis
  - Strut-and-Tie Model (STM) analysis
- Analysis of pile driving records
- Load testing
  - Pile load test
  - Rail girder load test











Finite element analyses will provide a more accurate estimate of the forces and moments in the structure. A 3D analysis will account for contributions from a wharf deck and transverse deck beams.

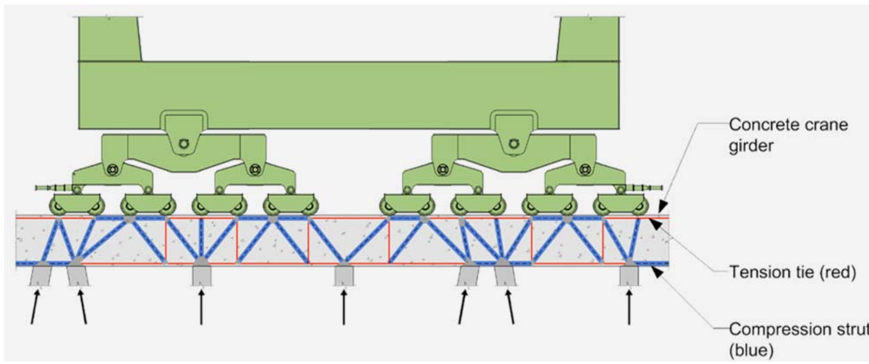
Strut-and-tie analyses are a nonconventional method of analyzing a girder system and are worthwhile when shear strength controls for infrequent loads, e.g., overload and storm events.

When soil strength controls, if pile driving records are available or if select piles are exposed and driven a little farther with an impact hammer, geotechnical analysis of the driving conditions often can justify additional capacity.

Load testing can also be practical; in particular, if information is not readily available for the above approaches, if the above methods require significant effort, if there is reasonable confidence in the structure to be tested, and if testing conditions are reasonable.

Load testing can be time consuming and disrupt operations.

# Strut-and-Tie Model (STM)

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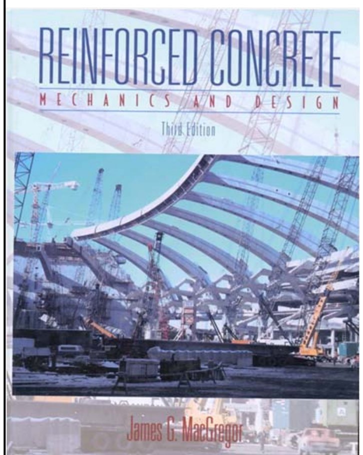
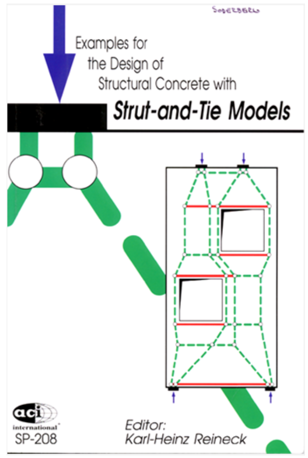
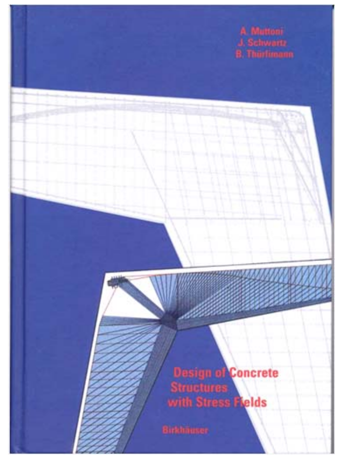
The strut-and-tie method can often justify increased shear strength over conventional beam shear strength analysis. With this method, the girder is mathematically converted into a truss with chords, verticals, and diagonals, and the strength of those elements are calculated.

# STM References Worth Reading

MacGregor | Reineck | Muttoni



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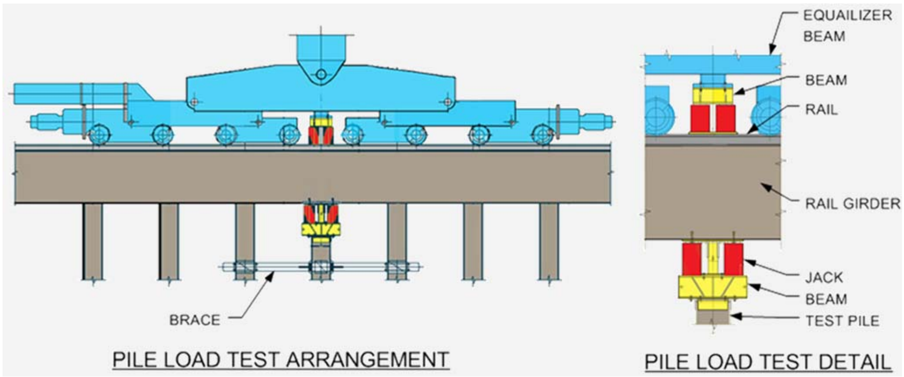
These are strut-and-tie method references that we recommend. Strut-and-tie is a well-established method used in Europe, the US, and elsewhere.

# Pile Load Test

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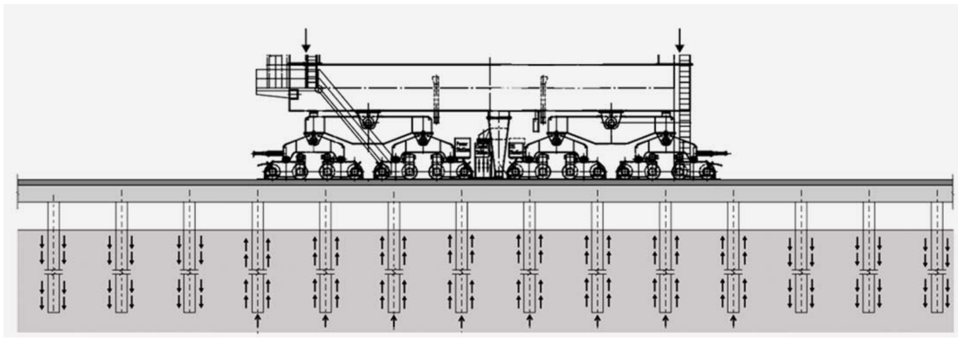
We have performed pile load tests where piles have been cut, braced, and jacks have applied load to the cut pile using the girder, crane above, and adjacent piling for the necessary reaction.

# Girder Load Test



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We have performed girder load tests where the entire girder system, girder and piling, are loaded.

This approach, if practical, is favorable in that the entire load path can be tested and confirmed.

## Results

Typically, it is practical to justify additional capacity.

Liftech has performed about 20 girder capacity studies.

Justified increased capacity in about 90% of the studies, sometimes very large increase.

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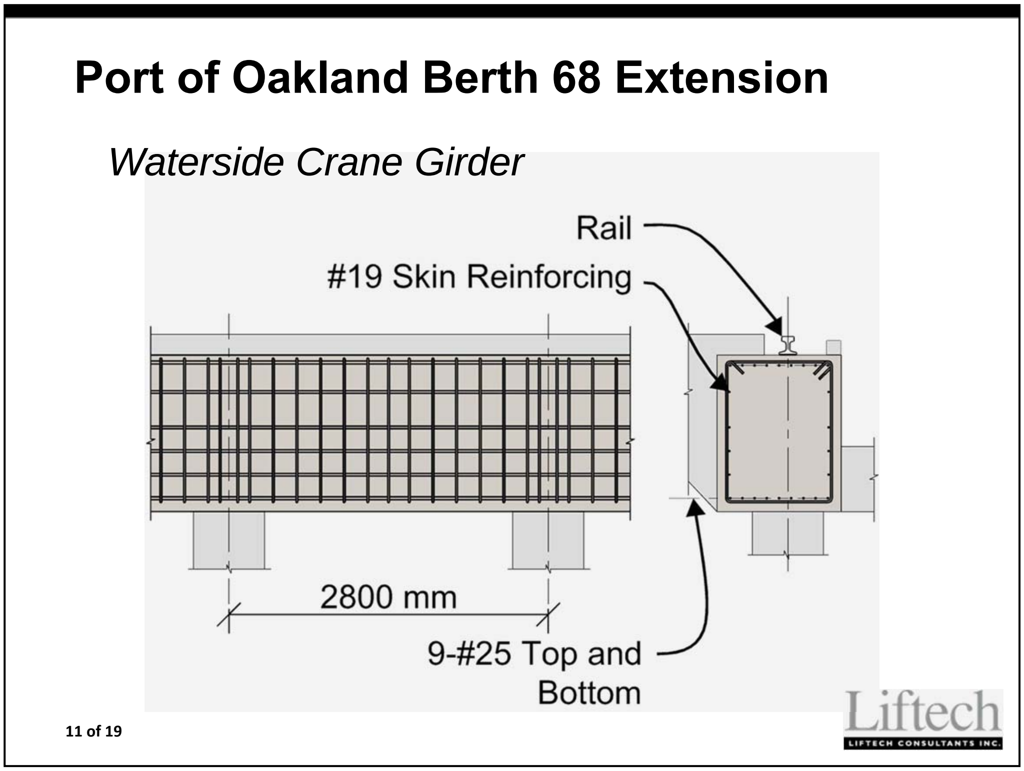
It is typically practical to justify increased crane rail girder capacity. Liftech has performed about 20 such studies and we have justified increased capacity in about 90% of them.

## Case Studies – Strut-and-Tie

**Port of Oakland Berth 68 – USA**

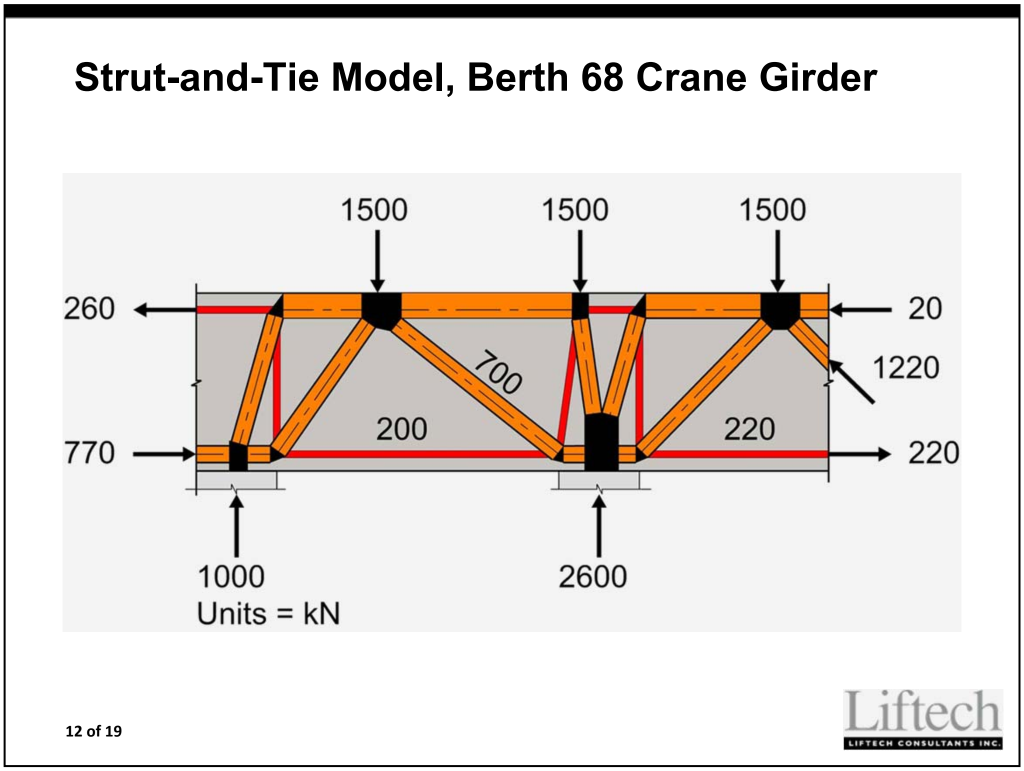
**Virginia Port Authority**
**Portsmouth Marine Terminal - USA**

Now I will present two projects that involved using the strut-and-tie method, one at the Port of Oakland and one at the Portsmouth Marine Terminal in Virginia.




In both cases, the girder shear capacity controlled.

This slide presents some properties of the Berth 68 waterside crane girder.




This slide presents a portion of the strut-and-tie analysis performed for that girder.

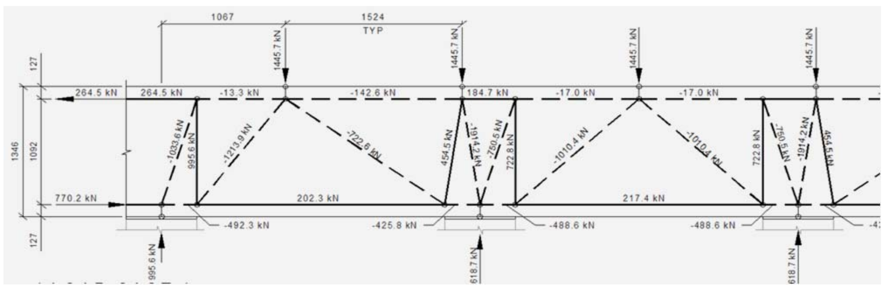
The thick orange lines represent compression struts carried by the concrete and the thinner red lines are tension ties carried by the reinforcing.

# Capacity Increase with STM

Oakland: 50%

Virginia

- End spans: 0%
- Interior spans about: 25%

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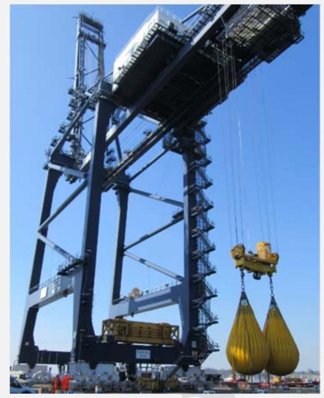
This slide presents a summary of the results for the two projects. In Oakland, the rated capacity was increased by 50%. For the Portsmouth project, we were unable to justify additional capacity in the end spans of the girder but justified an increase in capacity of 25% for the typical spans, or most of the girder system.

# Case Studies
# Girder Load Test

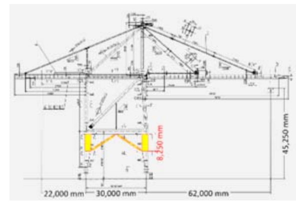
## Felixstowe Trinity III



The last case study I will present is for the Felixstowe Trinity III wharf where load testing was employed at the landside girder.

# Felixstowe Trinity III Rail Girders

*Project – Feasibility Study to Increase Lift Height of Ten Quay Cranes by 8 m*




Evaluation Process
- Prepare concept design, estimate weight
- Estimate crane wheel loads
- Analyze rail girder system strength
  - Conventional analysis
  - Strut-and-tie model analysis
- Calculate revised capacity
- Compare crane loads vs. revised capacity

Finding
- Landside crane loads still exceeded revised capacity

Next Step – Girder Load Testing

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For this project, Felixstowe wanted to raise existing cranes by about 8 m.

Liftech developed a concept raise design and calculated wheel loads.

We analyzed the landside girder system for the larger loads and determined the revised capacity was deficient.

Load testing of the entire girder system using the crane was most practical to justify the required capacity.

## Load Test per ACI 318-05: Chapter 27

*Test Load = 1.3 *(Crane Load + Rail Girder Weight)*

Apply test load in four increments

Maintain full load for 24 hours

Check girder vertical deflections

Dmax = deflection under full test load

Dmin = deflection under no load after 24 hours

Acceptance criteria

Dmin ≤ 0.25 Dmax

No cracking or spalling

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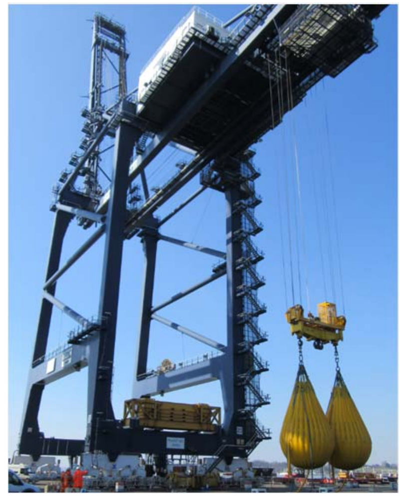
A girder load test program was developed in accordance with American Concrete Institute guidelines. Test loads were applied at four levels of loading. Loads were applied for 24 hours. Acceptance was based on maximum deflections, residual deflections, and if there was residual cracking or spalling.

# Felixstowe Trinity III Load Test

100 t ballast on landside sill beam
95 t water ballast under cargo beam

Total test load on rail – 61 t/m



**Result = Adequate Capacity**

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The load test of the landside rail involved installing 100 t of test ballast on the landside sill beam of the crane and 95 t of water ballast lifted by the cargo beam at the backreach position, providing a total of 61 t/m test loading on the rail.

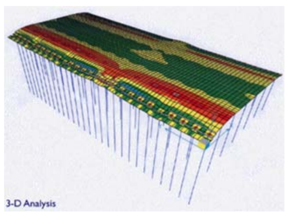
The test was practical for this condition and justified the capacity needed for the larger cranes that were required.

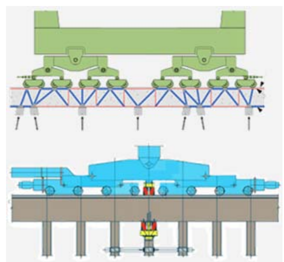
Since then, Felixstowe modified their cranes and the girder system has performed well.

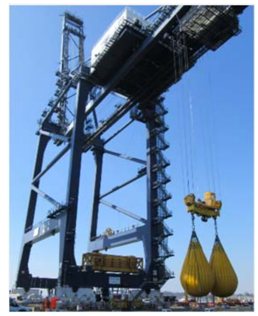
# Conclusion

Your crane rail girders may have more capacity than they are rated for.

Justifying larger girder capacity without upgrades is often practical.







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