Your wharf may be stronger than you think

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Over time, vessel and crane sizes have increased dramatically. This continues as the maritime industry is experiencing another wave of larger vessels and cranes. The Panama Canal expansion and Triple-E class vessels are already impacting container terminals. Many terminals now face the challenge of accommodating larger vessels and cranes.

Often wharf owners find that they have insufficient crane girder rated capacity and only consider strengthening options. Before proceeding with expensive strengthening, owners should study the capacity of their existing crane girders. For a variety of reasons, crane girders are often stronger than their rated capacity due to early design methods and tools, cautious designers, or both. Using modern methods, engineers can often justify increased girder rated capacities without expensive strengthening upgrades.

Looking at methods of analysis

Various modern engineering methods are available to evaluate girder capacities. The most appropriate method depends on the nature of the structure, what controls the strength of the structure, and what capacity must be justified. Three of the more significant methods are presented here.

Three dimensional finite element analysis

Finite element analysis (FEA) is a relatively modern analysis tool not commonly used in design more than 30 years ago. Compared to earlier analysis methods, FEA provides a more accurate calculation of forces in the wharf structure, in particular when the structure supports the crane loading in multiple ways, eg. if the crane girders are integrated into a deck structure or have transverse beams. In these situations, a three dimensional FEA can often justify additional capacity.

Strut-and-tie model analysis

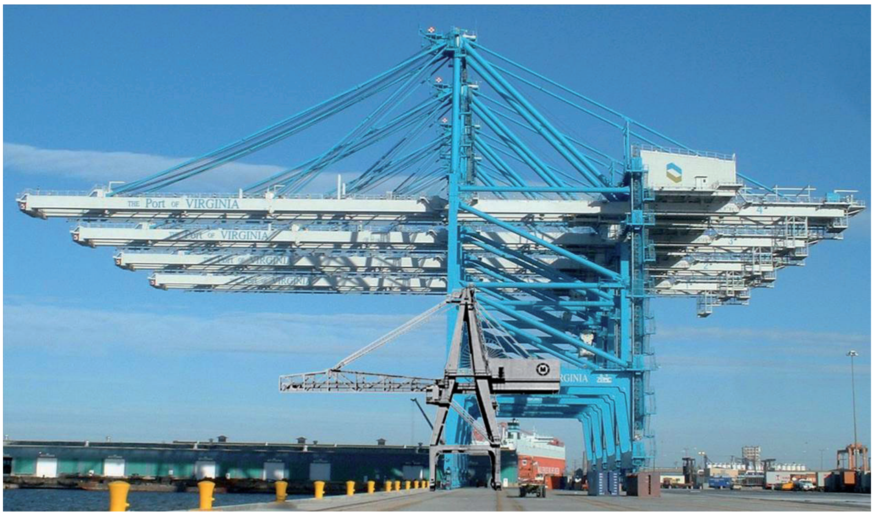
The strut-and-tie analysis method has only recently been integrated into US design codes by AASHTO in 1989 and ACI in 2002. This method involves considering the girder structure as a truss comprised of compression struts (concrete) and tension ties (steel reinforcing).

This method is most suitable when shear capacity controls the girder strength and when the controlling load is infrequent or extreme, where temporary or limited cracking can be tolerated. This method typically justifies much larger shear capacities than traditional methods.

Pile load testing

If the capacity of the wharf is limited by the estimated soil strength, there are several techniques that can be used to justify additional capacity. The easiest and initial method is to evaluate the pile driving data using modern methods. If driving data is not available or if more capacity must be justified, tests can be performed.

Two types of pile tests are most common, pile dynamic analysis (PDA) testing and load tests. PDA is used to estimate capacity by striking a pile with a hammer sending a compression wave down the pile, and measuring the pile response, including the



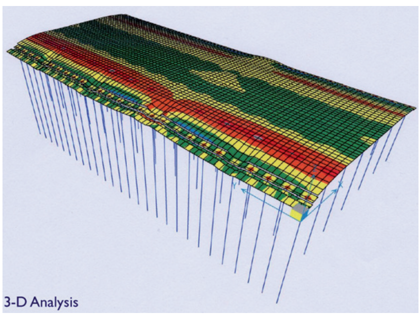


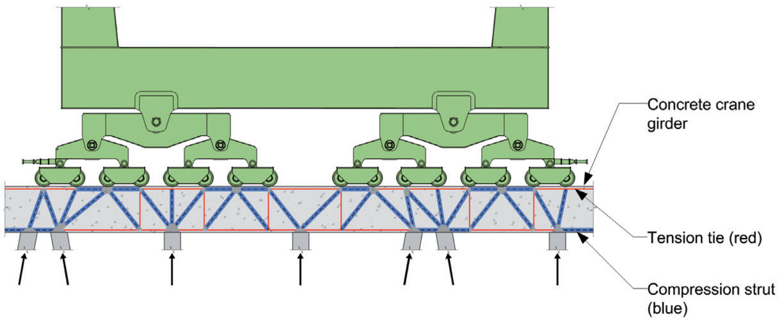
Figure 1(top): Comparison of first container crane and modern container crane sizes; Figure 2 (right): Three dimensional crane girder finite element analysis results.

strains and accelerations at the top of the pile. An analytical analysis is made of the test data to estimate the pile capacity. The PDA provides a more accurate estimate of pile capacity than from pile driving data. Additionally, soil 'sets up' over time, providing more strength than during installation.

Piles can also be loaded to determine strengths. Load tests typically involve applying a load on the pile using one or more hydraulic jacks that push against the bottom of the girder and typically use the weight of the crane to help resist the loading.

In conclusion

Larger wharf capacities can be justified using modern engineering methods. The engineering cost has been a fraction of the cost of strengthening. An additional benefit is that there is no impact to terminal operations. If you need larger crane girder capacities, before proceeding with expensive strengthening work, try justifying additional capacity using modern engineering methods.



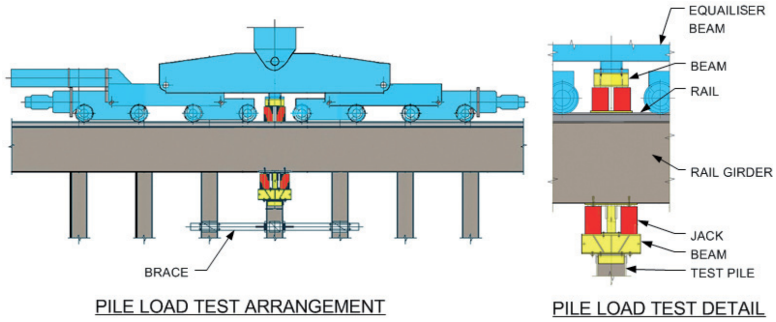


Figure 3 (top): Strut-and-tie model analysis;
Figure 4 (bottom). Pile load test arrangement and loading detail.

About the authors

Erik Soderberg is a Liftech structural engineer and vice president with nearly 20 years on the design, review, modification, and repair of a variety of structures, including over two dozen wharves, over 100 container cranes, and over a dozen bulk loader structures. Other structures include crane lift and transfer systems, and concrete and steel floats. He has participated in the design of over 1-1/2 miles of wharf and pier structures.

Yoshi Oritatsu is a Liftech structural designer and registered professional engineer with seven years of experience in the design, analysis, and modification of container cranes, large derrick cranes, bulk loaders, and wharf structures. His work includes the analysis of crane and wharf seismic response, including the effect of isolation and energy dissipation systems.

Michael Jordan is a Liftech structural engineer and CEO with over 50 years of experience. He is an internationally recognised expert in the container crane industry. He has been involved in the container industry evolution since participating in the structural design of the first container crane for Matson in 1958. Since then, he has designed the structures of hundreds of duty cycle cranes, prepared numerous specifications for the design of duty cycle cranes, and investigated fatigue damage problems and major failures caused by fatigue crack growth and brittle fracture.

About the company

Liftech Consultants Inc. is a consulting engineering firm, founded in 1964, with special expertise in the design of dockside container handling cranes and other complex structures. Liftech's experience includes structural design for wharves and wharf structures, heavy lift structures, buildings, container yard structures, and container handling equipment. National and international clients include owners, engineers, operators, manufacturers, and riggers.

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