



Washington State
Department of
Transportation

Partnering to Fill the Research Needs of an Underrepresented Highway System

Alaska and Washington State Advance Design of Ferry Berthing Structures

ANDREW METZGER

The author is Assistant Professor, Department of Civil and Environmental Engineering, College of Engineering and Mines, University of Alaska, Fairbanks.

Marine highways provide a necessary service for coastal communities in the United States. The Washington State Ferries (WSF) system, the nation's largest, provides service to more than 24 million passengers each year. Similarly, the Alaska Marine Highway System (AMHS) connects more than 33 coastal communities, most of which are accessible only by air or sea.

Problem

Marine highways are part of the U.S. highway system but often are overlooked in transportation studies. As a result, the knowledge base for this type of infrastructure is less developed than that for other modes of transportation.

For example, more needs to be known about vessel impact forces on the landing structures that

receive ferry vessels. The standard of practice for the design of these structures equates the kinetic energy of the approaching vessel to the elastic potential energy of the deformed structure that receives the impact. Assumptions must be made about the approach velocity, the vessel mass, and the energy transferred to the structure. These assumptions historically have produced uncertainty in design or an intentional overdesigning of the structure, which has an adverse effect on economy of design.

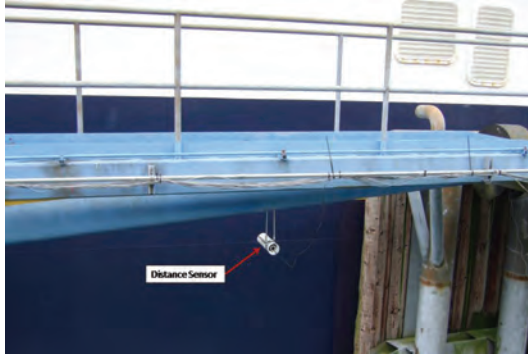
Solution

To address this gap in knowledge, WSF and AMHS initiated a research project to characterize the load environment of ferry landings, studying the vessel forces on the landing structures. The objective was to collect the information needed for reliable yet eco-

Ferry berth at Seattle, Washington, terminal, with linear motion transducers—cylindrical in shape—installed on the piers, just above the surface.



Distance sensor installation at Auke Bay.



nomical structural designs.

Researchers measured the vessel approach velocity, the displacements, and the internal forces as vessels came to a stop against a landing structure. Measurements were taken each time a vessel landed. The goal was to develop probability-based design criteria for vessel berthing demands. The Auke Bay terminal in Juneau, Alaska, and the Seattle–Bremerton terminal in Seattle, Washington, were chosen for study.

Instrumentation

The instrumentation at both sites measured several parameters of interest to engineers:

- ◆ Acoustic distance sensors measured the distance between the dock and the vessel five times per second. This information yielded an estimate of the vessel's velocity at impact. The photograph above shows a distance sensor installation.

- ◆ Rubber fenders that cushion the vessel's motion against the landing were instrumented with

linear motion transducers (LMTs) to measure the displacement during impact; the measurements were used to determine the force of the impact. The photographs on page 41 and below show LMTs installed to measure fender displacement.

- ◆ The vertical and battered support piles were instrumented with strain gauges, configured to determine the axial force in the piling.

- ◆ Another distance sensor oriented toward the water served as a tide gauge. Both study locations experience extreme tidal variation, which affects the elevation of the ship's sponson, the projection from the vessel that makes contact with the structure.

Onsite dataloggers controlled the instrumentation. Digital wireless modems connected to the dataloggers allowed remote control of the system, as well as the downloading of data over the cellular network.

Data

The Auke Bay and the Seattle–Bremerton terminal sites were monitored continuously for approximately one year. When a vessel reached a predetermined distance from the motion sensor, a programmed algorithm triggered the dataloggers to begin recording. The velocity at impact, the maximum fender displacement, and the pile force were identified and added into the database.

Histograms generated from the database were used to develop engineering design aids. Figure 1 (page 43) shows a sample histogram with a fitted probability density function.

The force imparted to the structure depends on



Closeup of linear motion transducer installed in Seattle.

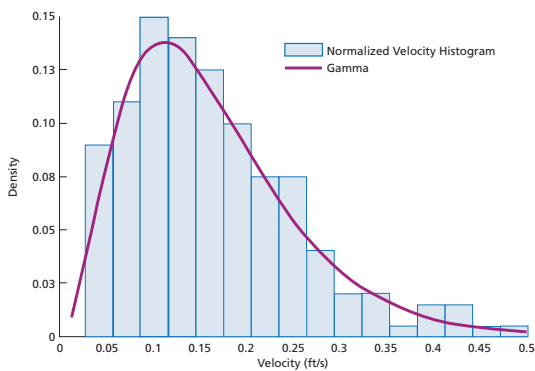


FIGURE 1 Impact velocity histogram with fitted probability density function.

the vessel's mass and impact velocity, as well as on other factors, all of which differ from berthing to berthing. A statistical analysis of the data from many berthing events, however, identified the approach velocities, forces, and impact energies that have a low probability of being exceeded. As a result, design criteria could be developed with a quantifiable degree of reliability.

Application

Engineers have applied the preliminary results from this project to reevaluate and revise internal design standards. Design charts summarize the research results, indicating parameter magnitudes and the probability that these will not be exceeded in a number of berthing events. The designer determines the number of anticipated berthing events for the design life of the structure and chooses the corresponding parameter. Figure 2 (at right) shows an example of an impact-energy design chart.

Technical Benefits

The results of this research project represent a significant advance for the design of ferry terminal structures and marine berthing structures. The monitoring system that was developed to measure the parameters associated with ferry berthing is applicable to other classes of vessels and to other berthing structures.

The project gathered the necessary data—such as impact force, approach velocity, and impact energy—for deriving statistically based engineering design criteria for the berthing demands of ferry vessels. Information derived from in situ measurements is a considerable improvement over the assumptions that support the current standard of practice.

Benefits of Partnering

AMH and WSF had similar research needs, but lim-

ited funding. At both study sites, the parameters of interest to engineers were the same. By coordinating efforts, the Washington State Department of Transportation (DOT) and the Alaska Department of Transportation and Public Facilities shared some equipment and labor costs.

The project would have cost each DOT working on its own approximately \$220,000. The joint sponsorship saved each state an estimated \$20,000 in labor and equipment, reducing the combined total costs to \$400,000. With matching funds from the Alaska University Transportation Research Center, the cost to each DOT for this project was \$100,000.

For more information, contact Andrew T. Metzger, Assistant Professor, Department of Civil and Environmental Engineering, College of Engineering and Mines, University of Alaska Fairbanks, 306 Tanana Loop, 271 Duckering Building, P.O. Box 755900, Fairbanks, Alaska 99775-5900; 907-474-6120; atmetzger@alaska.edu.

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Suggestions for Research Pays Off topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).

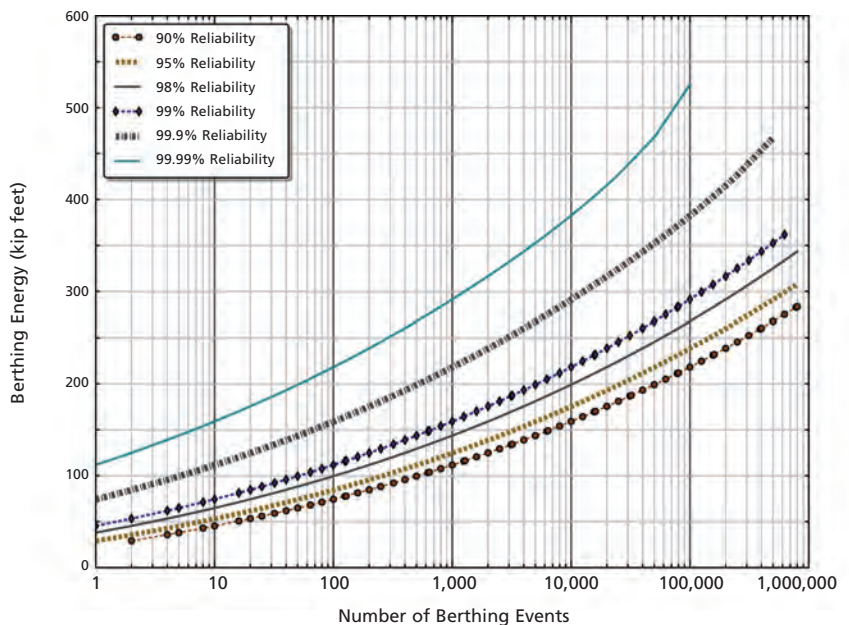


FIGURE 2 Impact energy design chart: reliability plot showing lognormal berthing energy in relation to number of berthing events.