Taking the Guesswork out of Berthing Energy Assessment

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Summary
A calculation method for assessment of berthing energy has been developed which uses Monte Carlo simulation to take advantage of all available data and maximise confidence in the calculation outcomes. It mathematically combines the variables that contribute to berthing energy, including berth characterisation, ship mix and frequency, variable cargo mass and berthing angle, minimising the need for qualitative judgement.

Keywords: Berthing energy, Monte Carlo simulation

Introduction

Assessment of berthing energy is fundamental to the design of any wharf structures. However, a significant amount of professional judgement, or guesswork, is typically needed to arrive at an answer. This includes consideration of site conditions, frequency of berthing, range of vessels, laden state of vessels, berthing angle, and risk of abnormal impacts.

With so much qualitative judgement required, different practitioners will invariably arrive at different conclusions for what the appropriate design berthing energy is.

The recent publication of PIANC's MarCom Working Group Report No. 145 [1] (WG 145) provides valuable information which can be used as the basis for an alternative methodology for assessment of berthing energy. With the availability of defined distributions of the relevant variables, a berth-specific Monte Carlo simulation can be performed to determine the characteristic (once in a lifetime) and design (abnormal) berthing energy.

This method has been trialled at Port Botany's Brotherson Dock container berths.

Berth characterisation

According to WG 145, berths are characterised as either Type A or Type B berths. In the case of the example project, a relatively small but sufficient set of berthing velocity measurements were available to enable a comparison with the larger WG 145 Type A data set. A site adjustment factor was accordingly agreed and applied to the WG 145 Type A velocities.

An appropriately large site data set could be alternatively processed and used to directly represent the distribution of berthing velocities.

Vessel size and berthing velocity distribution

WG 145 provides statistical distributions for berthing velocities by number of berthing events and by vessel size (DWT). These distributions can be arranged to calculate velocity as a function of both vessel DWT and cumulative probability.

WG 145 Section 6.8 describes a method by which a ship mix can be accounted for in determining characteristic berthing energy. This method is extended by the Monte Carlo simulation, where each discrete event is randomly assigned a vessel DWT according to the defined ship mix and then a berthing velocity is randomly assigned for that event according to the DWT and the corresponding cumulative probability distribution of velocity. In this way, the definition of the ship mix is effectively limitless. For example, historical records of vessel arrivals can be directly input to the simulation. When designing for the future, it is important that the ship mix be chosen with reference to the vessels that will likely use the berth throughout its lifetime.

The vessel's geometric characteristics in each event are automatically assigned by the simulation according to the DWT.

Displacement distribution

It is often not appropriate to assume that all vessels berth fully laden. Furthermore, it is typical that not all vessels arrive with the same proportion of cargo or ballast on board.

The cargo on board at the time of berthing is defined by the 'dead weight factor', as a proportion of the vessel's DWT. The dead weight factor for each event is assigned according to cumulative probability distribution. A single distribution can be defined for all vessels if appropriate, or it can be further refined by vessel size to account for where differences might exist for different trades, lines, draught limitations, etc.

The displacement, arrival draught and added mass are assigned for each event according to the vessel DWT and dead weight factor.

Berthing angle distribution

A continuous or closely spaced fender system such as that shown in Figure 1 adds an extra dimension to the complexity of capacity assessment. If the vessels' hull profile is defined with respect to berthing angle and the distribution of berthing angles is also known, this effect can be added into the Monte-Carlo simulation.

Figure 1 Fender System at Port Botany's Brotherson Dock. The capacity of the closely spaced fender system is proportional to the hull radius at the point of contact.

The relationships in WG 145 Appendix F have been used for this example of a container berth, to inform the cumulative probability distribution of berthing angle. Hull radius at the contact point and eccentricity coefficient are assigned for each event based on berthing angle. The berthing energy of each event is modified by the corresponding hull radius to account for the number of fenders contributing in that event.

Monte Carlo simulation results

The effect of the Monte Carlo simulation for the example project is shown in Figure 2. The characteristic berthing velocity calculated based on the largest fully laden vessel using the method of PIANC's MarCom Working Group Report No. 33 [2] (WG 33), using the Brolsma velocity Curve C is first presented. This is then contrasted against the same calculation using the WG 145 Type A velocity for the largest fully laden vessel. The characteristic value is calculated based upon the number of berthing events expected within the design life.

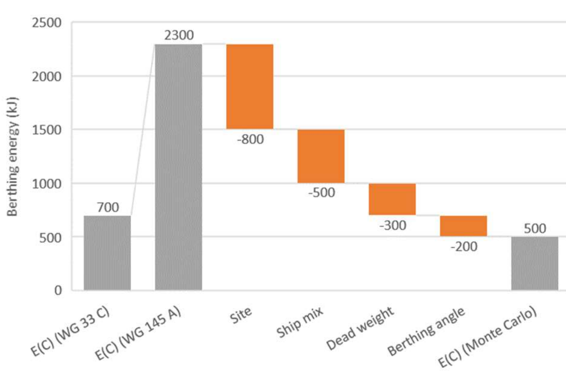

Figure 2 Example project berthing energy assessment contrasting with WG 33 assessment and showing the effect of adding variables to the Monte Carlo simulation.

The reductions in characteristic berthing energy are then presented for application of the site adjustment factor, and adding the distributions of ship mix, dead weight factor, and berthing angle to the simulation.

In this example, consideration of ship mix, dead weight factor and berthing angle have reduced the characteristic berthing energy by two-thirds.

Design berthing energy

It is suggested that the Monte Carlo simulation can be extended to define the abnormal impact factor. Figure 3 demonstrates extension of the Monte Carlo distribution of berthing energy well beyond the characteristic value at the design life of 50 years.

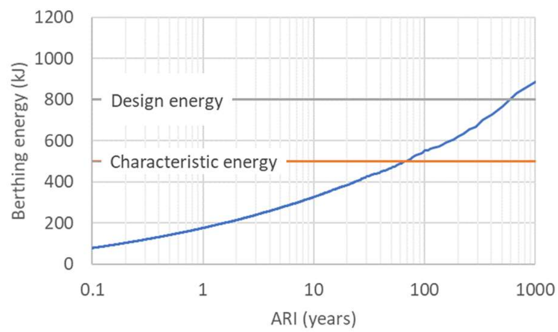

Figure 3 Monte Carlo distribution of berthing energy. The design berthing energy could be assessed by extending the distribution well beyond the design life.

Consistent with limit state design standards, the ARI of the ultimate event could be selected based upon importance of the berth and risk of damage. In the example above, an ultimate ARI of 500 years is nominated, effectively resulting in an abnormal impact factor of 1.6.

Conclusion

The contemporary availability of data and computing power means that berthing energy assessment can now be much more specific. The Monte Carlo simulation allows for quantitative account of all variables and minimises uncertainty or over-conservatism. Professional judgement must always be applied, but much less guesswork should be needed, and greater confidence should be achieved.

Acknowledgements

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References

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