Theme C: Evaluation of collision probabilities

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Theme C

Evaluation of Collision Probabilities

Chairman

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Technical Programme

The following papers were presented:

- O. Damgaard Larsen, Denmark
  Ship Collision Risk Assessment for Bridges.

- K. Kuroda, H. Kita, Japan
  Probabilistic Modeling of Ship Collision with Bridge Piers.
  Presented by Mr. H. Kita.

- M. Knott, U.S.A., D. Bonyun, Canada
  Ship Collision against the Sunshine Skyway Bridge.
  Presented by Mr. M. Knott.

- M.J. Barratt, United Kingdom
  Evaluation of Collision Probabilities for Offshore Structures.

- M.A.F. Pyman, J.S. Austin, P.R. Lyon, United Kingdom
  Ship/Platform Collision Risk in the U.K. Sector.
  Presented by Mr. M.A.F. Pyman.

- S. Kristiansen, Norway
  Platform Collision Risk on the Norwegian Continental Shelf.

Discussion and Comments

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Paper Title : Ship Collision Risk Assessment for Bridges
Presented by: Mr. O. Damgaard Larsen, Cowiconsult, Consulting Engineers & Planners, Denmark

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Corrections:

(i) In fig. 1, page 114: The figure on the vertical axis "50 MN" should be read "500 MN".

(ii) In table 1, page 123: The probabilities given should be multiplied by 10^{-4}.

Discussion by: Mr. T.R. Kuesel, Parsons, Brinckerhoff, Quade & Douglas, U.S.A.

Probabilistic analysis is a useful source of evidence for appraising collision hazards, but the results should be considered cautiously. Records of actual bridge collapses indicate that a disturbingly high proportion resulted from stochastic incidents, ranging from mechanical or electrical steering gear failures to the captain or pilot being asleep or drunk. In these cases the vessel is an unguided missile, and its course is not governed by any rational human control. Saul and Svensson noted that in 8 of 13 major collision accidents, the bridge was struck outside the main piers adjacent to the channel, in some cases up to a kilometer from the theoretical sailing line. This is not a probabilistic distribution. Mr. Larsen's advice to consult local mariners regarding historical experience is wise counsel.

Answer by: Mr. O. Damgaard Larsen

I agree entirely in Mr. T.R. Kuesel's observation, that the majority of serious ship collision accidents have been caused by ships hitting the bridge at some distance from the navigation channel.

One important reason, which has appeared from our studies of actual collision cases, is that most bridges are particularly vulnerable outside the navigation span, thus giving rise to more serious consequences if a collision is experienced. The general lesson from these cases is that the possibility of collision should be considered wherever ships, including low-draught ships in ballast are able to navigate.

When constructing a risk assessment model it is thus important to choose a probability distribution of uncontrolled ships which cover the entire width of the waterway, so that adequate probability of collision is attributed to the bridge section, far from the navigation channel.

Paper Title : Probabilistic Modeling of Ship Collision with Bridge Piers
Presented by: Mr. H. Kita, Kyoto University, Japan

Corrections:

There are two mistypes in the manuscript in the preliminary report:

i) in eq.(3) in page 122, "$l_k\sin\theta+$" should be "$l_k\sin\theta$".
ii) in eq.(8) in page 122, the condition "$X_k \leq X_k^*$" should be "$X_k \geq X_k^*$".

Discussion by: Professor W. Webster, Univ. of California, U.S.A

In my experience with collisions between two ships, I found that consideration of both the real geometry of the ship and realistic maneuvering paths is essential. A ship is much longer than it is wide, and as a result the swept area is much greater than its beam. Further, it should be recognized that ships do change course instantly. When the rudder is first put to one side the ship actually sways first in a direction opposite to that in which one wishes to move. It is only after the ship achieves a significant yaw angle that the center of gravity of the ship passes the original path line. As a result, the stern swings significantly and represents a great danger to the bridge piers.

Answer by: Mr. H. Kita.

The authors would like to express their gratitude for Professor W. Webster's discussion on our paper. Our view on the discussed point is as follows:

The effects of swaying of the stern in altering course on the collision probability can be treated in the present model by considering a circle with the greater diameter representing the ship size. For instance, when the usual drift angle and kick are considered, the diameter of the circle should be employed as two times the ship width. In this case, its effect on the increase of the collision probability is less than 10%.

The effects of the factors simplified and assumed in the present model on the collision probability can be examined by the sensitivity analysis as discussed above. Therefore, the points to be improved in the present model should be considered on the basis of the sensitivity analysis, because a partial improvement of the model does not necessarily result in an improvement of the accuracy of the estimate. These will be examined in the successive studies.

Paper Title : Ship Collision against the Sunshine Skyway Bridge
Presented by: Mr. M. Knott, Greiner Engineering Sciences, U.S.A.

Discussion by: Mr. Lawrence Lehman, Berger, Lehman Associates, U.S.A.

"Least Cost" span configurations may not represent the best solution in mitigating ship collisions with bridge elements. Additional "first" costs to lengthen spans are a form of insurance against future damage, or collapse. What effect is the Knott/Bonyun study having on the choice of span arrangements for this, or other water crossings?

Answer by: Mr. M. Knott

The risk analysis for ship collisions with the Sunshine Skyway Bridge was performed after the horizontal and vertical geometry of the bridge had been independently established. The risk and cost effectiveness analysis was then used to develop and evaluate the pier protection alternatives proposed for the project. The authors fully agree with the discussion by Mr. Lehman that establishing horizontal and vertical geometry for bridge elements based only on "least cost" is misleading. The incorporation of pier protection costs in the total bridge cost will, in most circumstances, result in longer and higher spans in order to minimize the total cost of the project.

As an example, recent preliminary design by Greiner Engineering for a high level bridge crossing the James River ship channel near Richmond, Virginia (U.S.A.) resulted in a recommendation that the main span be increased in horizontal clearance from 425 feet to 660 feet, because of the high costs for building the necessary pier protection structures in the deeper water of the river. The authors believe that the design of new bridges crossing navigable waterways must incorporate the costs of constructing adequate pier protection in the total planning for the project.

Discussion by: Mr. G.H. Patrick Bursley, National Transportation Safety Board, U.S.A.

The technical problems associated with ship impacts on bridge piers, bridge structures, and offshore structures and the underlying risk analyses are necessarily based on a given location and alignment of a bridge or a particular site for an offshore structure. Lest the point be overlooked in the search for the solutions to technical problems I would suggest that the initial ingoing that must be made is whether the risk of a ship collision can be reduced, i.e., is the location (and alignment) of the bridge or structure optimal with respect to the navigational difficulties which the mariner encounters in the waterway. Minor adjustments in location (and alignment) not only are generally more feasible than initially may be acknowledged but frequently they can drastically reduce the probability of a collision with an obvious effect on the risk analysis and the necessary ameliorative measurer.

Answer by: Mr. M. Knott.

The authors fully concur with the comments by Mr. Patrick Bursley of the U.S. National Transportation Safety Board. Our paper and others presented at this conference contain sufficient methodology to evaluate the probability and impact of vessel collisions with bridges and what reductions in vulnerability can be achieved by modifying the location, alignment or structural configuration of a proposed bridge. The implementation of these methodologies should result in the improved safety of bridges crossing navigable waters.

Discussion by: Mr. Bejon Panthaky, Hindustan Construction Co. Ltd., India

In table no. 4 figures of costs of various protection measures are indicated. However in absence of total cost of the bridge it is not possible to evaluate the impact of protection cost in the total cost of the bridge project.

The author has described a U type island enveloping 2 Piers. Such an island appears dangerous if a vessel goes behind the island and gets entangled there in which case it will be almost impossible to take the vessel out. What has the author to say?

In islands enveloping many piers, the hydrology of river is also seriously affected. Has any study been made in this regard?

Answer by: Mr. M. Knott.

Mr. Panthaky's comments are appreciated. The total cost of the new bridge is approximately 115 million dollars (U.S.). The implementation of a 6-pier protection structural system, navigation improvements electronic navigation system, and the motorist warning system repress approximately 23 percent (26 million dollars) of the total bridge cost. With respect to Mr. Panthaky's comments on the island geometry, the geometry of the channel/bridge crossing angles and the hydraulics of the bay show very little probability that a ship would be approaching the islands from a direction which would take them into the backside of the u-type island. The impacts of the islands on the hydrology of the bay was key element of the preliminary design and was investigated using numerical modeling of the problem. Additional physical modeling will be undertaken during the project final design.

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Paper Title : Evaluation of Collision Probabilities for Offshore Structures
Presented by: Mr. M.J. Barratt, National Maritime Institute, U.K.

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Discussion by: Professor W.D. Rowe, AURA, U.S.A.

All of the models shown are multiplicative in nature, but do not show error bands for the errors which also propagate multiplicativity. It is important not just to show error bands from such estimates, but to show the variability of the estimate. This means that expected value, which are estimates of central tendency, are not adequate for this purpose. Error analysis of the variance of the distributions are required.

Answer by: Mr. M.J. Barratt

The errors in the estimates of the model components are more or less quantifiable depending upon what is being estimated. Thus, taking the simple model: Collision risk = traffic flow x fog collision risk index x constant, the actual traffic flow rate may be measured, and the errors estimated on the basis of different size samples. This also applies to measurements of visibility, for use in computing the FCRI.

However, the errors in the constant and the index itself cannot be quantified in this way, depending as they do on analogies with other types of collisions, whose relevance can only be assumed. For this reason, estimates of the relative risks at different locations are to be preferred to absolute values, at present.

Discussion by: Dr. John Gardenier, U.S. Coast Guard, U.S.A.

1) Risk has been treated as probability of collision (impact). By conventional scientific definition, "risk" is a probability distribution of (adverse) consequences. To be complete, risk estimates must encompass both impacts and consequences of impacts.

2) Estimates of impacts relative to traffic density are pre-scientific hypotheses. To become scientific estimates, impacts must be analyzed relative to alternative exposure terms - and also using alternative probability distributions. Only when alternative exposures and distributions have been investigated by three or four independent researchers with common results, will impact probabilities become scientific.

   These authors work is valuable, indeed necessary. It is, however, preliminary rather than conclusive.

Answer by: Mr. M.J. Barratt.

Shipping routes are generally not well defined in open sea conditions, and often it is only possible to give an average exposure over a distance of several miles. However, work is proceeding to provide reliable estimates of traffic distributions across routes, which should improve the precision of such estimates.

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Paper Title : Ship/Platform Collision risk in the U.K. Sector
Presented by: Dr. M.A.F. Pyman, Technica Limited

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Correction:

Change in terminology: "Cowboy Vessel" should read "Errant Vessel".

Discussion by: Professor W.D. Rowe, AURA, U.S.A.

Same discussion as printed under above paper by Mr. M.J. Barratt.

Answer by: Dr. M.A.F. Pyman.

Error bounds have been calculated for the risk results presented, but are not discussed in the published paper due to lack of space.

Discussion by: Dr. John Gardenier, U.S. Coast Guard, U.S.A.

Same discussion as printed under above paper by Mr. M.J. Barratt.

Answer by: Dr. M.A.F. Pyman.

The risk estimates do include both probabilities and consequences. The consequences expected are of serious damage to the installation.

Discussion by: Dr. L.C. Zaleski, C.G. Doris, France

Both Dr. Pyman and Mr. Kristiansen have mentioned a figure of 10^{-3} per year, but:

- Pyman has presented it as a risk level
- Kristiansen, as a collision probability.

In order to avoid any possible misunderstanding I insist: A risk is a product of probability of an event and of its consequences.

Let us have in mind: The international CEB model code places the mean figure of an acceptable probability of failure of a conventional building, as the one inside of which we are sitting at present, at a level of 10^{-5} per year, to be divided, (fortunately for us) by the number of lives endangered. The design of an offshore platform results, when applying the present regulations, in a probability of failure of 10^{-7}, or even less, when calculated on the whole "life" of the structure. Therefore, I understand, the figure of 10^{-3} per year, mentioned by both authors, represents well a probability of ship/platform collisions in general, but not of the ones involving some significant damages. This latter would be obtained by multiplying the above figure by a set of factors, obtained from an appropriate probabilistic approach, and should certainly be lower than the accepted failure probability of 10^{-7} or similar, for an offshore structure correctly designed.

Answer by: Dr. M.A.F. Pyman.

The risk level of 10^{-3} presented in the paper is indeed the product of an event and its consequences. The consequences of a collision between a merchant vessel travelling at normal speed and unaware of the platform in its path are expected to be, at the very least, significant damage to the installation. The risk levels quoted thus relate directly to the risk of significant damage to the installation. The fact that these figures are high, is a quantitative expression of the widespread concern among governments and operators of the potential danger.

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General comments on theme C.
Evaluation of Collision Probabilities
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<u>Comment</u> by: Dr. Yahei Fujii, Marine Traffic Studies, Japan

We Japanese have contributed to the calculation of collision probabilities by providing over 80% of the total for the purpose. Of course, the number of collisions are not limited to Japanese waters. I wish similar analyses could be made for either European waters or American waters to estimate the probability of collision on the common basis in the world.