Determination of Accidental Actions for the Remaining Lifetime of Bridges

Claus KUNZ
Senior Engineer, Director
Head of Department Structural Engineering,
Bundesanstalt fuer Wasserbau
Karlsruhe, GERMANY
claus.kunz@baw.de

Claus Kunz, born 1958, received his civil engineering degree from the Technical University of Karlsruhe, Germany. He worked for Bundesanstalt fuer Wasserbau and the German Waterway and Shipping Administration in different positions caring about hydraulic engineering structures. He chairs national and international coding and working groups. His main area of research is related to reliability aspects in civil engineering.

Summary

Existing bridges have sometimes to be evaluated considering ship impact. Using present codes for accidental actions would often lead to rehabilitation measures or to new structures which might not be efficient regarding the rareness of the serious ship collision events to bridges. Therefore a method has been developed to determine ship collision forces as time-dependent action for the remaining lifetime of an existing bridge. This method, called remaining life expectancy concept, is based on the design concept of the Eurocodes which is a reliability-based design procedure. It considers the principles of the common maintenance strategies and allows the safe and economic verification of existing bridges considering their experienced lifetime. The contribution explains the methodology of modern ship impact determination by combining a load model with a probabilistic model as it is used for the design of new bridges. The adaption to remaining lifetime adapted dynamic impact forces is shown.

Keywords: accidental actions, ship impact, ship collision, bridge, safety concept, reliability, remaining lifetime

1. Ship impact as an accidental action

For the treatment of the ship impact a probabilistic load model was linked with a probabilistic collision model in order to get a distribution of probable impact loads, with which the design value is determined using coded or acceptable risk criteria.

The substructure of a bridge, i.e. bridge piers, might be hit by a frontal impact "FF", in most cases parallel to the longitudinal axis of the pier, and by a lateral impact "FL", in most cases perpendicular to the longitudinal axis of the pier. For both impact scenarios a bi-linear elastic-plastic load-indentation-function has been found to describe the deformation of the ship when the ship is hitting a rigid structure. The formulas are given in Annex C of EN 1991-1-7.

The probability of a collision is determined by a collision model, which considers the geometry of the waterway and the hit structure, the sailing line as well as the stopping ability of the ships. The formulas are given in the full paper version.

Since accidents are subjected generally to a POISSON distribution the impact load probability function has been transformed to an universal one-sided dimensionless function by

$$\lambda \cdot t_R = \frac{1}{1 - F_P\,(F)} \tag{1}$$

with λ as collision rate and t_R as return period of the (unwanted) event, see figure 1. By codes ship impact forces had been fixed for each waterway class, see table 1, and additionally the average return period between the unwanted failure events t_R of all accidental actions with $p_ü = 10^{-4}$ per year for the structure, which corresponds to $t_R = 10000$ years, had been defined.

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Using the background of the safety concept of the Eurocodes as a lifetime orientated safety concept the safety of structures has to be ensured by a target reliability β over the design lifetime T_N .

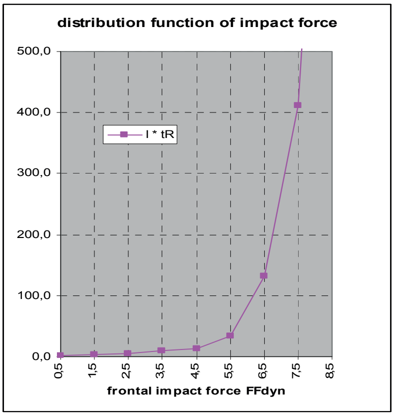

Fig. 1: Impact Distribution Functions for Frontal Impact "FF"

Table 1: Dynamic Impact Loads for Classified Inland Waterways

Waterway Class	Frontal Impact FF (MN)	Lateral Impact FL (MN)
III	*4,0*	*2,0*
IV	*5,0*	*2,5*
Va	*8,0*	*3,5*
Vb / VIa	*10,0*	*4,0*
VIb	*14,0*	*5,0*
VIc	*17,0*	*8,0*
VII	*20,0*	*10,0*

2. Ship impact for existing bridges during their remaining lifetime

Existing structures where no failure occurred can be evaluated regarding the remaining lifetime T_{NR} and getting assigned the target reliability which is r = 0,01 during lifetime for accidental ship impact. The concept is called remaining life expectancy concept by which Bundesanstalt für Wasserbau developed a consistent procedure for ship impact to existing bridges which had been edited as German code of practice "MNaBS". In consequence lower characteristic values for accidental actions are determined.

Using again POISSON distribution the failure probability p_f out of the stochastic risk leads to

$$p_f = (1 - e^{(T_{NR} / t_R)}) \tag{2}$$

and is converted to

$$t_R = \frac{-T_{NR}}{\ln(1 - p_f)} \tag{3}$$

and allows determining return periods corresponding to a certain remaining lifetime.

Investigations for typical waterway, bridge and collision conditions and regarding remaining lifetimes lead to reduced impact forces F = f(T_{NR}) which has been analysed as a percentage ratio towards the design impact load given in codes, figure 2.

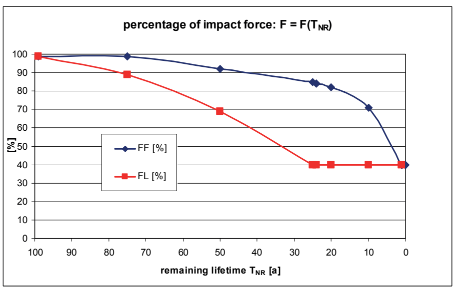

Fig. 2: Reduction of ship impact forces $F = f\,(T_{NR})$

Besides the remaining lifetime adapted dynamic impact forces MNaBS provides for existing bridges additionally recommendations for load bearing capacity limit state design, partial safety factors, how to get characteristics for older materials and a risk evaluation which might be performed dependent of the factor of utilization. By this some rehabilitations often expensive and inefficient which would be induced by ship impact evaluations could be reset while safety deficiencies are prioritised.