Water Engineering | Marine Technology

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FLOODSTAND:

Determination of discharge coefficients for a cross-flooding duct

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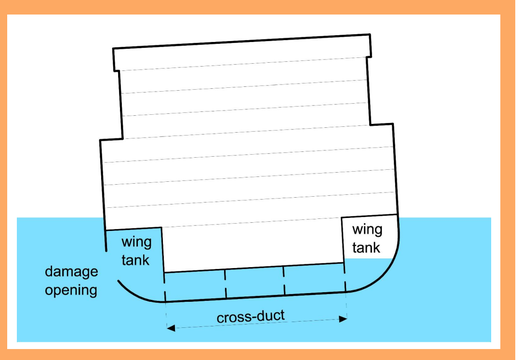
I. Background

Cross-flooding ducts are used to equalize asymmetric flooding and, thus, to decrease the heel angle of a ship in an emergency. The present design guidelines for cross-flooding arrangements involve uncertainties associated with the effect of variable structural factors.



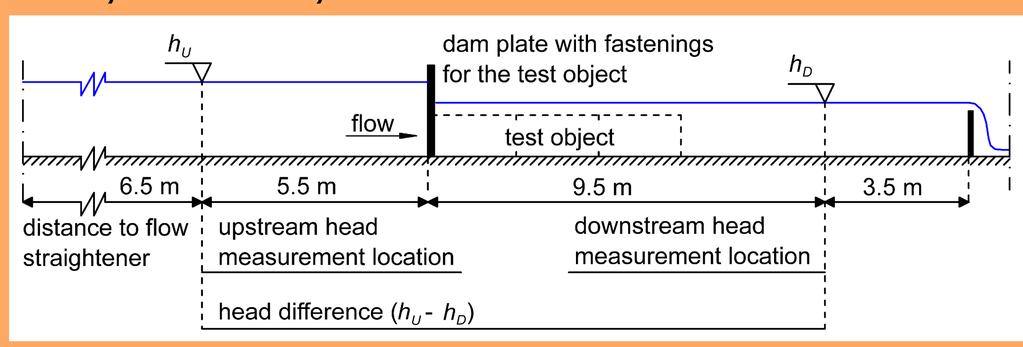
Ship cross-section with a typical cross-flooding arrangement

Factors affecting the discharge coefficient of a cross-duct

Factor	Effect on the discharge coefficient C_D	Investigated in present study
Number of girders in the cross-duct	An increased number of flow obstacles decreases the C_D of the entire structure	Yes. The length of the cross-duct and the corresponding number of girders was varied.
Opening form, crest length and sharpness of the opening edges	Depends on several properties of the opening	Yes. The influence of stiffeners attached to the girder was examined.
Distance between the girders	A smaller distance between the girders increases the C_D of the girders	No. The distance between the girders was constant
Incomplete jet contraction due to the approach channel	An incomplete contraction of the jet causes an increase in the value of the discharge coefficient	No.
Flow velocity	Contradictory reports in literature	Yes, to some degree. The discharge was varied.
The relative level of the downstream head (downstream head to opening height ratio, h_D/h_O)	A higher quotient of the downstream water level divided with the height of the opening is assumed to decrease the C_D	Yes. The downstream water level was varied.
Inclination	An increase of the inclination of the cross-duct is assumed to increase the C_D	Yes. The cross-duct was inclined at an angle of 7° in one of the test cases.
Size / scale effects	A smaller scale is assumed to increase the C_D	No. A study in scale effects would require experiments with a full-scale test object.
Number of openings on the girders	A girder with two manholes is assumed to have a higher discharge coefficient than a girder with one manhole.	No. The girders of the tested cross-duct had two manholes

II. Scale model experiments

Experiments were carried out to determine discharge coefficients C_D of a typical cross-duct, with a focus on the effect of structural components such as the girders, stiffeners, and web frame.



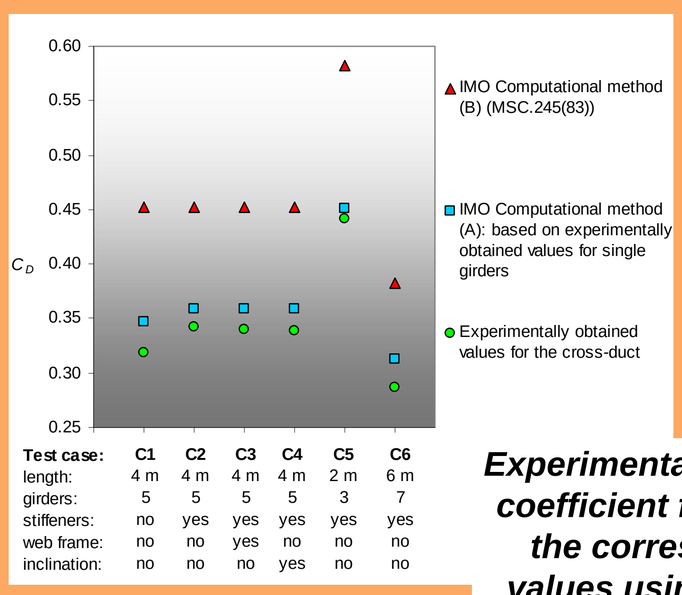
Longitudinal view of the experimental set-up in the flume

III. Test cases

Test Case	Description of the test object
C1	4 m long cross-duct (5 girders, two modules). No stiffeners. No web frame.
C2	4 m long cross-duct (5 girders, two modules). Stiffeners attached on the girders and the bottom and top of the duct. No web frame.
C3	4 m long cross-duct (5 girders, two modules). Stiffeners attached on the girders and the bottom and top of the duct. A longitudinal web frame in the middle of the cross-duct.
C4	4 m long cross-duct (5 girders, two modules). Stiffeners attached on the girders and the bottom and top of the duct. No web frame. The cross-duct was inclined at an angle of 7°.
C5	2 m long cross-duct (3 girders, one module). Stiffeners attached on the girders and the bottom and top of the duct. No web frame.
C6	6 m long cross-duct (7 girders, three modules). Stiffeners attached on the girders and the bottom and top of the duct. No web frame.

IV. Key results and conclusions

- **The structural stiffeners inside the cross-duct and on the single girders were found to significantly increase the value of the discharge coefficient C_D.**
- **The influences of the web frame and the inclination of the cross-duct on the value of the discharge coefficient were negligible.**
- **There is a risk that the discharge coefficients of cross-ducts are overestimated if the guidelines of the IMO Resolution MSC.245(83) are applied without properly considering the geometrical properties of the girders in the cross-ducts.**



Experimentally obtained discharge coefficient for the cross-duct and the corresponding computed values using the IMO guidelines

For further information:

- **FLOODSTAND deliverable D2.3 2010 "Pressure losses and flow velocities in flow through manholes and cross-ducts"**
- **Stening, M., Järvelä, J., Ruponen, P. and Jalonen, R. 2010. Determination of discharge coefficients for a cross-flooding duct. Ocean Engineering. (accepted)**

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