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FREE SURFACE EFFECTS ON THE STABILITY OF PASSENGER VESSELS: SOME COMPUTATION RESULTS

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ABSTRACT:

This paper presents some numerical results of direct calculation of the effects of free surface on the stability of six typical double decker inland passenger launches. It is assumed that the bulkhead spacing at the midship is the largest permissible one and the space is flooded. The results show that the wall sided formula gives a highly exaggerated picture of the problem. The formula, on the other hand does not represent the worst possible situation. It is also observed that the worst condition generally prevails at about 75% loading of the tank. The paper concludes that the designers should be careful about the method employed for estimation of the effects and none of the IMO or wall sided formulas should be considered fully reliable under all circumstances.

List of Symbols Used:

b	=	Maximum breadth of tank (m)
C_b	=	Block coefficient
C_m	=	Midship coefficient
$C\omega$	=	Water plane coefficient
h	=	Maximum height of tank (m)
I_{fs}	=	Moment of inertia of the free liquid surface at upright condition (m^4)
KB	=	Height from keel to LCB (m)
KML	=	Longitudinal metacentric height (m)
KMT	=	Transverse metacentric height (m)
I	=	Maximum length of tank (m)
LCB	=	Longitudinal center of buoyancy (m)
LCF	=	Longitudinal center of floatation (m)
Mfs	=	The free surface moment at any inclination in meter-tons.
v	=	Total tank capacity in m^3.

Greek Symbols;

γ	=	Specific gravity of the liquid in the tank
Δ	=	Displacement of the vessel (tonnes)
δ	=	v/(blh) = the tank block coefficient
θ	=	Angle of inclination (deg)

Introduction:

Bangladesh is a riverine country with a navigable waterway of 8,433 km during the monsoon and 5,222 km during the dry season. The river routes play a vital role in the movement of goods and passengers in a country of 144,000 sq. km. and a population of about 120 million. A total of 1,477 passenger launches carry 1.4 million passengers daily in 222 river routes. Out of these launches 144 are typical 'double decker' vessels. These are in addition to thousands of mechanized and non-mechanized country boats. The still water stability and stability against wind heel and passenger crowing of these vessels have been studied extensively by the authors[2,3,4,5]. One of the major hazards faced by all marine vehicles in general and these vessels in particular is the free surface effects. This is due to poor and non-watertight construction.

Free surface effect causes a virtual increase in the KG. The most common locations of the free liquid surface are fuel oil tanks, fresh water tanks etc. In oil tanker/water barges, strongest free surface causes from the cargo hold. Service tanks are generally small and do not influence stability. The subject vessels do not generally have large fuel or water tanks. The present study aims at quantifying the free surface movement due to floating of a tank placed at the midship with largest permissible length. The problem is basically of damaged stability but will be treated here with pure static approach.

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The results of direct computation have been compared with the wall sided formula and IMO method. Six such vessels of different sizes have been selected, the particulars of which are given in Table-1. A typical profile and Body Plan of such a vessel in given in Figure-1.

Methods of Estimation:

The conventional approach of incorporating the free surface effects is the wall sided formula[6]. Most of the text books recommend this method.

$$M_{f,s} = I_{fs} * \gamma \sin(\theta)/\Delta \quad \text{.......................} \quad (1)$$

IMO recommends the following method for estimation of the free surface moment[7].

$$M_{f,s} = v\, b\, \gamma\, k\, \delta^{0.5}$$

Where

$$k = \sin(\theta)/12 \{1 + \tan^2(\theta)/2\} \times b/h$$
$$= \{\cos(\theta)/8\} \{1 + \tan(\theta)/(b/h)\} - \{\cos(\theta)/12(b/h)^2\} \{1 + \cot^2(\theta)/2\}$$
$$\text{where } \cot(\theta) \leq b/h$$

Though not mentioned in the relevant publications but this method is apparently intended to estimate the worst condition.

Procedure of Analysis:

The object of the paper is to estimate the free surface moment by direct computation and draw comparison with the wall sided and IMO method. The requirements for the maximum length of subdivision under SOLAS Convention of 1978 involves calculation of the floodable length and multiplying the same by a factor of subdivision. A number of other factors volume of machinery space, margin line, passenger or cargo capacity etc. are also the parameters in the process of fixing the maximum allowable distance between bulkheads. Stability in damaged condition is calculated considering the permeability as dictated or guided by the rules.

Draft Inland Shipbuilding Rules of Bangladesh[9] offers a rather simple method and allows a maximum bulkhead spacing of 0.15 L + 6.5 meter, where L is the length of the vessel. In the present analysis, it is assumed that each of the six considered has a compartment of this maximum allowed size at the midship. The compartments are assumed to be partially flooded with water. The wall sided and the IMO formula are independent of the amount of flooding. Direct computations have been performed to estimate the moment due to shifting of the liquid with rolling. The compartments have been assumed to be 5%, 10%, 25%, 50% and 75% filled. The permeability is assumed to be 100%.

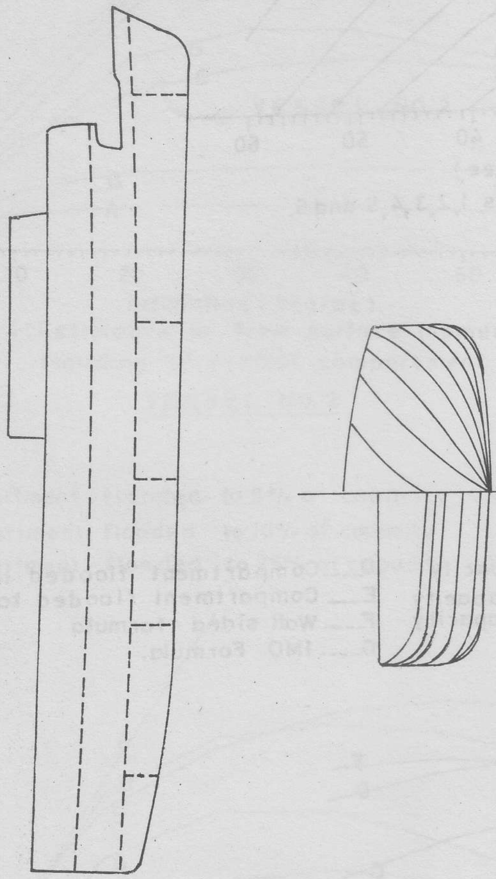
Results and Discussion:

Results of the computations have been plotted as in Figure-2 through Figure-7. The following observations may be noted:

1. For very small amount of flooding, the moment becomes virtually constant above 20 degrees inclination.
2. Direct computation results indicate that the worst condition will arise when the compartment will be flooded to an amount between 50% and 75% of capacity. The exact quantity depends on the hull form and the angle of heel.
3. The IMO formula indicates a flooding extent between 25% and 50% and at all inclinations are much lower that the maximum computed moments.
4. The wall sided formula can at best be used upto 20 degrees inclination. In high beam vessel (e.g., vessel 6) the limit may be as low as 10 degrees. Above this limit the wall sided formula indicates free surface moment much higher than actual.

Conclusions:

The results presented in the paper indicate that neither the wall sided formula nor the IMO method can be used to estimate the worst situation. Stability booklets should preferably use the IMO method rather than wall sided formula. It would be wiser to make direct calculations but this may be too rigorous for routine design works. It must be remembered that in case of actual rolling of the vessels, the picture is much more complicated than what appears here. This is because there exists a time lag between the rolling of the vessel and shifting of the liquid and realistic pictures can only be obtained with rigorous calculations and supporting model tests.



Eigure 1 : Profile and Body plan of a Typical Double Decker Passanger Vessel.

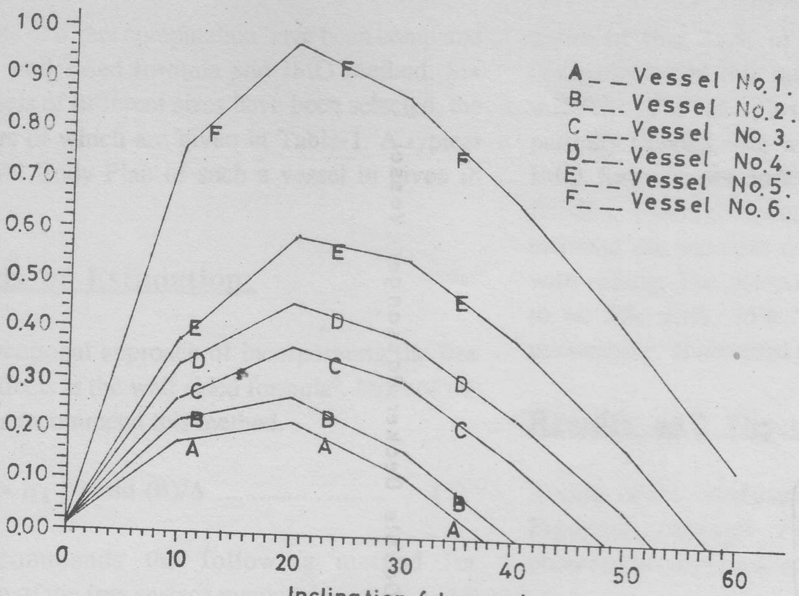


Figure 2: GZ carves of vessels 1, 2, 3, 4, 5 and 6.

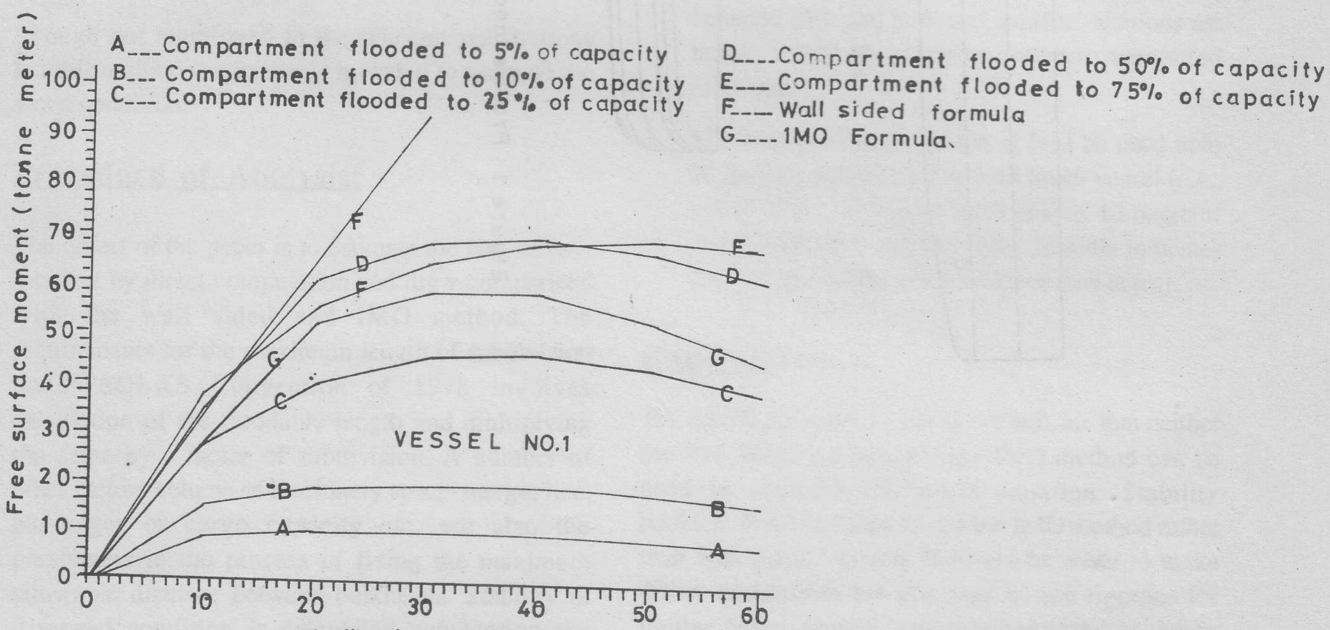


Figure-3 : Estimating of free surface moment for flooding of central compartment.

VESSEL NO.1.

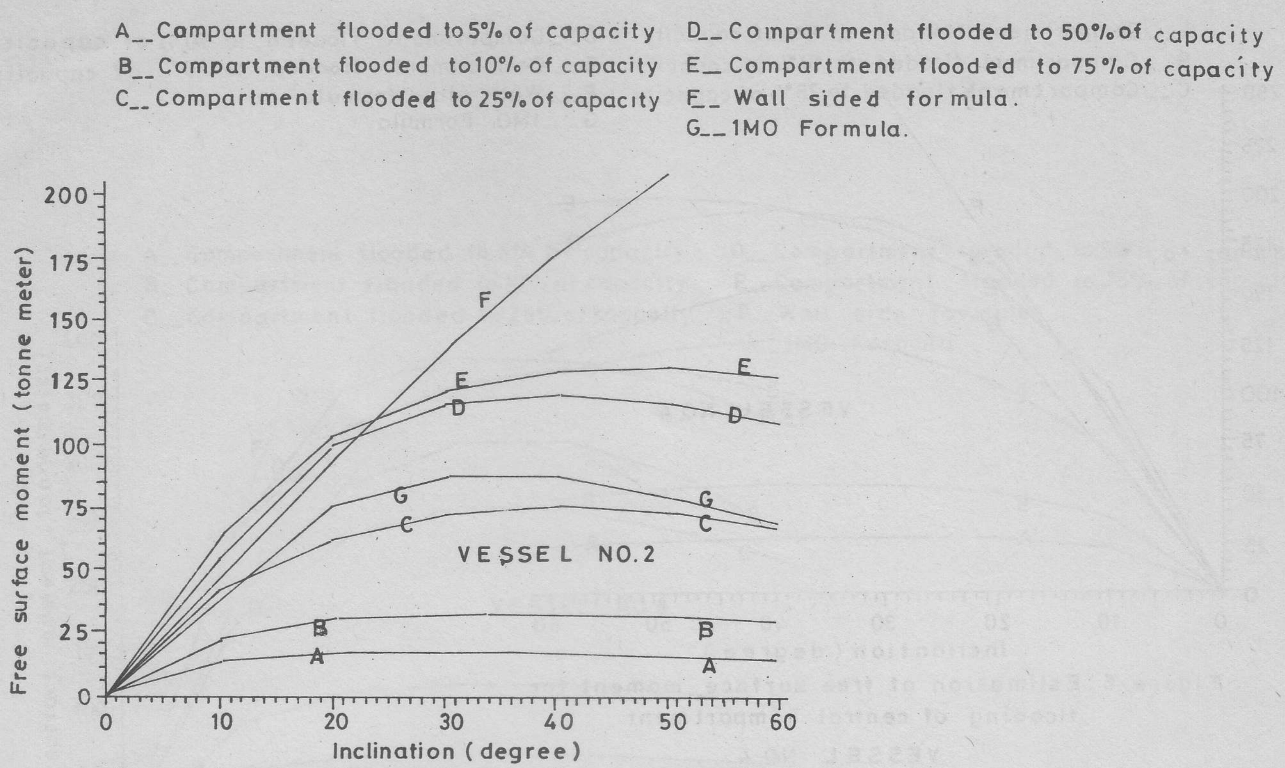


Figure 4: Estimation of free surface moment for flooding of central compartment

VESSEL NO. 2

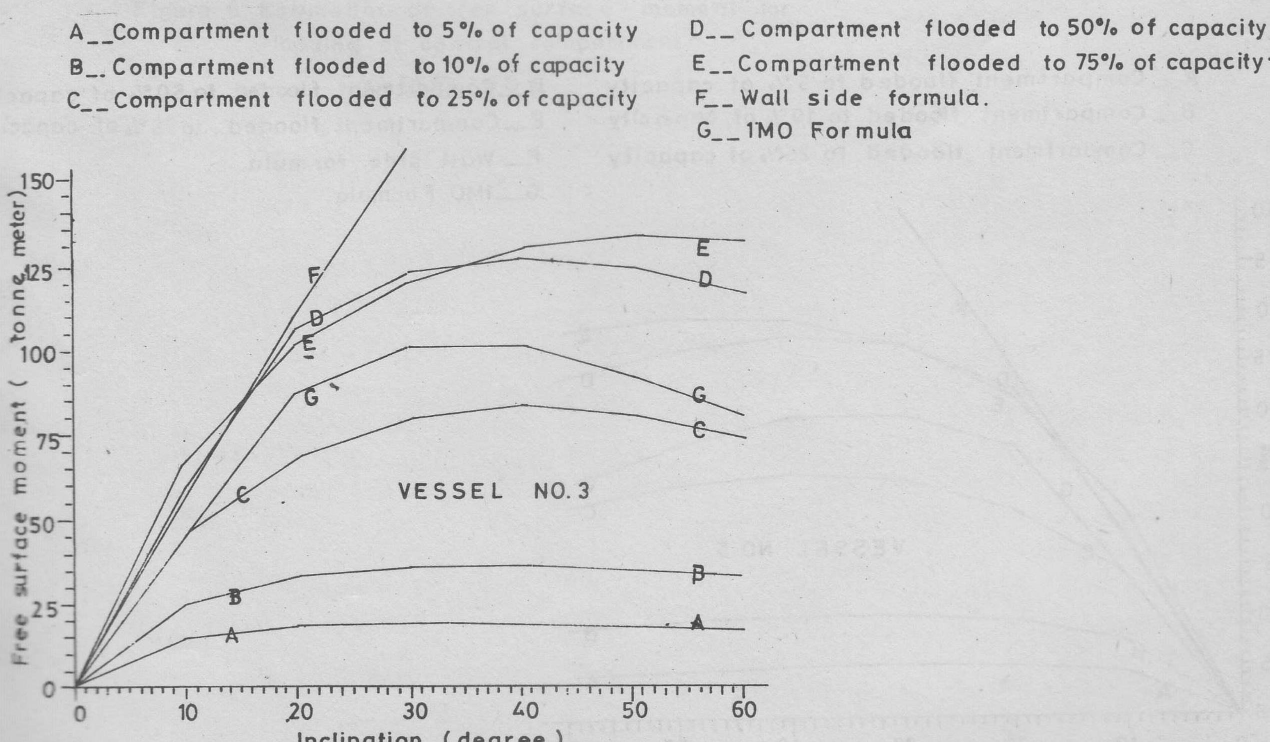


Figure 5 Estimatin of free surface moment for flooding of central compartment

VESSEL NO. 3

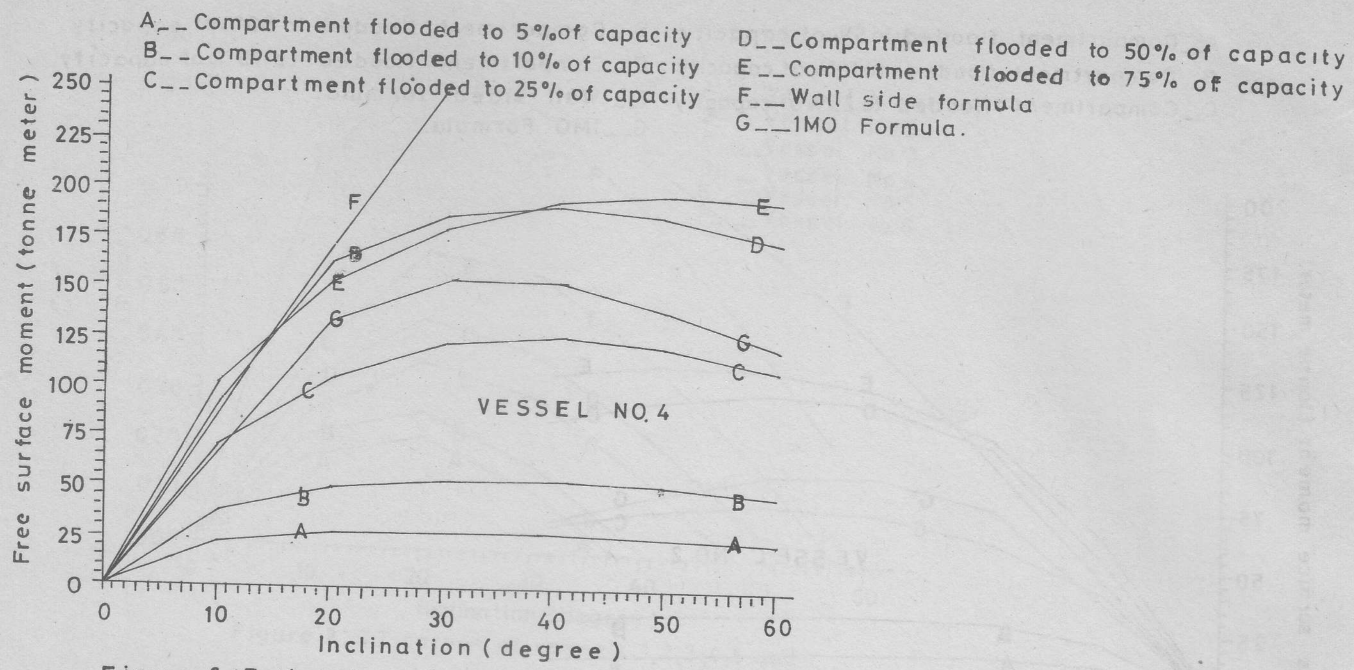


Figure 6: Estimation of free surface moment for flooding of central compartment

VESSEL NO.4

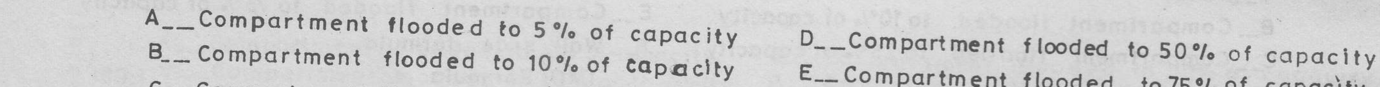


Figure 7: Estimation of free surface moment for flooding of central compartment

VESSEL NO.5

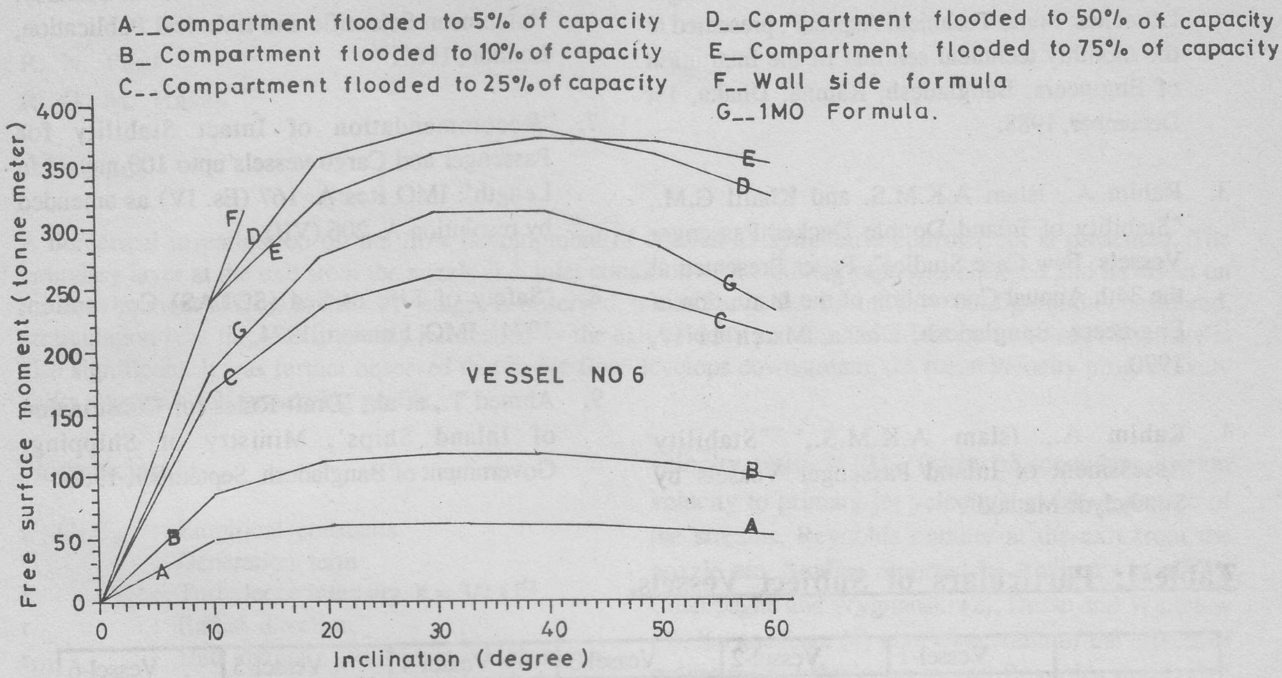


Figure 8: Estimation of free surface moment for flooding of central compartment

VESSEL NO.6

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Table-1: Particulars of Subject Vessels.

	Vessel-1	Vessel-2	Vessel-3	Vessel-4	Vessel-5	Vessel-6
Length	23.500	29.000	31.400	37.034	38.000	47.000
Breadth	6.100	6.710	7.000	7.920	7.930	10.660
Depth	1.600	1.910	2.000	2.218	2.075	2.280
Draft	1.300	1.579	1.651	1.826	1.757	1.790
C_b	0.565	0.610	0.627	0.679	0.652	0.611
C_w	0.836	0.849	0.866	0.901	0.857	0.843
C_m	0.924	0.897	0.888	0.884	0.906	0.866
LCB*	-0.392	-0.566	-0.268	0.031	-0.394	-1.399
LCF*	-0.929	-0.958	-1.059	-0.848	-1.172	-2.079
KMT	3.256	3.712	3.878	4.428	4.555	7.452
KML	36.016	49.954	57.386	72.944	75.515	109.261
KB	0.734	0.931	0.977	1.067	0.961	1.061

* Positive for forward of a midship.