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Stability of inland double decker Passenger launches: Comparison with statutory requirements

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ABSTRACT

This paper investigates the stability of three double decker passenger launches plying in the inland waters of Bangladesh. The stability particulars of the vessels have been calculated and compared with statutory requirements. It appears that moderate overloadings may also seriously jeopardize the stability. The necessity of evolving a suitable criteria for stability of inland vessels is also highlighted.

INTRODUCTION

Double decker launches play [Khalil (1985)] a major role in the movement of passengers in the inland waters. These vessels are almost the sole means of communication with the southern portion of the country from the capital city. In addition, these vessels also carry a small quantity of cargo. But this small cargo is expected to make a significant influence on the stability of the vessels. Unfortunately, these vessels numbering more than one hundred have been allowed to operate without adequate study of their stability. The researches in the field of stability assessment and causes of accidents of inland passenger vessels have been, at best, limited.

The first systematic data of passenger vessel accidents was published by Khalil (1985). This contained information on all accidents involving such vessels from 1981 to 1985, mentioning the names of the vessels involved, place of accident, cause of the accident and the loss of lives.

The annual figures of acccidents and losses of lives since 1981 are given below [Khalil (1985) and DOS(1990)].

Year	No. of Accidents	No. of Deaths
1981	10	60
1982	4	0
1983	7	50
1984	11	115
1985	12	80
1986	11	426
1987	11	51
1988	11	108
1989	5	32
1990 (till April)	8	162

As regards the cause of the accidents, an analysis is reproduced from the above referenced papers.

Causes	Percentage of Accidents
Overloading	40.43
Collision	38.30
Heavy Weather	17.02
Foundering	4.25

The overloading does not itself cause sinking of the vessel. But it is observed that the overlaoded vessels sometimes fail to get upright when inclined by a wave or by the action of a moderate wind. The capasize in heavy weather occurs due to the vessel's inability to withstand the effects of beam wind and

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crowding of panicked passengers to one side during rolling. Thus, it is observed that at least 57.45% of the accidents are stability related. And hence the stability assessment of inland passenger vessels deserves considerable attention.

Rahim (1988) addressed the stability aspect of inland double decker passenger vessels. Rahim et al (1990) carried out some case studies on stability of such vessels. The effects of hull proportions, form, wave, free surface, wind, passenger crowding were extensively studied by Rahim (1990).

The aim of this paper is to study the stability characteristics of such vessels. The GZ curves have been drawn and it is compared with the stability criteria of the International Maritime Organization (IMO) which has also been adopted by the Government of Bangladesh.

OUTLINE OF THE ANALYSIS

Three representative double decker passenger launches (see fig. 1) were selected for the analysis, particulars of which are presented in Table-1. The speed and the engine power are not shown because the analysis presented here is for static condition. Though dynamics of a vessel, to some extent, influences the stability characteristics of a vessel, conventional criteria for the assessment is solely based on statical stability curves. Only in the recent years, the importance of time varying roll response curve as an index of stability assessment is being emphasised, though any concrete regulation is yet to be formulated. That too does not consider the motion of the vessel itself, rather the interaction of the hull with an incident wave and resulting GZ curve is also a function of time [Barrie (1986)]. If the motion has to be taken into account, experimental works in a towing tank is probably the only means of predicting the stability characteristics of a vessel. Such experiments may make prediction for a specific vessel. So an enormous amount of work has to be done prior to the formulation of a generalized criteria. Since the objectives of this study is to compare the stability of inland double decker passenger vessels with statutory or conventional requirements, the present analysis assumes the vessels to be static in calm water. Like designers practice, the GZ curves are not trim corrected. Such corrections are also expected to alter GZ curves at least in some vessels where the location of the longitudinal centre of byoyancy (LCB) and longitudinal centre of floatation (LCF) are considerable distance away from midship, like vessel C of this study. However, the location of LCB of vessels A and B of this paper should not mislead any reader. Though the LCB is almost at the midship in those vessels, the overall shape of the forward and aft portions are much different in the two cases. As a result, they will respond in a much different way. As inclination increases, trim correction may become significant. This aspect has been extensively studied by Rahim (1990).

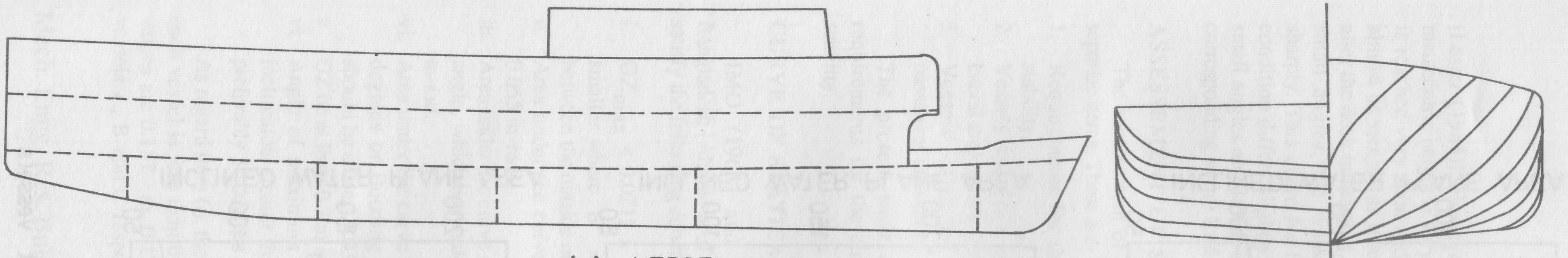
GZ curves have been drawn up for two conditions of each vessel, that is at full load condition and at 20% overload. Such overlaodings are very common in these vessels during occasions. In fact, sometimes the extent of overload is even much higher. The reason for including the overlaod condition is to quantitatively assess the sensitivity of the stability to overloading. The passengers are carried in the main deck and the upper decks. A small number of first and second class accommodations are available, the bulk of the passengers are accommodated in open decks and there is no longitudinal partition. Though the underdeck spaces are termed as cargo hold, the goods are largely carried over the main deck for convenience of loading and unloading.

This paper does not attempt to assess the stability at the worst conditions rather at ordinary situations. KG in the light condition is taken from inclining experiment results, the CG of the passengers at their normal living and that of the cargo above the main deck.

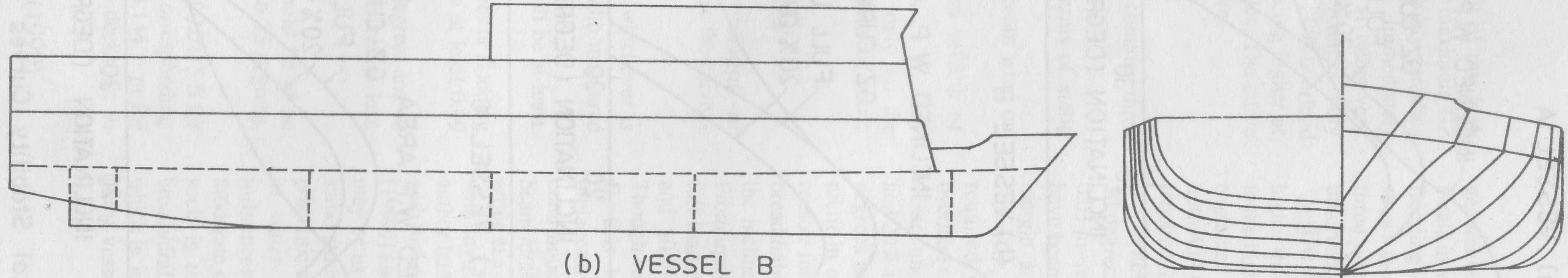
ANALYSIS OF THE STATICAL STABILITY CURVES

The statical stability curves of the vessels corresponding to the two conditions stated in Table-1 are shown in Fig. 2a through Fig. 2c. In the initial region, as in the case of all such curves, GZ is proportional to the angle of inclination [Gillmer (1975)]. The nature of the curves are common to that of vessels of all sizes and proportions. However, these have got some peculiarities which are explained below :

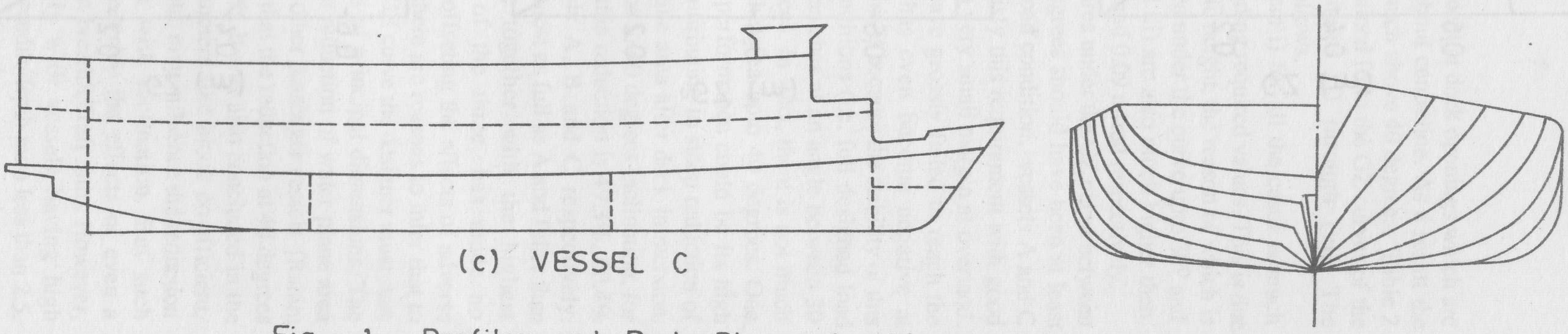
The initial metacentric height is very high which is due to high beam and low draft. Both of these factors have contributed to high BM. The BM increases as the square of the breadth and decreases linearly with draft



(a) VESSEL A



(b) VESSEL B



(c) VESSEL C

Fig. 1. Profiles and Body Plans of subject vessels.

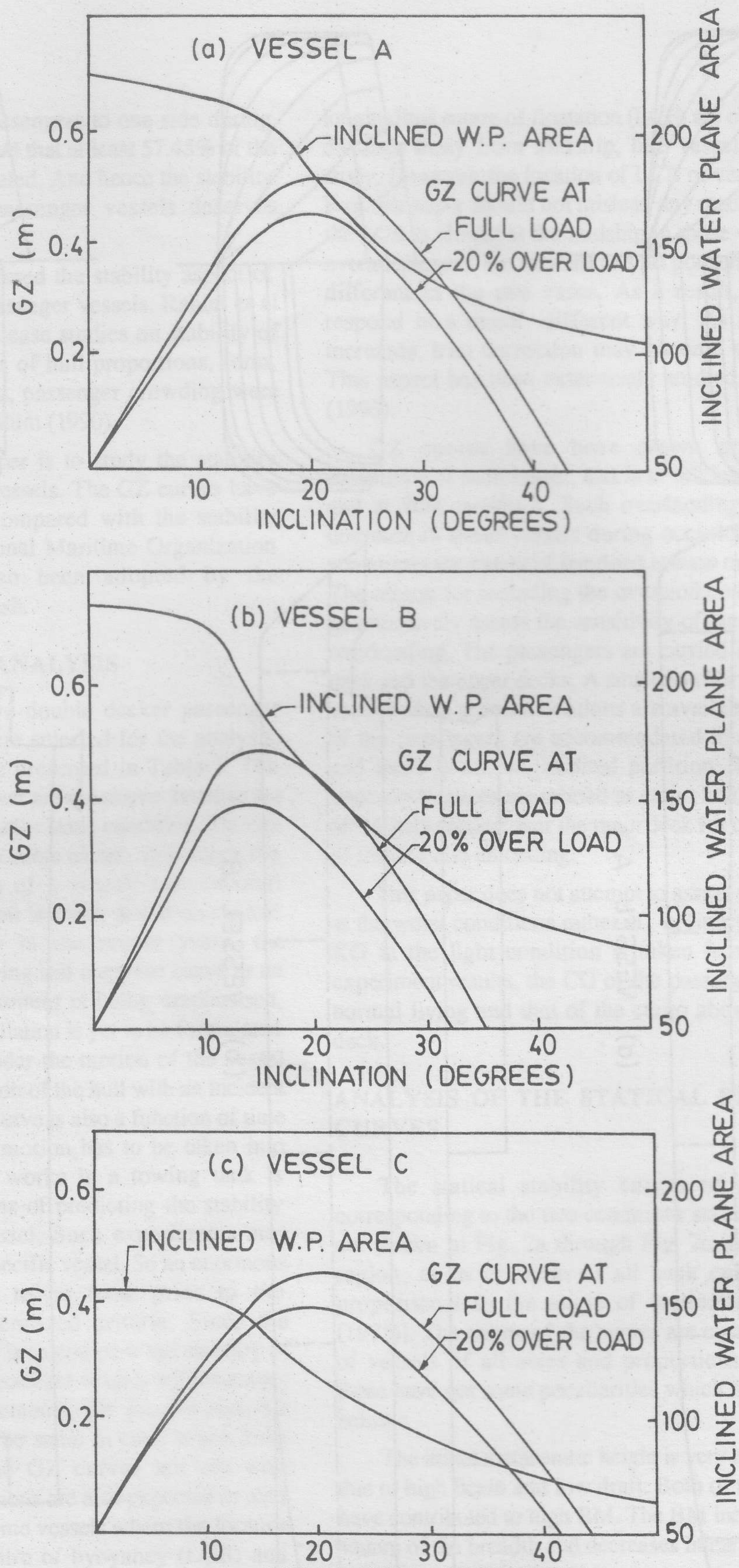


Fig. 2. Statical Stability Curves of subject vessels.

In fact, due to the presence of watertight superstructures, poop, forecastle and other erections in those vessels, the GZ increases more steeply even after deck immersion [Nickum (1978)].

The requirement under item (v) is also satisfied by vessels A and C with wide margin. For vessel B the required GZ is lower than that required by 0.01 m at full load and much lower at overlaod. The reason may again be attributed to those for items (iii) and (iv).

The maximum stability ocurs at a much lower angle than required. The case is worst in vessel B, the reasons are again probably those mentioned earlier. It has been observed [Rahim (1990)] that at breadth/depth ratio above 3.0, this condition (item vi) is the most difficult to satisfy. An impractically low value of KG is required if the maximum GZ is to occur at 25 degrees. Such is the case of all vessels having high breadth. For example, functional requirements of the offshore supply vessels necessitate a wide beam. For the same reasons, as those of the subject vessels, the maximum GZ occurs at an angle lower than 25 degrees i.e., minimum requirement [IMO (1968)].. Consequently a separate set of criteria was developed for such vessels [IMO res. A 469]· A bare minimum limit of 15^{o} was set for the angle of maximum GZ. To compensate, the requrements for the area under the GZ curve were made more stringent. Such a suitable criteria for the inland vessels of the country could possibly also be evolved.

The first row of the Table 2 indicates that the metacentric heights are quite high which are only due to large values of BM. The stability regulations require a very small value of GM (0.35 m).

Lastly, the regulations also do not insist on any minimum value of the angle of vanishing stability (θ_V). But the correspnding figures of the subject vessels are really low and not acceptable by common practices and conventions, specially that of vessel B. A reasonable suggestion would be to incorporate a clause requiring a minimum angle of vanishing stability which could also naturally take care of the situations arising in case of item (v) of this analysis.

In fact, no statutory criterion contains provisions for minimum allowable θ_V . Neither the Rahola Criteria [Rahola (1939)], the first major proposed one, nor IMO (1968) had any requirement for minimum value of θ_V. This was considered at the time of adoption of A. 167. But ultimately no such requirement was added. Necessities were felt at different levels and many discussions were held. For example, the USCG criteria for towing vessels issued on 1st December, 1972 required θ_V to be minimum 60^{o}. Following capsize of a Norwegian flag vessel HELLAND HANSEN in 1976, the concerned flag state introduced rules implicity requireing $\theta_V > 80$ degrees [Henrickson (1980)]. Statistical data of vessels considered safe and the capsized ones indicated that it will not be possible to agree on an acceptable minimum value of θ_V. An international consensus could not be achieved in this regard due to the facts stated below :

i. Calculated value of θ_V depends on trim, wave particulars, orientation of vessels with wave, superstructures etc.

ii. At large angles the GZ value are influenced greatly by factors like free surface, shift of cargo, suspended weight etc. So theoretical calculation of GZ at large angles (where GZ generally vanishes) bears less practical significance.

iii. A large minimum acceptable value of θ_V would obviously be desirable. But this may not be practical for certain vessels like offshore supply boats or vessels desitined for shallow water.

iv. No theoretical technique is known which can predict the influence of θ_V on probability of capsize.

v. An arbitrary limit might on one hand fail to contribute to stability and on the otherhand appear as a design constraint.

Further it was observed that the existing criteria which is concerned with the GZ curve upto 40 degrees automatically ensures a reasonably large value of θ_V. In light of the above mentioned facts, the possibility of incorporation of θ_V in the stability criteria was dropped.

However, an attempt to formulate a minimum required value of θ_V for inland double decker passenger vessels may be argued for the following reasons.

i. The effect of trim on stability has been observed to be insignificant [Rahim et al (1990)], wave height is very small in inland waters and are generally ignored in stability calculations.

Designers may be induced to incorporate watertight superstructures to increase θ_V.

ii. It is true that due to free surface, shift of weight etc. the calculated value of GZ at large angles bears little practical importance. But it may be remembered that all the stability criteria practiced presently are on ordinal scale rather than on absolute scale [Krappinger (1982)]. So a requirement for minimum vlaue of θ_V will help in comparing stability of different inland passenger vessels.

iii. A large minimum acceptable value of θ_V would certainly be desirable but the attempt should be to quantify the absolute minimum value of θ_V which will ensure adequate stability of such vessels.

iv. As long as no theoretical technique is available, a statistical or experimental technique, or a combination thereof, may be used to correlate θ_V with probability of capasize.

v. Since the size, proportion etc of inland double decker passenger launches of the country is within a very narrow range, it may not be difficult to set a limit of θ_V which will contribute to better stability and at the same time will not appear as a design constraint.

CONCLUSIONS

It is evident from the above results that the inland double decker passenger launches do not satisfy the conventional criteria of stability. The vessels studied are essentially of sizes, proportions and types much different from those for which the criteria were originally formulated. So a more rigorous study is to be carried out to formulate appropriate set of rules.

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TABLE 1 : PARTICULARS OF SUBJECT VESSELS

	VESSEL A		VESSEL B		VESSEL C	
	Full load	20% over load	Full load	20% over load	Full load	20% over load
Length O.A (m)	38.56	38.56	37.35	37.35	32.00	32.00
B.P. (m)	36.36	36.35	35.67	35.67	28.95	28.95
Breadth (m)	7.315	7.315	7.927	7.927	6.710	6.710
Depth (mld)	2.133	2.133	1.980	1.980	1.910	1.910
Draft (m)	1.372	1.432	1.372	1.451	1.300	1.365
Displacement (tonne)	215.2	227.9	228.3	247.1	137.1	147.1
Water plane area (m^2)	220.2	225.2	235.9	239.9	156.1	158.5
Midship area(m^2)	8.660	9.101	9.000	9.602	7.012	7.400
Cb	0.589	0.599	0.587	0.602	0.542	0.553
Cp	0.683	0.689	0.710	0.721	0.674	0.685
Cvp	0.712	0.717	0.704	0.710	0.675	0.678
LBC*(m)	0.220(A)	0.360 (A)	0.165(A)	0.359(A)	1.565(A)	.645(A)
Passenger (Persons)	500	600	550	660	335	402
Cargo (Tonne)	25.0	30.0	50.0	60.0	20.0	24.0
Payload (tonne)	63.56	76.27	92.41	110.0	45.83	55.0

* (A) for aft of amidhsip.

TABLE 2 : GZ CURVE DATA (Ref : Fig. - 2)

		VESSEL A		VESSEL B		VESSEL C	
	Min3 Limit	Full load	20% over load	Full load	20% over load	Full load	20% over load
Metacentric Height (m)	015m	1.867	1.721	2.354	2.094	1.903	0.396
i. GZ_{max} (m)	See below	0.520	0.450	0.484	0.390	0.476	0.396
ii. Area upto 30^{o}	0.05 m-rad	0.1891	0.1639	0.1731	0.129	0.1700	0.1476
iii. Area upto 40^{o}	0.09m-rad	0.2320	0.1918	0.1773	0.1169	0.2123	0.1760
iv. Area between 30^{o} and 40^{o}	0.03 m-rad	0.04239	0.0279	0.0004	0.0016	0.0423	0.0287
v. GZ at 30^{o}(m)	0.20	0.384	0.304	0.190	0.070	0.348	0.268
vi. Angle of Max^{m} Stability	0.20	20.5^{o}	20.0^{o}	15.5^{o}	14.4^{o}	20.5^{o}	19.5^{o}
vii. Angle of vanishing stability	None	43.0^{o}	40.3^{o}	35.5^{o}	32.0^{o}	44.3^{o}	41.6^{o}

0.0215 x B or 0.27 m whichever is minimum : 0.157 m for vessel A, 0.170 m for vessel B and 0.144 m for vessel C.

[Lester (1985)]. However, the benefit of this high metacentric height is very limited. The maximum GZ is reached very soon and then the stability vanishes almost as steeply as it had increased. Immediately after the deck immersion, which occur at rather very small angles, the waterplane area reduces very sharply. This curve for full load and 20% overload condition differs slightly; the latter being higher at small angles and lower at higher angles. The curve corresponding to full load only are drawn.

ASSESEMENT OF STABILITY

The assesement of the stability contains three separate items. These are-

1. Requirements for the curve of arms of static stability.
2. Vessels' capability to withstand beam wind on lateral area above water line.
3. Vessels' capability to withstand effects of passenger crowding.

The present work concentrates only on the requirements for the curve of the arms of static stability.

CURVE OF STATICAL STABILITY

IMO (1968) and statutory regulation of Bangladesh [Ahmed et al (1986)] require the curve to satisfy the following conditions :

i. $GZ_{max} < 0.0215 \times B$ or 0.27 m whichever is smaller where B = Ships breadth measured between the outside of frames.
ii. Area under the curve upto 30^{o} will be at least 0.055 m-rad.
iii. Area under the curve upto 40 degrees or flooding angle, whichever is less should be at least 0.09 m-rad.
vi. Area under the curve between 30 degrees and 40 degrees or flooding angle, whichever is less should be at least 0.03 m-rad.
v. GZ be at least 0.2 m at 30 degrees.
vi. Angle of maximum stability should be at an inclination greater than or equal to 25 degrees, preferably 30 degrees and over.

As regard item (i), the magnitude of 0.0215 B for each vessel is less than 0.27 m. The corresponding values are 0.157 m, 0.170 m and 0.144 m for vessels A, B and C respectively. The decks are in general watertight except at deck openings which are small in width and about centreline. As a result the flooding angles are much above 40 degrees. Table 2 shows the values obtained from the GZ curves of the three vessels for items (i) through (vi). The observations are as follows.

The GZ_{max} (item i) for all the cases is much higher than corresponding required values. This is due to the high metacentric height, the reason of which is explained earlier. Area under the curve upto 30^{o} and upto 40^{o} (item ii and iii) are also much higher than required 0.055 m-rad and 0.09 m-rad respectively.

In item (iv), the area under the GZ curve between 30 degrees and 40 degrees should have been at least 0.03 m- rad. At full load condition, vessels A and C have been able to satisfy this requirement with good margin and fails by a very small margin at overlaod. However, vessel B have grossly failed to reach the required value and has even become negative at overload condition. This is because the stability of this vessel under both conditions (i.e. full designed load and 20% overlaod) vanishes at an angle between 30 degrees and 40 degrees. In fact, there is not much merit in evaluating the area upto 40 degrees. One reason for this poor performance could be its high breadth/draft ratio contirbuting to steep reduction of the inclined water plane area after deck immersion. From upright condition to 40 degrees inclination, for full load conditions, this reduction is 49.3%, 60.4% and 50.6% in vessels A, B and C respectively. Though vessel B is almost as full as A and fuller than C, this hull shape, together with the highest metacentric height of the three, has made no contribution towards offseting the effects of adverse beam /draft ratio. So there are reasons to infer that to arrive at a reasonable GZ curve the designer must start with favourable ratios of principal dimensions. The author had studied the reduction of water plane area with inclination of six other passenger vessels [Rahim (1990)] and observed that the reduction at 40 degrees may be as high as 65%. It was also concluded in the same study that parameters like block co-efficient, prismatic coefficient etc. may influence the reduction of water plane area with inclination. But such influences can not override the effects of even a moderate difference in breadth/draft ratio. However, such is the case only with vessels having high breath/draft ratio. At breadth/depth ratio less than 2.5, which is, in fact, the case with most coastal and ocean going vessels the reduction in waterplane is retarded.