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ORIGINAL ARTICLE

Possible remedies for intact stability hazards involving contemporary small inland passenger ferries in Bangladesh

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Abstract On the basis of previous studies, a series of hazards involving the typical small inland passenger ferries operating in inland Bangladeshi waters have been identified. In particular, stormy weather conditions, overloading, and the risk of crowding to one side have been determined as the typical events that are likely to lead to capsizing in the intact condition. In this article, possible hazard mitigation measures are discussed, both from the regulatory and from the design point of view, for a small inland ferry that is very similar to one that actually capsized in the past. The addressed design options involve ballasting and hull modification by means of additional buoyancy above the waterline. From a regulatory point of view, it is proposed that the present weather criterion in force in Bangladesh be modified by increasing the wind speed to be accounted for and by considering the concurrent effects of wind, rolling, and the crowding of people to one side.

Keywords Transport safety · Inland water transport · Passenger ferry · Intact stability · Additional buoyancy · Hazard identification · Weather criterion

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1 Introduction

The river transportation of goods and passengers plays a vital role in the economic and social life of Bangladesh, and it is therefore of the utmost importance to guarantee high reliability in this fundamental sector. In particular, when the safety of people is of concern, it is essential to try to avoid the occurrence of tragic accidents involving the loss of life. However, accidents, especially involving passenger transports, have brought disrepute to this sector of Bangladesh's economy. A large number of people are killed every year in accidents involving passenger ferries. An investigation using accident data from various resources such as newspapers, journals, and personal communications to the relevant offices (e.g., the Bangladesh Inland Water Transport Authority and the Department of Shipping, Bangladesh) showed that more than 9,000 people have died or been reported missing in the past 25 years due to passenger ferry accidents [1].

Efforts are necessary both from the regulatory authorities and from the designers. The improvement of safety by means of regulatory options is based on the development of proper, physically sound, and well-based rules. In order to achieve such a goal, it is important to follow a rational path, starting from the identification of the possible hazards endangering the ship. Such hazards are strongly related to the design and operational practice, the geographical/

environmental characteristics of the navigation zone, and the level of development of the country in which the rules are applied. A similar path, based on hazard identification, is also useful in the design process in order to provide a design that is free as far as possible from macroscopic faults that could be overlooked by an insufficiently rigorous regulatory framework. The application of the formal safety assessment procedure, encouraged by the IMO [2], is an example of such a rational path involving both the designer and the administration.

A previous article [1] was aimed at analysing the hazards involved in these inland water passenger transport accidents in Bangladesh, with particular attention to the case of a typical small inland passenger ferry that is very similar to a ship that actually capsized and is representative of a class of ships currently navigating in Bangladesh. In the previous study [1] the accident data of the past 25 years were collected from various sources and analysed, showing that the combined effect of crowding associated with overloading and storms were the major causes behind a large number of intact stability failures. In addition, the analysis of historical data of maximum monthly wind speed in five locations in Bangladesh suggested that the mean wind speed currently considered in the weather criterion in force in Bangladesh [3] could reasonably be increased from 20.6 to 26 m/s; this would also harmonize the rule with the international standard in the IMO Intact Stability Code [4].

In this article we use the outcomes of the previous study, i.e., the identified hazards, in order to propose a possible alternative form of the weather criterion. In addition, for the analysed small passenger ship, the addition of totally enclosed inflatable lifting bags under the rigid fender is investigated as a possible, hopefully cost-effective design modification aimed at improving the design by increasing the ship restoring moment at large heeling angles through the provision of an additional reserve of buoyancy above the waterline.

Literature concerning the development of stability rules for inland transportation specifically addressing passenger ships operating in rivers seems to be scarce, and the authors were not able to find suitable references on the topic addressed by the present article. Other references are available, on the other hand, concerning inland transportation from a more general point of view. In the milestone work of Rahola [5] the problem of inland transportation is specifically addressed, but attention is given to Finnish waters, which possess characteristics that are significantly different from the characteristics of inland waters in Bangladesh. In particular, Rahola [5], mainly addresses the case of transportation in lakes, whereas most of the transportation in Bangladesh occurs in rivers. The currents in lakes are usually more limited than for rivers, but at the same time more fetch could be available (depending on the dimensions of the lake) for the development of waves; for rivers, the fetch is often much more limited. More recent work addressing the problem of inland transportation is found in the article of Hofman and Bačlov [6], in which attention is given more to the methodology of assessment of rolling motion rather than to the analysis of hazards involved in inland transportation. Moreover, the inland transportation of passengers is not considered. Nevertheless, Hofman and Bačlov [6] interestingly report (with a series of references) that stability rules for inland vessels are basically split into two groups: those applying a dynamic approach under the action of wind, and those applying a static approach. In both cases, however, Hofman and Bačlov [6] report that waves are not accounted for by inland rules. Our present work is, instead, much less general, since it is intended to address the problem of transportation of passengers in a well-defined area (Bangladesh) and for a particular ship type (the so called "launches") starting from a dedicated hazard identification [1].

Unfortunately, the amount of research work on inland passenger ferry safety in Bangladesh is small. Among the few works available, Islam [7] checked safety matters of inland passenger ferries in Bangladesh from an economic point of view through finding the dependence of the first cost of the ferry and the internal rate of return (IRR) of the investment on the length-to-breadth (L/B) and breadth-to-draught (B/T) ratios of the ferries. One fascinating piece of work was the investigation of the influence of some parameters on stability of inland passenger vessels using the Strathclyde method and the Lyapunov method by Rahim [8] and Rahim et al. [9]. These articles studied and compared the stability of three different passenger vessels in Bangladesh. The line plans of the vessels were collected and the stability was assessed for the full load condition. The IMO wind heel criteria and passenger crowding criteria were applied to the vessels. The results showed that smaller vessels tend to be more at risk of capsizing than larger ones. The results also showed that the crowding of passengers on one side during a crisis posed a greater risk than the beam wind. In reality the two phenomena occur simultaneous during a storm, and the risk is greatly enhanced. It was also observed that, although the vessels have a very high initial metacentric height, the righting arm (GZ) reaches its maximum value at very small angles (less than 20°). At larger angles, GZ vanishes very quickly with inclination. Deck immersion also takes place at small angles. All these facts result from the low draught coupled with the large breadth of the vessels. The low draught is necessitated by the shallow nature of the rivers in Bangladesh, and the high beam is driven by the commercial consideration of carrying the maximum number of passengers. The article concluded with the necessity of developing appropriate criteria for inland vessels operating in Bangladesh, which are significantly different in character from vessels operating anywhere else in the world.

2 Description of the sample small inland passenger ship

A thorough description of the sample inland passenger vessel addressed in this article is provided in a previous article [1]. The ship under investigation, a small launch (SL) as they are called in Bangladesh, is very similar to a small inland passenger vessel that actually capsized in Bangladesh.

Two loading conditions are considered:

- The full load condition.
- A condition with a 50% overloading.

The 50% overloading condition is used because analysis of the data from accidents [1] showed a relevant number of cases for which overloading was present. It is noted that the maximum draught for this ship is, according to the position of the perpendiculars, around 1.2 m, and this draught could only be achieved, according to the available data, by means of a relevant quantity of ballast (35 t). This large amount of required ballast poses some question as to the actual draught at which the ship is operated.

The body plan of the SL ship is shown in Fig. 1. Data for the two loading conditions and the main particulars of the ship are given in Table 1 (the two values for the lateral projected area are for clear openings and for when openings are obstructed by curtains). In the full load condition it was assumed that a person weighs 75 kg.

The analysis of past accidents identified stormy weather and overloading as the principal causes behind a large number of accidents in the intact condition [1]. In particular, for the ship under analysis, the crowding of passengers to one side was identified as a dangerous event able to endanger the ship, especially with the concurrent action of beam winds [1].

3 Proposal for a weather and crowding criterion

From the analysis of hazards carried out in the previous study [1], it seems that the large number of passengers on board the considered SL ship renders crowding to one side the most dangerous hazard. The effect of beam winds has been found to be a less demanding hazard in terms of steady equilibrium angle; however, the analysis of accidents [1] has shown a significant number of capsizes in stormy condition with overloaded ships. It is thus important, at the design stage and during the approval process, to take into account the possibility of the concurrence of the above conditions.

The weather criterion presently in force in Bangladesh [3] considers only the effect of beam winds at a uniform lateral pressure of 316 N/m^2. In the authors' opinion, compliance with such a criterion does not necessary lead to a sufficiently safe ship because of a failure to acknowledge the possible detrimental effect of the crowding of passengers to one side. In addition, the pressure to be taken into account in the present criterion is about 62.7% of the pressure that should be accounted for if a speed of 26 m/s were considered, according to the findings from the analysis of wind data [1]. It could be argued that a reduction of the speed with respect to that obtained from meteorological stations should be introduced due to the boundary layer effects close to the ground. Nevertheless, it is the authors' opinion that, because the ships we are concerned with are carrying people, any relaxation would be inappropriate. In addition, very localised storms (tornadoes) are not uncommon in Bangladesh: such storms can be associated with much higher wind speeds than 26 m/s.

According to such reasoning, we would like to propose a criterion very similar to the present weather criterion concerning the application framework, but in the new criterion the effect of the mean wind speed and gusts are combined with the effects of the crowding of passengers to one side. The idea is to substitute the mean heeling lever due to wind (usually called l_{w1}) with the sum of the heeling levers due to passenger crowding to one side and a beam

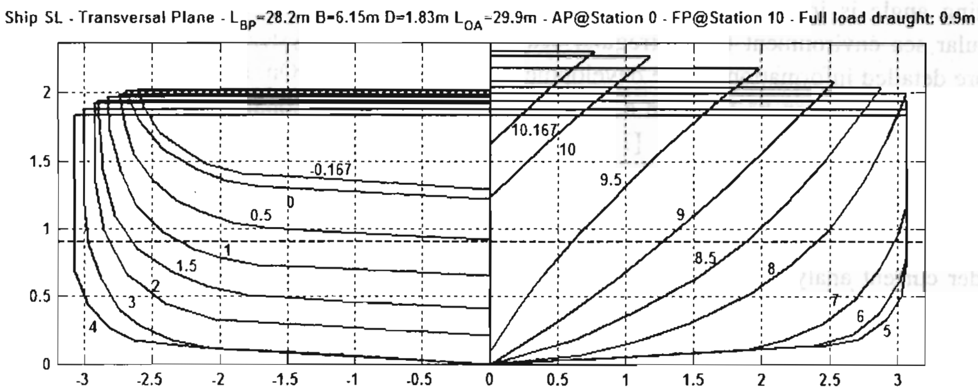

Fig. 1 Body plan of the small launch (*SL*). L_{BP} length between perpendiculars, B breadth, D depth, L_{OA} length overall, *AP* aft perpendicular, *FP* fore perpendicular

Table 1 Reference loading conditions

	Full load	50% overloading
Length between perpendiculars, L_{BP} (m)	28.2	
Breadth, B (m)	6.15	
Depth, D (m)	1.83	
Draught, T (m)	0.900	0.971
Volume, ∇ (m^3)	88.0	97.5
Vertical position of the centre of buoyancy above the baseline, $\overline{KB}$ (m)	0.528	0.568
Transverse metacentric radius, $\overline{BM}_T$ (m)	4.002	3.721
Vertical position of the centre of gravity from the baseline, $\overline{KG}$ (m)	2.061	2.189
Transverse metacentric height, $\overline{GM}$ (m)	2.469	2.100
Mass of passengers and crew (kg)	19,050	28,575
Lateral projected area exposed to wind, A_{lat} (m^2)	71.6 (107.8)	69.6 (105.8)
Vertical distance between the assumed centre of application of the wind force and the centre of application of the drift reaction, Z (m)	2.711	2.740

wind. Similarly, the total heeling lever under gust conditions is considered to be given by the sum of the wind heeling lever under gust conditions $l_{w2} = 1.5\ l_{w1}$ and the heeling lever due to passenger crowding to one side. The requirement of dynamic survival (based on the relative magnitudes of so called "area b" and "area a", i.e., area b $\geq$ area a) is considered to remain the same.

There is, however, a point that needs additional discussion, i.e., the dynamic roll motion to be taken into account. In the IMO weather criterion [4], the rolling amplitude due to the action of waves is determined as follows:

$$\varphi_1 = 109 \times k \times X_1 \times X_2 \times \sqrt{r \times s} \tag{1}$$

where the product $k \times X_1 \times X_2$ essentially accounts for the ship damping and the effects of bilge keels (if present). The factor r is the effective wave slope and it is calculated on the basis of the quantity $(\overline{KG} - T)/T$, where T is the ship's draught and KG is the vertical position of the centre of gravity from the baseline. Factor s is the wave slope, which is determined according to a table depending on the ship roll period. In Eq. 1, an empirical reduction of 30% in the rolling angle is implicitly considered in moving from a regular sea environment to an irregular sea environment. More detailed information on the development of the IMO weather criterion can be found in a recent IMO document [10] and in Francescutto et al. [11]. If we look at the 'Application' section of the recent IMO circular for the alternative assessment of the weather criterion [12], we note that the B/T and the $(\overline{KG} - T)/T$ ratios for the ship under current analysis are outside the intervals for which the formulas for the coefficients of the weather criterion were developed. For this reason, we cannot consider the product $k \times X_1 \times X_2 \times \sqrt{r}$ to be accurate enough. The small draught of typical river ships operating in Bangladesh is likely to put many of them outside the applicability of the IMO weather criterion formulas for the rolling angle associated with the action of waves. In addition, the rolling angle depends strongly on the assumed wave steepness, s, and the relation between the wave period (assumed to be equal to the natural roll period, i.e., the criterion assumes linear resonant rolling) and the wave steepness is given in the work of Sverdrup and Munk [13]. This latter work is based on observations of waves at sea, and thus the factor s represents an open sea environment and is thus suitable for seagoing ships. The environmental conditions in inland rivers are completely different, and from some aspects, are much more complicated. In river navigation, hazards such as strong currents, whirlpools, and turbulent water are present; these hazards usually do not occur at sea. The response of a ship to such excitations is, basically, unknown, and is likely to be very difficult to predict due to the difficulty in providing a good model of the water flow to be taken into account as the input process for the calculation of ship motions. For these reasons, the application of the IMO formula for φ_1 when dealing with inland water transportation is likely to be inappropriate and to lack a physical basis.

On the other hand, it is very difficult to provide a rational alternative, due to the aforementioned difficulties, to achieve a sound prediction/estimation of the rolling behaviour. Therefore, in this article, we assume that a constant, ship-independent value for the angle of roll φ_1 is an appropriate choice. The biggest problem is to rationally decide a suitable value, given that there is almost a complete lack of available data from ships in operation. What can be guessed is, however, that strong synchronous rolling for ships sailing in rivers is not a likely situation because the limited fetch leads to poorly developed waves and because of the quite irregular flow. Based on these arguments, it is the authors' opinion that the actual rolling motion to be accounted for should not be extremely large, and, therefore, a value of 10° was used here, although this figure is open to debate.

Curtains are often used to protect people from the wind and rain [1], and they significantly obstruct the apertures available on the ship's side through which the wind could in principle flow. For this reason, in our analysis, openings on passenger decks should be considered closed or, at least, significantly obstructed. In the following calculation, we will consider the openings to be fully obstructed.

For the crowding of passengers on the SL ship, we have assumed a movement of 100% of the passengers on board to a position equal to 70% of the half-breadth of the ship. The application of the proposed criterion in the case of the full load condition is shown in Fig. 2: the ship does not pass the criterion. The criterion is not fulfilled due to the combined effect of several factors, i.e.:

- The large *B*/*T* ratio, leading to the position of the maximum of the $\overline{GZ}$ curve being slightly below 25°.
- The corresponding relatively small range of positive $\overline{GZ}$ curve.
- The large heeling moment due to the crowding of passengers.
- The significant heeling moment due to wind.

In addition, due to the small angle of deck submergence (slightly more than 18°), the requirement of a steady equilibrium angle of less than 80% of the deck submergence angle or 16°, whichever the less, cannot be fulfilled. In the overloaded condition, the situation is even worse, because the ship cannot even statically sustain the combined effect of crowding to one side and the mean wind. It can thus be said that, from the application of the proposed criterion, the design should be considered as not satisfactory and as potentially dangerous.

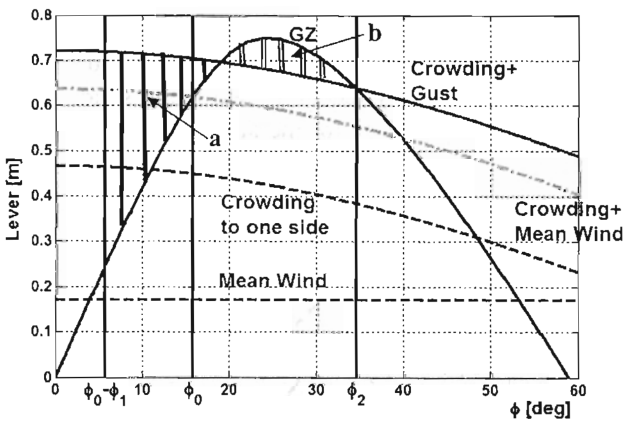

Fig. 2 Application of the weather and crowding criterion in the full load condition ($\phi_{fl} = 58.8$, $\phi_{ds} = 18.3$, $\phi_0 = 15.7$, $\phi_1 = 10.0$, $\phi_2 = 34.6$, area $a = 0.049$, area $b = 0.013$). *GZ* righting arm, ϕ_{fl} flooding angle, ϕ_{ds} deck submergence angle, ϕ_0 equilibrium angle under the action of steady wind and crowding to one side, ϕ_1 assumed rolling amplitude, ϕ_2 minimum among 50°, the angle of vanishing stability, and the flooding angle. Angles are measured in degrees and areas in m × rad. The stability criterion is not fulfilled because area $b <$ area a

4 Proposal of modification: fitting of additional buoyancy

In Sect. 3 we have seen that the SL has a $\overline{GZ}$ that is to be considered insufficient when the combined effect of wind, passengers' crowding to one side, and rolling is of concern. For this reason we have investigated the possibility of modifying the ship design in order to improve the restoring capabilities of the vessel, bearing in mind the necessity of a relatively easy and cost-effective modification.

The basic idea is to supply the ship with an additional reserve of buoyancy above the waterline in such a way as to increase the restoring moment, especially in the range of maximum $\overline{GZ}$. Typical passenger ferries operating in Bangladesh are fitted with a rigid fender at deck height, extending transversally with a length depending on the particular ship. For the ship under analysis, the breadth of the fender is 0.6 m, as shown for the midship section in Fig. 3. Such rigid fenders are used to protect the ship hull during berthing and during loading/unloading operations (and it is not uncommon to see people standing on it).

A tentative proposal is thus to provide additional buoyancy to the ship by exploiting the clear area below the fender. The requirements for the ship modification are:

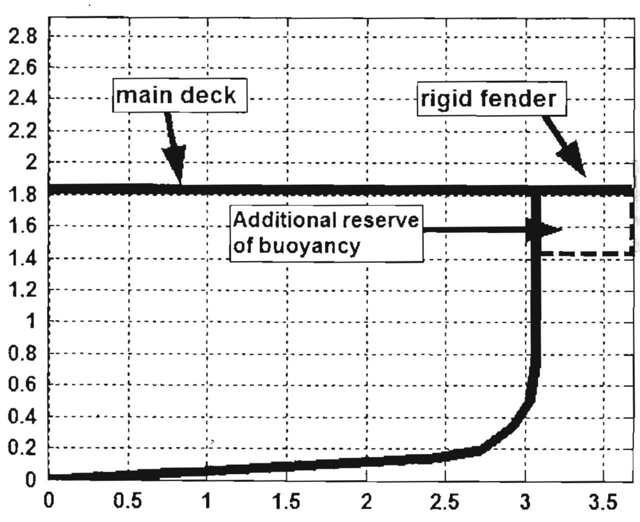

Fig. 3 Rigid fender at the midship section (Sect. 5), showing proposed additional buoyancy

- The modification shall be easy and not expensive.
- The modification shall not interfere with the normal ship operation.
- The additional buoyancy shall be effective in increasing the maximum righting lever.
- The modification shall not involve modification of the hull.
- The modification shall not excessively reduce the payload.

We have thus considered the possibility of adding such buoyancy through totally enclosed inflatable lifting bags to be fitted in position under the rigid fender by means of suitable guides and connections. Such buoyancy aids could be easily filled with air by means of an air pump connected to the main engine. In addition to providing additional buoyancy, the inflatable bags could also be considered effective as protections from collisions, thus increasing the inherent ship safety with respect to this latter hazard. Moreover, in the case of a breach of the hull, the presence of such bags, if not damaged, could provide a safe, although limited, additional reserve of buoyancy.

The selection of the dimensions of such a buoyancy reserve is governed by the actual breadth of the fender and by the freeboard at the maximum allowed draught. The ship under analysis has a maximum allowed draught of 1.2 m, with a depth of 1.83 m. If we assume that 0.2 m should be left clear between the water plane and the bottom of the lifting bags, a maximum height of about 0.4 m is obtained. It is to be said that this height could be increased by reducing the maximum allowed draught: the reduction in the maximum payload that the ship could carry would be compensated for by the additional safety. The geometry and the position of the additional reserve of buoyancy are shown in Fig. 3.

The longitudinal extent of the buoyancy reserve has been assumed to go from Sects. 1 to 9, a total of 22.6 m. From a survey of commercially available lifting bags, we have estimated that, for the assumed dimensions, the weight of a bag 1 m in length is below 10 kg, including the necessary connections to the hull. This means that the total additional weight due to the modification is estimated to be below 0.5 t; the total gained reserve of buoyancy is about 11 t.

Figure 4 shows the righting arm curves for the SL ship in the original and modified configurations for the two tested loading conditions: the improvement in the $\overline{GZ}$ curve for both tested loading conditions is evident. The maximum $\overline{GZ}$ still occurred at quite low heeling angles due to the large *B*/*T* ratio; however, the value of the maximum was increased, on average, by about 22%.

In order to check the effectiveness of the proposed modification on a rational basis, we have again applied the proposed weather and crowding criterion described in Sect. 3 to the modified ship for the full load condition. The results of the application are shown in Fig. 5, where it can be seen that the modified ship is able to fulfil the requirements thanks to the additional restoring moment. For the sake of comparison, in Fig. 5, the $\overline{GZ}$ curve of the original design is also shown. Therefore, from the obtained results, it seems that the proposed modification is worthy of attention due to its potential for improving the safety of the SL ship with limited effort.

It is, however, important to underline that the proposed modification, although providing an improvement, it is not able to solve the issue of concurrent crowding to one side and gusting wind in the overloaded condition, as shown in Fig. 6.

5 Ballasting as a possible alternative

As already mentioned in Sect. 2, about 35 t seems to be missing to achieve the maximum allowed draught. When the ship cannot achieve the design draught at full load, Bangladeshi authorities usually recommended fixing solid ballast on the ship to compensate for the lack of weight.

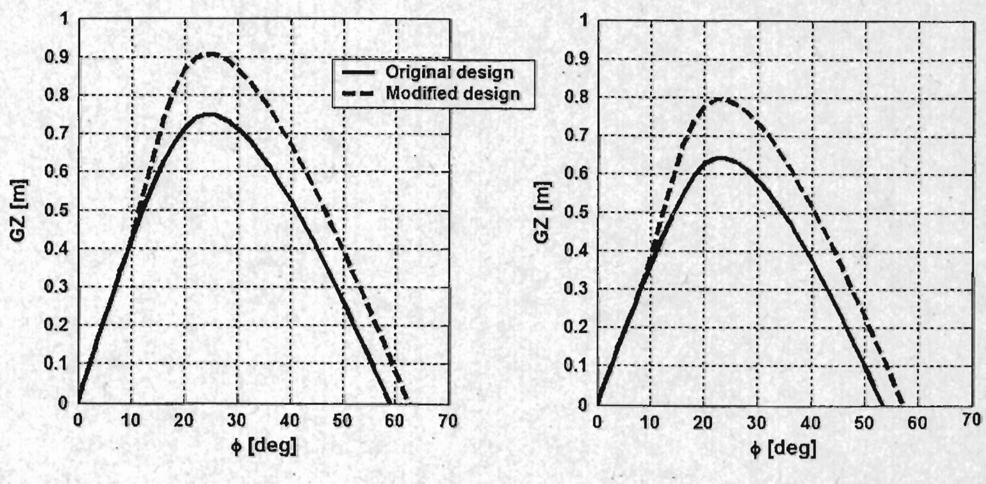

Fig. 4 $\overline{GZ}$ curves for the SL ship in the two tested loading conditions for the original design and the modified design with additional buoyancy. *Left* full load, *right* 50% overload

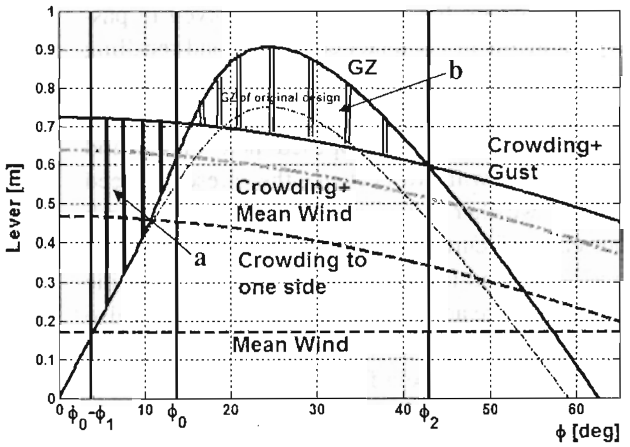

Fig. 5 Application of the weather and crowding criterion to the modified SL at full load condition ($\phi_{fl} = 64.8$, $\phi_{ds} = 19.1$, $\phi_0 = 13.7$, $\phi_1 = 10.0$, $\phi_2 = 42.9$, area $a = 0.060$, area $b = 0.072$). Angles are measured in degrees and areas in m × rad. The criterion is fulfilled

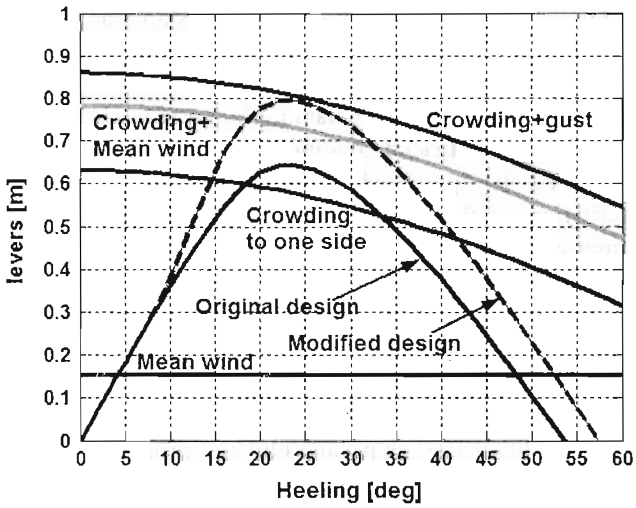

Fig. 6 Concurrent effect of crowding to one side and gusting wind in the 50% overloaded condition

Therefore, we have investigated this possibility as an alternative to the idea of fixing additional buoyancy reserves above the waterline. A total ballast weight of 35 t has been considered, and, in addition, 7 t of cargo in the cargo holds has been assumed. The data for the corresponding loading condition are reported in Table 2.

The $\overline{GZ}$ curve for the ballast and cargo loading condition is compared with the full load case in Fig. 7. We can see that the metacentric height in the ballast condition is reduced due to the decrease in the metacentric height as the draught increases, and also the maximum $\overline{GZ}$ is reduced. However, the range of positive stability is increased by about 10°, and therefore the righting arm in the ballast condition is larger when the angle of heel exceeds about 36°.

Table 2 Data for the ballast and cargo loading condition

	Ballast and cargo
T (m)	1.2
∇ (m^3)	130.0
$\overline{KB}$ (m)	0.697
$\overline{BM}_T$ (m)	3.039
$\overline{KG}$ (m)	1.551
$\overline{GM}$ (m)	2.185
Mass of passengers and crew (kg)	19,050
Cargo (t)	7
Ballast (t)	35
A_{lat} (m^2)	62.9 (99.1)
Z (m)	2.840

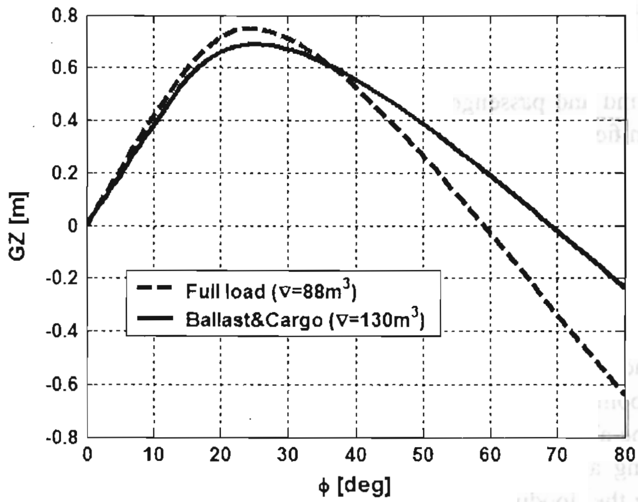

Fig. 7 $\overline{GZ}$ for the SL with and without ballast. ∇ volume

The angle at which the engine room floods in the absence of a hatch cover, with and without the presence of hatch coamings, was calculated when analysing the possible hazards endangering the ship in a previous study [1], leading to a flooding angle of about 41° with hatch coamings 0.5 m in height, and about 28° in the absence of hatch coamings. Such values correspond to the zero trim condition: in case of stern trim, the corresponding flooding angles with and without hatch coamings decrease. The deck submergence angle has been determined to be 11.8° with zero trim. In the case of deck submergence, the change of trim has a limited effect.

The SL ship was checked using the weather and crowding criterion in the ballast condition, and the downflooding angle was considered as the angle of flooding of the engine room without the presence of hatch coamings. The results are shown in Fig. 8. We note that the increase in the displacement has reduced the levers of the moments

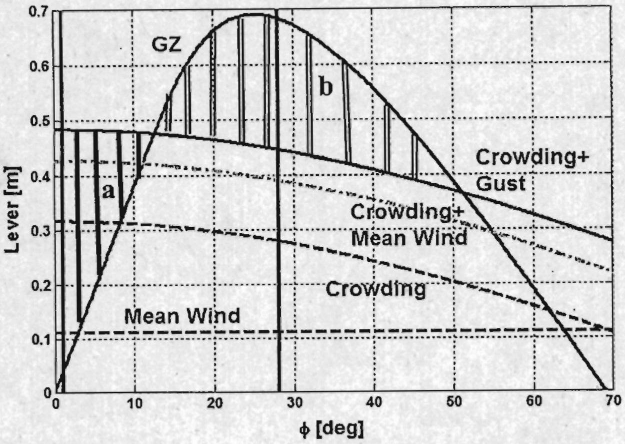

Fig. 8 Application of the weather and crowding criterion to the ship in the ballast and cargo condition ($\phi_{fl} = 28.1$, $\phi_{ds} = 11.8$, $\phi_0 = 11.1$, $\phi_1 = 10.0$, $\phi_2 = 28.1$, area $a = 0.044$, area $b = 0.047$). Angles are measured in degrees and areas in m × rad. Although the basic stability criterion (area $b >$ area a) is met, the footnote criterion $\phi_0 < 0.8 \times \phi_{ds}$ is not met

due to wind and passenger crowding to one side, and this has a significant positive effect. Nevertheless, the increased draught leads to a loss of freeboard, with a consequent decrease in the deck submergence angle: for this reason the ship is not able to fulfil the requirement for the equilibrium angle under steady wind and passengers' crowding to one side to be less than the minimum between 80% of the deck submergence angle or 16°. It is important to note that, in the absence of hatch coamings, the angle of flooding of the engine room is, as already said, quite small. This means that, in the absence of hatch covers, the righting arm curve for heeling angles greater than 28° should be calculated assuming the flooding of the engine room, and this would lead to a drastic decrease in the restoring capabilities of the ship.

As a final comment, it seems that the ballasting of the ship, although being a viable option for reducing the effect of wind and passenger crowding, is not free of drawbacks, since the increase in the displacement means a significant decrease in the freeboard. In addition, the presence of such a large amount of ballast is considered not economically effective due to the increased ship power required and the resulting increased fuel consumption, without any benefit in terms of the payload.

6 Final remarks

Starting from a previous study [1] in which an analysis of hazards involving small inland passenger vessels was carried out, this article represents a natural continuation in the direction of risk mitigation both from the design and the regulatory point of view. Bearing in mind that overloading and stormy weather are the main factors involved in passenger ferry accidents in the intact condition, and recalling the previous analysis of a historical series of maximum monthly wind speeds at five locations in Bangladesh [1], a modified weather criterion is proposed here. The wind speed is increased with respect to the present speed assumed by the weather criterion in force in Bangladesh [3], the presence of curtains obstructing the windows is taken into account, and the effect of crowding to one side and of a beam wind are added together. A discussion is also provided to explain why the application of the standard IMO weather criterion formula for the angle of roll due to the action of beam waves [4] cannot be considered suitable for application to typical inland passenger vessels operating in the rivers of Bangladesh.

A small passenger ship, representative of the typical small "launches" operating in Bangladesh, was analysed from a rational point of view, starting from the identification of possible hazards involving the ship in the intact condition reported in a previous study [1]. The ship was analysed with respect to the hazard of concurrent beam wind, rolling, and crowding of the passengers to one side, showing that the limited reserve of stability in the assumed full load and in the overloaded conditions does not allow the ship to fulfil the proposed modified weather and crowding criterion for the assumed set of concurrent hazards. To improve the ship's safety, a modification of the design was analysed, in which the original ship is equipped with additional buoyancy above the waterline to increase the restoring lever at large heeling angles without influencing the resistance characteristics of the ship. The proposed modification has been shown to be effective in the full load condition (the ship can fulfil the proposed criterion); however, in the overloaded condition the modification is not sufficient to allow the ship to withstand the effect of gusty wind combined with crowding to one side and rolling. Ballasting, as an alternative, was also investigated (being at présent the recommendation/requirement if a ship at full load does not reach its maximum draught); however, the results showed that the effectiveness of ballasting could be largely reduced by the risk of flooding of the engine room in the absence of hatch covers (resulting from the loss of freeboard). The proposal put forward in this article of providing the ship with additional above-water reserve buoyancy is worthy of additional investigation concerning its actual applicability, cost effectiveness, and impact on the safety of the small launches operating in Bangladesh. Moreover, it would be interesting to carry out similar types of analyses, based on rational hazard identification and proposals of mitigation, on a wider range of ship types, embracing also larger ships. It is indeed likely that ships of different sizes, having a different ratio between the weight of passengers onboard and the ship displacement, will respond in different ways to the same hazards.

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References

1. Iqbal KS, Bulian G, Hasegawa K, Karim MM, Awal ZI (2008) A rational analysis of intact stability hazards involving small inland passenger ferries in Bangladesh. J Mar Sci Technol. doi:10.1007/s00773-008-0016-3
2. IMO Document, MSC/Circ. 1023, MEPC/Circ. 392 (2002) Guidelines for formal safety assessment (FSA) for use in the IMO rule making process, London, 5 April
3. Zulfikar MM (2005) Preventing accidents of inland ships: law and ordinance; inland ship (stability) rules 2001 (in Bengali). H. A. Publishers, Dhaka
4. IMO (2002) Code on intact stability for all types of ships covered by IMO instruments. IMO, London
5. Rahola J (1939) Judging the stability of ships and determination of the minimum amount of stability, especially considering the vessels navigating finnish waters. Ph.D. Thesis, Technical University of Finland, Helsinki
6. Hofman M, Bačlov I (2005) Weather criterion for seagoing and inland vessels—some new proposals. In: Proceedings of the international conference on marine research and transportation (ICMRT'05), Ischia, September
7. Islam MR (1997) Techno-economic analysis applied to safety of inland passenger vessels. M.Sc. Engineering Thesis, Department of Naval Architecture and Marine Engineering, Bangladesh University of Engineering and Technology
8. Rahim A (1990) Study of the effects of wind and passenger crowding on the safety of inland passenger vessels. M.Sc. Engineering Thesis, Department of Mechanical Engineering, Bangladesh University of Engineering and Technology
9. Rahim A, Islam AKMS, Khalil GM (1994) Weather and passenger crowding criteria on the stability of inland passenger vessels. J Inst Eng (India)
10. IMO Document, SLF48/4/5 (2005) Proposal on draft explanatory notes to the severe wind and rolling criterion (submitted by Japan), London, 10 June
11. Francescutto A, Umeda N, Serra A, Bulian G, Paroka D (2004) Experiment-supported weather criterion and its design impact on large passenger ships. In: Proceedings of the 2nd international maritime conference on design for safety, Sakai, pp 103–113
12. IMO Document, MSC.1/Circ.1200 (2006) Interim guidelines for alternative assessment of the weather criterion, London, 24 May
13. Sverdrup HU, Munk WH (1947) Wind, sea and swell. Theory of relations for forecasting (Pub. No. 601). US Navy Hydrographic Office, Washington, DC