Development of a Prototype Tsunami Lifeboat

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The lesson learned from the tsunami disaster of the Great East Japan Earthquake (March 11, 2011) prompted the Central Disaster Prevention Council to present a guideline that city planning should be improved to the extent that a place of refuge can be accessed within about 5 minutes on foot. However, no effective way of implementing this guideline has been found for areas that do not have large-scale refuge accommodations such as hills or tsunami refuge buildings, or for nursery schools, kindergartens, or elderly people. Given this situation, Shikoku Transport & Tourism Bureau organized an investigation committee to study the possibility of creating a tsunami lifeboat. This paper describes the development and design process of the prototype tsunami lifeboat carried out as a part of the research of this investigation committee. The results of some examinations for proving that the prototype tsunami lifeboat has sufficient structural strength to withstand collisions and is sufficiently stable are included in this paper.

1. Introduction

The Great East Japan Earthquake of March 11, 2011 devastated the Pacific coast of the Tohoku region and the surrounding area with a seismic intensity reaching 7 and the associated massive tsunami. The lessons learned from the disaster prompted the committees for technical investigation of the Central Disaster Prevention Council to present a guideline in September 2011 that "city planning should be improved such that a safe place of refuge can be accessed within about five minutes by foot."(1) Meanwhile, in March 2012, the advisory council of the Cabinet Office revealed its estimation that in the worst case scenario a massive tsunami as high as 34 m could hit Kochi Prefecture. This would happen when one of the largest earthquakes ever recorded takes place in the Nankai Trough and the likelihood that this will happen within the next 30 years is 60-70%.(2) This height is far beyond the level assumed in the past. Therefore, the tsunami shelters and shore protection facilities built by the time this tsunami strikes will have an entirely new level of disaster to deal with.

In light of the guidelines and the current situation, future tsunami disaster prevention measures clearly need to prioritize and reinforce evacuation measures to help residents escape to a safe refuge and save their lives even when a larger tsunami than expected strikes. Accordingly, current measures that "block" tsunamis must be expanded into comprehensive tsunami measures by developing shore protection facilities.

Given this situation, in February 2012, the Shikoku Transport & Tourism Bureau of the Ministry of Land, Infrastructure, Transport and Tourism organized an investigation committee to study the possibility of creating a tsunami lifeboat. The investigation committee proposed an evacuation system using a lifeboat mounted on large vessels according to requirements established by the "International Life-Saving Appliance Code (LSA Code), pursuant to the International Convention for the Safety of Life at Sea (SOLAS)," because basic performance of the shipboard lifeboat is ideal for escaping from a tsunami by floating. Discussion on the necessary institutional design has also begun.(3)

Requirements of shipboard lifeboats according to the LSA Code include ① self-righting design (to right itself when capsized), ② unsinkability when flooded, and ③ a certain amount of resistance to impact (i.e., structural strength to withstand lateral impact against the ship's side at an impact velocity of 3.5 m/s, as well as falling into water from a height of 3 m without sustaining damage that will affect its functionality). As such, reinforcement and improvement of the ability to withstand possible events caused by tsunamis (e.g., collision with debris and structures, violent shakes, and capsizing) are considered relatively easy. Preparing for tsunamis by using lifeboats offers advantages such as ① relatively inexpensive cost per evacuee compared to other measures (seawalls, tsunami evacuation towers, tsunami evacuation buildings, and the like), ② greater freedom of choice for placement, and ③ application of existing technologies for shipboard lifeboats to provide basic life-saving functions.

In August 2012, the Shikoku Transport & Tourism Bureau publicly sought the business sector for companies that would participate in a more detailed study by organizing a competitive bidding for a plan entitled “Study on the practical application of a prototype tsunami lifeboat.” The IHI group organized a project to file an application for the proposal, successfully winning the bidding to engage in the study which had the goal of building a lifeboat for practical application by the spring of 2013.

The study comprised ① devising an impact resistant design for foreseeable collisions with debris and structures, and a self-righting design against rocking and capsizing, ② fabricating a prototype tsunami lifeboat, and ③ conducting performance tests to validate the design. In addition, test rides and questionnaire surveys were organized with stakeholders and citizens of the municipalities where the tsunami lifeboats are planned to be introduced as a pilot program to examine the impact of the interior design on the comfort of the evacuees with special consideration for psychological factors. The outcomes are presented in this paper.

2. Overview of the prototype lifeboat

Figure 1 presents the external appearance **-(a)** and a view of the interior **-(b)** of the prototype made in this study. The design conditions and main specifications are presented in **Table 1**. These specifications were determined through discussions among experts from the investigative commission on tsunami lifeboats and from the technical committee on practical application of tsunami lifeboats, as well as the Shikoku Transport & Tourism Bureau, which organized the committee and commissioned this study.[(3)-(5)]

(a) External appearance

(b) View of the interior

Fig. 1 The prototype tsunami lifeboat

3. Strength design, safety design, and validation tests

3.1 Events assumed for design

Figure 2 illustrates cases **-(a)** through **-(d)** of collisions with buildings and other structures when the lifeboat is carried onshore by a tsunami’s run-up wave. This study assumed a head-on collision as would happen when the boat fails to maneuver around a structure for some reason as illustrated in **Fig. 2-(a)**.

Considering the streamline shape of the lifeboat, the highest impact velocity would presumably be observed with a head-on collision. Such a direct collision at the bow is believed to present the most perilous conditions, because the collision energy cannot be diverted elsewhere, unlike when the boat is made to spin around. In this study, therefore, the prototype lifeboat was designed to withstand a head-on collision with a design tsunami velocity of 10 m/s. In considering possible lateral collision against the ship’s side, half of the design tsunami velocity, or 5 m/s, was assumed given the larger projected area of the hull against the plane perpendicular to the direction of motion of the hull.

3.2 Reinforcement method

The way the shock-absorbing function was added and reinforcements were installed on the prototype lifeboat is presented in **Fig. 3**. Shock-absorbers were attached to absorb the collision energy and mitigate the impact (**Figs. 3-(a)** and **-(b)**) and a ring-shaped steel member (reinforcement: **Fig. 3-(c)**) was used to transmit the load to the hull in the form of an in-plane force. Shock-absorbers and reinforcements were attached all around the hull from the bow along the side to the stern so that impact to any area can be absorbed.

3.3 Strength evaluation method

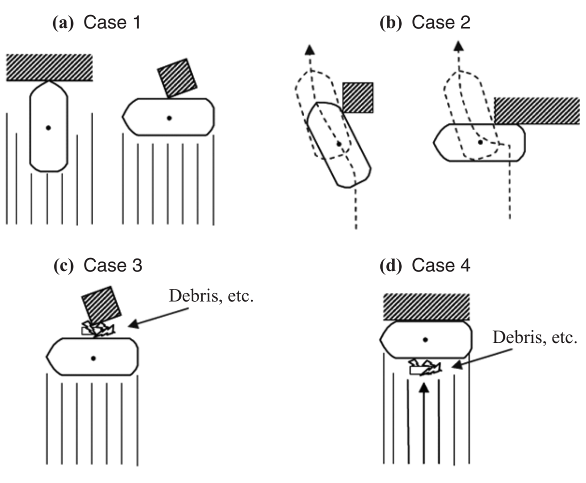
The examination flow according to the employed strength evaluation method is presented in **Fig. 4**. In this method, calculation was mainly made by finite element simulation. The finite element model was developed based on the basic test performed in advance (compression test of the shock-absorbing material). The calculation and evaluation method were validated with the drop impact test using the actual lifeboat (**Section 3.6**).

3.4 Selection of shock-absorbing material

Polypropylene foam typically used as fender material for patrol boats and as shock-absorbing material for vehicle bodies and seats was chosen as the shock-absorbing material for the prototype lifeboat. Prior to the design, a

Table 1 Main specifications of the prototype tsunami lifeboat

Item			Unit	Description
Design conditions	Estimated drifting range		—	Range of tsunami run-up onshore and the drawback that carries the lifeboat offshore
	Estimated number of days adrift		d	7
	Design tsunami wave velocity	Head-on collision	m/s	10
		Side collision	m/s	5
	Allowable acceleration		G	15
Key specifications	Total length (including shock-absorbing materials)		m	8.4 (length) × 3.0 (width) × 3.1 (height)
	Mass	Full load	t	7.1
		Empty	t	5.1
	Draft	Full load	m	0.62
		Empty	m	0.47
	Passenger capacity	Seating capacity	Persons	25
		Maximum capacity	Persons	35 (including 10 persons standing)
Key equipment	Living space	Number of seats	Seats	25
		Seat specifications	—	All seats can be reclined and can be adjusted for children and adults 10 persons can stand or 2 persons can lay down with room to spare
	Toilet	Location	—	Rear on the port-side
		Size	mm	900 (length) × 640 (width) × 1 900 (height)
		Description	—	Separated from the living space by a wall with a door
	Ventilation unit	Natural ventilation	—	2 in the living space
		Forced ventilation	—	1 in the toilet
	Supplies	Water	l/person	7
		Food	kcal/person	5 600
		Other	—	Medicine, heat/cold insulation kits, batteries, toilet treatment materials, chargers, etc.
	Lighting device	Lantern	units	12
		Model	—	Portable LED lantern
	Lighting (windows)	Front	places	2
		Side	places	4
		Back	places	2
	Life-saving equipment	Radar reflector	unit	1
		Life-jacket	piece	1
		Flare for distress signal	piece	1
	Fire extinguishing system	Fire extinguisher	unit	1 (Type 10)
		Sprinkler system outside the hull	set	1
	Radio communication device		—	GPS mobile phone (carried in by evacuees)
	Position reporting system		—	AIS-SART (automatic identification system)
	Door		places	5 (front, back, left, right, and on the canopy)
	Exterior painting		—	International orange
	Interior color		—	Beige-brown



(Note) Source : Material presented at the second investigation committee to study the possibility of creating a tsunami lifeboat

Fig. 2 Various collisions of a lifeboat with structures

dynamic compression test in which a weight was dropped onto a sample was conducted to obtain the stress-strain curve in order to determine the optimal combination of thickness and expansion ratio for the resin foam. Based on the results, a prospect of achieving strain within the practical range (around 70% or less) was gained for head-on collisions with an expansion ratio of around 20 times and a thickness of 1.25 m and for side collisions with an expansion ratio of around 20 times and a thickness of 0.35 m.

3.5 Strength evaluation result

Impact simulation was conducted using a finite element model to determine the resulting acceleration and the resulting stress to make sure that the maximum resulting acceleration was no greater than 15 G. The structural strength was then evaluated by verifying that the resulting stress is smaller than that based on the design conditions of existing shipboard lifeboats (side collision with a velocity of 3.5 m/s).

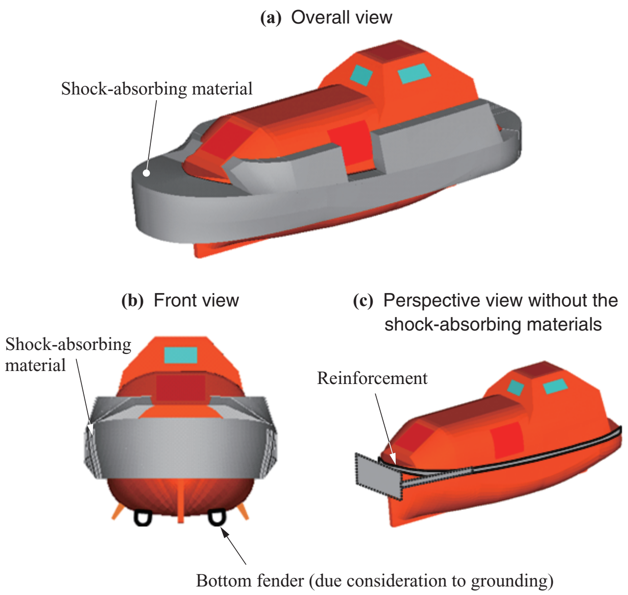


Fig. 3 The concept behind the shock-proof system of the boat hull

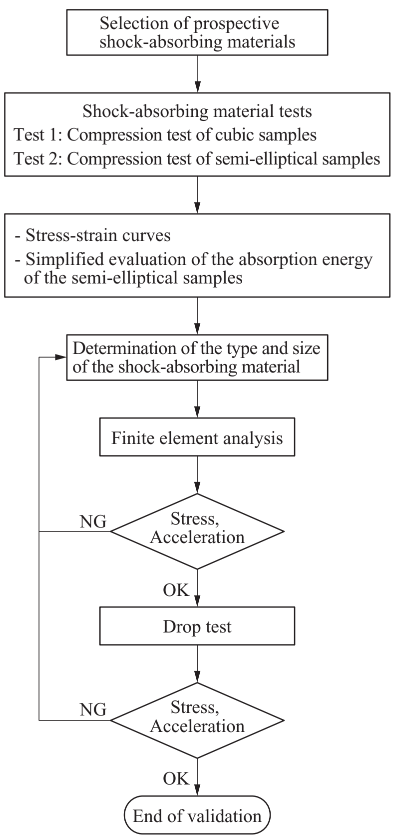


Fig. 4 Strength evaluation flowchart

Figure 5 presents the simulation model of the prototype lifeboat. The modeling of the shock-absorbing material was based on the characteristics obtained from the basic test (compression test) with the material. Only the outer hull was modeled and Young's modulus for the Glass Fiber Reinforced Plastics (GFRP) was entered by assuming a sandwich structure comprising the inner and outer hulls.

The simulation result is shown in **Table 2**. Given the

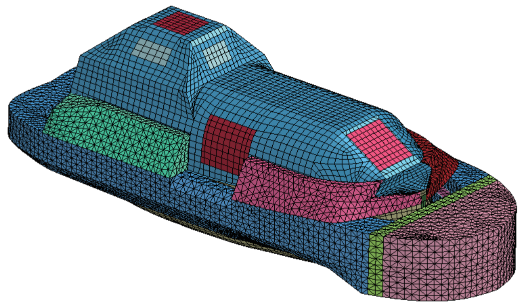


Fig. 5 Simulation model

Table 2 Simulation results

Analysis conditions			Analysis results	
Lifeboat type	Impact portion	Impact velocity (m/s)	Maximum acceleration (G)	Maximum stress ratio [*1] (–)
Existing lifeboat	Side	3.5	18.5	1.00
Prototype lifeboat	Side	5.0	11.7	0.88
Prototype lifeboat	Bow	10.0	12.4	0.43

(Note) *1: Von Mises equivalent stress

comparative nature of the evaluation, stress is represented as the ratio of the maximum stress observed in the simulation with the prototype lifeboat to the maximum stress observed in the simulation with an existing lifeboat. Based on the results presented in **Table 2**, the prototype lifeboat was confirmed to satisfy the required standards with an acceleration below 15 G and a stress ratio less than 1.0 in all cases.

3.6 Drop impact tests

In order to validate the design method and the strength of the prototype lifeboat's hull, drop impact tests were conducted by simulating a head-on collision.

3.6.1 Testing method

The test was conducted by using the drop test facility at the Akagi Testing Center of the Central Research Institute of Electric Power Industry. **Figure 6** shows the view of the drop impact test using the test facility. The sample lifeboat was hoisted with a crane from the stern side and subsequently dropped onto the concrete blocks prepared for the drop test. The drop surface of the test facility can

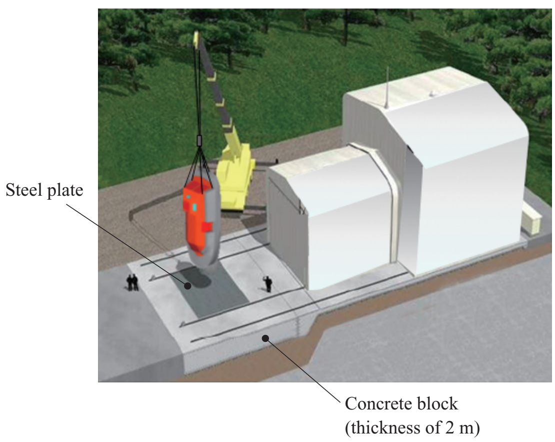


Fig. 6 Diagram of the drop test

be approximated to the steel surface even when a 100-ton-class steel container is dropped from a height of 9 m. As the mass of the prototype tsunami lifeboat is 7 t and the drop height is roughly 5 m, both values are sufficiently small for the facility's specifications in terms of testing capacity.

3.6.2 Testing conditions

The drop impact tests were conducted twice with the conditions as specified in **Table 3**. The sample lifeboat was dropped from a relatively low position in the first test to check the instrumentation system and operation of the drop test system. The second test simulated a design tsunami velocity of 10 m/s. Given the preliminary nature of the first test, a smaller drop velocity of 5 m/s was set. The test conditions for the second test needed to simulate as accurately as possible, the same conditions as the lateral collision at a flow velocity of 10 m/s for the assumed tsunami. Accordingly, a physics model as presented in **Fig. 7** was devised. The kinetic energy immediately before the lateral collision at the velocity of 10 m/s was equated with the change of potential energy when the deformation in the shock-absorbing material peaks in the drop test. The absorption energy of the shock-absorbing material depends not only on the height of the hoisted lifeboat, but also the amount of compression of the shock-absorbing material itself. Accordingly, the compressive strain of the shock-absorbing material was set at 50% based on the preliminary simulation result. In this manner, the hoist height of 4.47 m and an collision velocity of 9.37 m/s were set as the testing conditions as derived from the simplified physics model.

3.6.3 Test results

Figure 8 shows the lifeboat before and after the drop in the second test. After the test started, the hull was dropped in a vertical direction, after which it bounced about three times and then slowly leaned against the supportive frame that keeps the hull from overturning before coming to a complete halt. The hull did not touch any structures including the supportive frame when it was dropped and bouncing, which makes it a valid drop test.

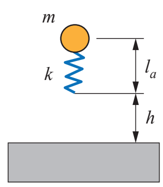
Table 4 compares the results of the drop tests and the simulation. The time-series data of acceleration in the vertical direction as measured in each part of the hull in the second test are presented in **Fig. 9**. A maximum acceleration of roughly 11 G was experienced by the hull in the second test, which is the test that simulated the flow velocity of 10 m/s as assumed for the design tsunami in this study. This figure is sufficiently smaller than the allowable acceleration of 15 G. The shock-absorbing material was removed after the drop test for visual and sample inspections, which revealed no particular damage, demonstrating that the prototype lifeboat has sufficient strength.

Table 3 Drop test conditions

Condition item		Unit	1st test	2nd test
Impact velocity	Lateral collision [*1]	m/s	(5.70)	10.0
	Drop test	m/s	5.00	9.37
Estimated deformation		m	(0.39)	0.65
Hoist height		m	1.27	4.47

(Note) *1: Estimated value for the lateral collision
( ): Calculated from the test results

(a) Simplified model



(b) Formula

$$mg(h + l_a) = mg(l_a - \delta) + E_{ab}$$

Hence:

$$E_{ab} = mg(h + \delta)$$

Equating with the kinetic energy:

$$mg(h + \delta) = \frac{1}{2}mv^2 \rightarrow h = \frac{v^2}{2g} - \delta = \frac{v^2}{2g} - l_a\varepsilon$$

(Note)
m : Mass of the hull
k : Spring constant
l_a : Thickness of the shock-absorbing material
h : Hoisting height
g : Gravitational acceleration
δ : Compression of the shock-absorbing material
ε : Strain of the shock-absorbing material
E_{ab} : Absorption energy of the shock-absorbing material
v : Lateral collision velocity

Fig. 7 The simple model of a collision

(a) Before the drop **(b)** After the drop

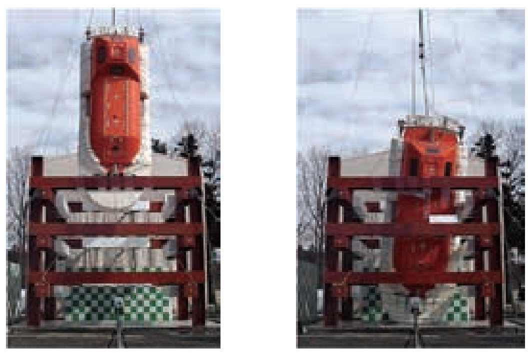


Fig. 8 Photograph before and after the drop test (2nd test)

Table 4 Comparison between the results of a drop test and a simulation

Item	Unit	1st test			2nd test		
		Preliminary simulation	Test	Post hoc simulation	Preliminary simulation	Test	Post hoc simulation
Collision velocity	m/s	5	5.03	5.03	10	9.26	9.26
Gravitational acceleration	m/s^2	None	9.81	9.81	None	9.81	9.81
Maximum acceleration [*1]	G	6.1	6.5	6.9	12.4	11 [*2]	12.4
Maximum strain of the shock-absorbing material	%	27	30	31	55	57	55
Residual strain of the shock-absorbing material	%		0			Top : 4.2 Bottom : 3.1	

(Note) *1: Impact force is expressed in acceleration.
*2: The average value is presented here while the maximum measured value is equivalent to 12.2 G considering that the latter value is the high-frequency component observed at the stern.

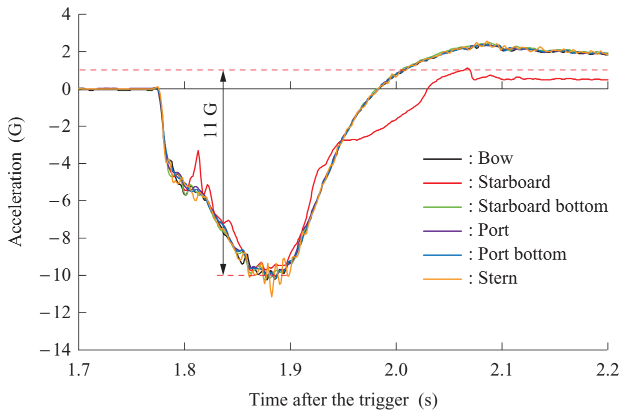


Fig. 9 Acceleration in the vertical direction of each part (2nd test)

Table 4 presents the simulation results before and after the drop test. The preliminary simulation was conducted according to the testing conditions in **Table 4**, whereas the post hoc simulation was conducted by inputting the actually measured velocity in addition to the testing conditions while taking gravitational acceleration into account. The test results and the simulation results matched fairly well as indicated by **Table 4**. **Figure 10** shows a photograph taken by a high-speed camera capturing the moment when the shock-absorbing material in the bow section reached peak strain and the simulation result at the same timing. Both deformed shapes match fairly well, which verifies that the simulation accurately represents the characteristics of the shock-absorbing material.

These results demonstrate that the prototype lifeboat is strong enough to withstand a head-on collision at a velocity of 10 m/s and that the resulting acceleration is kept below the design acceleration of 15 G. In addition, the design method was validated by the great accuracy in simulating the drop test.

4. Evaluation of the self-righting design and validation test

The lifeboat must be self-righting (able to automatically revert to the original upright position after being tipped over) even when there is rocking, capsizing, or any other likely events when it is carried by tsunami waves. While the prototype lifeboat was based on a shipboard lifeboat with a self-righting design, it was necessary to ensure and verify the self-righting design because of the reinforcement ring and shock-absorbing materials mounted onto the prototype lifeboat.

4.1 Self-righting design

The self-righting design of the prototype lifeboat was achieved mainly by altering the shape of the shock-absorbing materials. First, the basic sizes of the reinforcement ring and shock-absorbing materials in the light of strength design were determined in order to verify the self-righting design (GZ curve) of their shapes based on calculations. The design is complete if the self-righting design is verified (i.e., the self-righting force remains positive in the entire range of the GZ curve). Otherwise, anywhere the self-righting design proves imperfect (i.e., a negative self-righting force is found on the GZ curve), the shape of the shock-absorbing materials on a section with small impact on the strength evaluation must be modified and then the self-righting performance recalculated. The shape was obtained by repeating this convergence process.

Once the prototype lifeboat was fabricated, the final GZ curve of the lifeboat as shown in **Fig. 11** was obtained by performing calculations using the measurement results of the mass and the center of gravity. The figure indicates that the shape of the lifeboat is designed to have a positive self-righting force at all angles from 0 to 180 degrees.

4.2 Validation test of the self-righting design (at-sea test)

A validation test was conducted at sea to verify the self-righting design. The self-righting force is the least when the prototype lifeboat is fully loaded, which constitutes the severest conditions. Thus, the test was conducted while the lifeboat was fully loaded with dummy weights mounted on the seats for the evacuees (25 persons). In the test, slings were attached beforehand around the hull floating on the sea in order to artificially capsize the hull by drawing up the slings with a crane on the quay. The slings were then rapidly let out in order to release the capsized lifeboat. The view of the at-sea test is presented in **Fig. 12**. The lifeboat

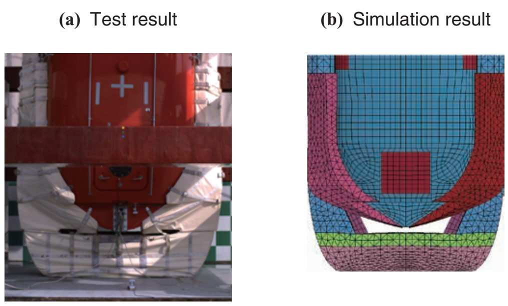


Fig. 10 Comparison of the deformation between the test and the simulation (2nd test)

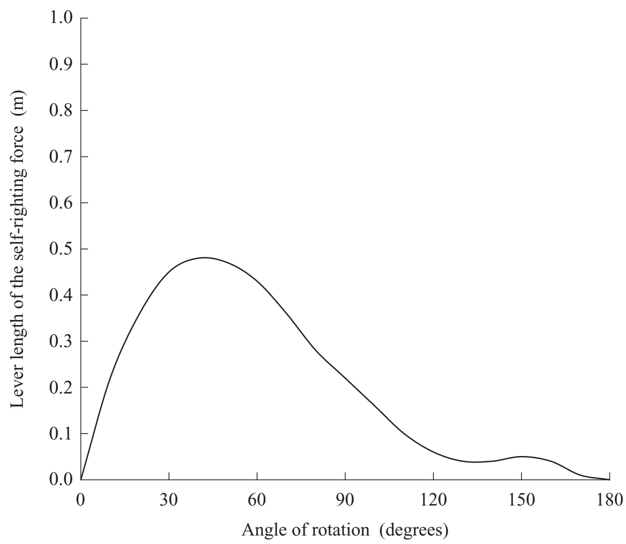


Fig. 11 GZ-curve of prototype tsunami lifeboat

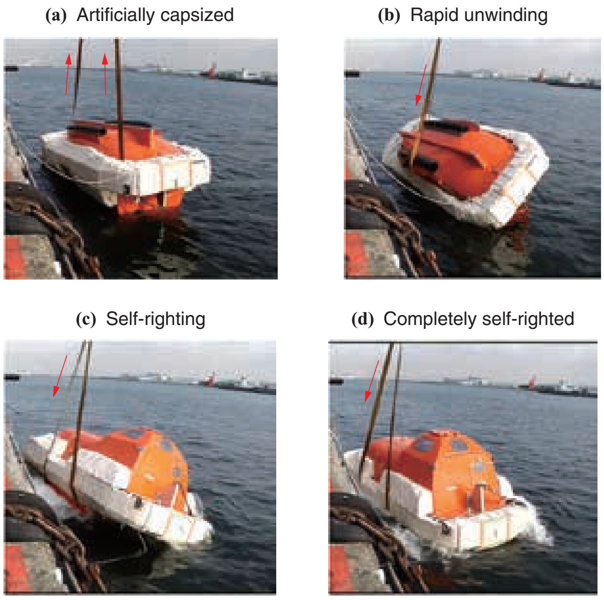


Fig. 12 Self-stability check on the sea

regained an upright position by itself, which validates the self-righting design of the prototype lifeboat.

However, as indicated by the GZ curve in **Fig. 11**, the self-righting performance is weak in the range of angles between 120 to 150 degrees (almost capsized orientation), which may make it difficult for the lifeboat to return to an upright position depending on wave conditions. In order to ensure better self-righting performance, possible measures include addition of ballast to the lower section of the hull to lower the center of gravity, reduction in the thickness of the shock-absorbing materials, and addition of shock-absorbing materials on the upper section of the hull.

5. Comfort design inside the lifeboat

Existing shipboard lifeboats are designed for use by trained sailors. However, tsunami lifeboats are intended for the evacuation of citizens including vulnerable evacuees (e.g., infants, the elderly, and the disabled). The interior and equipment must be planned to ensure their comfort and safety.

Moreover, in the event of a massive tsunami, the extensive damage may require a large number of people to live together for several days on the lifeboat. Therefore, the design of the interior of the tsunami lifeboat also needs to take their psychological well-being into consideration.

In this study, the interior and equipment of the prototype lifeboat were planned and installed for the evacuees to be able to endure a stay onboard for a maximum of seven days.

5.1 Protection of evacuees from various events while drifting

The lifeboat will possibly rock violently, collide with debris, buildings, and bridge piers, or experience other events while adrift after a tsunami has struck. In order to protect evacuees from injuries inside the lifeboat as a result of these events, the following measures were taken.

5.1.1 Measures against injuries to evacuees caused by collisions and rocking

Sitting on a cushioned seat, the body of each evacuee is fixed by a 4-point seatbelt. As fixing the torso alone may cause whiplash to the neck or injury to the head during a violent collision, a hold-type headrest that securely embraces the head was selected as shown in **Fig. 13**. The handrails and ceiling were cushioned with resin foam and the like to prevent inadvertent bruising when the lifeboat rocks or capsizes.

As an indicator for head injuries in the event of a collision, the Head Performance Criterion (HPC) is commonly applied for representing the extent of the shock sustained by the head in an accident. This is presented as Equation (1):

$$HPC = \left\{ \left(t_2 - t_1\right) \left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a \mathrm{d}t \right)^{2.5} \right\}_{\max} \quad \cdots\cdots\cdots\cdots\cdots (1)$$

a represents the resultant acceleration (units: G) whereas t_1 and t_2 denote any two points of time during the collision which are 36 ms or less apart.

Head injury is considered non-vital if the HPC is less than 1 000.[6, 7] This study also applied this reference value to check the effect of installing the headrest. The calculation demonstrated that a clearance between the head and the headrest's cushion of 50 mm resulted in an HPC of 330 or less given the softness of the headrest's cushions, which compress by 20 mm or more under an impact acceleration of 15 G.

5.1.2 Measures against penetration by reinforcing bars, etc.

Debris resulting from earthquakes and tsunamis include numerous sharp objects such as broken pieces of buildings and reinforced structures. Particular danger is posed by the reinforcing bars inside a collapsed building's pillars and broken power poles. While the shock-absorbing materials and the GFRP hull can resist penetration to a certain extent, it is not impossible for reinforcement bars to penetrate the lifeboat and injure the evacuees depending on the location of penetration. As the last shield against penetration by

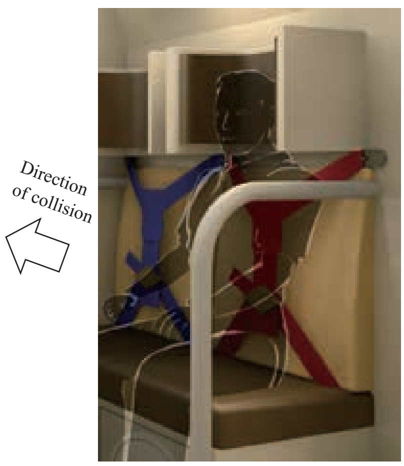


Fig. 13 Hold-type headrest

sharp objects, polycarbonate plates with high resistance to penetration were attached to the seating and back surfaces of the seats to protect the bodies of evacuees.

5.1.3 Measures against fire inside and outside the lifeboat

Fire extinguishers were installed to quickly extinguish any fire inside the lifeboat. Flame-resistant and flame-retardant materials were used for the interior as much as possible.

Furthermore, manual sprinkler pumps and outlets were installed to prevent the hull from catching fire from the outside. The GFRP used in the outer hull is self-extinguishing.

5.2 Living space and equipment with consideration to the psychological well-being of evacuees (Figs. 14 and 15)

5.2.1 Layout and space

A flat floor and wide space were secured by removing the middle section of seats found in existing shipboard lifeboats upon which the prototype was based. The flat floor can be used as space for bedridden evacuees or for lying down to rest and relax, but also serves the purpose of storing drinking water in the built-in containers underneath the floor.

One additional storage space for each evacuee was prepared under each seat. The space occupied by the engine room of existing shipboard lifeboats was replaced with cabinets to secure more storage space.

5.2.2 Color and brightness inside the lifeboat

A calm beige-brown color was selected for the interior, while bright colors were effectively employed to make the most of the diffusion effect of the incoming light from the windows. Still, complementary colors (orange and blue) were used for essential objects that need to be visible and identifiable during an emergency (e.g., seatbelts) in the same manner as with existing shipboard lifeboats.

A total of eight windows were installed for light — four in the canopy in the front, back, left, and right, as well as four round windows on respective doors (front, back, and sides). A total of 12 portable LED lanterns were installed as lighting devices inside the lifeboat. Lanterns were chosen so that they could be used outside the lifeboat. There is one lantern per two persons.

5.2.3 Toilet

There is no toilet in existing shipboard lifeboats because they are designed only for use by trained sailors. Their food is designed to minimize bodily waste. In contrast, toilets are essential in tsunami lifeboats intended for evacuees, with special consideration for women.

The prototype lifeboat is equipped with a toilet space at the rear on the port side. It is separated by a 15-mm-thick wall from the living space. A sound generator was installed to provide privacy. A solar power ventilator was also installed for forced ventilation.

5.2.4 Enhanced functionality and comfort of the seats

Tsunami lifeboats are intended to accommodate evacuees with various body types, including children and the elderly. Therefore, a reclining seat that can be used by both children and adults was devised as shown in **Fig. 16**. The idea was applied to all the seats in the prototype lifeboat.

5.2.5 Means of communication while drifting

A massive tsunami causing extensive damage will

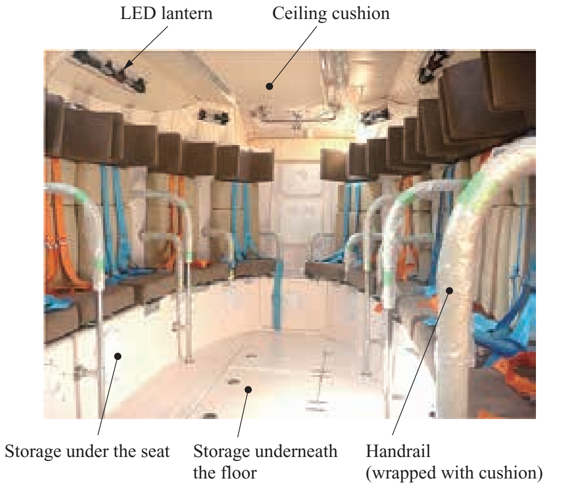


Fig. 14 Internal view of the fore of the prototype tsunami lifeboat

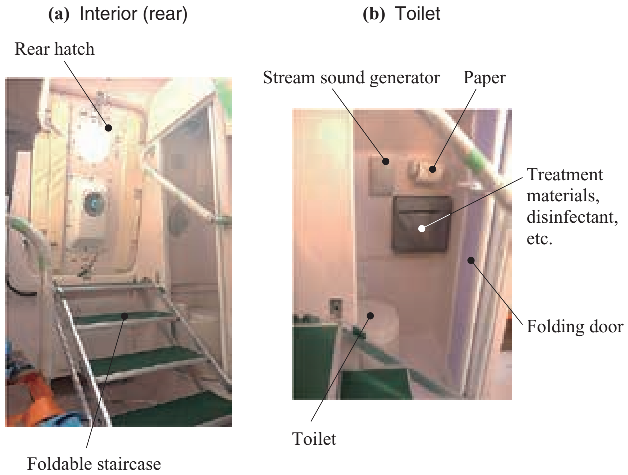


Fig. 15 Internal view of the aft and toilet space of the prototype tsunami lifeboat

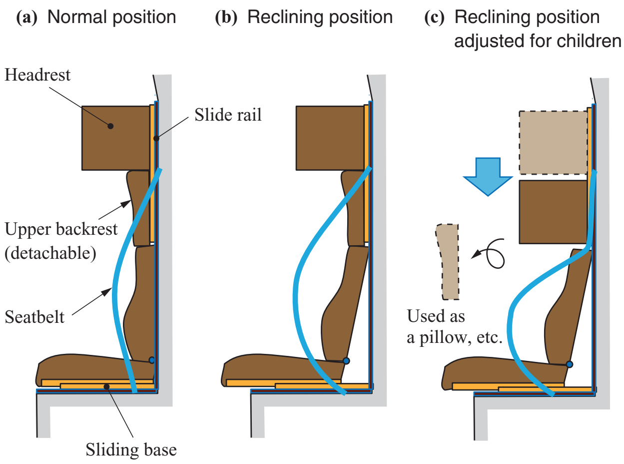


Fig. 16 Structural design of the seats in the prototype tsunami lifeboat

inevitably carry many tsunami lifeboats in many different directions both offshore and onshore, and their occupants will be forced to wait for rescue. Given such an assumption, the following means of communication are believed to be necessary in order to make rapid rescue possible.

(1) Interactive communication by voice (mobile phones or radio)
(2) Ability to locate the lifeboat's position (GPS)
(3) Ability to identify the lifeboat (transmission of registered identification signal)
(4) Ability to react to signals from the rescue team (radar, etc.)

These functions can be achieved by a single international VHF transceiver. Unfortunately, its use requires a person to be qualified as a Maritime III-Category Special Radio Operator with prior training as the device is not user-friendly.

For communication and identification, any devices that require licenses should be avoided. Instead, it is advisable that an ordinary mobile phone, a satellite mobile phone, and an AIS-SART or the like be installed. (An AIS-SART is a combined automatic identification system and search and rescue transponder.)

6. Public demonstration and pilot program

After a series of validation tests and completion of interior installation work, the prototype lifeboat was made available for public viewing in a demonstration organized by the Shikoku Transport & Tourism Bureau. The public demonstration was organized in three locations to invite the media and stakeholders of the municipalities where introduction of the tsunami lifeboats is intended to solicit their opinions. Moreover, as a pilot program, a test ride was organized with groups of "vulnerable evacuees," a term referring to people who may not be able to take care of themselves such as kindergartners and the elderly.

The public demonstration was combined with a questionnaire survey of the test riders, in which mostly favorable comments were obtained as indicated by **Fig. 17**. There were also critical comments which offered insight toward achieving popular use of the tsunami lifeboat. Valuable opinions were also gained from the citizens, kindergarten teachers, the elderly, and other participants, all of which helped troubleshoot matters the team had been unaware of.

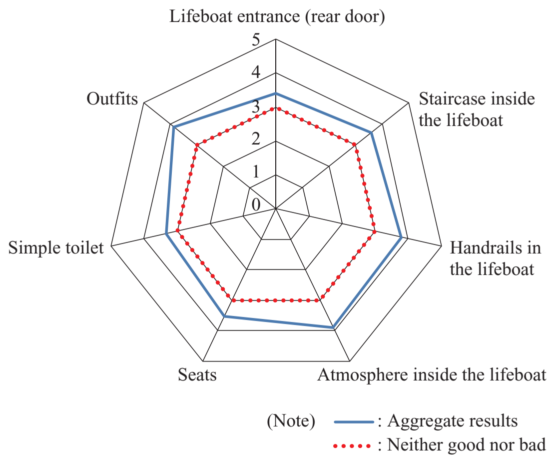


Fig. 17 The results of a questionnaire about the prototype tsunami lifeboat

7. Conclusion

A prototype tsunami lifeboat was fabricated to undergo a collision test (drop test) to validate the ability of the shock-resistant design to withstand collision with debris and structures, and an at-sea test for validating the self-righting design, which deals with rocking and capsizing. The results of the validation tests and the simulations matched fairly well, which also validated the design method.

Moreover, as it will be used by tsunami evacuees, points for improvement of the interior were included in the design of the prototype lifeboat. Test rides and questionnaire surveys were organized for citizens and stakeholders of selected municipalities as a pilot program for studying the collision of such improvements. Mostly favorable feedback was obtained, while critical comments also offered valuable hints for further improvements.

Given these results, the essential features of the tsunami lifeboat (including its strength, self-righting design, and comfort) were verified. Tsunami lifeboat guidelines will be developed based on these outcomes. In the subsequent stage, wider application of the tsunami lifeboat will be pursued. IHI intends to establish its production and supply system while addressing the challenges for improvement that were identified regarding the prototype lifeboat.

— Acknowledgements —

This study was conducted as a part of the "Study on the practical application of a prototype tsunami lifeboat," which was commissioned by the Shikoku Transport & Tourism Bureau. The successful implementation of this assignment owes greatly to the valuable advice and guidance from the director and involved officers of the bureau, as well as the members of the technical committee organized by the bureau.

The cooperation of the members of the Craft Department at Isogo Works of Japan Marine United Corporation was instrumental in completing a prototype lifeboat in the short development period of less than half a year and safely completing the public demonstration from which favorable feedback was obtained. We would like to take this opportunity to express our deepest gratitude.

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