

Ship Stability

Ch. 11 Static Equilibrium State after Flooding Due to Damage

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Myung-II Roh

Department of Naval Architecture and Ocean Engineering
Seoul National University

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Ch. 11 Static Equilibrium State after Flooding Due to Damage

1. Change in Position Due to Flooding
2. Lost Buoyancy Method
3. Added Weight Method

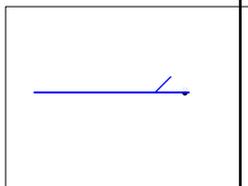
Introduction

In general, the document which contains the following list is submitted to ship owner and classification society, and get approval from them 9 months before steel cutting.

- Principle particulars
- General arrangement
- Midship section plan
- Lines plan
- Hydrostatic table
- Bonjean table
- Tank capacity table
- Light weight summary
- Allowable Minimum GM Curve
- Trim & stability calculation (Intact stability)
- **Damage stability calculation**
- Freeboard Calculation
- Visibility Check
- Equipment number calculation
-



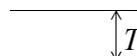
Today's main subject!



1. Change in Position Due to Flooding

Damage of a Box-Shaped Ship

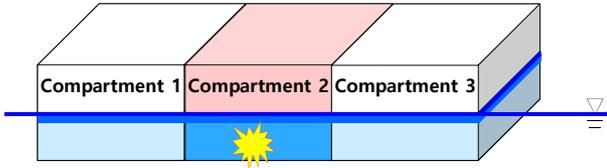
- ✓ A ship is composed of three compartments.



When a compartment of the ship is damaged, what is the new position of this ship?

Damage of a Box-Shaped Ship (Immersion)

 When the compartment in the **midship** part is damaged, what is the new position of this ship?



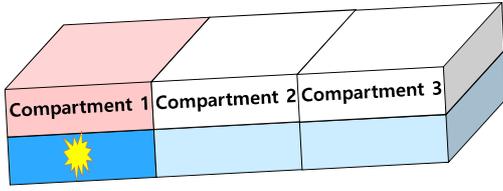
The position of the ship will be changed.

* The new position of the ship can be calculated by **the lost buoyancy and added weight methods**.

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Damage of a Box-Shaped Ship (Immersion, Trim)

 When the compartment at the **after** part of the ship is damaged, what is the new position of this ship?

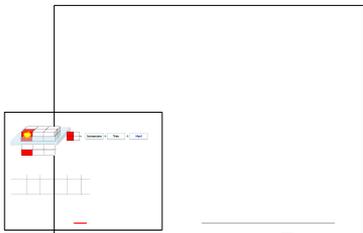


The position of the ship will be changed.

Immersion

 +

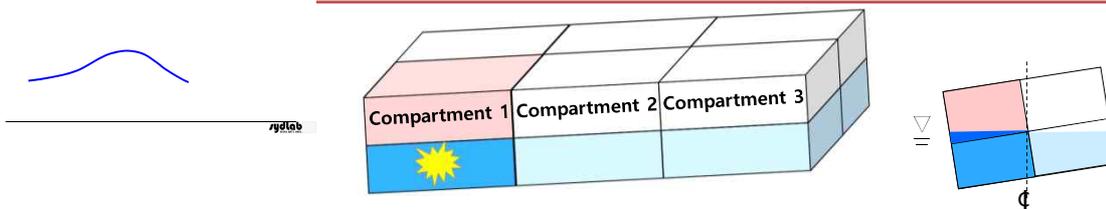
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Damage of a Box-Shaped Ship (Immersion, Trim, Heel)

The ship is composed of "six" compartments.

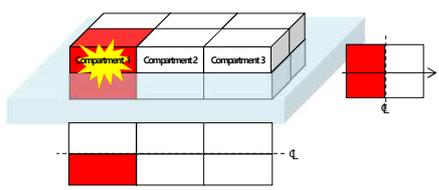
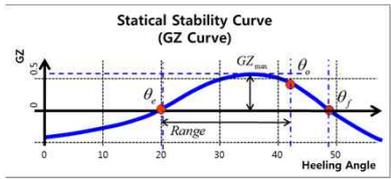
When the compartment at the **after and right** part of the ship is damaged, what is the new position of the ship?



The position of the ship will be changed.

Immersion + Trim

Two Methods to Measure the Ship's Damage Stability

How to measure the ship's stability in a damaged condition?

Method : Calculation of survivability of a ship based on **the position, stability, and inclination in damaged conditions**

Method : Calculation of survivability of a ship based on **the probability of damage**

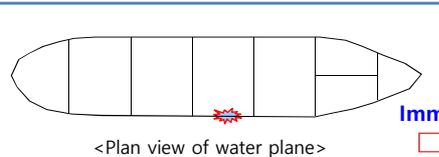
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Change in Position Due to Flooding (**Immersion**)

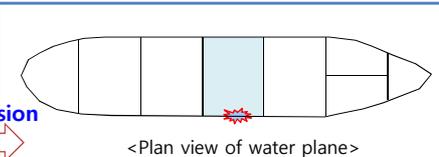
? What happens if the compartment located in the **midship** part of a ship is damaged?



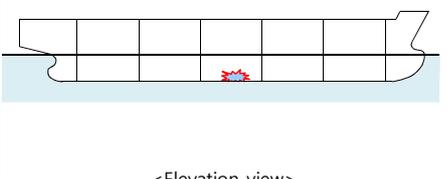
<Plan view of water plane>

Immersion

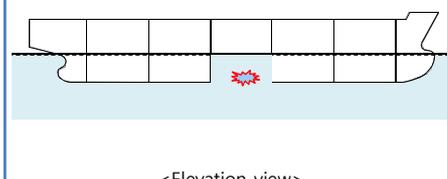




<Plan view of water plane>



<Elevation view>



<Elevation view>

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Change in Position Due to Flooding (Immersion, Trim)

? What happens if the compartment located in the **after** part of a ship is damaged?

The diagram illustrates the process of immersion and trim. It starts with a plan view of the water plane and an elevation view of the ship's hull. A red starburst indicates a compartment in the after part is damaged. An arrow labeled "Immersion" points to the next stage, where the water level in the damaged compartment has risen. A second arrow labeled "Trim" points to the final stage, where the ship's longitudinal axis has tilted downwards at the stern due to the added weight.

<Plan view of water plane> <Plan view of water plane>
 <Elevation view> <Elevation view> <Elevation view>

Immersion Trim

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Change in Position Due to Flooding (Immersion, Trim, Heel)

? What happens if the compartment located in the **fore and right** part of a ship is damaged?

The diagram illustrates the combined effects of immersion, trim, and heel. It starts with a plan view of the water plane and an elevation view of the ship's hull. A red starburst indicates a compartment in the fore and right part is damaged. An arrow labeled "Immersion" points to the next stage, where the water level in the damaged compartment has risen. A second arrow labeled "Trim" points to the final stage, where the ship's longitudinal axis has tilted downwards at the stern. A third arrow labeled "Heel" points to a section view, which shows the ship's cross-section tilted to the right (port side) due to the weight of the water in the damaged compartment.

<Plan view of water plane> <Plan view of water plane>
 <Elevation view> <Elevation view> <Section view> <Elevation view>

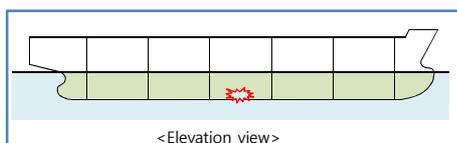
Immersion Trim Heel

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2. Lost Buoyancy Method

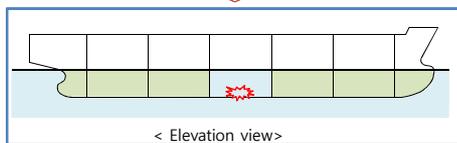
Concept of Lost Buoyancy Method (1/2)

* Hydrostatic Equilibrium
 Displacement(Δ) = Buoyant Force = Weight(W)



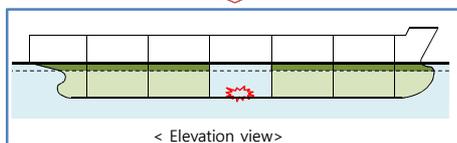
A damage occurs.

■ : Volume which contributes to buoyancy



The lost buoyancy must be regained by

■ : Additional volume which contributes to buoyancy (regained buoyancy)



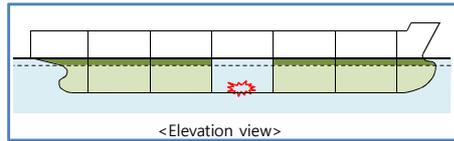
Lost buoyancy method

"The water that enters the ship is considered still part of the sea, and the buoyancy of the flooded space is lost."

Concept of Lost Buoyancy Method (2/2)

* Hydrostatic Equilibrium
 Displacement(Δ) = Buoyant Force = Weight(W)

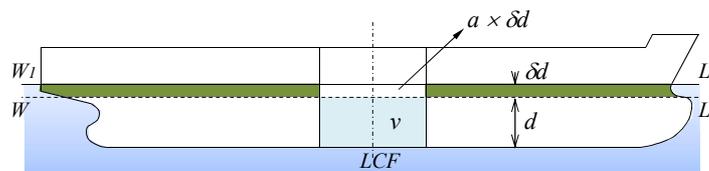
Lost buoyancy method



- : Volume which contributes to buoyancy
- : Additional volume which contributes to buoyancy

- In this method, it is assumed that the flooded compartment has free communication with the sea.
- The flooded compartment can be considered as a sieve (or filter), and that offers no buoyancy to the ship. Only the intact portions of the ship on either side of the flooded compartment contribute to the buoyancy.
- Since buoyancy has been lost, it must be regained via an increase in the draft.
- The ship will sink until the volume (or displacement) of the newly immersed portions equals the volume (or displacement) of the flooded compartment.

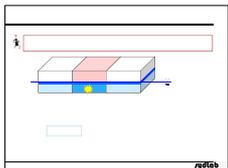
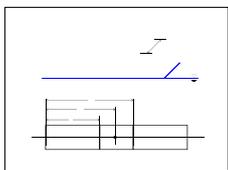
The water that enters the damaged compartment is considered as an , and the buoyancy of the flooded space is .
 And the loss of buoyancy is regained by an increase of draft.



Loss of buoyancy: Sea water flooded into the damaged compartment is considered as part of the sea

$$\rho \cdot g \cdot v = \rho \cdot g \cdot (A_{WP} - a) \cdot \delta d$$

- A_{WP} : water plane area of the ship (Including water plane area of the damaged compartment)
- a : water plane area of the damaged compartment
- d : Draft before the compartment is not damaged
- δd : Draft change due to damaged compartment
- v : Volume of damaged compartment below initial water plane



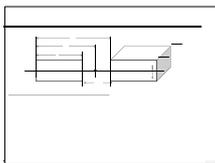
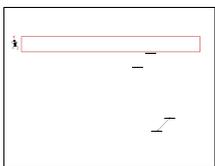
[Example] Damage of a Box-Shaped Ship (Immersion) (1/6)

✓ A ship is composed of three compartments.

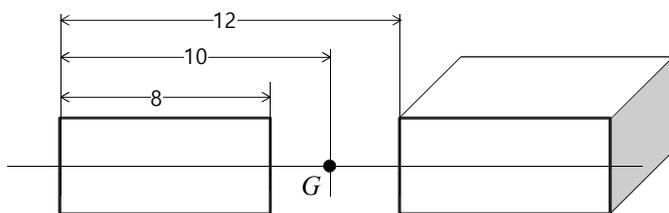
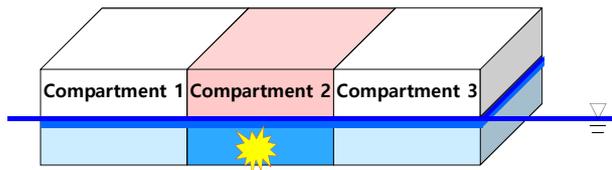
$$T = 1.5$$

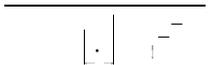
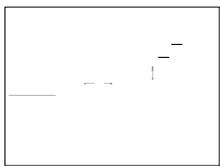


 When a compartment of the ship is damaged, what is the new position of this ship?



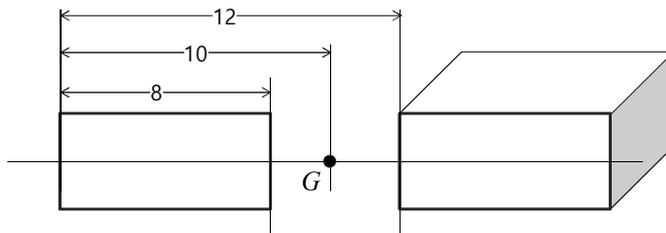
[Example] Damage of a Box-Shaped Ship (Immersion) (3/6)





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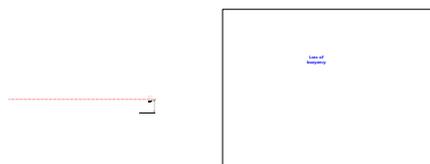
[Example] Damage of a Box-Shaped Ship (Immersion) (5/6)



Another method

Water plane area:
Draft after immersion:

where



3. Added Weight Method

Concept of Added Weight Method (1/2)

* Hydrostatic Equilibrium
 $\text{Displacement}(\Delta) = \text{Buoyant Force} = \text{Weight}(W)$

<Elevation view>

<Elevation view>

<Elevation view>

A damage occurs.

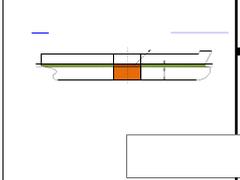
■ : Added weight

Added weight will be equilibrium with the buoyancy regained by

■ : Additional added weight
 ■ : Additional volume which contributes to buoyancy

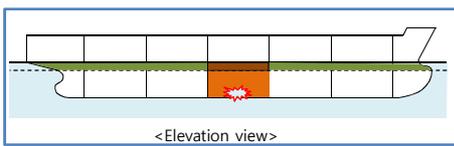
Added weight method
 "The water that enters the damaged compartment is considered as an **added weight** with no loss of buoyancy."

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Concept of Added Weight Method (2/2)

Added weight method



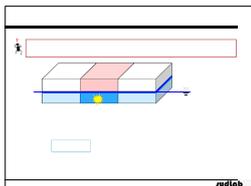
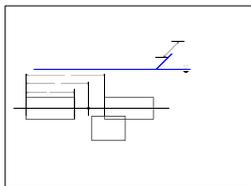
- : Added weight
- : Additional added weight
- : Additional volume which contributes to buoyancy

- The water that enters the damaged compartment is considered as an **added weight** with no loss of buoyancy.
- This is a **misnomer**, since water in space open to the sea and free to run in or out does **not actually add to a ship's weight**.
- For calculation purposes, it is **convenient** to regard such flooding water as adding to the displacement.
- However, it **must be remembered** that the resulting (virtual) **displacement not only differ from the initial displacement**, but varies with change in trim or heel.
- Since the added weight method involves a **direct integration of volumes** up to water plane at the damaged condition, it is just as **well adapted to dealing with complex flooding conditions** as with simple ones.

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$$\delta d = \frac{v}{A_{WP} - a}$$



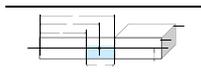
[Example] Damage of a Box-Shaped Ship (Immersion) (1/9)

✓ A ship is composed of three compartments.

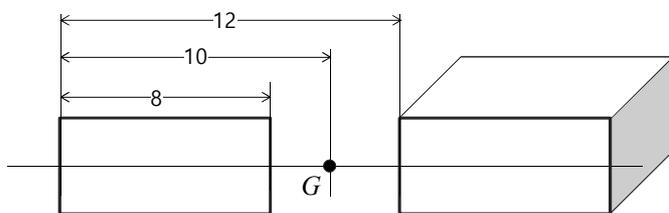
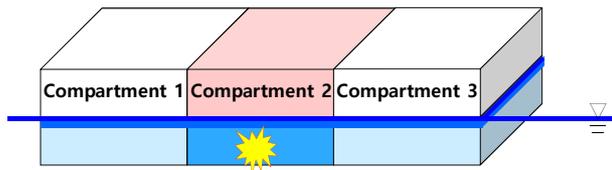
$$T = 1.5$$



 **When a compartment of the ship is damaged, what is the new position of this ship?**

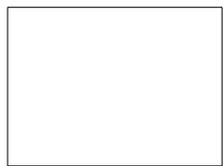


[Example] Damage of a Box-Shaped Ship (Immersion) (3/9)



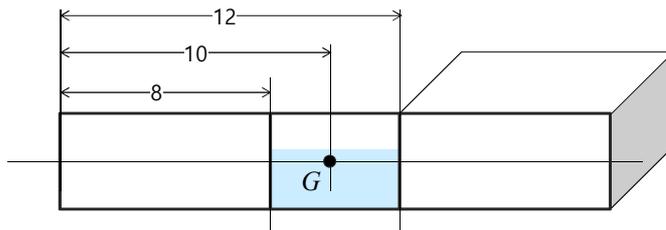
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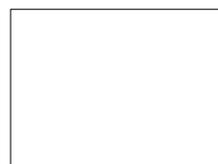


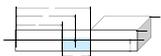


[Example] Damage of a Box-Shaped Ship (Immersion) (5/9)

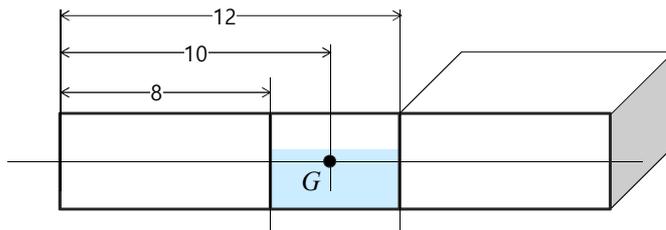


The volume of flooding water:
The additional buoyant volume:
Because





[Example] Damage of a Box-Shaped Ship (Immersion) (7/9)



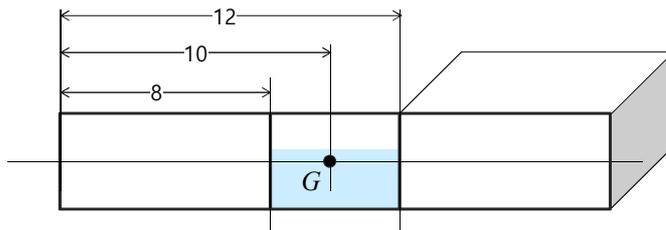
KG by the added weight method



Free surface effect caused by the flooding water:
The moment of inertia of the free surface in the flooded compartment



[Example] Damage of a Box-Shaped Ship (Immersion) (9/9)



Metacenter height
The changed displacement

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