A Numerical study of hydraulic characteristic changes by Incheon Bridge construction in macro–tidal environment

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Introduction

- After the construction of the Incheon Bridge, the width of the fairway decreased, resulting in changes in hydraulic characteristics and sediment movement.
- However, few studies have been conducted to understand the change in the hydrodynamics due to the construction of the Incheon Bridge.
- In this study, the effect of a decrease in channel width on tidal and residual current changes was analyzed through a numerical model.

Model setup

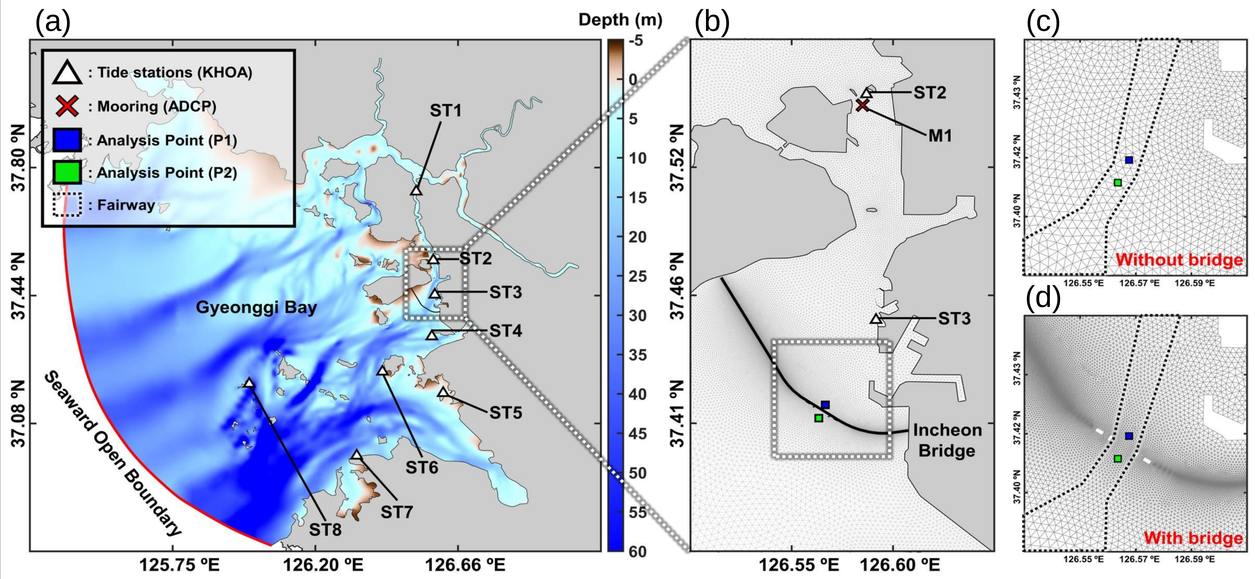


Fig. 1. (a) Map showing a model domain and bathymetry for Gyeonggi Bay. (b) Magnified map showing grid and mooring locations near Incheon Bridge. Comparisons of model grid resolution between without bridge (c) and with bridge (d). The water level data at eight tide stations (ST1–ST8) were obtained from Korea Hydrographic and Oceanographic Agency (KHOA) (white triangles). Red x symbol indicates the Moorings (M1). Blue and green boxes are fixed points selected for comparison without and with Incheon Bridge construction.

Table 1. Model configurations

Finite-Volume Community Ocean Model (FVCOM)				
Input condition	Grid	Information	Three-dimensional triangular unstructured grid	
		Number	Without bridge	Node: 60,882 and element: 115,443
			With bridge	Node: 78,181 and element: 149,607
		Resolution	Without bridge	55 – 4,500 m
			With bridge	20 – 4,500 m
	Bathymetry		Korea Hydrographic and Oceanographic Agency (KHOA)	
	Freshwater runoff		WAter resource Management Information System (WAMIS)	
	Tidal forcing		TPXO8-atlas (M_2, S_2, K_1, O_1, and N_2)	
	Simulation period		2020/01/20~2020/03/15 (56 days)	

Validations

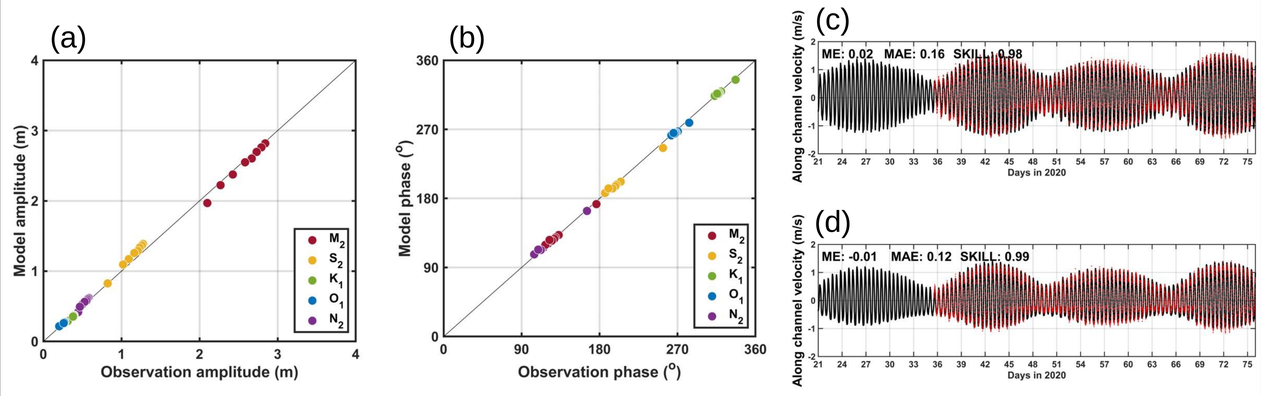


Fig. 2. Model-observation data comparisons for tide level and along-channel velocity. (a–b) Comparisons of tidal constituent amplitude and phase at ST1–ST8. (c–d) Time series of along-channel velocity between the observation data (red dots) and simulation (black line).

- **Error analysis**

$$ME = \frac{\sum(M_n - O_n)}{N}$$

$$MAE = \frac{\sum|M_n - O_n|}{N}$$

$$Skill = 1 - \frac{\sum(M_n - O_n)^2}{\sum(|M_n - \overline{O}| + |O_n - \overline{O}|)^2}$$

M_n: *model data*
O_n: *observation (obs.) data*
N: *number of obs. data*
$\overline{O}$: *time averaged obs. data*

1. **ME (Mean Error)**: Under– (< 0) and over– (> 0) estimation of model data for observation data
2. **MAE (Mean Absolute Error)**: Average deviation between the observation data and model data
3. **Skill (predicted Skill)**: Accuracy of model data for observation data (0 – 1)

- Skill values for the tides: All **0.99** (ST1–ST8)
- Skill values for near-surface and near-bed along-current velocities: **0.98** and **0.99** (M1)

Results

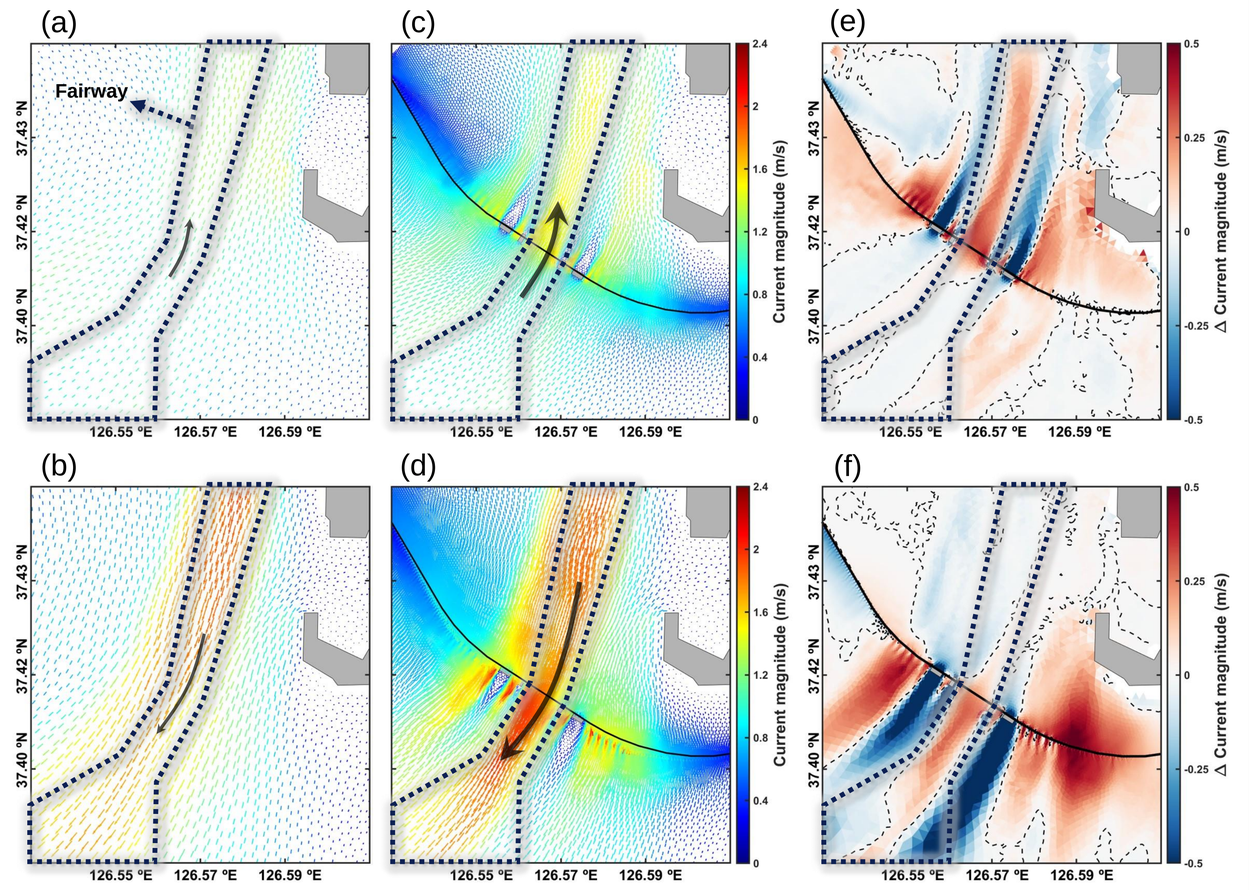
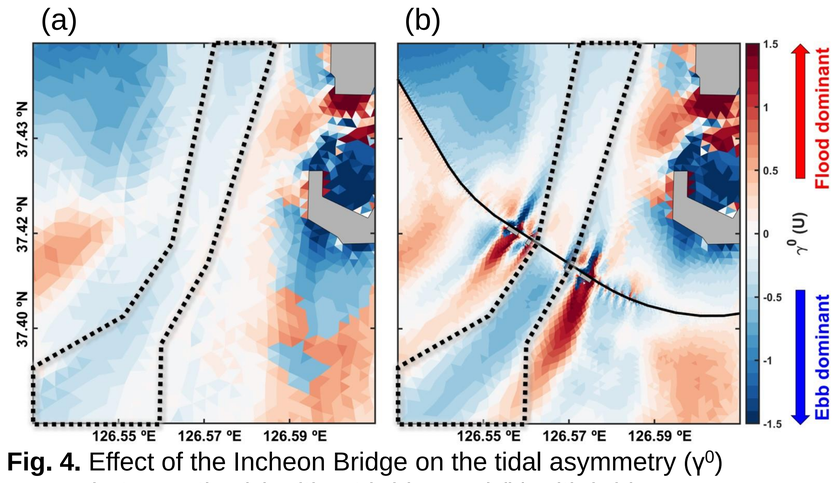


Fig. 3. Effect of the Incheon Bridge on the near-surface flow patterns during spring tide. (a–b) Magnitudes of flood/ebb currents without bridge, (c–d) magnitudes of flood/ebb currents with bridge, and (e–f) difference of magnitude of flood/ebb currents (with – without).

[Flood and ebb tidal current velocity]

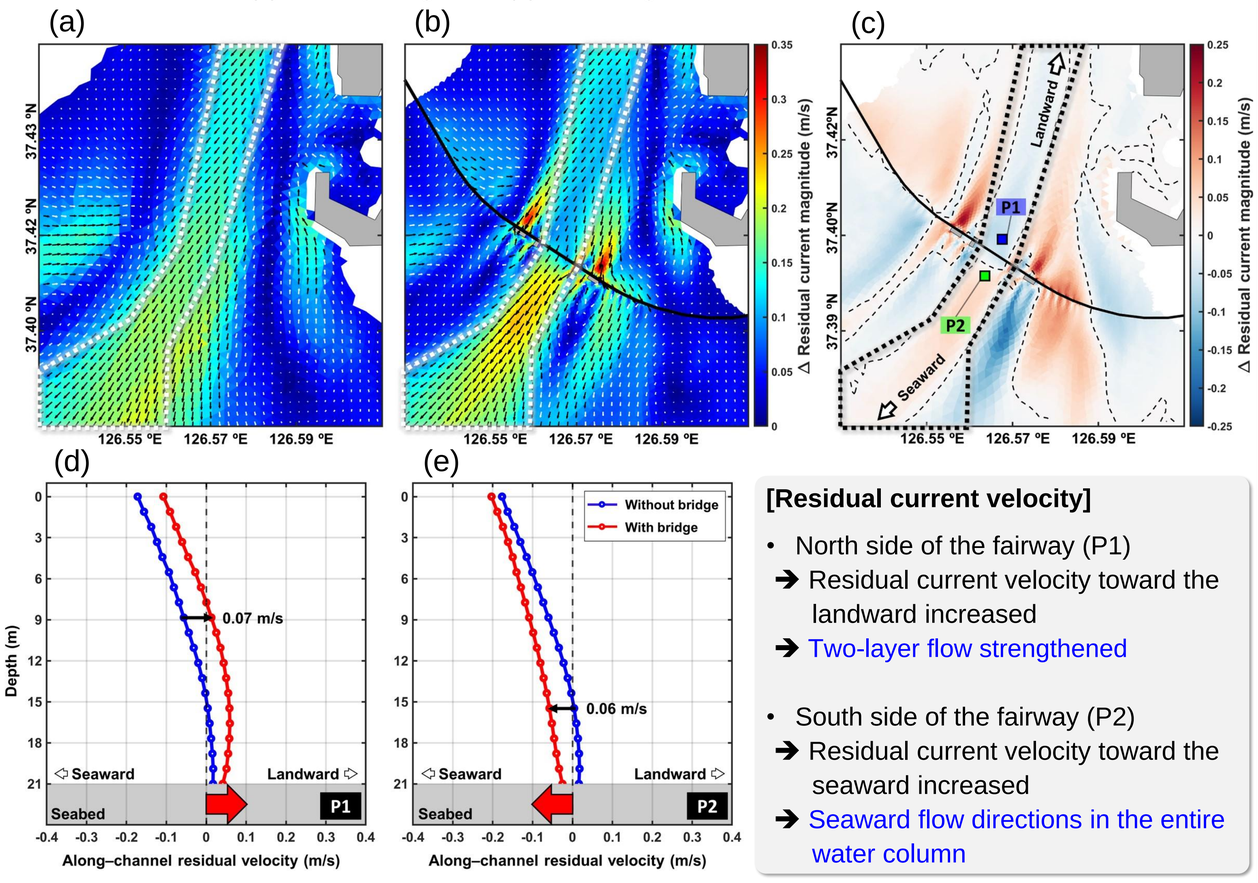
- Blocking effect of the piers ➔ Fairway current magnitude changes during flood and ebb currents
- Change in magnitude during flood current ➔ Mainly occurs on the south side of the fairway
- Change in magnitude during ebb current ➔ Mainly occurs on the north side of the fairway



[Tidal asymmetry]

- North side of the fairway
  ➔ Increased magnitude in flood current
  ➔ ebb–dominance weakened
- South side of the fairway
  ➔ Increased magnitude in ebb current
  ➔ ebb-dominance strengthened

Fig. 4. Effect of the Incheon Bridge on the tidal asymmetry (γ^0) between the (a) without bridge and (b) with bridge.



[Residual current velocity]

- North side of the fairway (P1)
  ➔ Residual current velocity toward the landward increased
  ➔ Two-layer flow strengthened
- South side of the fairway (P2)
  ➔ Residual current velocity toward the seaward increased
  ➔ Seaward flow directions in the entire water column

Fig. 5. Changes in residual flow before and after the construction of the Incheon Bridge. Spatial distribution in the magnitude of the near-surface residual velocity (a) without bridge, (b) with bridge. (c) Difference of magnitude for residual current velocity (with – without bridge). Vertical residual current distribution at (d) P1 and (e) P2.

Conclusions

- Due to the blocking effect of the piers of the Incheon bridge, the tidal current magnitude and tidal asymmetry have been changed.
- With the change in tidal asymmetry, the vertical two-layer flow of the residual current was intensified on the north side of the fairway.
- Therefore, the effect of local structures such as Incheon Bridges can play a key role in tidal and residual characteristics of coastal areas.

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