Lecture Notes in Civil Engineering

Stefanus Adi Kristiawan
Buntara S. Gan
Mohamed Shahin
Akanshu Sharma *Editors*

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ICRMCE 2021, July 8–9, Surakarta, Indonesia

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Foreword

The International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE) is a triennial conference that aims to provide a forum for researchers, academicians (professors, lecturers, and students), government agencies, consultants, and contractors to exchange experiences, technological advancement, and innovations in the world of civil engineering, specifically in the fields of rehabilitation and maintenance. The previous four ICRMCE conferences took place successfully in 2009, 2012, 2015, and 2018. Hundreds of researchers worldwide attended these events to present their scientific papers in various areas of civil engineering such as material engineering, structural engineering, geotechnical engineering, transportation engineering, and construction management.

This year's conference was organized by Sebelas Maret University in collaboration with Mataram University. The conference was initially scheduled offline in Mataram, Indonesia. However, due to the escalating coronavirus (COVID-19) outbreak and the need for social distancing, we decided to hold the conference online. Some reputable universities and institutions are participating in the current ICRMCE as partners. Among them are Nihon University, University of Stuttgart, National Taiwan University, TU Delft, Hiroshima University, Diponegoro University, Muhammadiyah University of Yogyakarta, Jenderal Soedirman University, University of Jember, UPN Veteran East Java, the National Center for Research on Earthquake Engineering (NCREE) Taiwan, Himpunan Ahli Konstruksi Indonesia (HAKI), and Himpunan Ahli Teknik Tanah Indonesia (HATTI).

The ICRMCE 2021 was successfully held on July 8–9. Presenters who joined this conference came from Japan, Singapore, Malaysia, China, Vietnam, Taiwan, England, the Netherlands, Kuwait, and Indonesia. Furthermore, several outstanding keynote speakers gave a presentation of the state-of-the-art findings in the field of civil engineering. Our esteemed speakers are Prof. Shyh-Jiann Hwang (National Taiwan University), Prof. Buntara Sthenly Gan (Nihon University), Dr. Edgar Bohner (VTT Technical Research Centre of Finland), and Prof. Mohamed Shahin (Curtin University).

In the process of organizing this conference, we received invaluable motivation, advice, and support from several individuals and institutions. I intend to express my gratitude and appreciation to all of them. First, my most profound appreciation goes to all organizing committee members who worked day and night preparing this conference. Special thanks to the conference and media partners for their generous support. We also express our gratitude to Prof. S.A. Kristiawan (Sebelas Maret University), Dr. Ing. Akanshu Sharma (University of Stuttgart), Prof. Mohamed Shahin (Curtin University), and Prof. Buntara Sthenly Gan (Nihon University) for their willingness to serve as the editors of the 5th ICRMCE proceedings.

Halwan Alfisa Saifullah
The 5th ICRMCE Chairman

Preface

Civil engineering infrastructures are the backbone for the continuous development of civilization. Managing these infrastructures is essential in keeping the quality of services they provide to the community. A decline in the performance of key infrastructure will have an impact on the quality of these services, which in turn can cause social and economic problems. A variety of factors affects the performance of infrastructure. In each case, the declining performance of infrastructure requires an appropriate and adaptive response to offer effective solutions. Protection, maintenance, repair, and retrofitting are part of the various solutions that can be implemented. All of these solutions are assisted by technological developments related to repair materials, methodologies, systems, management, and operational efficiency, as well as economic and social considerations.

Infrastructure performance is also inevitably affected by exposure to hazards originating from natural and environmental conditions such as earthquakes, landslides, and floods, among others. Therefore, hazard mitigation is also an interesting topic of discussion. In addition, risk reduction and safety are among the most important issues of infrastructure management. Finally, various perspectives on sustainability in civil engineering are also covered in this conference.

This book is a collection of papers presented at the 5th International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE) 2021 that deals with the issues stated above. The papers are grouped into sequential themes representing the structure of this book:

- Part I: Factors affecting performance of buildings and infrastructures
- Part II: Assessment, protection, maintenance, repair, and retrofitting of buildings and infrastructures
- Part III: Maintenance management of buildings and infrastructures
- Part IV: Hazard mitigation
- Part V: Risk reduction and safety management
- Part VI: Sustainability aspects in transportation engineering
- Part VII: Sustainability aspects in construction projects

- Part VIII: Sustainability aspects in water resources management
- Part IX: Construction materials for sustainable infrastructures

Postgraduate students, researchers, and practitioners who would like to update their knowledge on the topics above will find this book very useful.

Surakarta, Indonesia

Stefanus Adi Kristiawan
Chief Editor

Contents

Wind-Generated Wave Simulation on Payangan Beach Utilizing DELFT3D

Enggar Setia Baresi, Retno Utami Agung Wiyono, and Wiwik Yunarni Widiarti

Abstract The Southern Coastal area of Jember has been damaged almost yearly by coastal flooding and high waves, especially Payangan Beach. A study on high waves is urgently needed for disaster risk preparedness. This study is conducted to model the high waves and simulate the effect on the beach. Delft3D-Wave model is used to provide a spatiotemporal characteristic of the event. The focus of the study is to analyze the high waves on Payangan Beach generated by wind forces. The domain model is a curvilinear grid with a grid size ranging from 130 m until 900 m. National bathymetric data and CDS Copernicus wind data were utilized as data sources. The simulation outcomes have shown that waves are generated far from the coastline across the ocean inside the fetch area. The simulations show the significant wave height increase during the high waves event according to specific meteorological characteristics from 1.6–2.0 m on normal days and exceeding 3.2 m when the high waves hit.

Keywords High waves · Delft3D · Wind-generated waves

1 Introduction

Shoreline is the point of intersection between land and sea. In this area, ocean energy reacted to the land vice versa. The system that works in this reaction mostly caused by the natural movement of the ocean which transferring energy into the system. Coastal zones are directly affected by the ocean forces especially beach and near-shore zone. Therefore, this particular area is the most dynamic in all coastal areas [1].

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The most common form of ocean energy is wave. The linear waves theory or small-scale wave amplitude theory is derived from Laplace equation for irrotational flow. The equation gives solution of periodic velocity for irrotational flow which later can be utilized to derive equations from various waves characteristic for example water level, velocity, particle acceleration, waves propagation speed, and others [2].

According to the previous study conducted in Southern Seas of Jember, this particular area has high amount of energy transfer about 190 MWh/m/year with significant wave height up to 4 m [3]. In Payangan Beach, a beach located in Southern Seas of Jember, high waves occurred annually e.g. 2018 [4]. There is no known study that simulate spatial variation of high waves in this area. Thus, this study is crucial for the various purpose related to high waves effect on the Payangan Beach coastal area.

This study aims to simulate high waves and analyze the significant wave height in Payangan Beach in the last five years. Every year, this particular location hit by high waves in late July when the atmosphere pressure shift in the Indian Ocean. But only in 2020, the high waves occurred in May, two months prior to the usual period of the event. This study focused to analyze the high waves on the study site on a small-scale simulation by using national bathymetric data.

2 Methodology

2.1 Study Area

Payangan Beach exposed directly to waves coming from Indian Ocean that can measure up roughly from 2 to 5 m in a bad weather condition. Average significant wave height in Payangan Beach during normal days is ranging from 1.6 to 2.0 m. This beach has natural defense against large waves and even massive tidal wave in a form of sand dunes and highest slope compared to other two beaches nearby (Fig. 1).

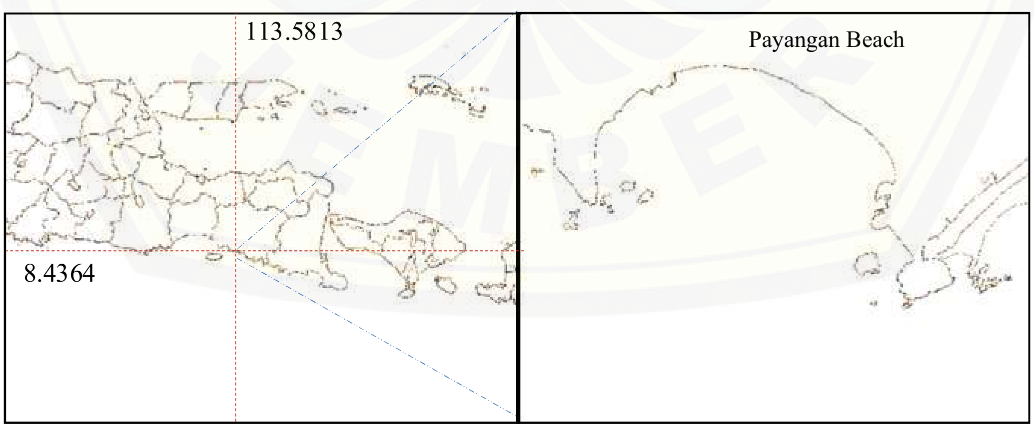


Fig. 1 Study location in east Java (left); the zoom-in map of study domain and study site at Payangan Beach (right)

Table 1 Wind data distribution

Wind speed (knot)	Wind direction (%)								Days (%)
	N	NE	E	SE	S	SW	W	NW	
0–3	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.14
3–6	1.74	2.90	1.88	0.39	21.11	0.24	3.77	0.43	32.46
6–9	3.38	4.11	2.71	0.24	16.91	0.24	5.89	0.97	34.44
9–12	2.42	2.46	1.21	0.14	13.91	1.01	6.76	0.97	28.89
12–15	0.14	0.05	0.10	0.00	1.59	0.29	0.24	0.05	2.46
15–18	0.00	0.00	0.10	0.00	0.77	0.29	0.14	0.00	1.30
18–21	0.00	0.00	0.00	0.00	0.10	0.05	0.00	0.00	0.14
21–24	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00	0.10
30–33	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.05
Days	7.68	9.52	5.99	0.77	54.64	2.17	16.81	2.42	100.00

2.2 *Wind Data Analysis*

Wind data of this study was obtained from Class III Meteorological Station located in Banyuwangi which was the closest wind station to the study site. The data that was obtained from Class III Meteorological Station is the final wind data derived from u10 and v10 wind data. In the equation below [5, 6], the Ø means meteorology wind direction angle in radians.

$$u = -|V| \sin \emptyset \tag{1}$$

$$v = -|V| \cos \emptyset \tag{2}$$

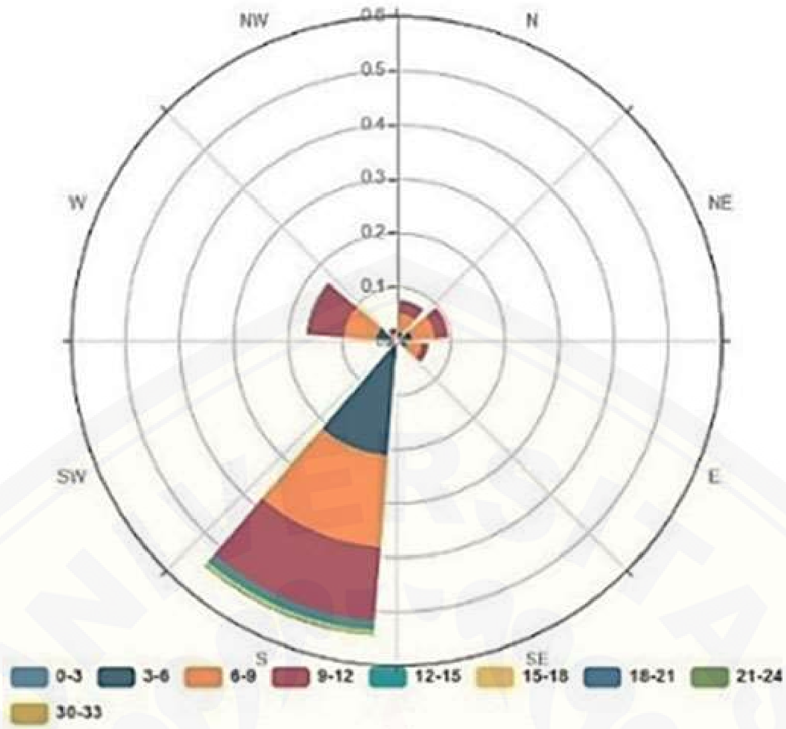
$$|V| = \sqrt{\left(u^2 + v^2\right)} \tag{3}$$

In addition, spatial variation of wind data namely ERA5-Interim wind data was obtained from Climate Data Store Copernicus that was measured by Aeolus satellite. The data that was gathered classified within 3 speed interval, $0 < U < 3$, $3 < U < 6$, $6 < U < 9$, up to $30 < U < 33$.

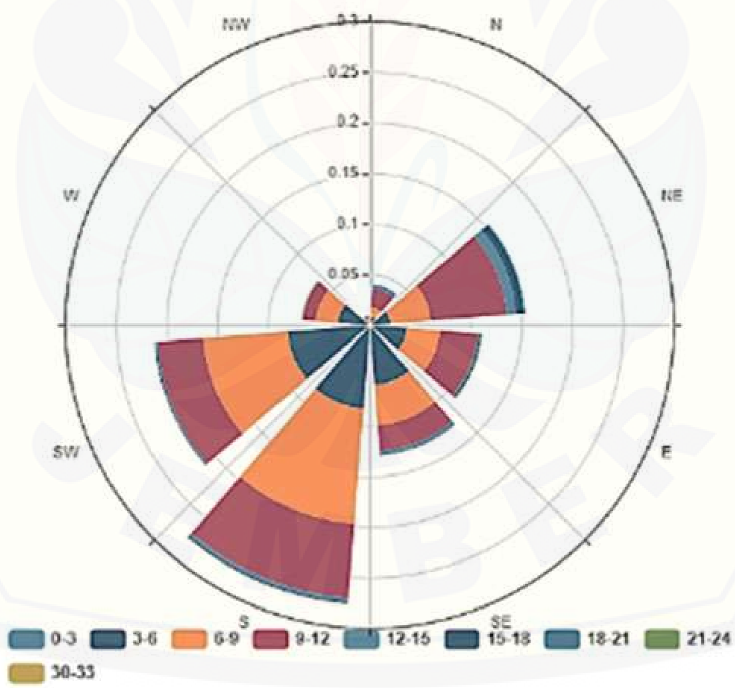
Table 1 shows wind data distribution and Fig. 2 shows wind rose of the study location. Based on the data, the main direction of wind is South (225°) which is 54.64% from total wind data.

2.3 *Wave Simulation Using Delft3D*

Delft3D-WAVE is able to compute various geospatial even meteorological parameters, wave dispersion calculation, wave generation by wind force, non-linear interaction between the waves, and wave dissipation [7]. In this study, Delft3D-WAVE is utilized based on the Simulating Waves Nearshore (SWAN) spectral model.



(a)



(b)

Fig. 2 Wind rose based on **a** peak wind direction; **b** mean wind direction

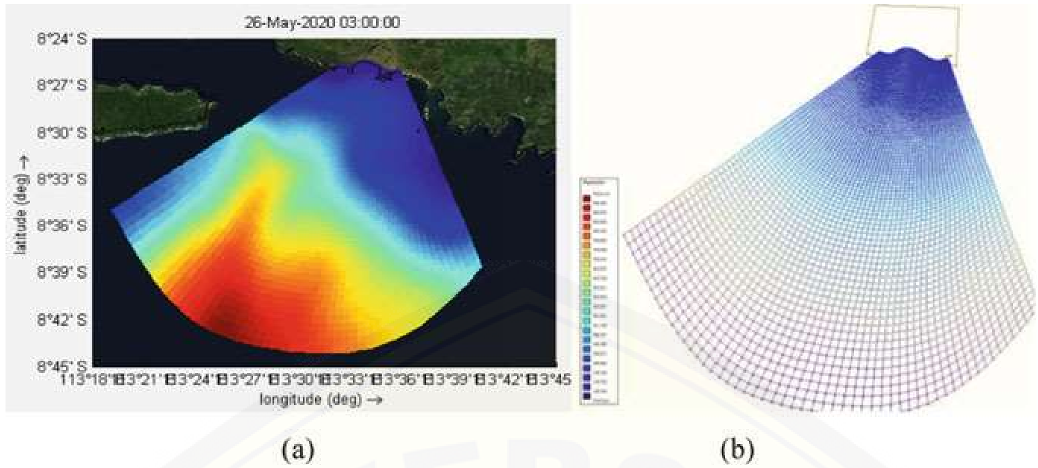


Fig. 3 **a** Depth generated from bathymetric data projected on ESRI visual; **b** simulation grid

In this study, bathymetric data that was used is the bathymetric data obtained from Indonesian Geospatial Information Agency with 6-arcsecond resolution. Wind input used in this simulation is taken from Class III Meteorological Station which have temporal resolution of 24 h (daily). In addition, wind data from ERA5-Interim provided by CDS Copernicus which have temporal resolution of 1 h (hourly) is used to generate meteo file as input file in Delft3D simulation. The bathymetric data is mapped in Fig. 3a. The grid used within the study domain ranges from 138.346 m to 946.482 m shown in Fig. 3b.

3 Results

3.1 Simulation Results

Generally, results of Delft3D-WAVE simulations in 2017, 2018, 2019, and 2020 show significant wave height of 2.5 m to 4.5 m nearshore and around 5 m offshore. The high waves in 2018 almost similar to those in 2017 with the difference margin around 5–10%.

Figures 4 and 5 show simulation results based on SWAN modeling in Delft3D when high waves occurred on July 25th, 2017. Figure 4a shows significant wave height of 2.5–4.5 m at the coastal area. Those high waves may be the cause of coastal flooding in the coastal area as occurred on July 25th, 2017. Figure 4b shows peak wave period more than 11 s in offshore while in coastal area, peak wave period ranges from 6 to 10 s. Figure 5 shows that waves approaching the beach at angle of 80° and shifting to 70° then around 55° to 60° when the waves arrive at the beach.

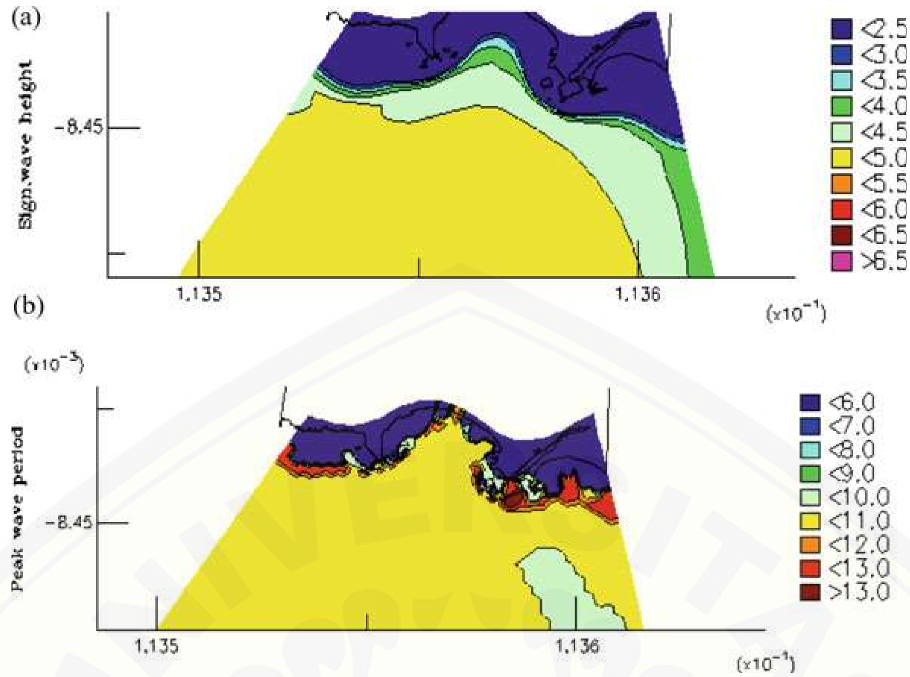


Fig. 4 Simulation result on July 25th, 2017. **a** Significant wave height; **b** peak wave period

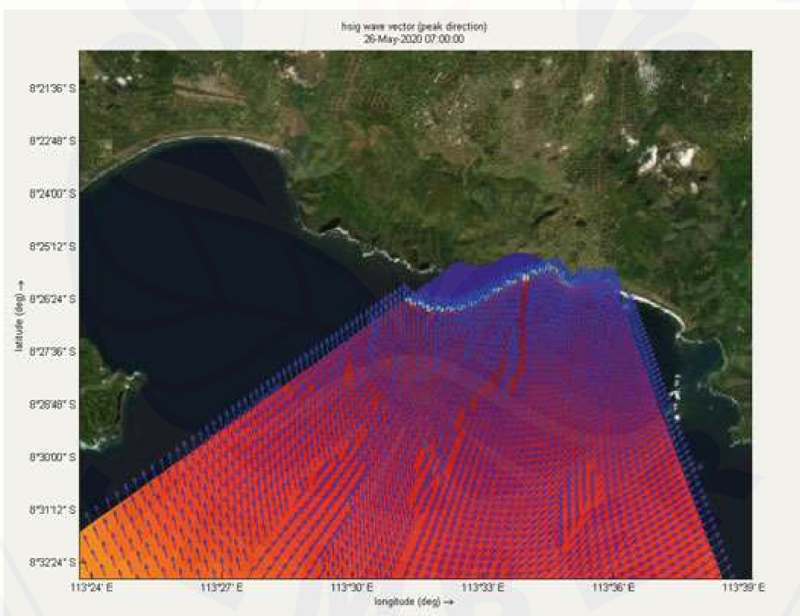
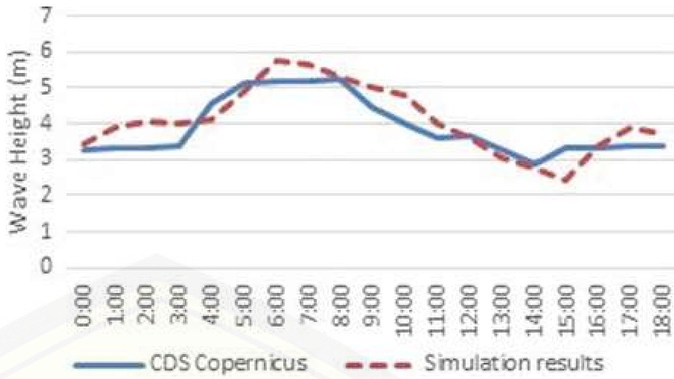


Fig. 5 Peak wave direction

Fig. 6 Comparison between simulated significant wave heights and CDS Copernicus observation data on July 2017



When high waves occurred, maximum wave height at 20 km offshore from Payangan Beach reached 3.9 m until 5.5 m. The simulation results coincide with the observed data from CDS Copernicus.

Figure 6 shows comparison between simulated wave heights on July 25th, 2017 and CDS Copernicus observation data. The results show that the highest simulated wave height was 5.8 m at 6 am, while based on CDS Copernicus observation data, the highest wave height was 5.2 m at 7 am. The simulated results show close prediction of CDS Copernicus data. The waves were generated from 8.55 m/s wind speed.

Simulation result in 2019 is different from those in 2017 and 2020 because the wave height is outstanding. The peak direction (Fig. 7a) not from 80° but vary from 62° to 77.5°. The significant wave height reached 6 m to 7 m in nearshore of Payangan Beach (Fig. 7b).

Figure 8a shows comparison between simulated wave heights on July 26th, 2019 and CDS Copernicus observation data. The results show that the highest simulated wave height was 6.9 m at 8 am, while based on CDS Copernicus observation data, the highest wave height was 5.9 m at 8 am. Although there are simulated results overestimated the observed wave height, the simulation was able to reproduce the similar time of maximum wave height at 8 am. The outstanding high waves were also confirmed by the captured video shown in Fig. 8b.

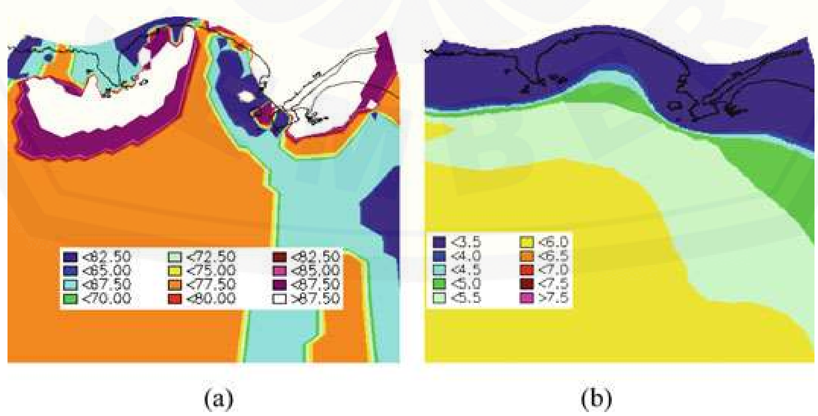
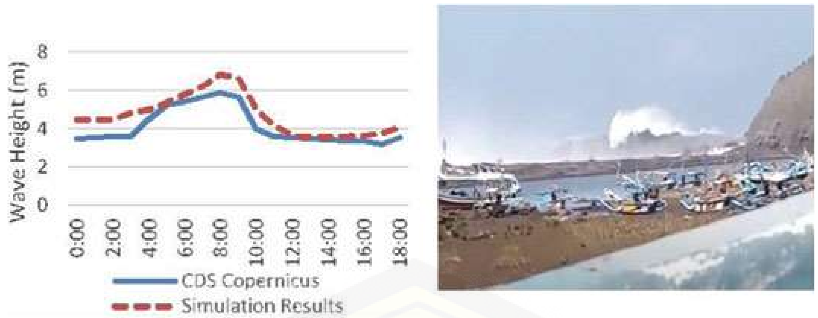


Fig. 7 Simulation result on July 26th, 2019. **a** Peak wave direction; **b** significant wave height



(a) (b)

Fig. 8 **a** Comparison between simulated significant wave heights and CDS Copernicus observation data on July 26th, 2019; **b** Payangan beach high waves documentation [8]

(a) (b)

Fig. 9 **a** Comparison between simulated significant wave heights and CDS Copernicus observation data on May 2020; **b** Payangan beach high waves documentation on May 27th 2020 high waves [9]

Different from 2017 and 2019, in 2020 the high waves occurred not in July but in May. Figure 9a shows comparison between simulated wave heights on May 27th 2020 and CDS Copernicus observation data. The results show that the highest simulated wave height was 5.6 m at 6 am, while based on CDS Copernicus observation data, the highest wave height was 5.9 m at 6 am. The waves were generated from 7.42 m/s wind speed. The simulated results slightly underestimated the observed wave height. However, the simulation was able to reproduce the similar time of maximum wave height at 6 am. The high waves were also confirmed by the photo shown in Fig. 9b.

4 Structural Measures

In order to protect the beach along with the community living within the area of study in Payangan Beach, one of the best solutions is to create safety measures based

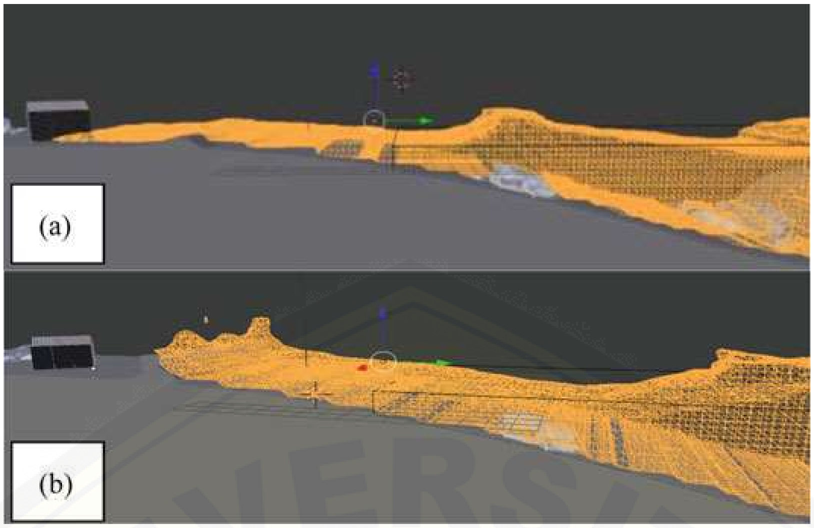


Fig. 10 High waves **a** without sea wall as protective measures; **b** with sea wall as protective measures

on the simulated wave height. Based on consideration and effectiveness according to the events, the best measures considered is to build a sea wall.

Sea wall is a coastal defense structure built parallel to the coastline to mitigate coastal flooding by blocking and or reflecting waves force to another direction so the wave will less affect the area protected by the sea wall. Sea wall vary in shape and type which based on the site condition. Payangan Beach condition require sea wall because of the direct wave effect on the beach during high waves.

Figure 10 show illustration of Payangan Beach without sea wall (Fig. 10a) and with sea wall (Fig. 10b). Without sea wall, waves will propagate to the coastal area and inundate residential area. By constructing sea wall, waves will be reflected and the residential area will be protected from severe inundation.

5 Conclusions

High waves occurred at Payangan Beach is significantly high because of the direct exposure of wind and wave from the open ocean. Wind meteorological direction is from the South with wind speed vary from 3.9 m/s to more than. When high waves occurred, the wind speed vary from 5 m/s to 16 m/s and generate waves with significant wave height of 3.4–5 m.

The high waves occurred in 2015, 2016, 2017, and 2018 show significant wave height of 2.5–4.5 m nearshore and around 5 m offshore with difference margin around 5–10%. However, in 2019 high waves occurred with significant wave height reached 6–7 m in nearshore of Payangan Beach. The significant wave height creating massive wave that visible from the distance. In 2020, high waves occurred two months prior than the other five years which always occurred in late July.

Preventive measures must be taken into consideration to protect the coastal area and residential area located in Payangan Beach. The most effective solution is to build coastal protection structure to cope with high waves and inundation that caused the coastal flooding. Sea wall has high efficiency to hold waves energy and to protect the residential area from inundation. However, with this solution, there may be sediment transport around the seawall. Further study is necessary to analyze coastal protection structure and the effect to the beach.

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