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***Corresponding author:** Farhad Sakhaee, School of Engineering, Parks College of Engineering, Aviation and Technology, Saint Louis University, USA; Email: farhad.sakhaee@slu.edu

ORCID: https://orcid.org/0000-0002-9645-8563

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Shoaling, Refraction and Diffraction in Waves

Farhad Sakhaee*

School of Engineering, Parks College of Engineering, Aviation and Technology, Saint Louis University, USA.

Abstract

This paper presented the phenomenon of shoaling, refraction and diffraction in near coastal areas.

Most of us consider tsunamis as very tall waves, but the reality is their amplitude is quite small in ocean. In other words, the tsunamis get much taller as they approach the coastlines. We know this process as shoaling. The degree of destruction of tsunami waves depends on how high they shoal. The causes which create such waves are related to the fundamental characteristics of waves and their variations in deep and shallow Waters. Shoaling is not only related to tsunamis but generally happens when waves go from deep to shallow water, when the waves approach the continental shelf and specifically at the coastlines. Waves slow down and their high increased, finally shoaling occurs.

Keywords: Ocean Waves, Tsunami, Shoaling, Refraction, Diffraction.

Introduction

As the waves get closer and closer to the coast, the seabed exerts a massive force on them which gradually slows down the waves, increase their heigh and shoaling happens [1-6]. The amplitude of tsunami waves is a small, mainly less than one meter. but they can shoal up too many meters in shallow waters [7-10]. For New Zealand a tall tsunami wave could run up to almost 30 ft (10 meters) higher than the normal sea level, that's about the height of a three-story building [11-13]. In the 2004 Boxing Day to tsunami waves rich to 45 to 90 feet. (15-30 meters) [14-17] (Figure 1**).** shows a schematic of ocean waves as they get close to the coast.

Shoaling Characteristics

When waves slow down, they start to bunch together so they have a shorter wavelength than before. The wave equation below verifies it. Speed = frequency X wavelength. It shows that when a wave's speed decreases, the wavelength is shorter than before while wave's frequency remains the same.

$$V = f X \lambda \qquad (1)$$

The interpretation of the above formula is that the shorter the wavelength the higher waves height is. The wave squeezed hence the height increased.

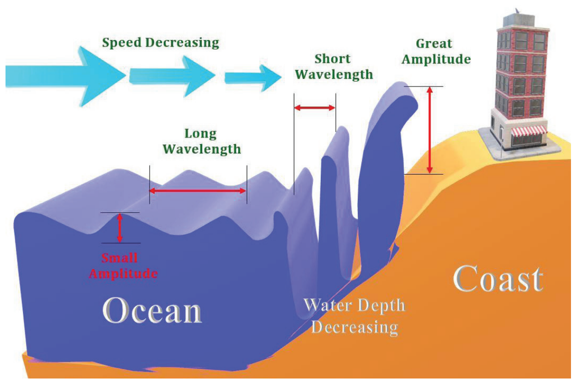

Figure 1: A schematic of ocean waves as they get closer to the coast.

Energy Conservation in Shoaling

A tsunami wave in deep ocean moves freely, hence having kinetic energy. As it gets closer to the coast it slows down, height increases, and the wave squeezes. One can say a big chunk of the kinetic energy transformed into potential energy inside the squeezed wave. In other words, high potential energy in high waves approaching the coast is due to gravity. It can unleash devastating energy when it runs over the land. As the waves generate at their source in deep water, they travel from deep water to shallow water passing the intermediate zone and approaching shallow water also called the surf zone (Figure 2). shows a transition of waves from deep water to intermediate and finally shallow water regions.

Based on the conservation of energy law, when the waves approaching the coastline the shape and the characters change drastically for example as they are getting closer to the coastline velocity and wavelength decrease while the height increases to conserve the energy flux. Waves in deep water have sinusoidal shape, lower heights and wavelength, as they enter the surf zone their velocity and wavelength decrease, seems like the waves are squeezed and a high potential energy stored in it while the height increases (Figure 3). below shows the transformation of the waves from their source into deep water which is called the sea waves having a wide spectrum, move to intermediate zone and form the swell waves and finally squeeze to from a surf wave.

(Figure 4) below shows how waves generate within deep water at their source, for example a fault beneath the ocean bed creates the waves pushing them upwards towards the surface. The propagating waves toward the coastlines undergo a change in their sinusoidal shape. Waves pile together to create smaller wavelengths while their height increase and carry a large potential energy which if unleashed on the coastal can inundate vest areas result in devastating flooding.

Shoaling usually happens in shallow water. If the water depth is less than half of the wavelength it is called a shallow water wave in deep water swell waves develop passing the transition zone and enter to surf zone. In surfing zones there is a breaking point where the crest of high wave brakes and moves toward coastal areas (Figure 5). below shows the breaking point of a wave.

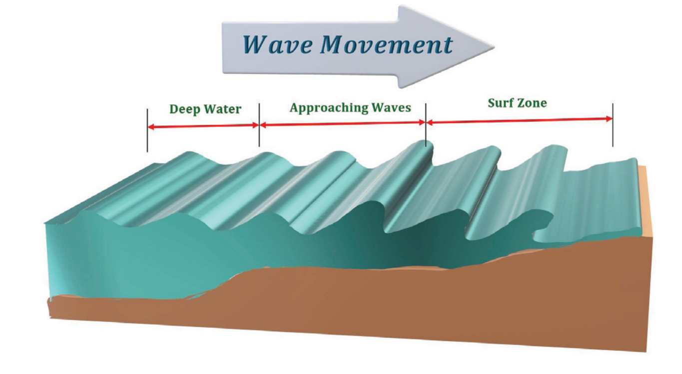

Figure 2: Schematic of hydraulic jump.

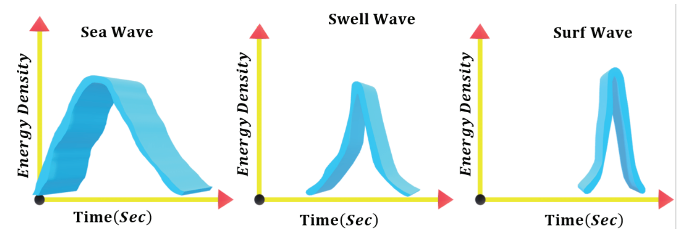

Figure 3: Waves transformations.

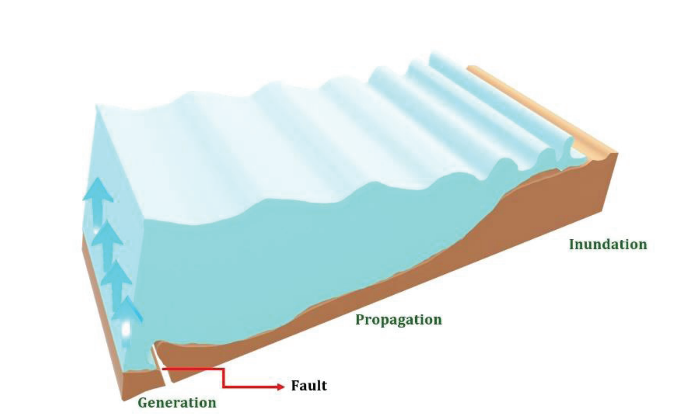

Figure 4: Shoaling causes inundation.

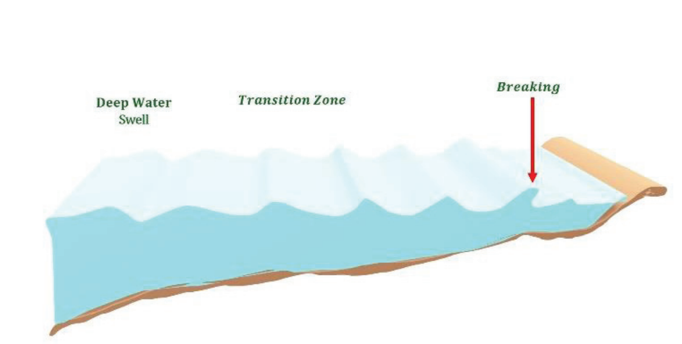

Figure 5: Shoaling causes inundation..

Wave Refraction

The other phenomenon in ocean waves is called refraction which mainly refers to the bending of the wave in shallow water [18-21]. This bending is because the portion of the wave which is closer to the coastal area locates in shallow water and the other part in deep water. The variation of bed elevation which induces refraction of a wave. (Figure 6) below shows a schematic of wave refraction. (Figure 7) below shows a schematic of wave refraction alongside a real image of wave refraction. Another scenario for wave fraction may observed around a circular island.

Wave Diffraction

Diffraction refers to a term in ocean waves as they dissect when they collide to an external obstacle such as breakwater, groins and Jetties [11, 22-26]. (Figure 8) below shows a schematic of waves diffraction. (Figure 9) below shows a real image of wave refraction in coastal areas alongside the schematic.

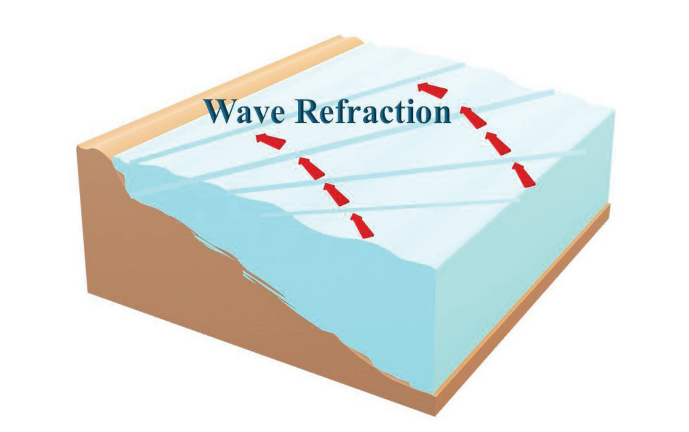

Figure 6: Schematic of a wave refraction.

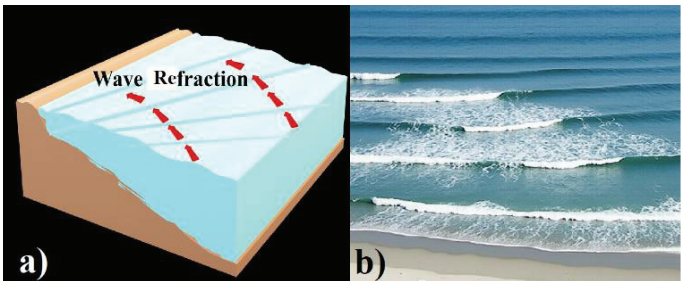

Figure 7: (a)Schematic of a wave refraction. (b) a real image of wave refraction.

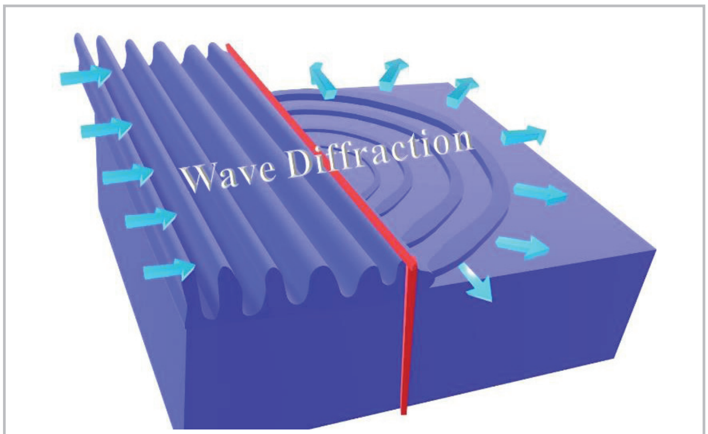

Figure 8: Schematic of a wave Diffraction.

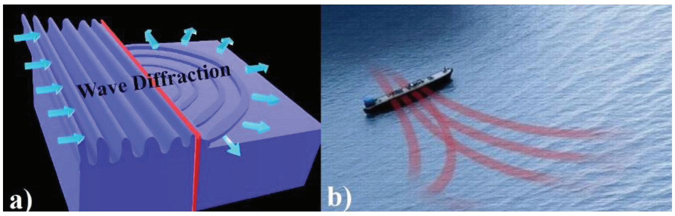

Figure 9: (a)Schematic of wave diffraction. (b) a real image of wave diffraction.

Conclusion

In the Journey of a wave from its creation at source in deep water until it reaches to the coastal area it undergoes different processes and passes through different stages. In deep water it is called sea wave, in transition zone called swell wave and finally in the surf zone called surf wave. Acknowledging each of these stages and their specification in terms of the wavelength, energy density, wave height and other specifications help us in designing the coastal structures such as breakwaters groins and jetties more effectively. It is not only the specifications and the details of the transition zones and the wave itself but also knowing the phenomenon related to shallow water such a shoaling, wave refraction and diffraction enhances the design and also durability of Marion structures.

Declaration of Conflict of Interests

The author declares that there is no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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