Wave Measurements at the Pensacola Wave-Attenuation-Device Site

Submitted by

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INTRODUCTION

A field experiment was conducted on July 25, 2006 at the Greenshores CRI wave-attenuation-device site in Pensacola Florida. The goal of the field study is to quantify the wave-height and wave-energy reduction achieved by the CRI wave attenuation devices. This was accomplished by simultaneously measuring wave conditions in the offshore area and at various locations in the sheltered area. The functioning of the wave attenuation device in terms of reducing wave height and wave energy can be quantified by comparing the offshore wave conditions with that in the sheltered area.

This short-term, one day, study was designed to examine the functioning of a specific layout of CRI wave attenuation devices under a specific wave condition. It is not the goal of this study to document long-term performance, e.g., wave reduction under various wave and water-level condition. It is also not the goal of this study to examine the functioning of different structural configurations. Longer-term measurements and numerical wave modeling are recommended for future studies.

STUDY AREA AND THE SPECIFIC FIELD CONDITIONS

The study area is located along the north shore of Pensacola Bay immediately west of the Pensacola Three Mile Bridge (Figure 1). The study site is open to a substantial fetch to the south and southwest. Figure 2 shows the aerial view of the study site and the locations of the wave measurements. The CRI wave attenuation devices serves as a continuation of an array of rubble mount breakwaters. The east end of the structure is about 50 meters from the bridge. The structures were installed in water depth of approximately 1.5 m.

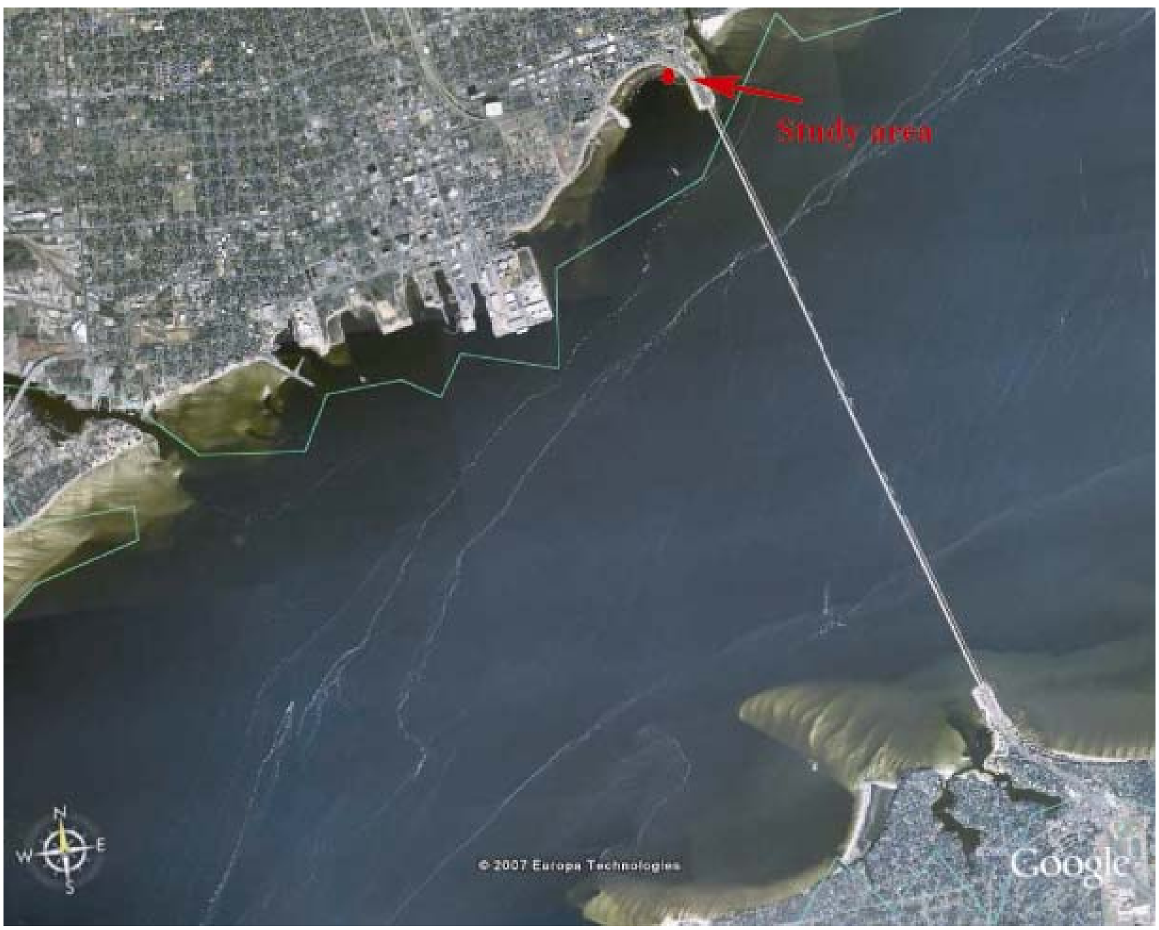

Figure 1. The greater study area, note the considerable fetch to the south and southwest. The causeway is approximately 5 kilometers.

Figure 2. Aerial view of the study site and locations of the wave measurements.

The measurements were conducted on the afternoon of July 25th, 2007 during a falling tide. The water level during the measurement period was close to mean water level. The tidal range in the study area is small, roughly 0.3 m. As typical of summer condition, land breeze with offshore direct wind dominated in the morning. The study site was calm with minimal wave activity. In the afternoon, landward directed sea breeze generated choppy waves at the study site. The data collected by this study should represent a typical summer sea breeze conditions.

The wave measurements were conducted at five different locations, including one offshore site and four sites in the sheltered area (Figure 2). The offshore site is roughly

30 m seaward of the structures with a water depth of 1.5 m. Site 1 in the sheltered area was selected to be close to the gap between the structures and the seawall along the causeway, with a water depth of 1.4 m. The purpose of site 1 is to quantify the wave transmission through the gap. Field observations also indicated considerable wave reflection from the seawall. Wave conditions at site 1 are also influenced by the reflected wave. Site 2 is located near the western end of the structures. Based on field observation, limited wave energy was transmitted through the gap between the CRI wave attenuation devices and the rubble mount breakwaters. Also, site 2 is relatively far from the seawall and should have a significantly reduced influence as compared to site 1. Site 3 is approximately one half of the length of the CRI field landward. Site 4 is approximately one length of the CRI field landward. The goal of sites 3 and 4 is to examine the extent of the wave sheltering by the CRI structures. It is worth noting that the wave attenuation devices and the rubble mount structures form a nearly continuous array of structure. The sheltering area is different from typical segmented breakwaters.

EQUIPMENT, SAMPLING SCHEME, AND DATA ANALYSIS

Two Sontek Triton wave gages were used for the field measurements. Although the Triton is capable of collecting directional information, only non-directional information, i.e., wave height and wave period, will be used here. One Triton wave gage was deployed offshore and remained at the offshore site during the entire measurement from 13:30 to 18:00 eastern standard time. This gage provided a continuous offshore wave conditions for comparison. One wave gage was used to measure the wave conditions in the sheltered area. This gage was moved from site 1 through site 4. The wave gages were mounted on a stable steel pipe which was pounded into the substrate (Figure 3).

Figure 3. Installation of the Triton wave gage at Site 1.

To better capture the high frequency wind waves, the wave gages were sampled at 4 Hz for 128 seconds. Given the high frequency wave, with a peak period of about 2 second, the 128-second sampling is adequate to provide reliable statistical values. The wave gages were installed as close to the water surface as possible to minimize signal attenuation through the water column. The wave measurements were conducted every 10 minutes. The nearshore wave gage was installed at each site for one hour to provide 6 measurements at each nearshore site.

Standard frequency domain analysis was conducted to obtain significant wave height and peak wave period. Although the wave gages were close to the water surface, standard depth attenuation correction was still conducted to ensure representation of high-frequency information. Wave analysis was conducted using the power spectral analysis module in MATLAB.

RESULTS AND DISCUSSION

Visual Observation

Wave height and energy reduction by the wave attenuation device is apparent from visual observation (Figure 4). Much calmer water is observed landward of the structure. Considerable amount of wave energy entered the protected area from the gap between the structure and the seawall (Figure 5). In addition, waves reflected from the seawall are also visible in Figure 5. The reflected waves tend to be somewhat better organized than the choppy wind waves.

Figure 4. Visual comparison of the wave conditions seaward and landward of the structure.

Figure 5. Wave propagation through the gap between the structure and the seawall (beyond the bottom of the picture). Note the reflected waves propagating nearly parallel to the structure.

Measured Wave Conditions

Overall, the measured wave conditions confirm the qualitative visual observations. It is worth emphasizing again that the wave height and energy reduction described below pertains directly to the specific configuration of the Greenshores structure. Different structural configuration may result in very different patterns.

Significant wave height reduction was measured at all the sites, although sites 2, 3, and 4 showed much more reduction than site 1. Site 1 is influenced by the wave transmission through the gap between the seawall and the structures, and the reflected waves from the vertical seawall (Figure 5). Figures 6 through 9 illustrate examples of raw wave data collected at the offshore control site and the various sites in the shelter zone. The wave height reduction can be observed directly from these figures.

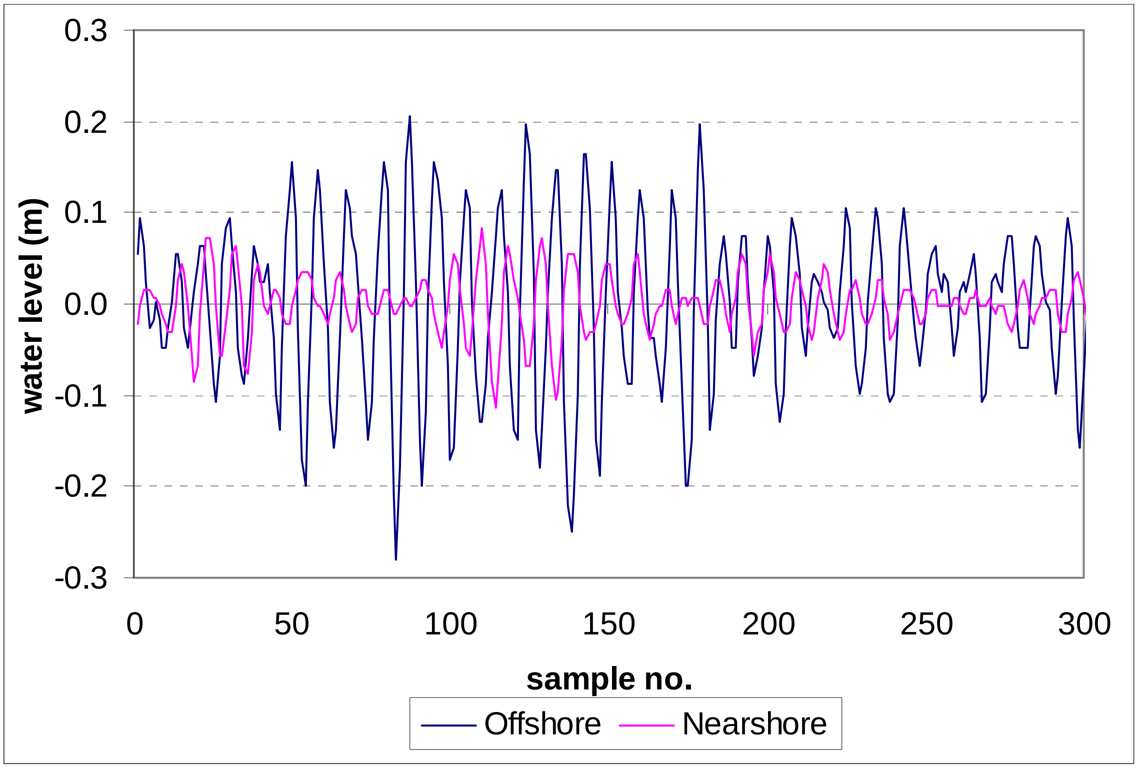

Figure 6. A portion of water level records comparing the offshore condition and condition at site 1, at 14:00 hours.

At site 1, considerable waves, as compared to the offshore condition, were measured (Figure 6). The relatively well-organized higher waves are those reflected from the seawall. Due to the specific location of site 1, i.e., near the gap and the seawall, this site may not provide a typical case for well protected areas. Some wave height variations were measured during the entire experiment. Figure 6 represented the highest offshore waves measured during the entire afternoon.

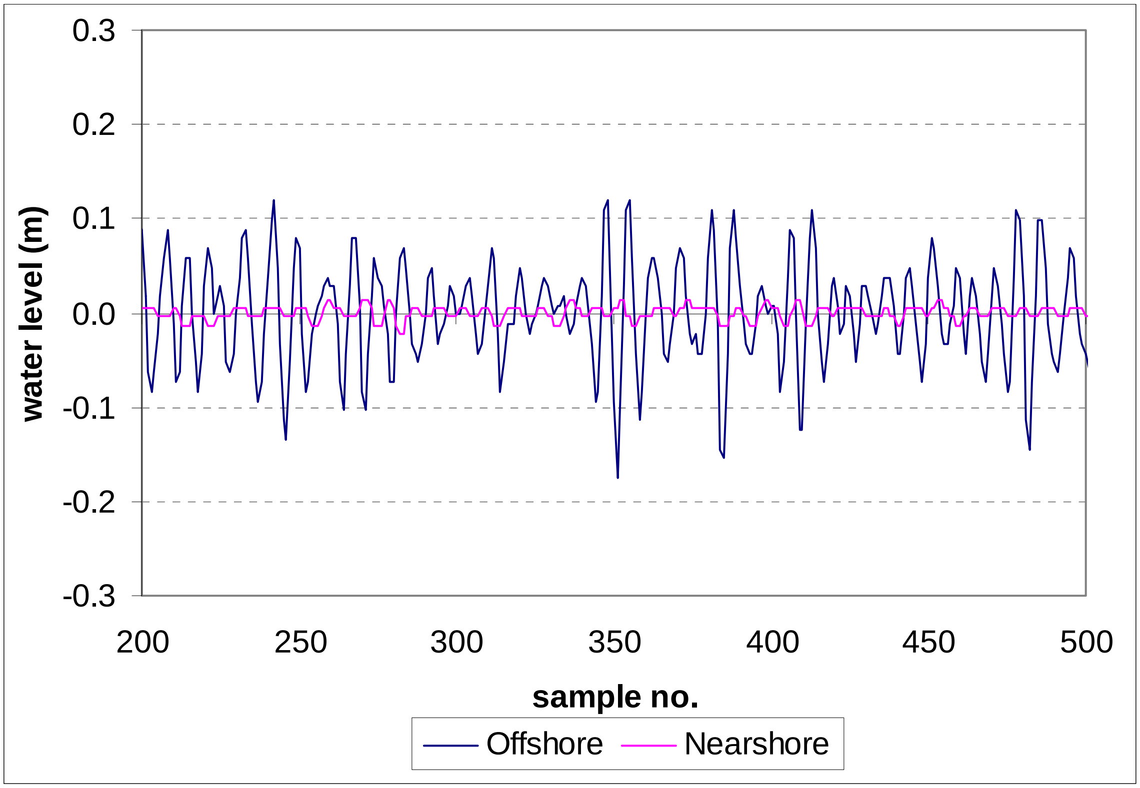

Figure 7. A portion of water level records comparing the offshore condition and condition at site 2, at 15:20.

At site 2 location near the western end of the wave attenuation device, much smaller waves were measured, as compared to the waves at site 1. The much greater wave reduction resulted from a combination of 1) minimal wave transmission through the very small gap between the wave attenuation device and the rubble mount structures and 2) substantial dissipation of the reflected waves from the seawall. The data from site 2 also indicate that although there are gaps between individual blocks of the wave attenuation device, little wave energy transmits through the small gaps.

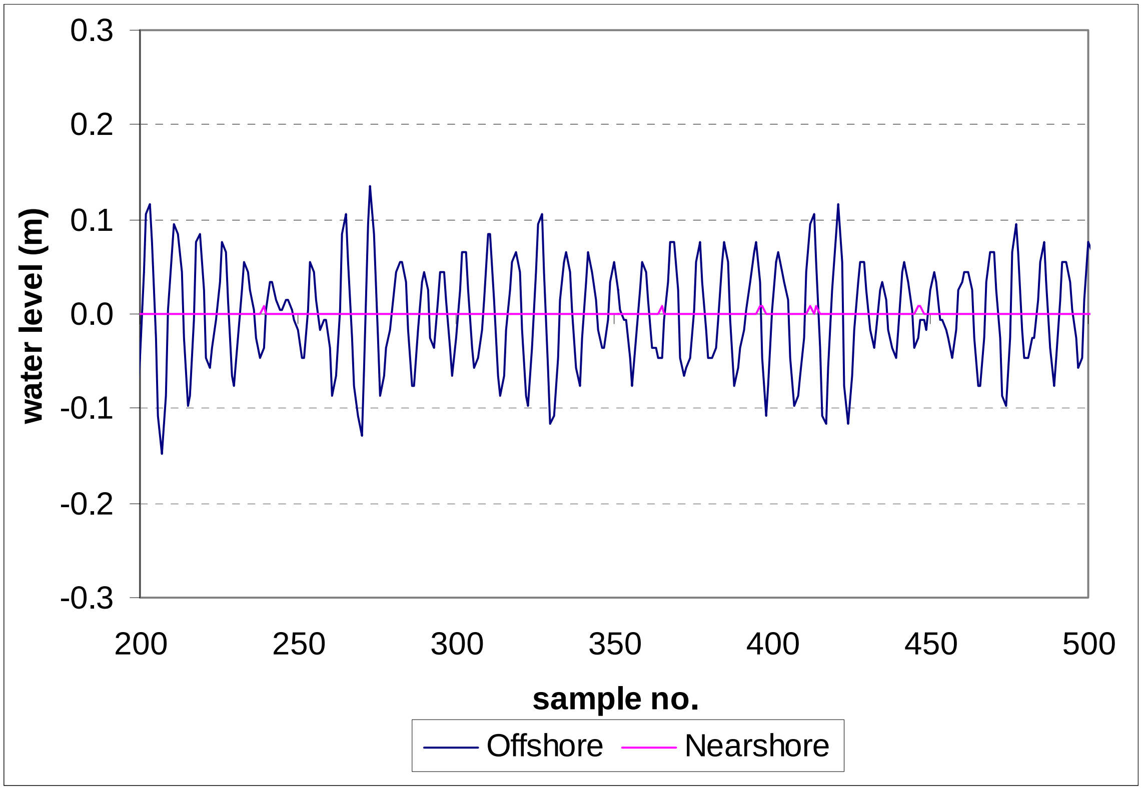

Figure 8. A portion of water level records comparing the offshore condition and condition at site 3, at 16:30.

Sites 3 and 4 located at a half and one structure length landward of the structure. Nearly no waves were measured at these two sites (Figures 7 and 8). Small wind ripples with wave length on the order of 0.3 m were observed in the field. However, these very high frequency ripples cannot be measured by the present wave gages. The nearly complete wave energy reduction as these two sites were also influenced by the specific configuration of the wave attenuation device and the rubble mount breakwaters. This is not the case for typical segmented breakwaters.

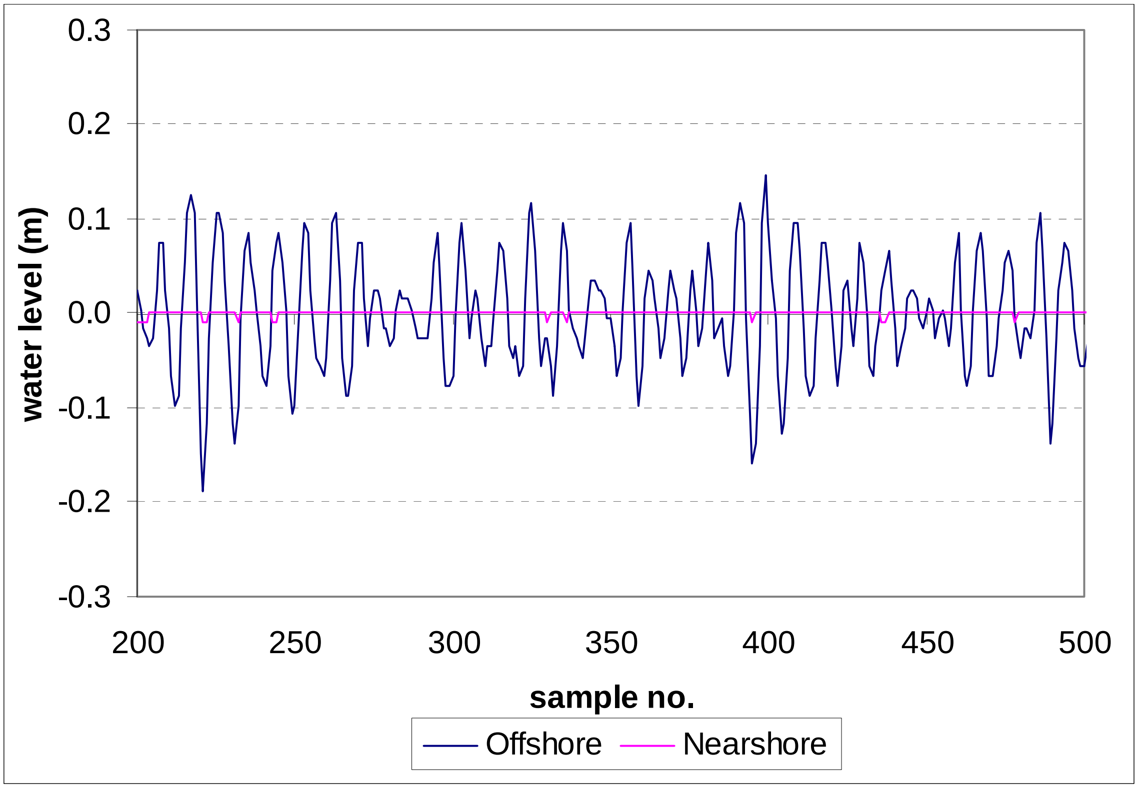

Figure 9. A portion of water level records comparing the offshore condition and condition at site 4, at 17:30.

Figure 10 summarizes the peak wave period measured at the offshore wave gage during the entire experiment. Overall, the peak wave period remained largely similar, ranging from 1.6 to 2.4 seconds. The short wave periods during the first two measurements and the subsequent increase represent the wave growth as the sea breeze strengthening throughout the afternoon. Over most of the afternoon, the wave period remained at approximately 2 seconds. Wave periods measured at site 1 are similar to those measured at the offshore gage.

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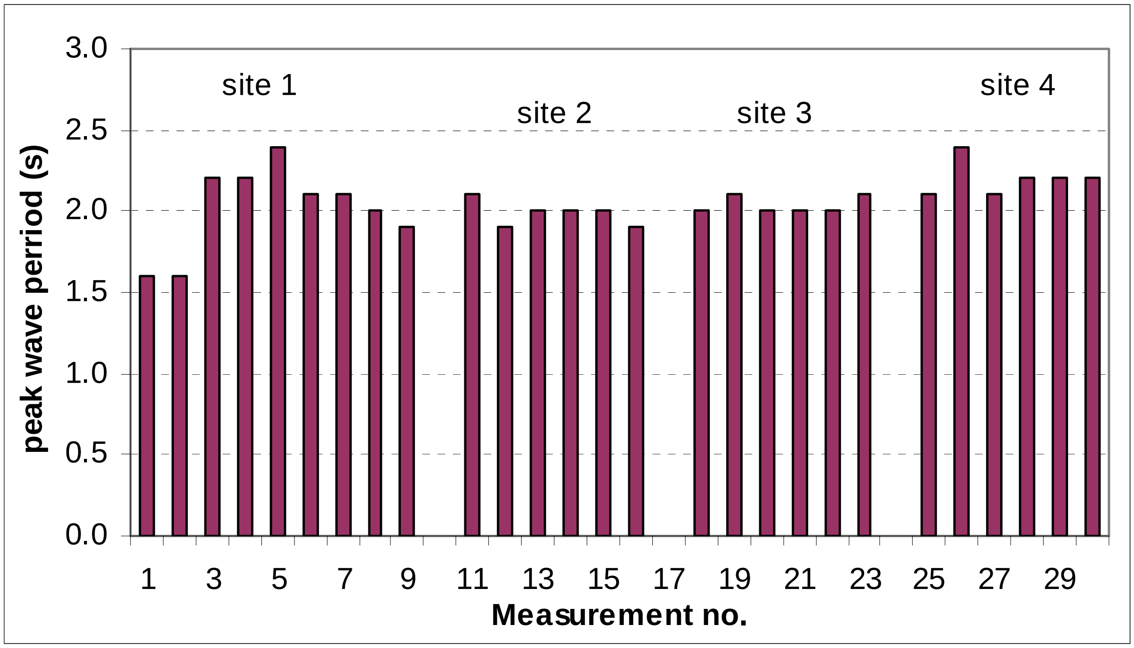

Figure 10. Summary of the measured peak wave period.

Figure 11 compares the measured significant wave height at the offshore and nearshore sites. Except at site 1, dramatic wave height reduction was measured at all the protected sites, similar to that observed visually. Although this particular wave reduction pattern is a direct result of the specific structural configuration, Figure 11 demonstrates that the wave attenuation device is capable of reducing wave height by nearly 100%. For this specific case, the top of the wave attenuation device was exposed and the incident waves were locally wind-generated high frequency choppy waves.

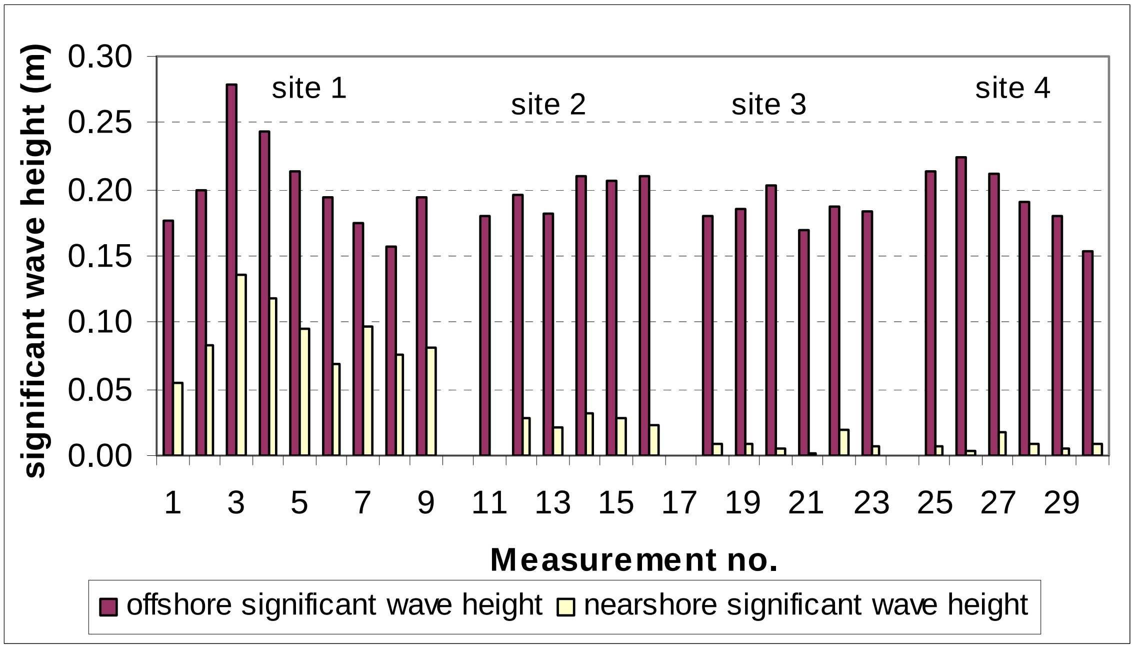

Figure 11. Summary of the measured significant wave heights at the offshore and nearshore sites.

Figure 12 summarizes the percentage reduction of significant wave height and wave energy. At nearly all four sites, the wave height was reduced by more than 50% and wave energy was reduced by more than 80%. The relative less wave-height and wave-energy reduction at site 1 is caused by wave transmission through a substantial gap plus reflected wave from the vertical seawall. Three of the four sites in the protected area showed over 80% wave-height reduction and nearly 100% wave energy reduction for the particular structure configuration and incident wave conditions.

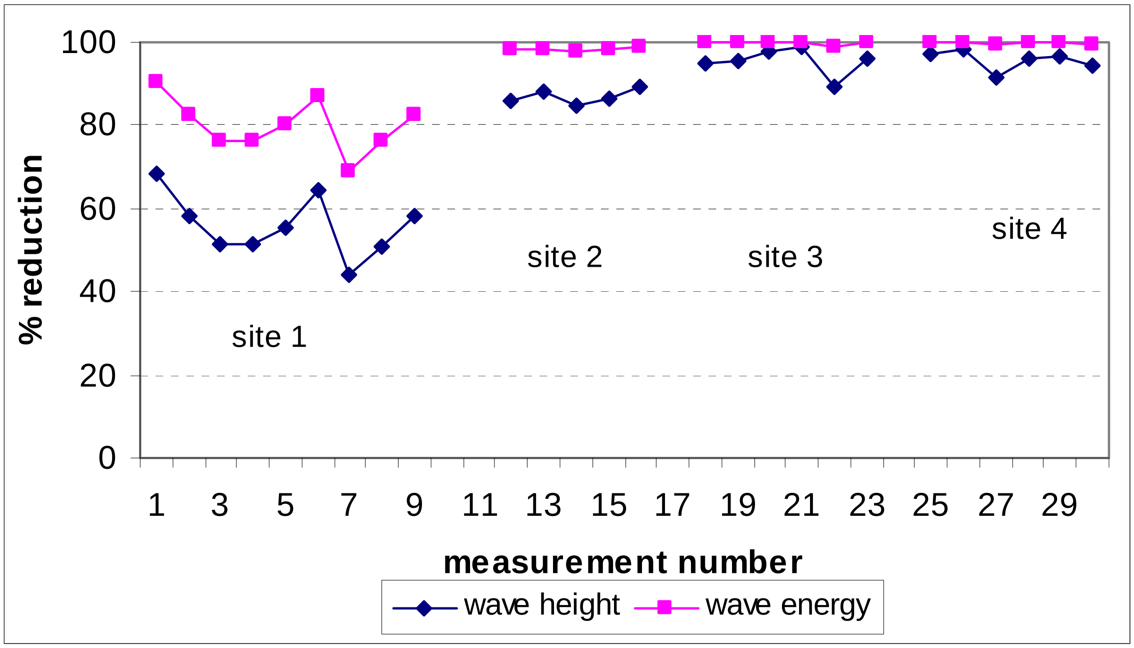

Figure 12. Summary of the percentage wave-height and wave-energy reduction.

SUMMARY

Overall, substantial wave-height and wave-energy reductions were measured at all the sites in the protected area of the CRI wave attenuation devices. At site 1 with considerable wave transmission, the incident wave height was reduced by 56% on average, with an average wave-energy reduction of 80%. At site 2 with limited wave transmission from offshore, the incident wave height was reduced by 87% on average, with an average wave-energy reduction of 98%. At sites 3 and 4 further landward of the structure, due to the dissipation of the little transmitted waves, both the incident wave height and wave energy was reduced by nearly 100%.

In summary, this field measurement shows that the wave attenuation device is capable of reducing both wave height and wave energy substantially, e.g., over 80%. The functioning the wave-attenuation device is strongly influenced by the design and configuration of the structures. Characteristics of the incident wave may also have significant influence on the wave reduction.