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Recent Improvement of Coastal Wave-Tide Observation and Textbooks Publication

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1. INTRODUCTION

Coastal wave and tide information is very important in various occasions for port and harbor engineers, in the stages such as port and harbor planning, maritime structure design, maritime construction management, and coastal disaster study. This paper introduces recent improvement of Japanese coastal wave-tide observation and information system named as NOWPHAS (Nationwide Ocean Wave information network for Ports and HArbourS). Development and improvement of the NOWPHAS has been achieved during recent decade in the following points of view (Nagai,2002a, 2002b).

(1) Development and nationwide installation of the Doppler-type Wave Directional Meter (DWDM) (Takayama,et.al.,1994; Hashimoto,et.al.,1996)
(2) Directional and infra-gravity wave observation and expression system(Nagai,et.al.,2000, 2002a, 2002b)
(3) Observation of tsunami profiles (Goda,et.al., 2001, 2002)
(4) Development of the COMEINS (Coastal Oceanographic and MEteorological Information System) (Goda,et.al., 2001)
(5) Development of the On-site composite wave-tide observation system (Goda,et.al., 2002)
(6) Publication and Korean Translation of Textbooks (Goda,et.al.,2001, 2002; Nagai, 2002b)

2. NOWPHAS

NOWPHAS, the Japanese coastal wave observation and analysis system, has been operated since 1970 by the Ports and Harbors Bureau of the Ministry of Land, Infrastructure, and Transport and its associated agencies including the Port and Airport Research Institute (PARI) (Nagai,et.al, 1994). Fig.1 shows network of Japanese coastal wave observation system (NOWPHAS) in March 2002. At fifty-six stations coastal wave observation data are obtained and sent to PARI by telecommunication line.

Among them at nineteen stations newly developed DWDM wave sensor are installed. At the other stations, USW (Ultra-Sonic Wave gauge) sensor or combination of USW and CWD (Current meter type Wave Directional meter) are most commonly used in NOWPHAS system. These wave gauges are all sea-bed installed type at water depth 10 to 50 m.

3. DEVELOPMENT OF DWDM

Development and nationwide installation of the Doppler-type Wave Directional Meter (DWDM) was completed. DWDM, a new type of wave gauge, was put into practical use in 1995 after long years' cooperation research among PARI (Port and Airport Research Institute), JAMSA (JApan Marine Surveyors Association), and Kaijo Co. DWDM enabled us to obtain

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directional spectrum information with one single sea-bed installed sensor by application of the Doppler Principle of the acoustic signal in the sea. DWDM also realized infra-gravity wave observation with one single seabed installed sensor. Photo.1 shows the seabed installed DWDM sensor, and Fig.1 shows the observation principle of DWDM (Hashimoto, et.al.,1996).

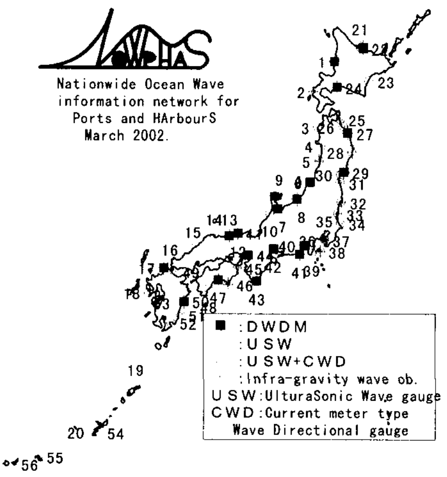

Fig. 1. NOWPHAS Network.

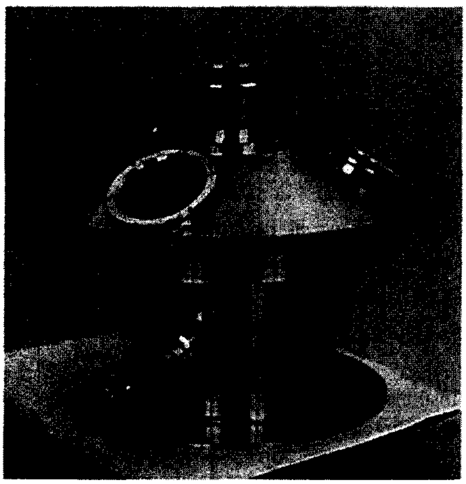

Photo. 1. DWDM Seabed Installed Sensor.

Photo.1 is DWDM seabed installed sensor, which is to be installed on seabed with maximum water depth 50m. Fig.2 shows observation principle of DWDM. Ultrasonic signal output to vertical direction takes the same rule to the existing USW. In addition, three components of oblique directional ultrasonic signal output are for the directional wave measurement. By applying the Doppler effect each oblique directional water particle velocity in arbitrary layer can be obtained. Numerical method to obtain directional spectrum from the obtained data has also been developed by PARI (Hashimoto,et.al.,1994, 1997).

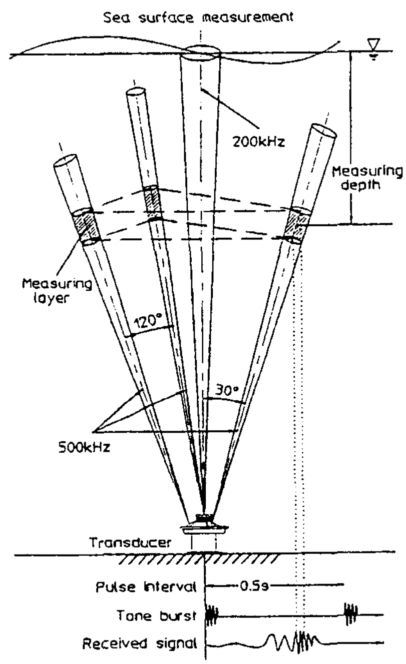

Fig. 2. Observation Principle of DWDM.

4. FREQUENCY BANDED WAVE EXPRESSION

Directional wave observation and expression system has been established. Frequency banded expression based on directional spectrum analysis was newly applied to the NOWPHAS observed wave data processing. With the frequency banded expression, NOWPHAS made it possible to clarify complicated sea states with the mixture of swells and wind waves (Nagai,et.al.,1997, 2002a).

Fig.3 is an example of observed double peak directional spectrum at the station No. 41 of the NOWPHAS network shown in Fig. 1 at 2:00 on January 9, 1998. Low frequency swell from South direction and high frequency wind wave from Northeast (NE) direction coexisted. In such shape of spectrum it is impossible to express wave direction with single parameter. If peak direction is applied, wave direction should be south as the vertical dotted line shows in the figure. And if average direction is applied, wave direction should be Southeast (SE) as the vertical straight line in the figure shows. It means that if we try to express wave direction in single parameter, the result may be different depending on the definition. For this reason the author proposed frequency banded wave height and direction for directional wave expression.

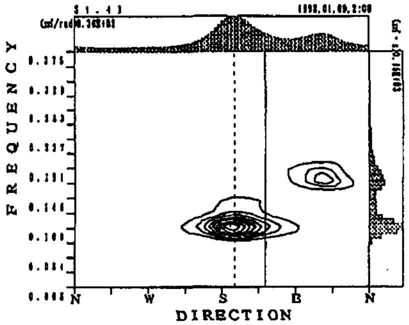

Fig. 3. Observed Double Peaked Directional Spectrum.

The new concept of the frequency banded wave power is defined in the equation (1).

$$m_{12} = \int S(f)df \qquad (1)$$

Where the integrated frequency range is defined as between b1 and b2. By applying a well-known equation (2) between significant wave height and frequency spectrum integration in case of b1=0 and b2= ∞, frequency banded wave height is defined as the equation (3) in the frequency range b1 and b2.

$$H = 4\sqrt{m_0} \qquad (2)$$

$$H_{12} = 4\sqrt{m_{12}} \qquad (3)$$

With the concept of the frequency banded wave height it is possible to reduce the number of parameters to explain the frequency spectrum.

Fig 4 shows weather maps around Japan on February 19 and 20 in 2002, when double peaked low pressure passed north side of Japan from the Japan Sea to the Pacific Ocean. Strong wind was observed in northern Japan Sea coast area around NOWPHAS station No. 1, Rumoi, area on February 19. But in the central Japan Sea coast around NOWPHAS station No. 7, Toyama, wind was relatively weak.

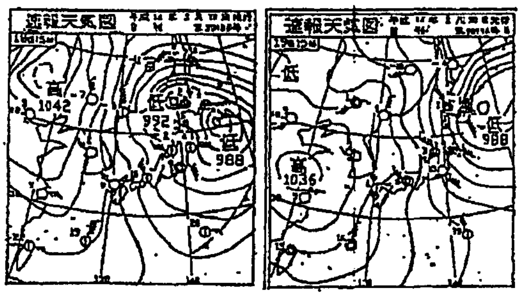

Fig. 4. Weather Maps on Feb.19th and 20th in 2002.

Fig 5 shows the frequency banded wave height time history on the same days at the NOWPHAS stations No. 1 and No. 7. On February 19 at station No. 1 wind wave growth can be observed in the figure, first from the higher frequency components and gradually to the lower frequency components. On the other hand at the station No. 7 wave energy was very low during whole the day of February 19 in every frequency band. Rapid low frequency components growth in the frequency band 10 to 15 seconds is observed early in the morning on February 20, while high frequency components energy remains in low energy. This is the typical Yorimawari-Wave in the Toyama Bay, transmission of low frequency components swells from northern part of the Japan Sea without existence of high frequency components.

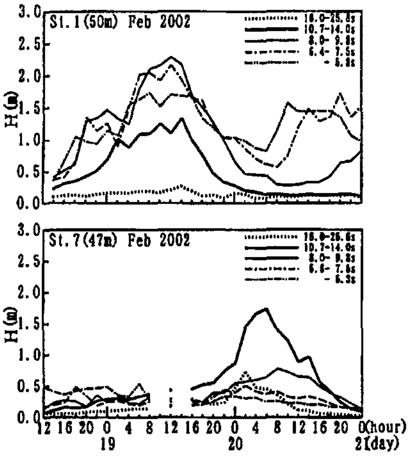

Fig. 5. Time Series of Frequency Banded Expression.

5. TSUNASMI PROFILE OBSERVATION

Fig.6 shows 1996 Irianjaya earthquake tsunami profiles observed at the NOWPHAS station No. 38, outside of Tokyo Bay (Habu), and No. 37, entrance of Tokyo Bay (Kurihama). In the figure relatively high frequency wind wave and swell components are eliminated by numerical low-pass-filter. At both stations dominant tsunami period was found to be about 15 minutes. But the tsunami arrival time and amplitude are different. As the arrows in the figures show station No. 38 observed the first tsunami arrival 40 minutes earlier than station No. 37, it means tsunami observation at outside of Tokyo Bay is very important for tsunami disaster prevention in Tokyo Bay because earlier tsunami profile catch is possible. In the station No. 37 tsunami amplitude increase is obvious for the 1.5 hours after first tsunami arrival, which is due to topographical resonance effect. Natural resonance period at the Tokyo Bay entrance between Kurihama and Kanaya, opposite side of the bay is estimated around 15 minutes, that coincide the tsunami period in Fig. 6.

Fig.7 shows 2001 Peru earthquake tsunami profiles observed at NOWPHAS station No. 27, Kuji station faced to northern Pacific Ocean. The upper figure shows significant wave height and the lower one shows low frequency components corresponding wave heights. During three days from June 24 to 27, and keep almost constant values and no tsunami effect can be found. On the contrary the lower figure shows frequency banded low frequency components wave height time history. In the frequency band longer than 600 s (10 min.) shows immediate increase from 4:00 to 8:00 in the morning on June 25, and high energy condition with equivalent wave height around 10 cm continued about half day, that is due to the tsunami arrival.

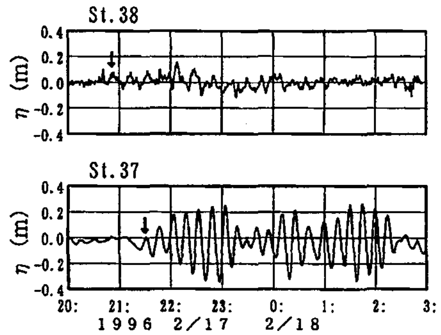

Fig. 6. 1996 Irianjaya Earthquake Tsunami Profiles.

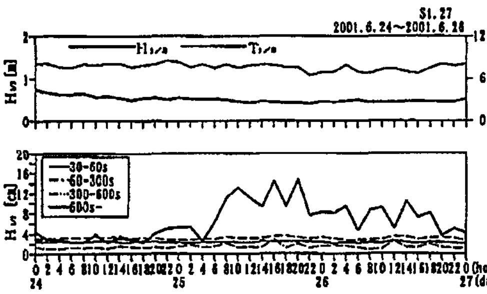

Fig. 7. 2001 Peru Earthquake Tsunami Profiles.

6. REAL TIME INFORMATION SYSTEM (COMEINS)

Real time NOWPHAS coastal wave observation data and meteorological numerical data by Japan Meteorological Agency (JMA) are combined in the Coastal Oceanographic and Meteorological Information System (COMEINS) developed by Coastal Development Institute of Technology (CDIT). COMEINS system started in 1997, providing nationwide users reliable and precise coastal wave prediction information, which helps safe and economical maritime works such as constructions, cargo handling, navigation etc.

7. DEVELOPMENT OF THE ON-SITE COMPOSITE WAVE-TIDE OBSERVATION SYSTEM

Fig.8 shows the newly developed on-air acoustic type wave and tide gauge, by adding multi-reflectors to existing on-air acoustic type wave gauge. It was supposed to be difficult to measure on-site waves and tides simultaneously with one single on-air acoustic sensor, because that air temperature is not constant at the boundary area between air and seawater, which causes errors of long period seawater level fluctuation such as astronomical and meteorological tides. On-site tide level measurement was realized without constructing expensive tide wells by conducting direct precise estimation of the on-air acoustic velocity using multi-reflectors.

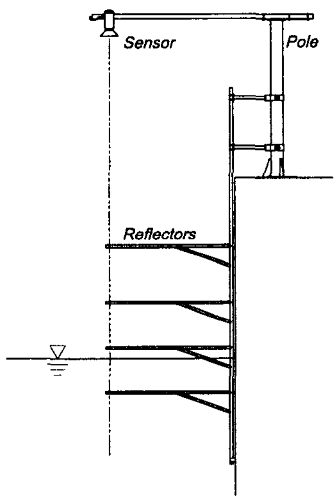

Fig.8. On-air Acoustic Wave-Tide Gauge.

Fig.9 shows concept of on-site wave overtopping rate measurement. Wave overtopping rate monitoring is very important for coastal disaster prevention. Nevertheless up to present time, reliable wave overtopping monitoring system did not exist, for difficulty of measurement and for difficulty of understanding phenomena, as wave overtopping varies in very short time and small horizontal distance. Newly developed on-site monitoring system shown in the Fig.8 made such difficult monitoring possible, by setting several pressure-type or step-type water detecting sensors along the sea-wall.

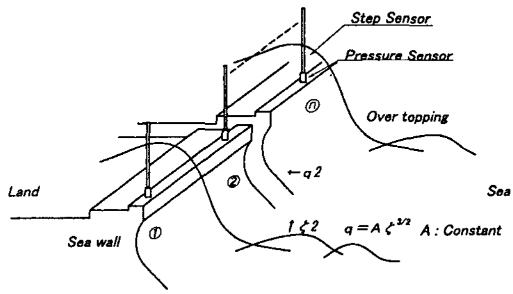

Fig.9. On-site Wave Overtopping Measurement.

8. PUBLICATION AND KOREAN TRANSLATION OF TEXTBOOKS

Development, utilization and disaster measures of marine and coastal area need to be considered wave and tide level. Wave and tide observation are important for the harbor project or construction. Reasonable understanding of coastal or marine observation is essential for effective and accurate application of valuable observation information. Marine observation information is useful not when data are obtained from the wave and tide gauge but when they are analyzed and managed. Authors believe that intellectual processing such as data analysis and management is worthy, not matter like observation gauge (instrument). In addition, such important wave and tide measurement technology made a tremendous progress during the last decade as above mentioned.

Therefore necessity of good textbooks of coastal wave and tide observation has been increasing recently. That's why the Coastal Development Institute of Technology established the Research Group of Marine Observation Data Analysis and Application headed by Prof. Yoshimi Goda in 1998. Two textbooks were recently published by the research group (Goda,et.al., 2001, 2002). And these books were translated to Korean language and published by Korean Ocean Research Development Institute (KORDI). These textbooks have following characteristics.

(1) One topic in one page

You can start to read from any page of the textbook, as there is one topic in one page. More figures, tables and photographs, less equations are inserted for easy reading.

(2) Easy to find key word

There are several key words bottom of each page and there is also index at back pages.

(3) Many references

References are provided in each topic.

(4) Many examples

These books provide many examples of observation procedures and wave observation data in case of disaster and help to understand for newly engineers in marine observation field.

(5) Show the new directional spectrum

As wave gauges spread widely in Japan, we can obtain on time data of directional spectrum. The textbook of Coastal Wave Observation provides the new indication method of wave information with converted wave height and direction based on spectrum analysis.

(6) Awarded Japan Ports and Harbours Association Prize

The textbook of Coastal Wave Observation is awarded Japan Ports and Harbours Association Prize on 22 May 2002.

9. CONCLUDING REMARKS

A wave measurement project is generally not favored by engineers, because it is quite expensive in cost, because it demands a lot of man-power with continuous attention, and because it must be continued for a quite long period before any meaningful result can be obtained. Nevertheless, the necessity and importance of wave measurement are being gradually recognized. It is expected that much more data will be accumulated in various waters of the oceans and seas around the world.

In this paper, author introduced the concept of the frequency banded directional wave expression. Obtained directional spectra are shown as the frequency banded energy equivalent wave heights and directions. Examples of annual directional wave spectral statistics at one of the NOWPHAS wave stations are introduced. An interesting fact is clarified that dominant wave direction differs to the frequency band.

A continuous data sampling system with longer time duration has been newly developed (Iwasaki,1996). The analysis of data observed in 1997 at 10 NOWPHAS wave stations yielded that average wave heights defined from the spectral energy of lower frequency than 0.033Hz were between 4cm and 8cm, which were ten or hundred times larger than the average significant heights estimated in non-linear bound wave theory (Bower,1992). The NOWPHAS new system clarified the arrival of the 2001 Peru Earthquake Tsunami.

Authors also introduced recently developed new on-site wave-tide monitoring system and wave overtopping monitoring system in this paper.

Recently published two Textbooks in Japanese and Korean languages are very friendly for the beginners of engineers in marine observation field and help to understand the basic knowledge. Authors sincerely wish that these books would contribute to improve coastal observation system, design, analysis, management and application in the future.

ACKNOWLEDGEMENTS

The Nationwide Ocean Waves information network for Ports and HArbourS (NOWPHAS) was developed and operated by many engineers and their assistants of the Ports and Harbors Buran of the Ministry of Land, Infrastructure and Transport, and its assciated agencies. Wave gauges and data collecting and processing system adopted in the NOWPHAS were born from more than 30 years' research in the P.A.R.I. and its cooperative organizations, including the Coastal Development Institute of Technology (CDIT), Japan Marine Surveyors Association (JAMSA), and their associating private companies.

Ecoh Co. and Kyowa-Shoko Co. helped the authors prepare figures used in this paper and arrange the layout of this paper. Korean Maritime and Port Association (KMPA) helped Korean Ocean Research and Development Institute (KORDI) and authors to translate and publish Korean language textbooks introduced in this paper. Authors would like to express sincere gratitude to those concerned persons.

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