

## CHAPTER ONE HUNDRED NINETY FOUR

### THE WAVE PRESSING PLATE FOR PROTECTING COOLING WATERWAYS OF COASTAL POWER PLANTS

by

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#### ABSTRACT

A horizontal plate laid on water surface to reduce the wave motion is proved to be effective theoretically and verified by model tests done at Tainan Hydraulics Laboratory. This principle has been put into practice on the northern coast of Taiwan for protecting a nuclear power plant cooling water intake against intruding waves.

The design and construction of wave prevention works of such type are described succinctly in the paper. Also the effect of wave diminishing has been affirmed by measuring the respective waves heights outside and inside of the wave pressing plate.

#### INTRODUCTION

Almost all of the nuclear and fossil power plants in Taiwan are constructed on coast of the island with cooling water intakes and outlets facing open sea. For many years the traditional layout of breakwaters has normally been used to protect these cooling waterway structures against typhoon and monsoon waves and the sheltering effect of breakwaters is efficient. However, as these waterways are not intended for navigation, the traditional layout of breakwaters may be unnecessary and too expensive. An attractive alternative is presented herein.

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Basis of this paper originates from the idea described by J. J. Stoker in his book "Water Waves" that a horizontal plate placed on water surface is able to reduce the waves transmitting under it. Following that idea, the authors thought that some practical arrangements could be developed to keep off the waves intruding into the cooling water intake basin of coastal power plants without resorting to the building of conventional breakwaters. When the second nuclear power plant located on the northern coast of Taiwan was planned in 1974, the authors started to investigate the feasibility of applying such type of wave prevention system. Then elaborate model tests were carried out and verified that such an idea is feasible. Furthermore, the construction cost will be much less in comparison with building breakwaters, approximately in the ratio of one to three. An estimated saving of US\$ 10 million can be achieved for Taipower Fourth Nuclear Project by adopting the wave pressing plate intake system constructed on rock against an intake system of traditional breakwaters constructed on beach.

#### THEORETICAL CONSIDERATION

Now, if we consider a horizontal plate located on water surface as shown in Fig-1

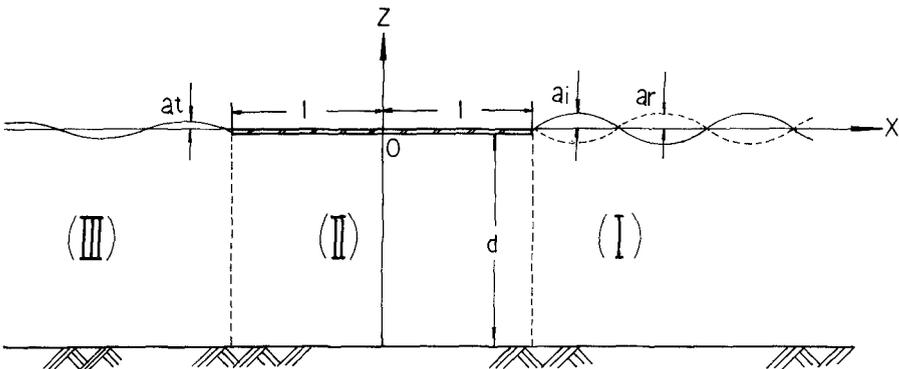


Fig - 1

From this figure, the wave motion can be divided into three regions, (I) an incidental wave region, (II) the wave motion being pressed by a horizontal plate and (III) a transmitting wave region. Since the wave motion is an inviscid, incompressible, irrotational flow and the water depth of such water way is small enough to assume the incidental wave as a long wave, the potential function of

wave motion can be written as

$$\Phi = \left. \begin{aligned} & \frac{A \cosh [k_0 (z+d)]}{\cosh (k_0 d)} \exp [i (k_0 x + \omega t)] \\ & + \frac{B \cosh [k_0 (z+d)]}{\cosh (k_0 d)} \exp [i (k_0 x - \omega t)] \\ & + \sum_{n=1}^{\infty} \frac{C_n \cos (k_n' (z+d))}{\cos (k_n' d)} \exp (k_n' x + i \omega t) \\ & + \sum_{n=1}^{\infty} \frac{D_n \cos [k_n' (z+d)]}{\cos (k_n' d)} \exp (k_n' x - i \omega t) \end{aligned} \right\} \quad (1)$$

Here, A, B, C<sub>n</sub>, D<sub>n</sub> are the arbitrary constants of integration. And the potential function will be satisfied with Laplace's equation.

$$\frac{\partial^2 \Phi}{\partial x^2} + \frac{\partial^2 \Phi}{\partial z^2} = 0 \quad (2)$$

Then applying the method of separation of variables and the boundary conditions of the above wave motion, we can obtain the potential functions in regions (I)(II)(III) respectively as follows:

$$\Phi_1 = A \exp [i (k_0 x + \omega t)] + B \exp [-i (k_0 x - \omega t)] \quad (3)$$

$$\Phi_2 = (C + D x) \exp (i \omega t) \quad (4)$$

$$\Phi_3 = E \exp [i (k_0 x + \omega t)] \quad (5)$$

And A, B, C, D, E will be solved from the continuous conditions of wave motion at the boundary of the horizontal plate, we got

$$\left. \begin{aligned} B &= \frac{i \lambda \pi \exp (2 i \lambda \pi)}{1 + i \lambda \pi} A \\ C &= A \exp (i \lambda \pi) \\ D &= \frac{i \lambda \pi \exp (i \lambda \pi)}{\ell (1 + i \lambda \pi)} A \\ E &= \frac{\exp (2 i \lambda \pi)}{1 + i \lambda \pi} A \end{aligned} \right\} \quad (6)$$

and the coefficient of wave reflection  $K_r$  and transmission  $K_t$  will be worked out respectively

$$\left. \begin{aligned} K_r &= \left| \frac{B}{A} \right| = \frac{\lambda \pi}{\sqrt{1 + (\lambda \pi)^2}} \\ K_t &= \left| \frac{E}{A} \right| = \frac{1}{\sqrt{1 + (\lambda \pi)^2}} \end{aligned} \right\} \quad (7)$$

where  $\lambda$  is the ratio of the horizontal plate length  $2\ell$  to wave length  $L$ , and  $A$ ,  $B$ ,  $E$  represent the amplitudes of incidental wave, reflecting wave and transmitting wave respectively. Equation (7) shows that the wave height behind the horizontal plate will be reduced effectively as the plate is made long enough.

#### HYDRAULIC MODEL TESTS

Before we commenced the hydraulic model tests for the cooling water intake of the nuclear power plant, various calculations had to be performed to estimate the water elevations of tide, storm surge, tsunami and intensity of waves due to lack of available field records except meteorological and tidal data in the vicinity of the plant site.

From the numerical calculations, the highest surge deviation caused by typhoons was determined to be 1.20m. Then based on the past records of submarine earthquakes from 1904 to 1963 in the north-east of Taiwan Island, the largest wave height and period of tsunami were calculated to be 10 meters and 49 minutes by Wilson's formula, and the height of run-up to be about 8 meters by Iida's empirical data which is close to the recorded value of 7.5 meter experienced at Keelung Harbor in 1918.

Furthermore, waves of typhoons were also calculated by numerical method. Four real typhoons passing through the northern coast of Taiwan were picked out, and in addition, three model typhoons advancing from east to west were also assumed into the computer program. The routes of these typhoons are shown in Fig-2, and the calculated result of the maximum wave height is 7.86 meters and the period is 8.78 seconds in NNE direction.

Finally, the numerical calculations of wave reflection in shallow water region in front of the second nuclear power plant were also performed.

Based on the above mentioned calculations, we proceeded with three dimensional physical model tests to measure wave features and to verify whether the general intake

layout of the second nuclear power plant was proper or not. Fifty-one test runs of experiments had been carried out and the best layout was determined.

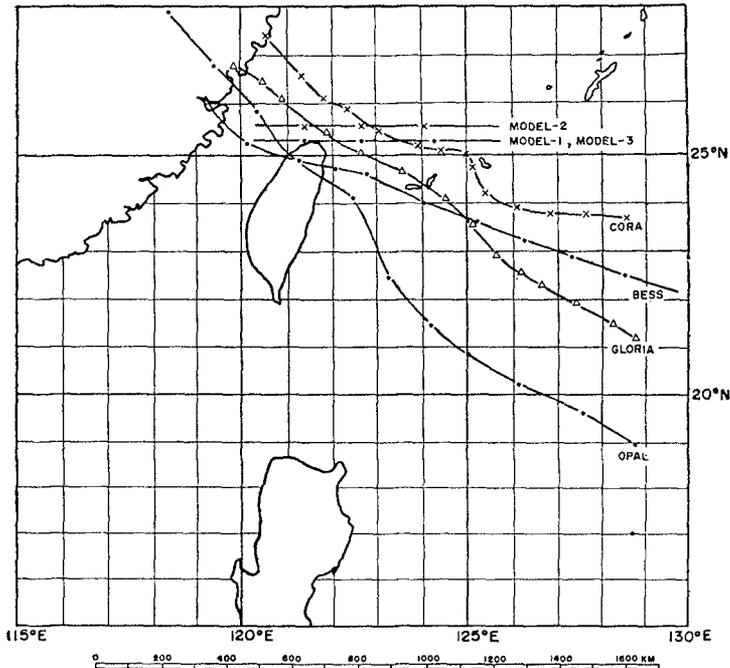


Fig - 2

Time interval between points: 6 hrs.

Afterwards, according to the best intake layout, the detailed experiments on the arrangement of wave dissipation structures were performed in a wave channel with circulation water system to simulate the coexistent situation of waves being acting on various structures and water being sucked through the intake basin. The scale of the model was decided to be 1:36, and wave features, water elevations and intake cooling water discharge were incorporated in this model. After a number of testing runs, we found that it was very important to determine the elevation of the horizontal plate located across the cooling water entrance and the tetrapod blocks installed in front of intake basin.

Experimental results indicated that with the horizontal plate, 18 meters in length, placed on the elevation of

+1.70 m and the tetrapod blocks raised to elevation +3.50m, the cooling water pumping system was able to suck cooling water through intake basin satisfactorily, because in most test runs, water surface fluctuations in front of the pump house were less than 40 cm. Such intake arrangement, though relatively complicate, will be more economical. And the flow patterns in the basin were observed incidentally. Eddies were recognized on both left and right portions of the basin, and flow velocity across the entrance was found to be smaller than 90 cm/sec. As a refinement splitter walls were added just downstream of the entrance, so that the flow would be more regulated to reduce the eddies. The plan view and side view of intake system of the second nuclear power plant were shown in Fig-3.

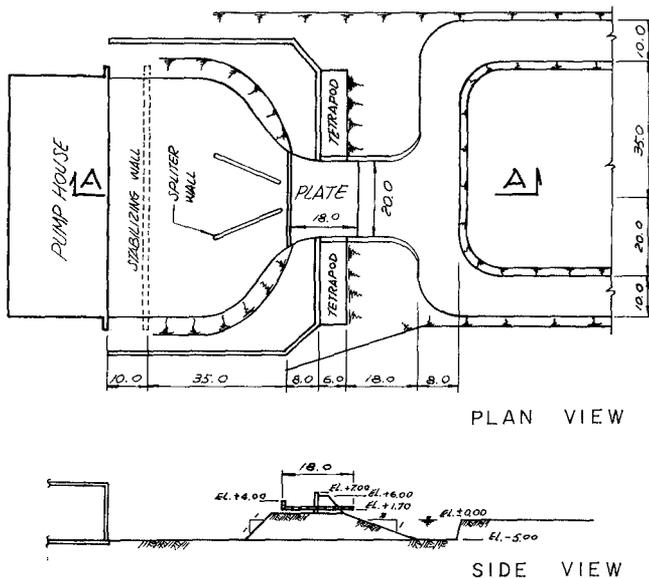


Fig - 3

After obtaining the test results of physical model, the authors set the vital design guides of the wave protection works for intake system of the second nuclear power plant: (1) a horizontal plate of 18 meters in length be placed on the waterway connecting lead channel with intake basin, (2) elevation of the horizontal plate be set at +1.70m and (3) tetrapod blocks be raised to elevation +3.5 m in front of the intake entrance. Moreover, two straight

piles of tetrapod blocks, one on each side, have been built to elevation +7.0 m for reducing wave overtopping in case of extraordinary high tide caused by typhoon.

Incidentally the lead channel arrangement also contribute to wave dissipation. Two parallel channels about 150 meters long and 50 meters apart are tied together by a cross channel to form a U-loop in front of the intake. Flow to the horizontal wave pressing plate is taken from the central portion of the cross channel so that waves rushing in along the parallel channels will have to make a right angle turn to enter into the tie channel in opposite directions. The opposing flows cause waves to die down considerably as can be seen from Photo-1.

#### CONSTRUCTION RESULTS

The construction works were completed in 1980 as shown in the following photos. Photo-1 is a birds-eye view of the intake system of the second nuclear power plant. Photo-2 is a rear view of intake structures taken from the pump house. Photo-3 is a front view of the horizontal pressing plate and entrance taken from lead channel and Photo-4 is a side view of the horizontal pressing plate with two splitter walls extending into the intake basin.



PHOTO - 1



PHOTO — 2



PHOTO — 3



PHOTO - 4

After operation of the second nuclear power plant, waves at an offshore point of 15 m deep below the low water level and water surface fluctuation in the intake basin have been measured constantly. Several typhoons attacked the coast and from records of the intake basin we found only five times when the maximum wave height exceeded 0.5m, but all the significant wave heights measured in those two years were below 0.3m. Fig-4 shows the wave records measured from 7th to 17th, August, 1982; the solid line record wave height at an offshore point of 15m deep below the low water level and dashed line recorded wave height in intake basin respectively. It is seen that the wave heights are greatly reduced while waves pass through under the wave pressing plate of the intake structure. The intake structure design has therefore been proven to be completely successful.



### CONCLUSION

According to the experience obtained from the model tests and the construction works in prototype, it would be worthwhile to introduce to the technical community the effectiveness of the wave pressing plate in protecting the cooling waterways and the potential saving in construction costs due to adoption of the wave pressing design. However, the application is limited to rocky coast for cooling water intake. Where sandy beach is near the rocky intake, the designer should be alert to sedimentation problem since during sustained rough weather more and more fine sand particles would be in suspension and move with the cooling water flow.

The wave pressing plate idea is also applicable to cooling water discharge on beach in a reversed direction of water flow. One typical example is the cooling water discharge at Hsinta Fossil Power Plant where two 500 MW units are in operation and two 550 MW units are under construction.

### REFERENCES

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