

CHAPTER 180

Abrasion at the Tanah Lot Temple - Bali - Indonesia, and Its Counter Measures

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1. INTRODUCTION

Tanah Lot Temple is situated in Tabanan Regency - Bali, on the coast of the Indonesian Ocean. Due to continuous wave attack, wind force, and weathering of the rock bank where the Temple stands, abrasion has occurred which is more and more threatening the existence of the Temple. Considering that Tanah Lot Temple is a sacred place for the Hindu Balinese people and a place of high cultural value, and also an important tourism, steps to save the Temple are imperative. The Central as well as the Regional Authorities, and also the Balinese community are very much interested in the effort to keep the Temple intact.

Measures have been undertaken to protect both the sea-side and land-side banks of the Temple rock bank. This paper only discusses counter measures of the sea-side bank of the Temple.

2. SITUATION AND CONDITION

Tanah Lot Temple is located on a small island with an area of about 1000 m². The Temple was established in the 16th century. Because of lack of information, we don't know precisely whether the temple was built on the island separated from or connected with the land. If the temple was built unseparable with the land and the separation with the land such a present condition is resulted from abrasion processes, it was truly remarkable work. Eventhough man at that time did not recognize sophisticated technology, they were able to locate the temple on the more stable area than of already eroded by wave and weather. Therefore, they are forced to wait for the tide to flow out, which lasts for a relatively short time only, to make their offerings. If there is a great number of templegoers, making the offering meets with difficulties. Not only because

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of the tide, but also of the relatively small area of the Temple, and the narrow access path which is used by the people both coming to and leaving the temple. Figure 1.a shows the situation of Tanah Lot Temple and figure 1.b shows coastal cross-section at the location of the temple. It can be shown from the figure the island where the temple is located rest on a reef flat that relatively solid. The temple is located around 30 m from the reef and 100 m from the land. At low tide the reef flat appears above low water level (LWL), while at high-tide the depth is about 2 m. Therefore, visitors are only able to reach the temple at low-tide. The outer reef is an area where its depth is relatively hard to be measured since the area is the location of breaker-zone. Water depth in front of reef-edge that can be sounded is about 150 m from reef-edge with depth of about 30 m. The depth at outer reef as read in the figure is based on linear approximation, with zero references = LWL. The condition of the Temple is critical, particularly at the southern corner where there is a hollow as shown on figure 1.c which might cause the Temple to collapse.

The process of abrasion of Tanah Lot can be explained as follows :

- a. The sea-waves break on the rock bank at the front part of the Temple. The wave energy erodes the bank and the bottom of the coast. Measurements reveal that the waves reach a height (H) of 2 to 3 M, with a wave period (T) ranging from 5 to 10 seconds.
- b. The mass of water flowing landward through the right and left banks of the Temple at high speed in conjunction with the incoming waves have created cracks/hollows in the bottom will take the bank stability at the upper part.
- c. The cracks resulting from geologic process and casities made by sea-animals have agravated the abrasion process.

3. PLAN OF COUNTER MEASURES

Protection of Tanah Lot Temple to be carried out using landward revetment that indirectly attacked by waves. Landward revetment consists of pillars and concrete flat as a buffer of sectors that possibly broken. The buffer pillar and concrete flat are modified in such a way so that look natural according to original temple bank condition. As stated in the introduction, the protection of the temple in the land direction could not be explained in detail since this protection is ba-

sically structural engineering and arsitecture not aspects of coastal engineering protection.

Protection of Tanah Lot Temple on the sea-side covers:

- Constructing a structures to protect the sea-side bank,
- Installing wave breaker in front of the sea-side of the island,
- Placing of stones and concrete blocks between the wave breaker and Temple bank.

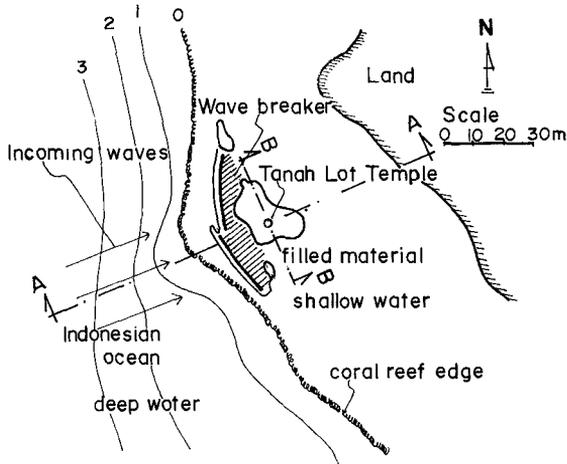


Fig. 1.a. Situation of Tanah Lot Temple

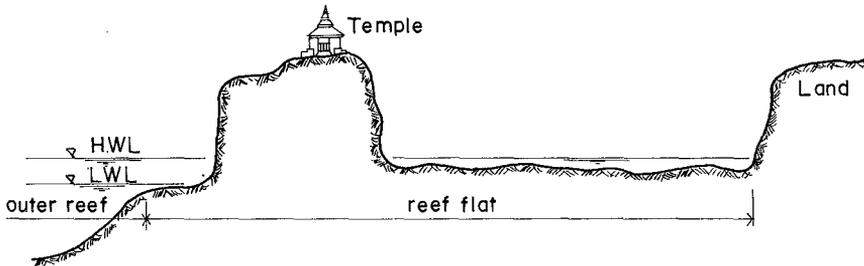


Fig. 1.b. Cross section of the beach (A - A)

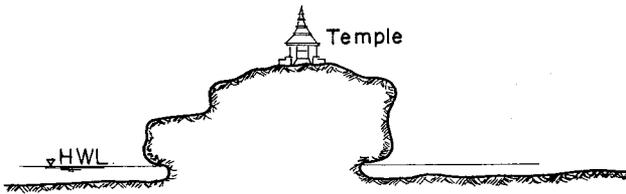


Fig. 1.c. Longitudinal section of the beach (B - B)

3.1. Information from the Public

From discussions, interviews and exchanges of ideas with the community the following were obtained :

- 1) The space both on the land-side and sea-side is not permitted to be closed.
- 2) To facilitate the offerings especially at times when there is a great number of temple-goers, the community propose :
 - to extend the area of the Temple grounds
 - to make different paths for going to and from the Temple.
- 3) For aesthetic, it is proposed to execute the coping of the problem with the assistance of an art so that the result could be natural and harmonious in line with the environmental condition.

3.2. Protection of the Sea Side Bank

Seaward revetment consists of lean concrete casted and joined with original temple bank, the thickness of lean concrete is 1.50 m. The use of lean concrete not only to strengthen but also to enlarge the area of temple and to construct road for outway from the temple. Originally the entrance and outway of the temple are in one channel and narrow make the visitors and pilgrimage have dif-

difficulty doing praying. However, after two-way road already constructed, the difficulty can be overcome. Like landward revetment, lean concrete also has been modified so that look natural.

3.3. Wave Breaker

Many alternatives in planning for wave breaker has been made such as by constructing seawall and concrete wall. However, because of difficulty in the implementation, the choice is by using wave breaker type rubble structure from tetrapod, and the weight of each unit of tetrapod is calculated on the basis of the design wave height $H = 3.0$ m. To place the tetrapods, heavy equipment is needed or a helicopter.

By the Hudson 1) formula,

$$W = \frac{W_r \cdot H^3}{K_d (S_r - 1)^3 \cotg \phi}$$

the weight of each tetrapod for various slopes ($\cotg \phi$) is :

$\cotg \phi$	Body (kg)	Head (kg)
1,5	2,490	3,950
2,0	1,900	2,450
3,0	1,250	2,250

3.4. Filled Material

Filled material is placed behind wave breaker, casted after wave breaker has been carried out. On the lower layer, it consists of graded stones with diameter between 0,1 and 0,4 m filled with concrete block and the thickness of the blocks are 0,50 m. By using layer cap made from concrete blocks, the area of the temple seaward become larger. It can be used at low-tide while at high-tide overtopping as a result of wave breaking continually occurs. In addition to enlarge the area, the main purpose of filled material is to stabilize wave breaker and to support wave attenuation. From field inspection, it is obvious that after setting filled material waves that attack the wall is relatively high. It results from watermass entering tetrapod arrangement. After casting of

filled material wave attenuation works well.

4. TECHNICAL EXECUTION

Since field situations are hard and narrow while local road is impossible to be passed by heavy vehicles the tetrapods are transported by helicopter, which has a maximum capacity of 2.0 tons. For this reason, it has been decided to use tetrapods with a maximum weight of 1.9 tons. In the execution, the helicopter will be able to place the tetrapods only 20 m at the nearest from the temple bank. The crest of the breakwater will be as high as the highest water level (HWL). The wave breaker will be ± 125 m in length, and the number of tetrapods to be placed 2,800. It has been explained in Chapter 3.1 that there will be an opening in the middle of the breakwater. Filled material will be placed behind the breakwater. The bottom part consists of an arrangement of stones and the surface of a concrete plate 0.5 m in thickness. Overlaying the concrete plate will be modified concrete blocks to produce a natural view. In the first stage of implementation, ten tetrapods which are placed separately move toward the temple bank because the bottom of beach is relatively slippery. However, after it was constructed in one unit type, the tetrapod arrangements are able to stand against waves. Until now part of body is relatively stable while in head sectors are estimated to transform to get its stability.

5. MONITORING RESULT

5.1. Change in Wave Characteristics

After the tetrapods have been placed, the waves will not directly hit the temple bank but break on the tetrapod arrangement. As the tetrapod arrangement has holes in it, breaking of the waves will be different from that on a massive surface. Fig. 2a shows the condition of the waves before construction of wave breaker. Waves break directly on the bank of the temple.

Fig. 2b shows the wave condition after construction of wave breaker. From Fig. 2b it is obvious that the tetrapod arrangement dampens the waves well. From point of view of protection, wave breaker already worked well while from the type of wave breaking, wave breaker have changed the original form.

Considering that one of the attractive features of Tanah Lot Temple is the beautiful wave - breaking against the rock, dampening of the waves might

reduce the attraction of the Temple. In order to produce a wave condition similar to the original one it seems that the tetrapod arrangement has to be cast to become a massive unit. Fig. 2c, shows the estimated wave condition after the tetrapods are casted. Casting can be done after the tetrapod arrangement has become stable.

5.2. Condition of tetrapod arrangement

The monitoring result reveals that the body part of the tetrapod arrangement, which currently has side slopes of 1 : 1.5, is relatively stable. The head part (ends of the tetrapod arrangement) with side slopes of 1 : 2, however, is not yet stable. Calculation in Chapter 3.1 turns out that for a tetrapod weighing 2,244kg and a wave height of 3 m, the side slopes are 1 : 3. A tetrapod arrangement with a weight of ± 1.9 tons is estimated to still undergo changes in its stabilization process.

6. CONCLUSIONS AND RECOMMENDATION

1. The tetrapod arrangement serving as a wave breaker is functioning well. However, if one desires a protective structure with a natural look, this break water should be modified.
2. It is estimated that the tetrapod arrangement will still be modified, especially the head parts, in view of the stability process.
3. Damping of the waves is successful, but it probably reduces the attraction of Tanah Lot Temple in terms of breaking of the waves. It is suggested to create a massive tetrapod arrangement in order that the breakers will be as beautiful as before.

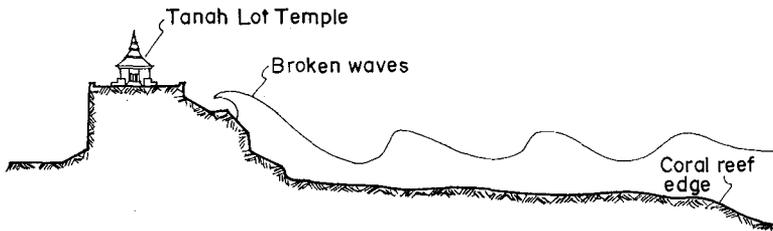


Fig. 2a. Wave condition before construction of wave breakers.

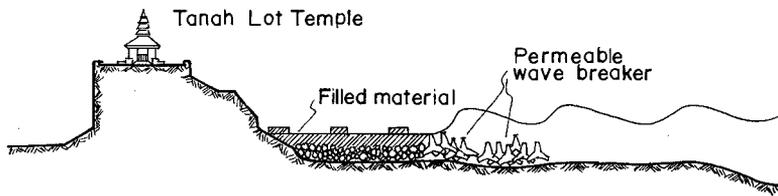


Fig. 2b. Wave condition after construction of permeable wave breaker.

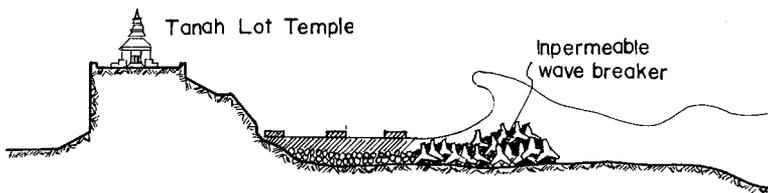


Fig. 2c. Estimated wave condition after construction of impermeable wave breaker.

7. ACKNOWLEDGEMENT

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