CHAPTER 55

# INVESTIGATION OF DESTROYED STRUCTURES AND THE RECONSTRUCTION PROGRAM; ISE-WAN TYPHOON


Senri Tsuruta

Director, Harbour Hydraulics Division, Transportation,
Technical Research Institute,
Ministry of Transportation


## INTRODUCTION

The powerful Ise-wan Typhoon destroyed coastal defence works along the Bays of Ise, Chita, and Atsumi, over nearly the entire length of the coastline, and also inflicted considerable damage on breakwaters, piers, and other harbour facilities.

The destruction observed in various structures show a close resemblance, and the ground leading to such destruction may be classified into several categories, indicating that these coastal structures possessed a common weakness against the destruction force of nature. This common weakness presents a particuler problem in planning and carrying out reconstruction works in the future.

## FACTORS LEADING TO DESTRUCTION

### 1. Insufficient resistance against scouring

The destruction of coastal embankments and seawalls may be said to have resulted from the scouring on the crown and back slope by the overflow of high tides and downfall of overtopping waves. Structures with the crown and back slope covered with concrete slabs remained undamaged, while the majority of those which were not covered were destroyed.

An example of destruction from scouring on the crown may be clearly observed in the seawalls in the southern part of the City of Tokoname. The cross sections and crown heights of the seawalls varied considerably as shown in Fig. 2-1, as they had been constructed at different times by different authorities. Wall A, a simple stone revetment was completely broken down. Wall C where the crown had not been completely covered was destroyed as shown in Fig. 2-2, and wall B, completely covered with concrete slabs remained undamaged. And the over-all collapse of the dike protecting the reclaimed lands of Kōei Shinden in the City of Handa was also due to the unfinished pavement on the crown (Fig. 2-3,4). Thick bushes of bamboos or miscanthuses often planted on the crown and back slopes to prevent the back-filling from being scoured were not quite effective under such strong overtopping as observed in the storm surge.

### 2. Decrease in crown height of embankment in an inlet or a river mouth

An embankment along the coast of an inlet or a river embankment is generally of an inferior structure with a lower crown height as compared

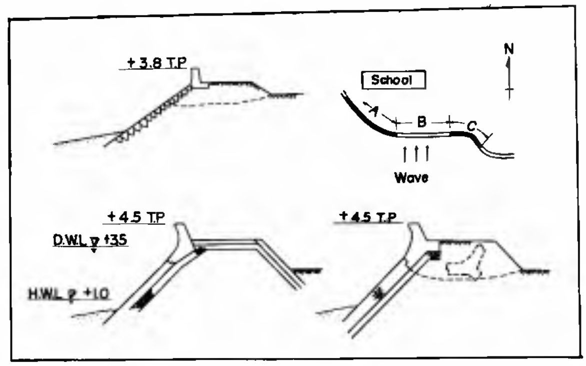


Fig. 2-1 Cross sections of sea walls at Tokoname City

Fig. 2-2 C-collapsed from line of juncture due to scouring of back-filling as the back slope was not covered with concrete slabs. B-seen in foreground.

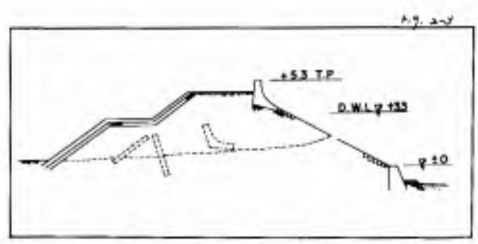


Fig. 2-3 Cross section of dike (Handa City)

Fig. 2-4 Total collapse of structure due to scouring of back slope by overflowing of sea water as pavement of crown was unfinished.

to coastal embankments, as they have not been designed to withstand the direct attack of wind waves generated by a typhoon. Moreover a sudden fall of the cross section is often found at junctions with coastal embankments. Embankments with different cross sections were destroyed at the junctions without exception. As a storm surge has a tendency to rise higher in an inlet on the sea coast, the crown height of an embankment should be desiged to possess sufficient height against the surge.

3. Weakness observed at a flood gate or a sluice-way

A flood gate or a sluice-way is exposed to severe wave action due to deep scouring in the front of the structure. Moreover structures of different weight tend to settle unevenly when constructed on soft ground. A rupture in the embankment at the location of the pump atation is considered to have lead to the collapse of the right bank of the River Shōnai, inundating the southern part of the City of Nagoya. Similar damages at flood gates and sluice-way were observed in various locations.

4. Lack of reinforcement of embankments against severe wave action

In the disaster following the Ise-wan Typhoon, there are only a few cases in which coastal embankments or sea walls were destroyed by the scouring of sea water overflowing the crown height with the rising of the tidal level. In most cases, the structures are considered to have been smashed by severe wind waves accompanying the storm tide. Destruction in the coastal embankments along the village of Tobishima in the County of Ama occured at the same site as in the case of the storm surge of Sept. 26, 1921. In both cases, the damage was caused by an unusually severe wave action as there had been a gut, that is, the water depth in front of the wall had increased considerably. Generally speaking, parts of embankments with obstacles in the front waters, or parts sheltered by a stretch of reclaimed land were spared of serious damage (Fig. 2-5). Therefore, steps must be taken to extend the wall height or reinforce the structure, particularly in waters where the concentration of waves or strong wave strokes are expected, to prevent similar disasters in the future. Furthermore, it must be noted that unusually severe wave actions occur along erosive coasts.

5. Settling or leak of filling

It is a very effective measure to cover the crown and back slope with concrete slabs in order to protect the back-filling against scouring by the overflow of high tide and the downfall of overtopping waves. But the filling is apt to settle or leak through gaps in the foundation and front stone works, leaving the interior in a hollow state and the structure will be in a dangerous condition against the attack of smashing waves (Fig.2-6). The settling or leak of the filling may be avoided and the structures will possess a strong resistance against scouring if a large quantity of loam or clay is available for the filling and the construction works are carried out with the utmost care. But in many cases, sand is the only material available when long embankments must be constructed on the coast in a short period of time. Therefore it would be advisable in such cases to consider the following measures: to make inspection holes in the crown

Fig. 2-5 Wall behind power transmitting tower remained in a little damage. ( Port of Nagoya)

Fig. 2-6 Wall smashed by waves as interior was in a hollow state from settling of sand filling. (Yokkaichi City)

Fig. 2-7 Completely covered structure collapsed from settling of sand filling for a length of over 100m as partition wall was lacking. (Port of Nagashima)

Fig. 2-8 Right side of the wall was saved by partition wall. (Yokkaichi City)

pavement at certain intervals for the replacement of the filling when necessary; to construct partition walls mentioned in the following paragraph; and to prevent the leak of the sand filling through the stone works by providing a complete cut-off and applying a mortar mixture in laying the stones.

6. Chain reaction of collapse due to lack of partition walls

In coastal embankments protecting low areas, especially dikes enclosing reclaimed land, disruption in one section will provoke numerous breaks along the entire length of the structure in a short period of time as dashing current of sea water will penetrate through the interior from the opening and wash out the sand filling, while strong waves will hit the surface of the structure from the exterior. Examples of such destruction over a distance of several hundred meters were to be found in many location (Fig. 2-7), as in embankments enclosing the reclaimed areas of Nabeta near Nagoya and Kinuura and Hekinan facing the Chita Bay. If the embankment had been provided with partition walls at intervals of twenty to thirty meters, destruction would not have extended over such length of the embankment (Fig. 2-8).

7. Inadequate design and method of construction

When the crown and back slopes of embankments were destroyed and the filling scoured as mentioned above, the parapet and front wall collapsed without exception from the line of junction. A wall of the conventional type supported in position by the back-filling will be easily turned over by slight wave force when the back-filling has been washed away. Therefore it would be advisable to adopt self-supporting structures such as a buttressed wall, and the parapet should be constructed so as to form one solid body with the front wall with re-entrant curves up to a height of two meters to repel attacking waves offshore.

## THE RESTORATION PROGRAM

As the reconstruction of structures damaged by storm surges caused by the Typhoon must be undertaken immediately, involving an enormous amount of funds, the Government summoned authorities in various fields to determine various standards for structures to be constructed.

1. Fundamental principle

(a) Every restoration plan for coastal areas, rivers, ports and harbours, fishery ports, drained and reclaimed lands, roads, etc. is to be drafted as a division of an over-all rehabilitation program, with due consideration for mutual relations and the geographical features of the district. Definite plans in one field which are to be carried out immediately may be closely related to plans in other fields to be undertaken in the future. The former plan will be modified if necessary when the latter plan takes definite shape. In carrying out the first plan, steps must be taken to prevent double investment of funds when applying modifications in the future.

(b) Field investigations and laboratory experiments should be undertaken at once to study various problems from an engineering point of view. Problems to be studied include the effect of the breakwater in reducing wave forces and storm surges; the influence of the breakwater over the vicinity; the characteristics of waves invading rivers and inlets; and the uprush of the storm surge.

2. Tide and waves

Plans for reconstruction will be based on the Ise-wan Typhoon in regard to the deviation of the tidal level and characteristics of attacking waves. The mean higher high water level in the typhoon season will be adopted as the astronomical tidal level.

3. The crown height of the embankment

The crown height of an embankment will be determined from various conditions of the hinterland, the types of structure, and the functions of the ports and harbours and fishery ports.

In districts lower than the sea level, or relatively low and flat areas with a dense population, the embankments will be designed to prevent any overflowing of sea water due to storm tide and waves of the scale considered in the program. Hence the standard crown height will be obtained from the total height of the maximum deviation of the tidal level, and wave height occured during the Ise-wan Typhoon, and the mean higher high water level in the typhoon season.

In isolated districts of high ground level with a relatively scarce population, overtopping of waves in times of storm surges will be tolerated to some extent depending on the actual condition of the district. But the embankments must be of sufficient height to prevent the overflowing of sea water and wave energy.

In the wharf and pier zones in ports and harbours as well as fishery ports, and industrial zones on the coast, the wall height should be limited to a height which will not interfere with loading and unloading of cargo and the productive activities of the industrial plants.

4. The structure of the embankment

An embankment in a certain district should be of a uniform structure, but it may be difficult to apply this principle in cases when a new embankment must be jointed to an existing embankment, or when the characteristics of the natural features, soil conditions, difficulty in acquiring the necessary land, and different purposes of construction call for a different type of structure. In such cases, the two different types of structures must be joined so as to prevent any failure from the joining points

Even when the embankment is constructed to avoid the overtopping of waves from the tidal level and waves adopted in the program, the crown and back slope should be covered with concrete slabs to protect the face and toe from scouring.

Special attention will be required in designing and constructing the structure so that voids will not appear within the covering of the body, and structural weakness will not be found in the parapet wall. If the soil condition is likely to cause subsidence of the structure in the future, appropriate measures should be taken in advance.

The body should be of a self-supporting structure as far as possible. Partition walls at intervals of about 30m would serve to prevent a failure in one section from affecting other sections of the embankment.

With a restoration program based on the above-mentioned standards for various engineering projects, reconstruction works are now in full swing to provide against the typhoon season in the coming year. We are also confronted with problems related to the timber basin and driftwood which greatly increased damage during the disaster, and the construction of earthquake-proof structures in a country frequently attacked by earthquakes as well as typhoons. Thus engineers in various fields are entrusted with the responsiblity of protecting the country and its people against the powerful force of nature.