Chapter 54

A BRIEF OUTLINE OF THE ISE-WAN TYPHOON

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INTRODUCTION

During the ten years from 1947 to 1956, typhoons with a maximum velocity of more than 34 knots have attacked Japan at an average of 26.8 times a year, inflicting damages amounting to 240 thousand million yen on the average each year (1946-1955). However, depending on the course and scale of the typhoon and the season of the year, except for damages to vessels, in some cases, the advantages outweigh the disadvantages as the abundant rain fall resulting from a typhoon is beneficial to agriculture and hydraulic power generation widely developed throughout the country. In the past, damages from typhoons consisted of storm and flood disasters with the flooding of inland waterways and landslides in mountainous districts due to heavy precipitation. However, lately, with the rapid progress of modern industries, cities with ports and harbors are expanding with the development of large industrial zones along coastal areas where raw materials can be obtained from foreign countries at low cost of transportation, and vast areas of land for the establishment of industrial plants can be acquired without encountering serious obstacles through land reclamation along the shores. These circumstances have called for the necessity of protecting the coastal areas from the direct attack of high tides and wind waves generated by typhoon. (See Table 1)

Table 1							
National	Funds	Invested	for	Land	Conservation		

	Year	1946	1951	1956	1960	note
Item River Con Sand Arr	n serva tion, estation	3,433	4,397	8 ,225	7,242	(hundred million yen)
For es t r y	Conservati	ion 315	551	920	1,062	
Coast Pro	ot ec tion	3	341	722	904	breakwaters not included

The coastal area around the Ise Bay with its large capacity of accommodating a huge population is a typical example of amazing urbanization of a rural district with the rapid development of large industrial plants

*Editors Note: Chapters 54 to 58, inclusive, form a group of papers on storm surge and damage caused by Typhoon No. 15, 1959, and were prepared by members of the Committee on Coastal Engineering, Japan Society of Civil Engineering, Tokyo, Japan.



Fig. 1-1 . The course of the Ise-Wan Typhoon

following World War II. An extensive development program had been drafted, a part of which had already been carried out, when suddenly the area was severely hit by Typhoon No. 15, with the death toll rising to 4600, and damages ancounting to 500 thousand million yen, in an unprecedented disaster, to the great shock of the entire nation. Almost all of the industrial zones throughout the country may be said to be subject to similar disasters. Nevertheless, in view of the geographical features of the country, the special characteristics of Japanese industries, and the over-crowded population, we have no alternative but to promote the development of coastal areas, and construction of ports and harbors, and the reclamation of new lands.

Under these circumstances, Typhoon No. 15 of 1959 was especially named the Ise-Wan Typhoon, and various circles concerned are seriously engaged in collecting and analyzing data of the typhoon in order to establish scientific measures for the protection of the coastal areas from typhoons in the future. Further progress in the field of coastal engineering is a matter of deep concern to the entire nation, and will serve much towards the general welfare of the people.

THE TYPHOON ON THE OCEAN

The low atmospheric pressure of 1008 mb on Sept. 21, 1959 was called Typhoon No. 15 from 9:00 hours, on Sept. 22. The tropical low atmospheric pressure rapidly developed into a violent storm only two days after it had been spotted in the southern seas, with a center pressure of 892 mb, maximum wind velocity of 75 m/s, and a 300 km radius at 15:00 hours, Sept. 23. Storm warnings were issued and the nation was on the alert as to the direction the typhoon was headed for. Information on the typhoon was broadcast every hour and the following announcement was made at 11:15 hours, Sept. 26. "Typhoon No. 15 is moving northward 350 km south of the Murotomisaki in Shikoku at a speed of 30 km/h. The typhoon is expected to pass the Kii Channel or hit some part of the Tokaido district tonight". Watching the course of the typhoon which changed from time to time, Vessels sought refuge in safe waters, and the inhabitants in coastal areas prepared for early evacuation.

At 18:13 hours, the typhoon hit the mainland 16 km west of the Shionomisaki with an instant maximum velocity of 60 m/s and a low atmospheric pressure of 929.5 mb at the center, the third lowest pressure recorded on land. Lately, with the aid of airplanes, we have been able to obtain accurate figures from observation of typhoons on the ocean, but in regard to observations on land, the figures obtained have always been quite accurate and may be relied upon for numerical comparison. Since 1900, 60 typhoons have hit the country with the atmospheric pressure at the center under 975 mb, but the typhoon Muroto (911.9 mb; Sept. 21, 1934) and the Typhoon Makurazaki (916.6 mb; Sept. 17, 1945) have been the only two with a low pressure under 930 mb. A typhoon which is a tropical low atmospheric pressure whirling counterclockwise, absorbing the moisture over the Pacific Ocean, often loses its strength as the eye expands during the travel over the sea. However, in this particular case, as the typhoon approached the country in full force, strong winds accompanied by violent waves and high tide would attack areas to the right of the course of the typhoon, while heavy rains would lash areas to the left of the course, bringing heavy destruction and serious casualties in both areas. According to the

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Meteorological Agency, the deviation of high tide exceeding 1 meter due to typhoons was reported in 14 cases in the years 1945-1948. In areas to the right of the typhoon, such deviation was observed in coasts 200 km from the center, while on the left side, it was only observed within 50 km from the center.

THE TYPHOON OVER LAND AREAS

The course of the typhoon is shown in Fig. 1-1. Betraying any favorable forecasts, the typhoon crossed the steep mountainous districts of the Kii Peninsula without any signs of a sudden loss of energy, and passed the Nagoya district about 30 km west of the city heading north at a speed of 70 km/h into Japan Sea.

Records at the Nagoya Meteorological Observatory registered the lowes atmospheric pressure of 958 mb at 21:30 hours and a maximum velocity (aver age of ten minutes) of 36.5 m/s, and an instant maximum velocity of 46 m/s at 22:00 hours. The maximum wind velocity of 36.5 m/s broke the past record of 32.9 m/s (Sept. 12, 1934). The most violent winds were recorded c coasts 40-100 km apart from the path of the center of the typhoon, and an instant maximum velocity of more than 60 m/s were recorded in a district a the mouth of Ise Bay. Along these coasts, steel tower, huge tress several hundred years old, and numerous houses were overthrown by high winds.

Due to the geographical features of the district, the maximum rainfal also was observed to the right of the course of the typhoon. In the town of Kumano on the coast, a heavy precipitation of 400.5 mm by far broke the past record of 321.4 mm/day. In mountain districts the rainfall reach approximately 900 mm. The heavy rains caused landslides earth-flows, and submergence and inundation of farmlands and inland districts suffered heav damages as well as coastal districts as will be mentioned later.

Wireless communication with the Kumanonada and Ise Bay district was cut off, as the typhoon passed the district on Saturday night and the powe source of all apparatus was inundated. With communication lines out of order and the electric lights put out, the portable radio was the sole mea of receiving communication, leaving the areas in complete isolation. Only the victims themselves were aware of the dreadfull disaster that had turne a vast area of land into a sea of muddy water, until helicopters flew over the district the following morning. (Fig. 1-2, 3)

COASTAL DAMAGES

Though the coasts along the Ise Bay, especially the Nagoya district is subject to the effect of meteorological high tides due to the geographical features of the area, the district has been apared of heavy damages from typhoons in the past. In the Osaka Bay, records of high tides have been registered 77 times in the past 60 years, while in the Ise Bay it has only been registered 14 times in 90 years. In a rare case, Typhoon No. 13 (950 mb; Sept 16, 1953), threatened to hit the district, but fortunately the center crossed the Ise Bay at low tide with the Port o Nagoya on the left side of its course so that though the maximum meteorolo gical high tide registered 1.0-1.5 m, the area suffered comparatively slight damages.

However, the powerful Ise-Wan Typhoon, with various unfavorable eleme



Fig. 1-2 Disrupted embankment near Kuwana City



Fig. 1-3 Southern area of Ama County covered with muddy water

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directly hit the defenseless area with an amazing force under extremely detrimental circumstances.

A record high tide of 3.55 m was registered in the Port of Nagoya. Meteorological high tide over 2 m (excluding "Tsunami" caused by earthquakes) have been recorded only six times during the fifty five years from 1950 to 1955 (table 2), showing that the high tide caused by the Ise-Wan Typhoon was a very extraordinary case.

Table 2Meteorological High Tide Caused by Typhoons

August 25, 1914	Ariake Kai	2.0-2.5 m		
October 1, 1917	Tokyo Bay	2.3 m		
September 16, 1927	Ariake Kai	About 3.0 m		
September 21, 1934	Ōsaka Bay	3 . 1 m	Typhoon	Muroto
September 17, 1945	Kagoshima Bay	2 m	Typhoon	Makurasaki
September 3, 1950	Ōsaka Bay	2.4 m	Typhoon	Jane

High tides accompanied by violent winds and waves brought heavy damages to large vessels which evacuated to safety outside of the port as well as small crafts moored in the port. About 200 boats (including 26 large vessels) ran aground, 340 boats (Including 10 large vessels) were sunk, 3000 boats were washed away, and 6500 boats (including 28 large vessels) were wrecked, bringing the total tonnage destroyed to 130,000 tons Authorities concerned are studying measures to provide for the safe evacuation of vessels in each port in times of typhoon.

Fishery harbours and pearl oyster beds cultivated in the inlets and harbours facing the kumano-nada also suffered heavy destruction. Structure were torn down, materials were washed away, and the pearl oysters were destroyed as the bottom soil was transferred to a considerable extent, and the sea water became extremely muddy.

In the Port of Nagoya, a total of 300,000 tons of imported lauan logs, each weighing 6-7 tons with a diameter of 1-1.5 meters were washed out of the timber basin by a rushing current of sea water, and going wild about the port, destructed houses and facilities causing many deaths and injurie. The timber basin will be moved to the western part of the port at the earliest possible date.

The electric power generating plant and oil tanks constructed on reclaimed land were inundated, and the 1,500,000 citizins were deprived of electric power and gasoline for several day. Plans are under study to construct a high stable sea-wall to protect these facilities. Other indus rial plants are also planning to instal electric motors and other key machinery on elevated positions to provide for early reopening of operations in event the plants may be inundated. Damages on seawalls and port and harbor facilities will be referred to in Chapter 55.

SCALE OF HIGH TIDE

The extraordinary high tide observed along the coast showed a wide local variation offering an interesting subject of study especially in relation to the existing emperical formula for the computation of high tide.

(in the case of Nagoya; H= $1.6743 \text{ p} + 0.16534 \text{ W} \cos \theta$; Miyazaki). The maximum tidal levels as shown in Fig. 1-4 were obtained from the records of tidal gauges at more than 30 stations, an extensive investigation of tide traces, and computations by the empirical formula.

In the Port of Nagoya, the highest record of tidal levels for the past 50 years was +2.97 m T.P. (1921) (T.P.: mean water level in Tokyo Bay). However, the maximum tidal level caused by the Ise Wan typhoon registered +3.90 m T.P., 93 cm above the past record, exceeding the mean high water spring in the port by 2.70 m. The extraordinary high tide was recorded at 23:15 hours on Sept. 26, when the tides were halfway between low water level and high water level at neap tide. As the astronomical tidal level would be 0.35 m, the meteorological tide due to the typhoon may be estimated to be 3.55 m. (Fig. 1-5)

This record high of 3.55 m may be considered to be the result of the conbined forces of several phenomena. Continuous strong winds from the sea swept the surface waters toward the shore; the sea surface rose with the passing of low atmospheric pressure; her own oscillation of the water in the bay might have occured with the surging of violent wind waves; the translation velocity of the typhoon equivalent to the propagation velocity of long period waves in the bay proceeding a resonant phenomenon; etc.

The piers in the port were constructed so that the top of the pier would stand about +3.00 m T.P., and the top of the coastal embankments and sea-walls were about 4.00-6.00 m T.P.. As high tides accompanied by waves of about 2 meters rushed against the coastal area bringing an extraordinary high tidal level in the bay, overflowing and overtopping of a tremendous amount of water, dashing currents, and overtopping waves separated by strong winds smashing areas far behind the embankment must have prevailed during the dreadful night storm.

Coastal embankments in the bay, and river embankments around the mouth of the river were disrupted, inundating 80,000 ha of low land. (Fig. 1-6) Embankments were destructed at every point where the overtopping wave are assumed to have exceeded 0.5 m.

Reports on waves will be omitted as they will be given in Part 3.

CONCLUSION OBTAINED FROM THE DISASTERS OF THE ISE-WAN TYPHOON

Areas affected by the Ise-Wan typhoon extended over the entire country even as far as the Kyushu district. Approximately 1,600,000 people were afflicted and 200,000 ha of cultivated land were inundated. However, it must be repeated that the heavy destruction and serious casualties occured in coastal areas particularly along the Ise Bay.

People who have lived in regions subject to the constant threat of storms and floods for generations have learned to protect their lives and possessions by constructing embankments around their community and storing food and seeds to raise new crops in small boats, all of which have proved to be quite helpful in cases of emergency.

In coasts subject to the frequent attack of high tide, fishermen build a special type of dwelling on elevated land sheltered by trees, and



Fig. 1-4 The highest tide and area inundated along the Ise-Bay coast



Fig. 1-5 Tidal record in the Port of Nagoya



Fig. 1-6 Area inundated near Nagoya City



Fig. 1-7 Proceeding of land reclamation

they are always ready to take refuge in tall public buildings. Few lives were lost even in the case of the Ise-Wan typhoon in such regions wellprepared for any emergency.

However, the coastal regions around the City of Nagoya developed from deltas formed at the mouth of a large river, where, from as far back as the 17th century, people began to drain the low lands building dikes farther and farther into the sea. (Fig. 1-7) Through a well-developed system of irrigation, the vast areas of land thus gained has become one of largest rice-producing centers in Japan.

With the march of times, the rice fields which hat always been as low as the mean water level were turned into large industrial zones, attracting a large population.

> Table 3 Population and Area of the City of Nagoya

	1879		1957	
Population	167,400		1,429,000	
Area	1,334	hectares	25,085	hectares

However, they neglected to take appropriate measures and invest sufficient funds for facilities to protect this low area from the attack of high tides. Moreover, 200,000 m/day of underground water was pumped our of about 1000 wells for industrial and irrigational purposes, resulting in a ground subsidence of more than 10 cm in the past ten years. Especially along the coasts, due to the earthquakes, the ground level was 50 cm on th average, and at some points 1.00 m, below the pre-war level. It may also be pointed out that necessary repairs on the old seawalls which had settled considerably had been neglected to a certain extent from the general lack consideration for the maintenance and repairs of existing facilities on th part of the authorities concerned. Moreover, the inhabitants were not ful aware of the great danger of living in this low area umpreparel for any disaster that might befall them some day.

As they had been enjoying the benefits of modern city conveniences such as transportation and communication facilities, and power and water s pplies, the confusion was beyond words once the area was inundated and lef in a primitive undeveloped state. They faced great difficulty in transpor ing, storing, and distributing relief goods and materials for rehabilitati as well as in determining methods of commencing reconstruction works.

Under bad weather conditions, two months passed before temporary repair works were completed elevating the inundated trunk highway, repairing the embankment extending 35 km, which was disrupted at 220 points, and draining the inundated area with the help of pump dredgers. Hardships encountered remain fresh in the minds of all concerned as it was a long ti before the abundant electric power supply was available in the devastated area, and the remains of old abandoned dikes lying far inland from the coast proved to be quite useful in the course of reconstruction works. Plans to prevent disasters from spreading over large areas, and other conclusions obtained from valuable experiences will be included in the rehabilitation program.

There is a Japanese proverb which says, "Disasters come around when they have been forgotten". According to the probability chart based on the records of maximum high tidal levels in the Port of Nagoya for the past 40 years, a high tidal level of +2.42 m T.P. will occur once in 20 years, a level of +3.00 m once in 300 years, and a level of +3.10 m only one in 500 years, but these figures merely represent the probability on paper.

A large number of the tidal gauges, wind meters and wave meters did not operate during the typhoon. However, in the case of the tidal gauge station in the Port of Nagoya, fortunately the recording appartus was installed on a high site, and the cap of the well was light enough to allow the pole of the buoy to stand 50 cm above the well with the rising of the tide, valuable records were registered until the surging began to withdraw.

A typhoon of a larger scale than the Ise-Wan Typhoon may strike any part of the country in the future. In order to establish an efficient program to prevent disaster, based on fundamental investigations, with due consideration for the economic problems involved, various research and investigation works have been undertaken through the cooperation of all authorities concerned. Hydraulic experiment are under way on the characteristics of high tides and wind waves generated by typhoons particularly along the coasts of Tökyo Bay and the Ösaka Bay which are most likely to be hit by a typhoon. We are also studying an accurate method of forecasting typhoons with the aid of a radar, Robbot Tide Gauge of the Water Pressure type, and an electronic computer, effective measures to be taken when attacked by typhoons, and plans after rehabilitation.

In closing, I would like to say that, at the present stage, to prevent disasters from typhoons, we have no alternative but to establish an appropriate and extensive program from the social, economical, scientific, and engineering point of view, based on an accurate knowledge of the typhoon itself and the subsequent natural phenomena, as well as a thorough understanding of the various conditions concerning the regions subject to the attack of typhoons in the future.

(Note: Immediately following the heavy destruction caused by the Ise Wan Typhoon, a committee was formed of 15 members from the authorities concerned, headed by the Director General of the Sience and Technics Agency, named "The Temporary Committee on the Prevention of Typhoon Disasters". The committee carried out an extensive investigation on the characteristics of the typhoon and the actual condition of the damages inflicted, and a detailed study on measures to be taken in the future to prevent similar damages, the result of which has been submitted to the government quarters. This paper has been based on the experience of the author as he participated in the investigation and discussions as a member of the committee.)