

CHAPTER 53

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN

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INTRODUCTION

Japan consists of 4 main islands named Hokkaido, Honshu, Shikoku and Kyushu, which, together with numerous smaller islands scattered around, are so aligned as to form a slightly bent arc off the eastern fringe of the Asiatic Continent. (See Fig. 1.) The dominant geographies of these islands are represented by relatively high mountains located in the center and narrow strips of plane lands lying along the coastlines. It is in these coastal planes that the cores of the Japanese industrial and other economic activities are deployed with swarming population. The entire area of Japan is approximately 320,000 km² and the surrounding coastlines are 14,560 km long.

Traditionally the economy of Japan depended heavily on agriculture and fishery, which necessitated active reclamation works around the estuarine lowlands as well as establishment of small fishery ports in great numbers at various parts of Japan.

The growth of her economical potency came to cast floodlight on the importance of marine transportation, and the commercial ports came to thrive at numerous estuary harbors. The land extension works along the coast line are even flourishing today, but they are aimed at creating the sites for modern industries. It should be emphasized that Japan has been utilizing the coastal areas to an utmost extent for survival as well as prosperity, and further that this trend is destined to persist also in the future in order to keep pace with her economical development.

Unfortunately, the geographical situations as well as other unfavorable natural conditions distinguish Japan as one of the most disaster-ridden countries in the world. The islands of Japan are pestered by the tropical cyclones or typhoons of the western Pacific which haunt her several times every year. They may hit her by a head-on landing or near-missing, leaving tremendous disasters in the wake. Worse still, seated right on the earthquake belt, she is also subjected to disasters caused by occasional crustal motions and tsunamis. Most of her long coastlines are where formidable energies of wind waves and ocean swells are let loose, which would claim for frequent destruction of maritime structures, erosion of coastlines, and sedimentation of harbor basins. Apart from the disasters

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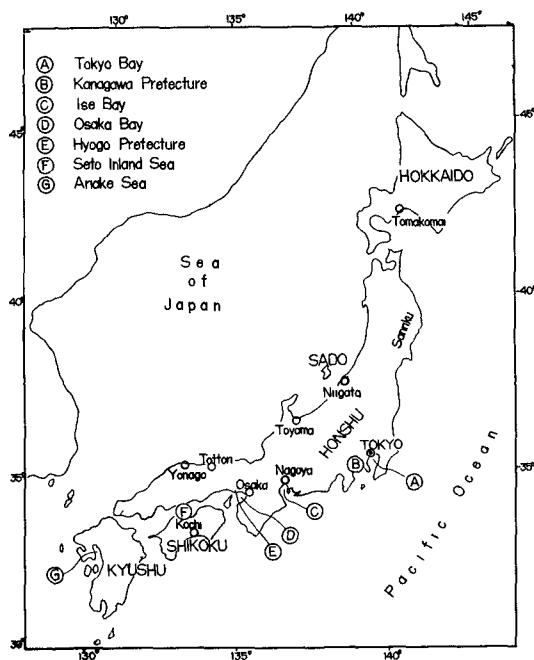


Fig. 1.

Fig. 1. Map of the Japan Islands

Fig. 2. Distribution of Epicenters and Magnitudes of Great Earthquakes (after H. Kawasumi)

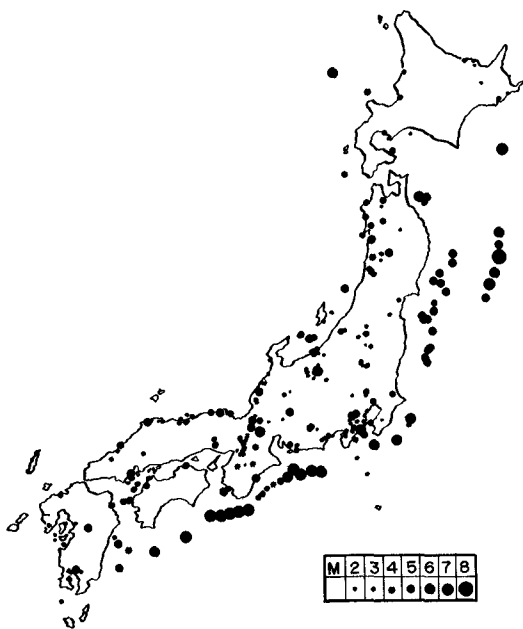


Fig. 2

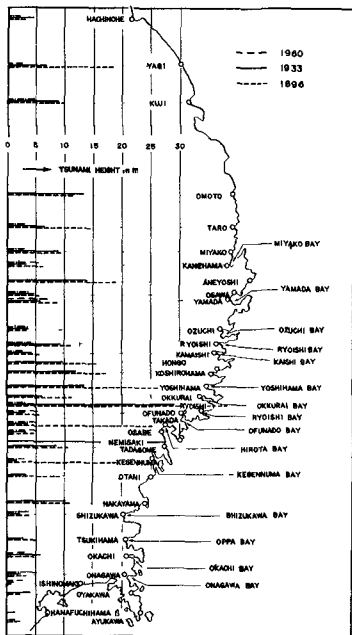


Fig. 3.

Fig. 3. Comparison of Maximum Water Levels due to Tsunamis in 1896, 1933 and 1960, above the Tokyo-Post datum (Approximately equivalent to M.W.L.) along the Sanriku Coast.

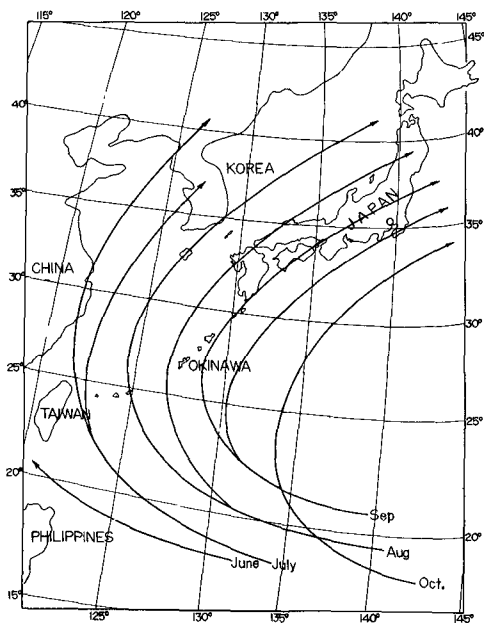


Fig. 4

Fig. 4. Ordinary Typhoon Paths

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for which the natural elements are primarily responsible, we must point out the effects of artificial interferences such as debris barriers, dams for power generation, flood control or water supply, diversion channels, river mouth jetties, breakwaters, and even coastal groins, which seem all to combine to account for recent progress of erosion along the various sandy coasts of Japan by working on the delicately balanced equilibrium of nature. The Japanese engineers face a number of such exceedingly intricate problems today. They have been striving to overcome and effectively control these problems in order to preserve the valuable coasts which she cannot afford to lose any more.

This paper will first introduce the general factors affecting the coastal problems in Japan, and proceed to discuss the patterns with which some of these factors were linked to produce particular coastal problems. We will next review the efforts and contributions made by the Japanese engineers to solve such problems. Finally the coastal protection works and practices will be presented with some representative examples.

FACTORS AFFECTING THE COASTAL PROBLEMS IN JAPAN

We may classify the factors which are considered to be related to coastal problems under four main categories: (1) geomorphological aspects, (2) meteorological and oceanographical aspects, (3) sediments, and (4) artificial interferences. We will discuss the factors with special emphasis on the characteristics particular to Japan.

Geomorphological aspects

The islands of Japan lie along the circum-Pacific seismic zone. Fig. 2 shows the epicenters and magnitudes of 343 great earthquakes which have been traced by H. Kawasumi from the records of the past 1350 years.⁽¹⁾ These earthquakes almost frequently produced the crustal motions which resulted in repeated elevation or subsidence of the earth levels along the coastal regions as well as on the sea bed. For instance it has been reported that the coastal areas of the Sagami bay were heaved by 1 to 2 m during the great Kanto earthquake in 1923.⁽²⁾ So pronouncing are these crustal processes occurring along the coasts that the engineers are compelled to regard the geomorphological movement as one of the principal factors influencing the coastal processes in Japan.

Meteorological and Oceanographical Aspects

There lies an outer belt of earthquake zone along the offshore of the Pacific coasts of Japan, where great earthquakes used to deform the ocean bed producing the tsunamis. Beside the tsunamis which were generated at the nearby epicenters, some traveled a long way to hit the Japanese coasts from a faraway center of their birth, such as one caused by the Chilean earthquake in May, 1960.⁽³⁾ Table 1 shows the great tsunamis ever recorded in history. The most outstanding of them all were the Sanriku tsunami in 1896 and 1933, and the Chilean-earthquake tsunami in 1960. They inflicted most formidable disasters on the Ria coasts of Sanriku, the north-eastern region of the Honshu island, which is exposed to the Pacific Ocean to the

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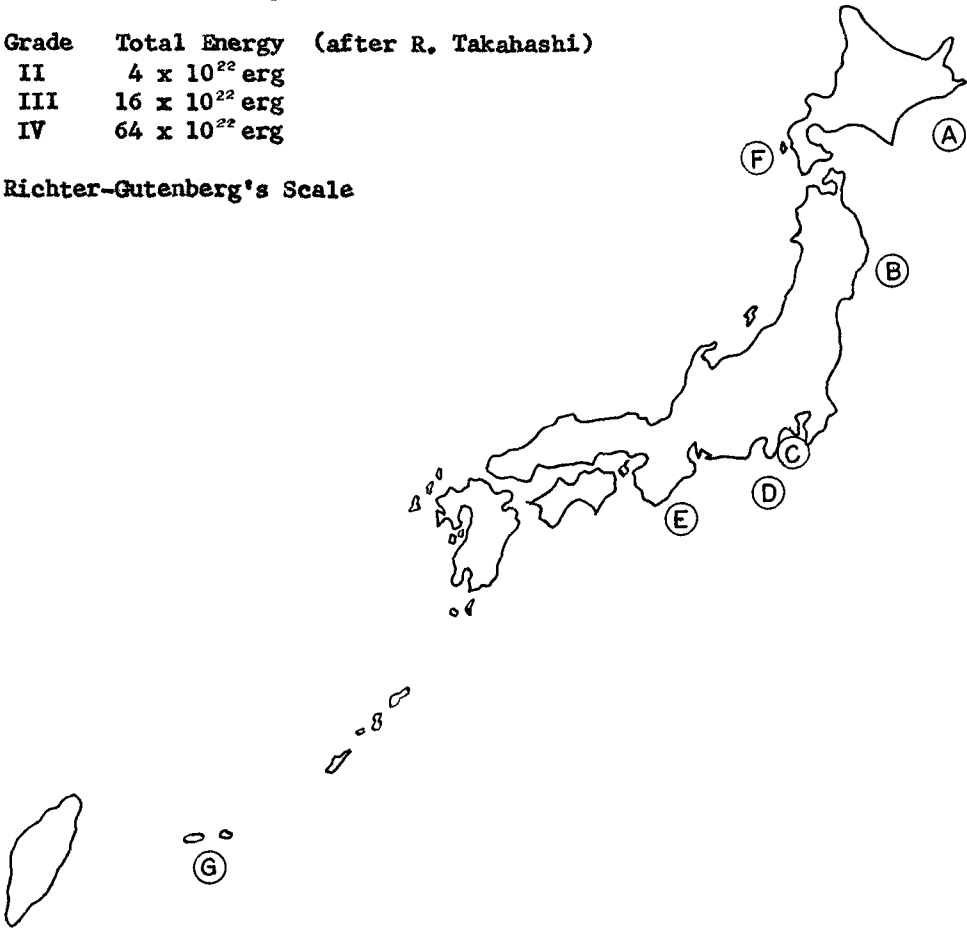
TABLE - 1

(1) Year	(2) Location	(3) Grade of Tsunami	(3) Magnitude of Earthquake	Year	Location	Grade of Tsunami	Magnitude of Earthquake
684	E	III	8.4	1771	G	III	7.4
869	B	IV	8.6	1854	D	III	8.4
887	DE	III	6.5	1854	E	III	8.4
1361	E	III	7.0	1896	B	IV	7.6
1498	D	III	8.6	1933	B	III	8.5
1605	DE	III	7.9	1944	D	III	8.3
1611	B	IV	8.1	1946	E	III	8.1
1703	C	III	8.2	1952	A	II	8.2
1707	DE	IV	8.4	1960			8.7
1741	F	III	6.9				

(1) See the Attached Map.

(2) Grade Total Energy (after R. Takahashi)
II 4×10^{22} erg
III 16×10^{22} erg
IV 64×10^{22} erg

(3) Richter-Gutenberg's Scale



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east. Fig. 3 compares the maximum run-up reached by these tsunamis at various localities. It must be noted that the patterns of the rising water inside the bay areas were different between the Sanriku-earthquake tsunami in 1933 (of the period of approximately 12 min.) and the Chilean-earthquake tsunami in 1960 (of the period of approximately 60 min.). Such difference is supposed to result from the relationship between the normal vibrational periods of the bays and those of the tsunamis invading them.

The natural forces acting upon the coasts are represented by the meteorological factors such as the violent winds generated by typhoons or migratory cyclones, and by the oceanographical factors such as waves and currents. Efforts have been made at various coastal areas of Japan to forecast the waves from meteorological data. On the other hand, mainly spurred by the recent development of harbor projects or purely for the purposes of coastal engineering studies, the actual measurement of wave has recently been accelerated shedding light to a great extent on the characteristics of the meteorological and oceanographical factors prevailing in the water around Japan.

The seas around Japan must be dealt with separately for the factors peculiar to each of the three sectors: (1) the Pacific Ocean coasts, (2) the Japan Sea coasts, and (3) the sheltered bays.

The Pacific Ocean coasts - Exposed to the great open sea of the Pacific Ocean, this sector is subjected to the influence of a typhoon during summer to fall. The ordinary path of a typhoon varies for each month. (See Fig. 4.) Table 2 shows the average number of typhoons generated in the southwestern sea of the Pacific Ocean and the number which landed on Japan, per annum. It is understood from the table that Japan is attacked at least by 2 or 3 typhoons annually which command an appreciable domain of influence with a formidable charge of destructive energy. One that carried the greatest energy was the Muroto typhoon which caused a great storm surge in the Osaka bay on September 18, 1934. The typhoon No. 15 of 1959, usually called the Ise-bay typhoon, is only next to the Muroto typhoon as far as the significance of the disasters due to a storm surge is concerned. (See Fig. 5.)

The most dominant waves occurring along the Pacific coasts of Japan are generated by the typhoons, which emanate forerunning swells for days well before its farthest perimeter comes to feel the coastlines. According to the studies made by T. Ijima, the periods of the typhoon swell recorded at the Japanese coasts range approximately from 12 to 14 seconds, and the significant wave heights from 1 to 2 m, rarely attaining 3 to 4 m. As the typhoon approaches the coastlines, i.e., as the decay distance is shortened the wave period tends to drop slightly, but only to increase sharply soon as the wave heights gain in magnitude.⁽⁴⁾ S. Nagai estimates the maximum height of the wave inside the typhoon No. 15, 1959, as 3.5 to 5.5 m, based on the sliding pattern of the breakwaters in the Wakayama prefecture.⁽⁵⁾ S. Unoki has presented the classified diagrams showing the distribution of wave heights and periods occurring in the deep water inside a typhoon from the records of the seafaring vessels and weather ships.⁽⁶⁾

The influence of a typhoon varies according to the path and the

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TABLE - 2

Statistics of Typhoon

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
No. of Typhoon Generated		0.2	0.2	0.2	0.4	0.9	1.4	4.1	5.7	4.8	3.1	1.5	1.1	23.5
No. of Typhoon which attacked Japan	Mean	-	-	-	-	0.02	0.11	0.31	0.76	0.82	0.33	0.03	-	2.47
	Max	-	-	-	-	1	1	2	4	4	2	1	-	7

TABLE - 3

Recent Record of Great Storm Surges (1900 - 1959)

Date	Location	Height in m
Aug. 25, 1914	Ariake Sea	2.0 - 2.5
Oct. 1, 1917	Tokyo Bay	2.3
Sep. 13, 1927	Ariake Sea	about 3.0
Sep. 21, 1934	Osaka Bay	3.1
Sep. 17, 1945	Kagoshima Bay	2.0
Sep. 3, 1950	Osaka Bay	2.4
Sep. 26, 1959	Ise Bay	3.5

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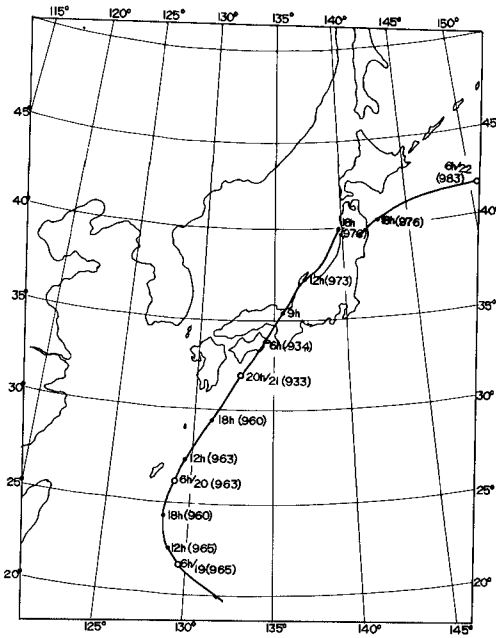


Fig. 5 (a)

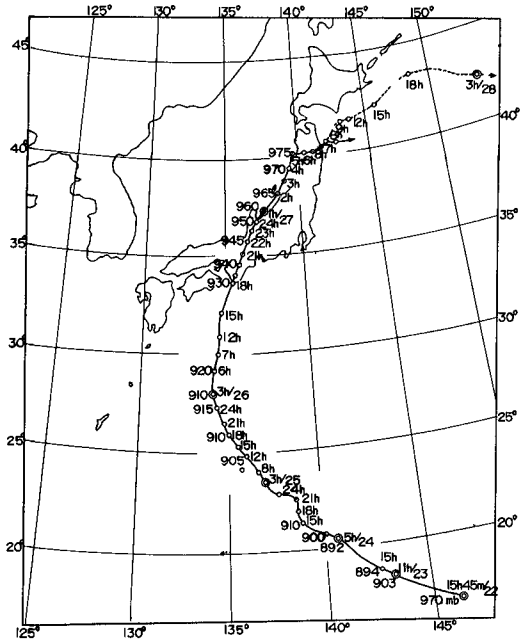


Fig. 5 (b)

Fig. 5(a). Path of Muroto Typhoon (Sept. of 1934)

Fig. 5(b). Path of Ise-bay Typhoon (Sept. of 1959)

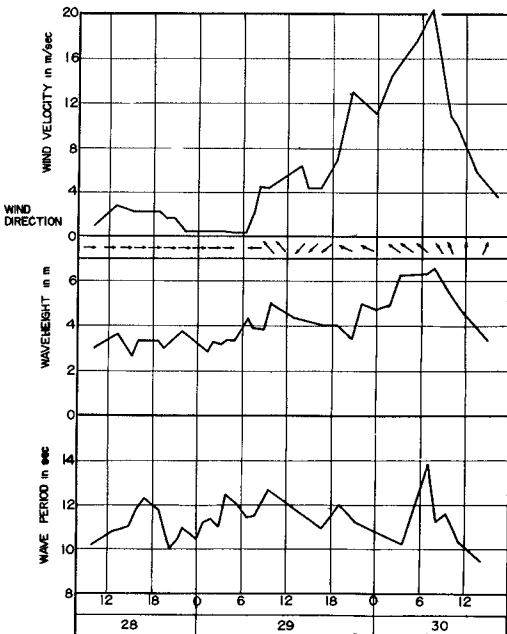


Fig. 6

Fig. 6. Record of Waves due to Typhoon No. 22, Sept. 1955, Recorded Outside the Kochi Port (after T. Ijima)

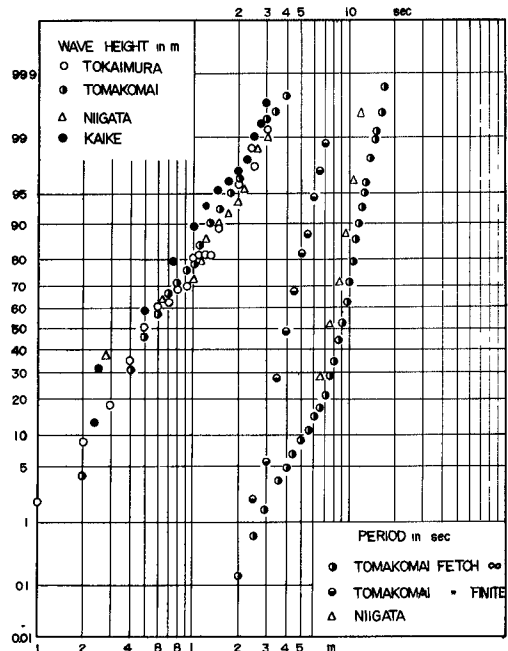


Fig. 7

Fig. 7. Cumulative Probability Distributions of Wave Height and Period along both the Pacific Ocean Coast and the Japan Sea Coast

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direction of the coastline exposure. The coasts west of the Tokyo area are thus subjected to greater influences of a typhoon than the coasts north-east.

Fig. 6 shows the waves due to the typhoon No. 22, September 1955, recorded outside the Kochi port by using a pressure-type wave recorder. This record shows the maximum wave of 6.5 m in height and 13.8 sec in period.

During winter and spring a family of lows migrate eastward from the Asiatic Continent across the islands of Japan. However, since the Pacific coasts are located at the lee, the waves due to the migratory lows seldom exceed 3 to 4 m in height and 10 to 11 sec in period.

Throughout a year, several isolated fetches occur simultaneously over the northwestern Pacific. The waves generated in them have a long distance of decay to cover before reaching our coasts. The Pacific coasts of Japan are constantly subjected to these long-range swells which, even in the most tranquil weather, attain the significant heights of approximately 0.5 m and periods of 9 seconds. Fig. 7 shows the cumulative probability distribution of the heights and periods of shallow water waves based on the visual observations made at Tokaimura and Tomakomai along the Pacific coasts, and at Niigata and Kaike along the Japan Sea coasts.

The Japan Sea coasts - The coasts facing the Japan sea are exposed to the confined fetches not exceeding 800 km in any direction. There is little influence of a typhoon here. The feature characterizing the Japan Sea coasts is a long spell of violent wind waves occurring during winter due to the migratory lows. Only swells of relatively short periods may occur here due to limitation in fetches. The pronouncing pattern which distinguishes the Japan Sea coasts from the Pacific coasts is that a complete calm dominates the Japan sea coasts occasionally due to absence of a fetch during June to August. On the other hand, during winter the sea is continually covered by a violent fetch after another which takes place in the wake of incessant passage of lows. Fig. 8 shows the probable occurrence of strong winds for each month in the vicinity of Niigata; Figs. 9 (a) and (b) show the probable occurrence of waves for each month respectively at Niigata and at Tokaimura (Pacific coast).

The results of field observation show that the significant waves occurring along the Japan Sea coasts seldom exceed 12 to 13 sec in period and 7 m in height.^{(4)&(7)} Based on the maximum duration for each magnitude of wind velocities derived from the records at Niigata in 1957 and 1958 and after some assumptions for simplicity, we evaluated the greatest possible waves corresponding to the maximum fetch length of 800 km by utilizing the generalized forecast diagram by Sverdrup, Munk and Bretschneider. The results are shown in Fig. 10, which give 5 to 8 m and 11 to 13 sec for heights and periods of the greatest possible significant waves expected at the Niigata coast. We are planning to test the adequacy of this treatment by actually measuring the waves at the Sado Island which is located 35 km offshore of Niigata.

The Sheltered bays - This category includes the bay area such as the Tokyo Bay, the Ise bay, the Osaka bay, the Seto inland sea, and the Ariake Sea, that

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are effectively sheltered from the ocean swells due to topographical situations. Violent waves found in these bay areas are caused by a typhoon passing nearby. When a typhoon passes the westside of the bay, i.e., when the bay is covered by the dangerous semi-circle of a typhoon, the significant wave invading the bay may attain as high as or less than 3 m in height and 6 to 7 sec in periods.

Far more serious than the waves is a storm surge occurring inside the bays due to wind set-up caused by a typhoon. Table 3 shows the records of the storm surge levels which occurred in Japan from 1900 to 1959. To quote K. Okuyama and S. Unoki: "The coasts along the Tokyo bay, the Osaka bay, the Seto inland sea and the Ariake Sea are haunted by storm surges, where the meteorological tide at times exceeds 2 m. The coasts of the Ise bay and the Kagoshima bay come next in fame for storm surges often attaining 1 m in levels."⁽⁸⁾ The Muroto typhoon in 1934 caused the record height of a storm surge amounting to about 3 m in Osaka harbor. The typhoon No. 15 in 1959 sent an extraordinary storm surge as high as 3.5 m in the Ise bay, the event being discussed in further details under the separate title in this conference. Since the coastal areas of these bays consist mostly of reclaimed lowlands where key industrial and agricultural establishments are thickly distributed, the consequent disasters are tremendous.

Sediments

The sediment process is as vastly important and also difficult to tackle as any process occurring along the beach. Back in 1953, the report by K. Aki, "Beach Erosion in Japan", referring to important eroding beaches in Japan, indicated that the cause of erosion is primarily attributed to deterioration of rivers as a source of sediment supply.⁽⁹⁾ A number of studies have since been performed trying to solve the coastal sediment problems in Japan. However, none seems to have succeeded in founding a quantitative measure to explain the physical process of the sediment motion along the beach.

Active movement of coastal sediments has produced sedimentation of anchorage basins and blocking of river outlets at many places in Japan. The important role played by eolian transport of sand should not be overlooked in this regard. It is estimated that roughly half of the sand which shoaled the basin of the Kashiwazaki port in Niigata prefecture had been derived from eolian transports.

There are numerous instances where the properties of sediment materials such as the particle size and size distribution as well as the bottom topographies played a role as extremely important to the sediment problems as winds, waves, and longshore currents. At the gravel beach the attribution of a concrete structure is so severe that the maintenance of the protective establishments present an annoying problem to the engineers.

Artificial interferences

Considering principal causes of erosion which is now in progress at various coasts of Japan, we find that it is mostly attributed to disturbance of the natural processes due to an artificial interference or another.

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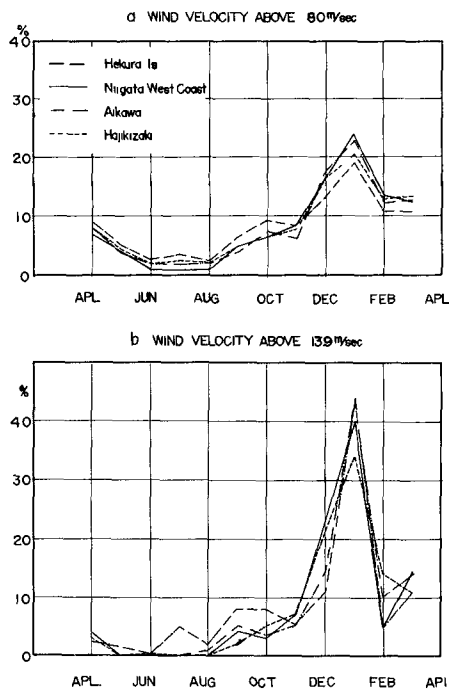


Fig. 8.

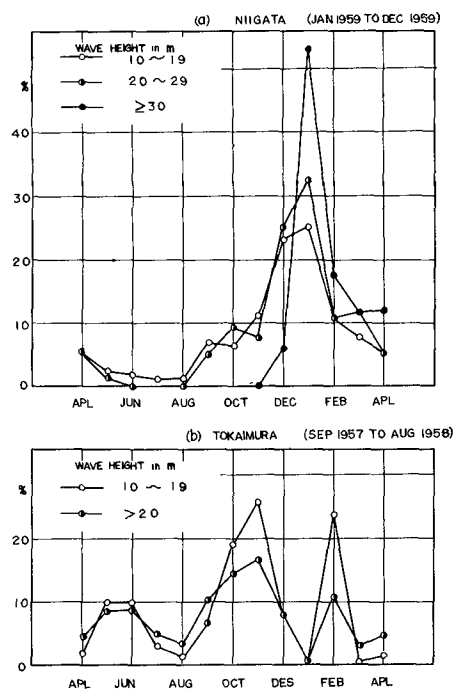


Fig. 9

Fig. 8. Probable Occurrences of Strong Winds in the Vicinity of Niigata
Fig. 9. Probable Occurrences of Wave Heights at Niigata (a) and Tokaimura (b)

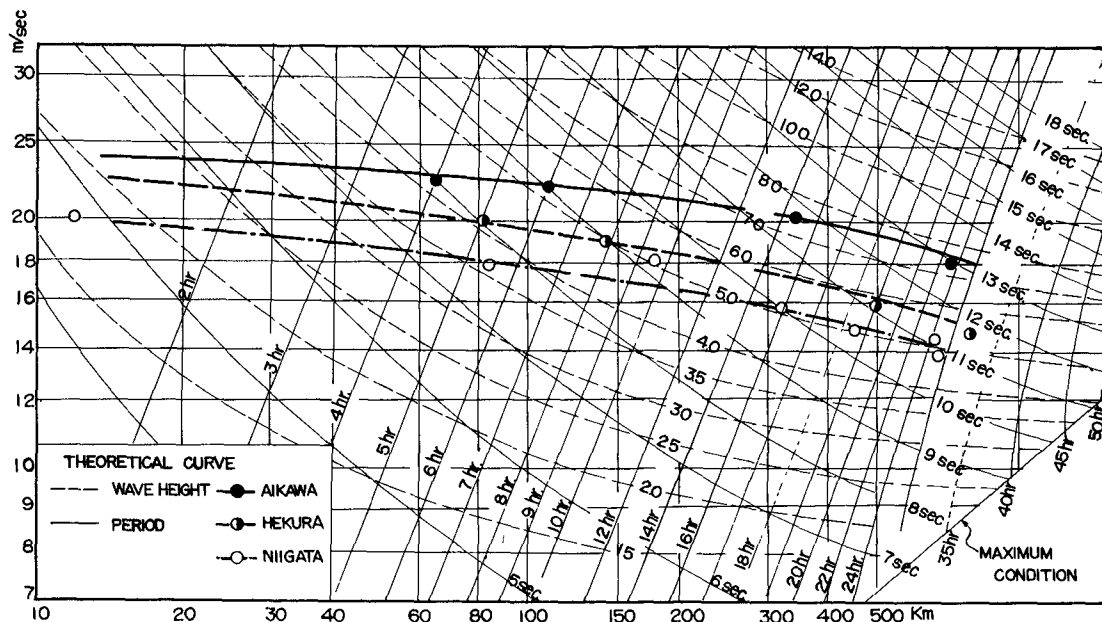


Fig. 10. Greatest Possible Significant Waves at Niigata Coast

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The most prominent instance is found in Niigata along the Japan Sea coasts. Since ancient years the Niigata city developed as an estuarine port at the mouth of the Shinano river and is today one of the most important ports along the Japan Sea coast. (See Fig. 11.) Formerly a tremendous amount of sediment was emptied from the mouth of the Shinano river which was then put in active movement along shore due to violent wind waves predominant during winter. As a result the river mouth was easily shifting its position, seriously hampering navigation through it. In order to maintain the navigation channel through the river mouth a project was initiated in 1896 to set up the training jetties and was completed in 1924 after repeated improvements. At the same time another project was started in 1909 to cut a flood way at a point approximately 58 km upstream of the river in order to free the Echigo plane from frequent flood disasters. Since the project was completed in 1922, the design flood discharge of $5,570 \text{ m}^3/\text{sec}$ was mostly diverted into the flood channel and the discharge through the original channel was kept below $270 \text{ m}^3/\text{sec}$ approximately. These grand projects helped to rid the Echigo plane of a flood disaster for ever, but at the same time they drastically cut the supply of sediment to the beaches adjoining the river mouth.

As these projects proceeded, a beach segment approximately 6 km long to the west of the river mouth began to retreat and the erosion has been so severe that today two rows of the coastal dunes have been completely washed away leaving only the half of the third dune. (See Fig. 12.) The beach to the east of the river mouth had been progressing at the rate of 30 m per year until the jetties were installed at the river mouth. As the Jetties were being constructed, the rate of shoreline progression was reduced and later, with completion of the flood channel upstream, an appreciable retrogression started over a stretch of 2 km. On the other hand, along the beach of Teradomari where the new flood channel empties a vast quantity of sediment into the sea (See Fig. 13.), the shoreline advanced remarkably.

The Niigata area is beset by an even more delicate problem which has arisen from another case of artificial interference. As the production of subsoil natural (soluble) gas was accelerated since 1949, the earth level has started to give way at an increasing rate. (See Fig. 14.) Today the subsidence has progressed to such an extent as to paralyze the port facilities as well as intensifying the beach erosion.

The decrease of sediment supply from the river ways also result from construction of dams for power generation, water supply or flood control or of debris barriers. Such examples are found at the Kaika coast, the Toyama coast (exposed to the Japan Sea), and the Toban coast (located in the Seto inland sea). There are coasts where the beach was eroded due to jetties or other shoreline barriers which acted to intercept the path of sediment from the source of supply. Such example is found at the Tanezaki coast (in Shikoku), and the East Katase coast (in Sagami bay).

Japan is abundant in problems of harbor sedimentation which have long been harassing the harbor engineers. There is the well-cited example of Isohama (along the Pacific Ocean coasts) which was completely disabled due to severe sedimentation. (See fig. 15.) A similar example is found in Iwafune which is located approximately 45 km north of Niigata and approximately 5 km south of the Miomote river. We should say that this fishery

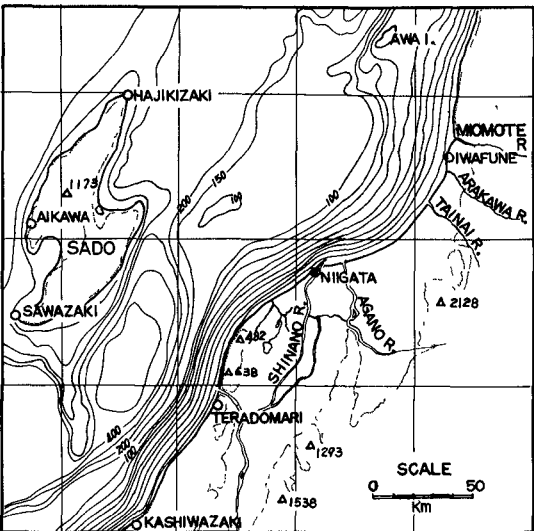


Fig. 11

Fig. 11. Location Map of Niigata

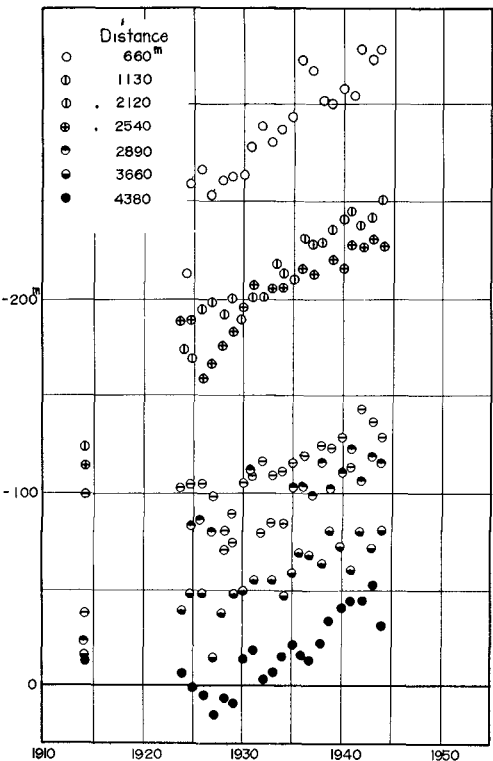


Fig. 12

Fig. 12. Retrogradation of Shore Line at Niigata West Coast in Comparison with that in 1889, Distance being measured from the Shoreward End of West Jetty at the Shinano River Outlet

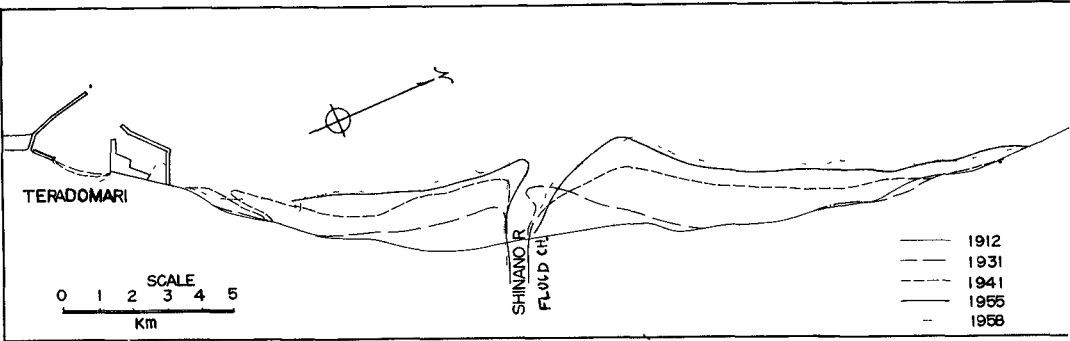


Fig. 13. Accretion of Sandy Beach at Teradomari

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harbor embodies the history of the Japanese engineers who fought coastal sediments with unswerving perseverance. Fig. 16 will aid to understand the background of this harbor where the design and alignment of the jet-ties have been repeatedly modified under the pressure of invading sediment.

APPROACHES TO COASTAL PROCESSES

The factors discussed in the preceding chapter combine in nature to present various patterns of coastal problem. The problems are so intricately constituted that it has only been these 15 years that a field investigation based on the scientific procedure and a laboratory experiment based on the results of such investigation came to prevail. We had to depend largely on the experiences of some limited number of engineers until the scientific approaches were introduced.⁽¹⁰⁾

The meteorologists and oceanographers have long been turning out an immense quantity of data on waves, but they mostly counted on visual observations until various types of instruments became available about 10 years ago. Today, a number of wave recorders, both step-resistance and pressure types, have been installed in Japan. The shore-based stereo-photography is also used in studying the shoaling waves.

The longshore currents are often measured by using floats or self-contained recorders. Fluorescent dye markers are also used both in and out of the surf zone.

Though supremely important, the measurement of the longshore sediment movement still lacks in adequate instruments. A box trap or a tube (or bamboo) trap is currently used in Japan, but the data which they provide fail to give the definite basis for a quantitative treatment. In order to verify the sand-arresting organism of a trap, the authors carried out a series of instant and cumulative sampling of suspended sediment in the field in parallel to a laboratory model test in a two-dimensional flume. Though the project is still in progress, we have succeeded in establishing a relationship between the concentration of suspended sediment and the efficiency of a tube trap.⁽¹¹⁾

At the present state the hydrographic sounding by lead or echo is a most effective and most widely used method for estimating the movement of sediment as well as changes in bottom topographies. The problem with the hydrographic survey today is to shorten the operation period, yet not to impair the accuracy of sounding data so that the wave conditions may not change during the operation.

The uncertainty in the scale effect seriously reduces the value of laboratory experiment, particularly one utilizing a movable bed. The method used by the Japanese engineers to overcome this difficulty is to follow a close reference between the model and the prototype by trial-and-error repetition.

A most pronouncing example of the overall coastal study in Japan is

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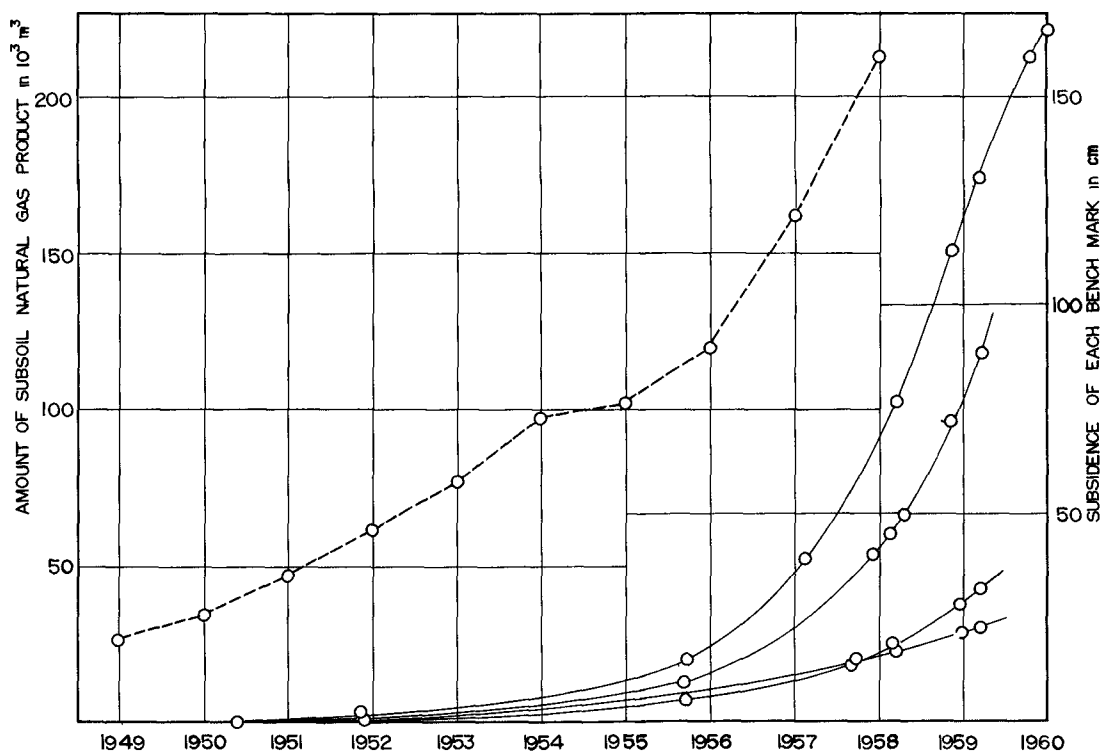


Fig. 14. Relationship between the Subsidence of Bench Marks and the Production of Subsoil Natural Gas.

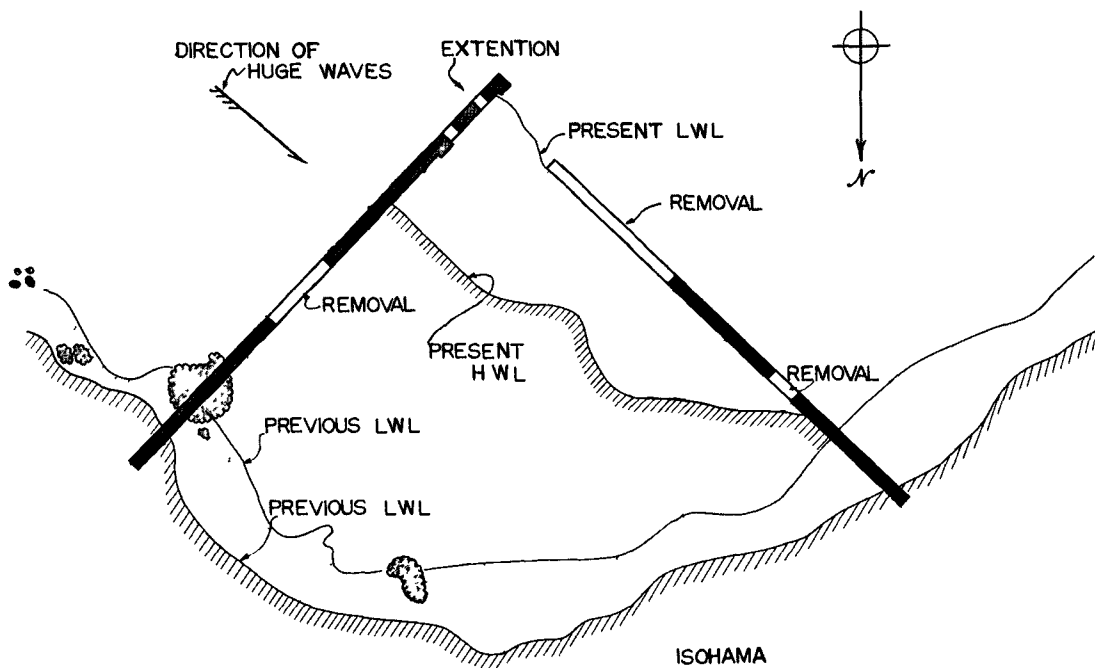
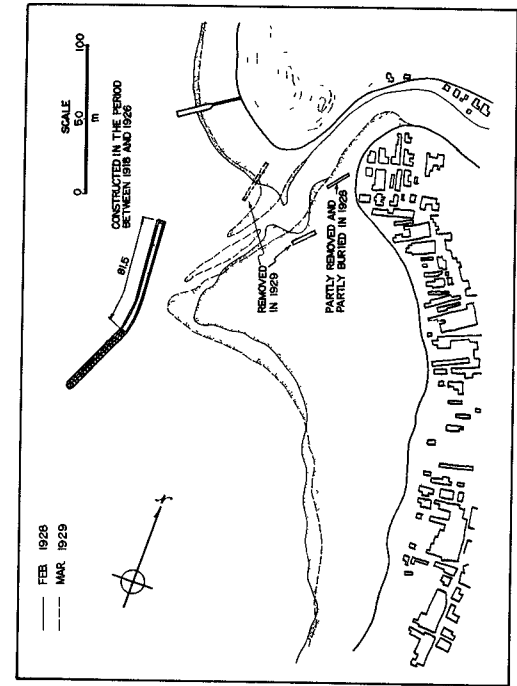
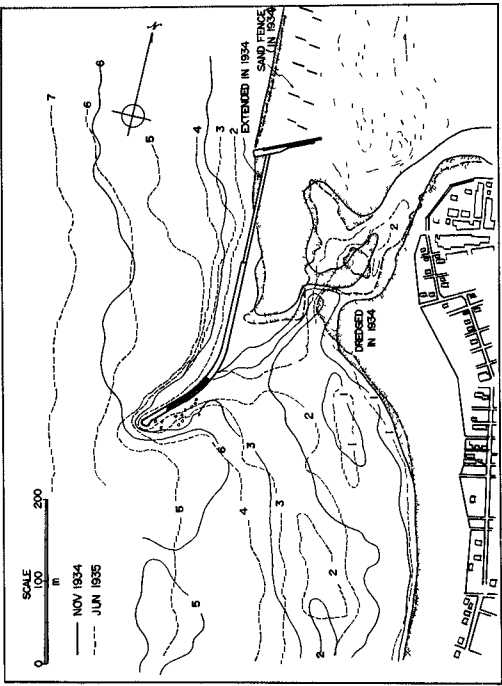


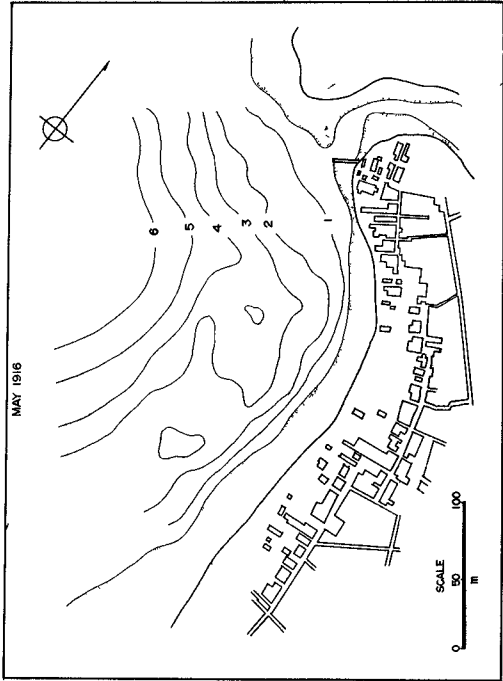
Fig. 15. Isohama Fishery Harbor (after M. Suzuki)



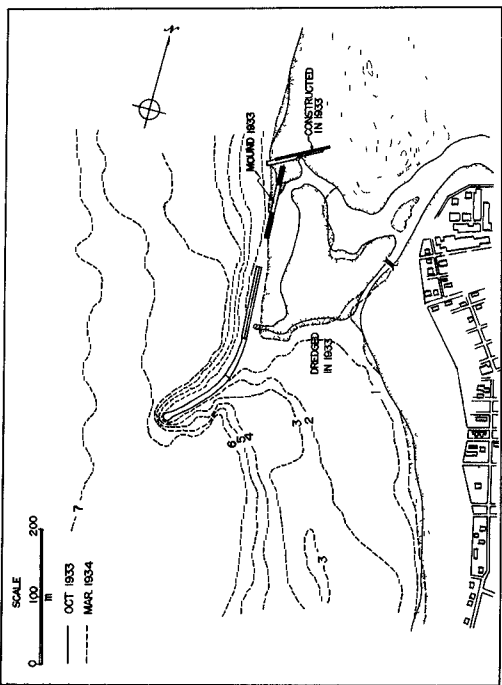
(a)



(b)



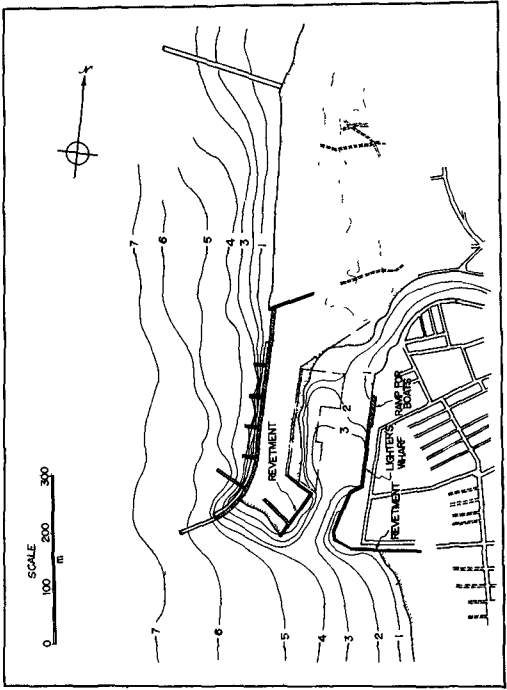
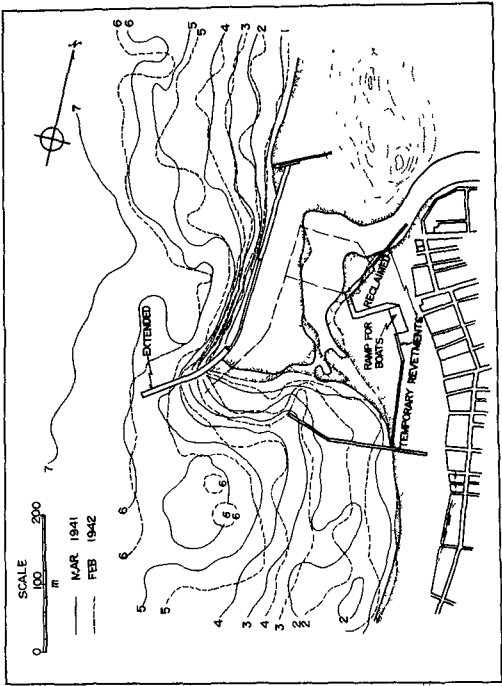
(c)



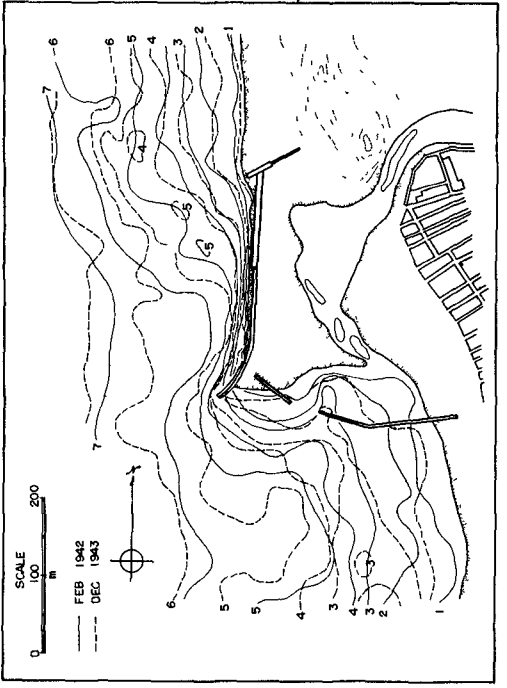
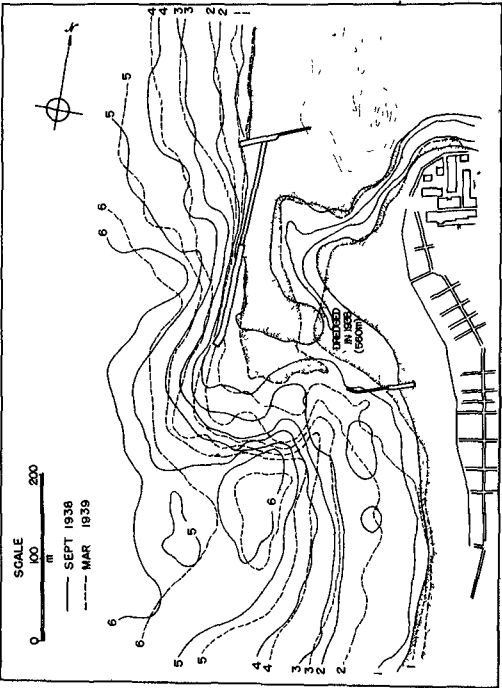
(d)

Fig. 16. Tsuruma Dike and Mound

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(f)



(e)

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found in the coast of Niigata. In order to deal with the problem of erosion, a committee was created in 1946 and after 5 years of strenuous field investigation and laboratory model experiments the results were published in an extensive report in 1951. In 1953, the prefectural office of Niigata set out on a long-range project of investigation with by far the comprehensive scope. Numerous revisions were made on the methods and instruments of investigation until of tolerably satisfactory arrangement was completed in 1957.

The purposes of investigation at Niigata consisted in (1) exploring the rate and physical processes of erosion, and (2) obtaining data to be used as the basis for planning protection works and their modifications. Since the coasts facing the Japan Sea are almost completely devoid of a lull during winter due to violent wind waves, an investigation by a boat is impossible. A cableway consisting of masts and track cables was set up in the perpendicular direction against the shoreline which is operated at the station located on top of the beach dune. The cableway could carry the recording or sampling instruments to any shallow water position regardless of the weather and sea conditions. (See Fig. 17 and Plate 1.)

The overall project of investigation is outlined below.

A. General investigation on shallow water areas

1. Hydrographic sounding - Once or twice per year, as far as the depth of 20 m and along the stretch of 20 km, by echosounding from a boat.
2. Sampling of bottom materials - Conducted simultaneously with the sounding operations.

B. Investigation of coastal establishment

1. Investigation on deformation of a submerged breakwater due to wave action.
2. Investigation on subsidence of a submerged breakwater due to wave action.

C. Investigation on natural forces

1. Direction and velocity of winds - Records from several stations scattered in the vicinity were collected to compare variability in direction and intensity of winds found inside a fetch of an appreciable width.
2. Observation of shallow water waves - The directions, heights and periods of shallow water waves in the depth of approximately 5 m and less were observed to determine the deformation of wave characteristics due to bottom topographies and the damping effects of a submerged breakwater. In order to determine the sheltering effect of the Sado Island two units of shore-based pressure recorders are being installed at Sado and Niigata in the depth of approximately 10 m.

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN

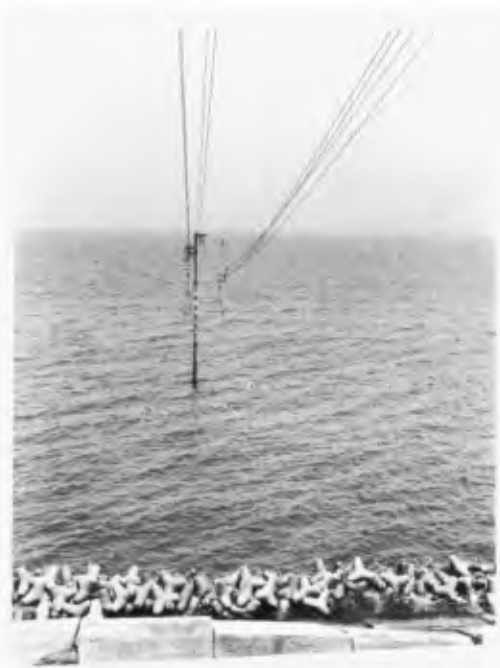
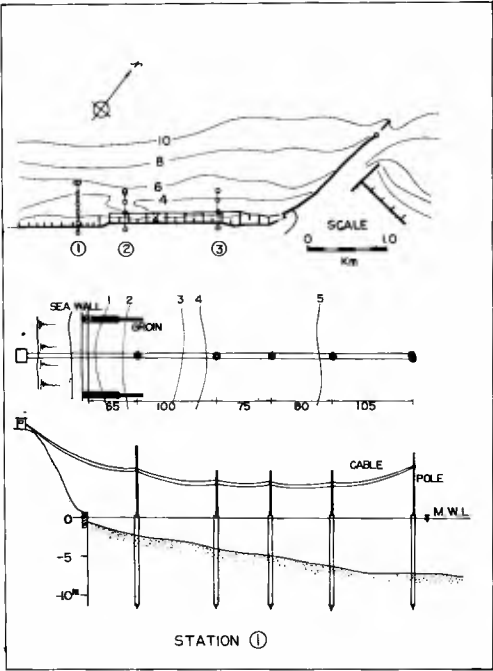


Plate. 1. Cableway



Plate. 2. Current Meter



Plate. 3. Fujiki-type Sampler



Plate. 4. Fijiki-type Electric Lead

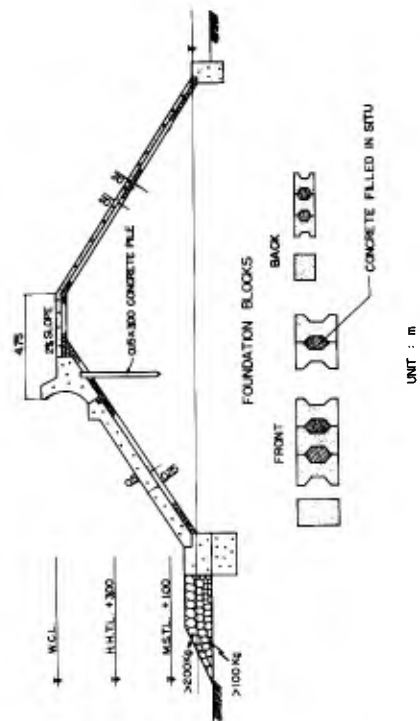


Fig. 18. Cross Section of Coastal Dike Constructed along the Ise-Bay

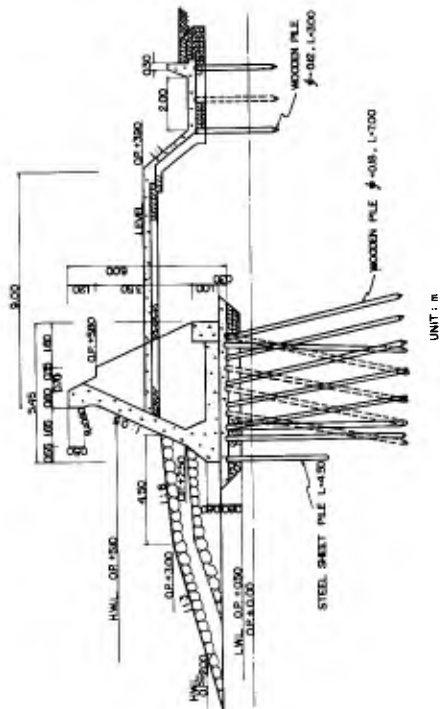


Fig. 19. Cross Section of Sea Wall at Amagasaki,

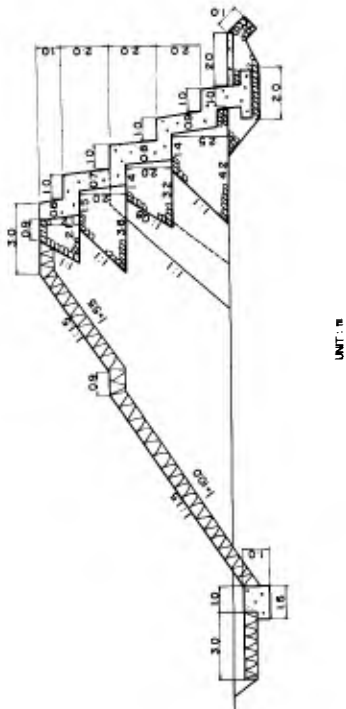


Fig. 20. Cross Section of Sea Wall at Taro

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN.

- D. Special installations to investigate surf-zone characteristics - A cableway system which was developed to make the investigation activities during winter storms possible, was designed to carry the following units to the zones in and out of the breaking point.
1. A self-contained current meter and a cross-blade float to measure current velocities and directions at an arbitrary level above the bottom. (See Plate 2.)
 2. Fujiki-type sampler for measuring instant concentration of suspended materials (See Plate 3.) and a tube trap for cumulative arresting of suspended sediment.
 3. Fujiki-type electric lead for sounding of the bottom topographies near the surf-zone. (See Plate 4.)

A recent technique of radioisotope was applied to the Niigata coasts in 1958 in order to trace the movement of bed materials.

This arrangement of various items of investigation has succeeded in supplying a great deal of information on the physical processes occurring at the beach under erosion, as was partly discussed in the preceding chapter.⁽¹²⁾ Our experience in Niigata has convinced us that a well-arranged project with refined instrumentation does really pay.

COASTAL PROTECTION WORKS AND PRACTICES

The design and construction of coastal protection works may vary according to the purposes as follows:

1. Defense against a storm surge:
2. Defense against a tsunami:
3. Prevention of beach erosion: and
4. Measures against sedimentation of a harbor basin or blocking of a river mouth.

Defense against storm surges

The bays and inlets west of the Tokyo area are dangerously exposed to the hazards of a storm surge. The key industrial centers such as Tokyo, Nagoya and Osaka are located in this region. Once a storm surge should occur at one of these area the resulting disasters would be tremendous due to valuable establishments and swarming population crowding the lowland. The serious subsidence caused by excessive exploitation of the ground water has reduced these industrial areas even more vulnerable to a storm surge.

One of the most popular measures to defend a storm surge is to besiege a lowland with coastal dikes or sea walls. (See Fig. 18.) However, such procedure may not be extended to the port areas, since it may interfere with the function of the port facilities. With some few exceptions such

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as found in Amagasaki, where an encircling dike completely embraces the port sector (See Fig. 19.) or in Osaka where a part of the downtown district was leveled up by filling soils, most of the ports in Japan are practically defenseless against a storm surge. The disasters caused by a storm surge due to the typhoon No. 15, 1959, are discussed by Otao and others in another paper of this conference.

Measures against tsunamis

The northeastern coasts of Japan have been frequently hit by tsunamis. Since the height of a tsunami is even harder to forecast than that of a storm surge, and since the underdeveloped coasts of northeastern Japan cannot afford financially to own expensive defenses against a tsunami which occurs only at a low probability of, say, once in 30 years, not much progress has been accomplished as to the measures against tsunamis. However there are places where the efforts have been made to build a coastal dike along the outskirts of the resident quarter (See Fig. 20.), or a wall right through the town, or a counter-tsunami grove along the shoreline.⁽³⁾

Measures against coast erosion

Several types of protection works have been employed in Japan: (1) sea wall, (2) groin, (3) submerged breakwater, (4) artificial nourishment, and (5) their combination. We will review the protection works actually applied to some of the important coasts of Japan.

Niigata coast - The situation up to 1952 was reported by S. Kuroda at the 18th Proceeding of International Navigation Congress and shall not be repeated here.⁽³⁾ Over a stretch of 2 km adjoining the west jetty of the Shinano river, the beach was protected with a combination of submerged breakwaters, coastal groins and sea walls. Also the shoreline area was nourished artificially with bed materials dredged from the navigation channel of the river mouth. Over a stretch of 5 km lying farther west, the shoreline was protected with coastal jetties and sea walls. Though the erosion ceased in the area thus protected, the open shoreline beyond the protected area began to retreat recently. To the east of the river mouth, the shoreline was protected with groins and sea walls. (See Fig. 21.)

The effects of these massive protection have been convincing. However the erosive action now began to gnaw at the shore protection works themselves. Our present concern is currently directed to the methods of maintaining and reinforcing the protection works off and along the shoreline.

A submerged breakwater slumped under impacts and scouring actions of the waves breaking overhead, resulting in an appreciable loss of the damping efficiency. It was reinforced with 4-ton tetrapod blocks to restore the height to the mean sea level, but the slump has been continuing. The infilling rocks of the piled groin also slumped and had to be replaced. The base of the sea wall was scoured by violent swashes and here also the tetrapod blocks were applied to protect it with fair success. A laboratory study was undertaken by the authors to examine the cause of the slump of a submerged breakwater and the scouring action at the base of a sea wall by using 1/20, 1/25 and 1/40 models, which turned out some useful suggestio

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN

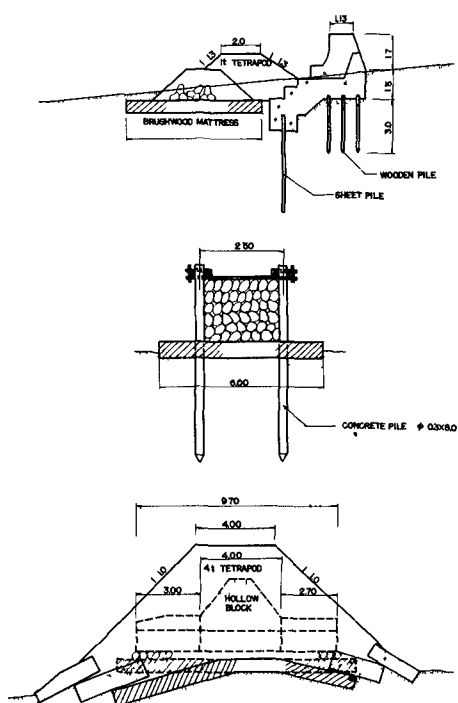


Fig. 21

Fig. 21. Cross Sections of Sea Wall, Groin and Submerged Breakwater at Nilgata West Coast

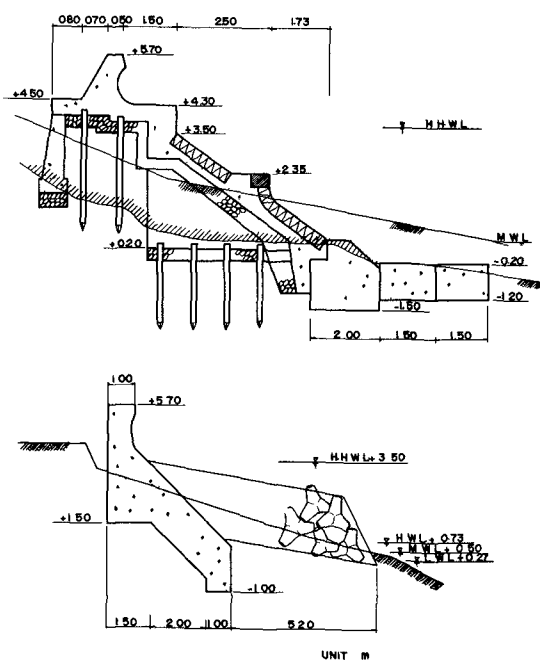


Fig. 23

Fig. 23. Cross Sections of Sea Wall at Toyama Coast

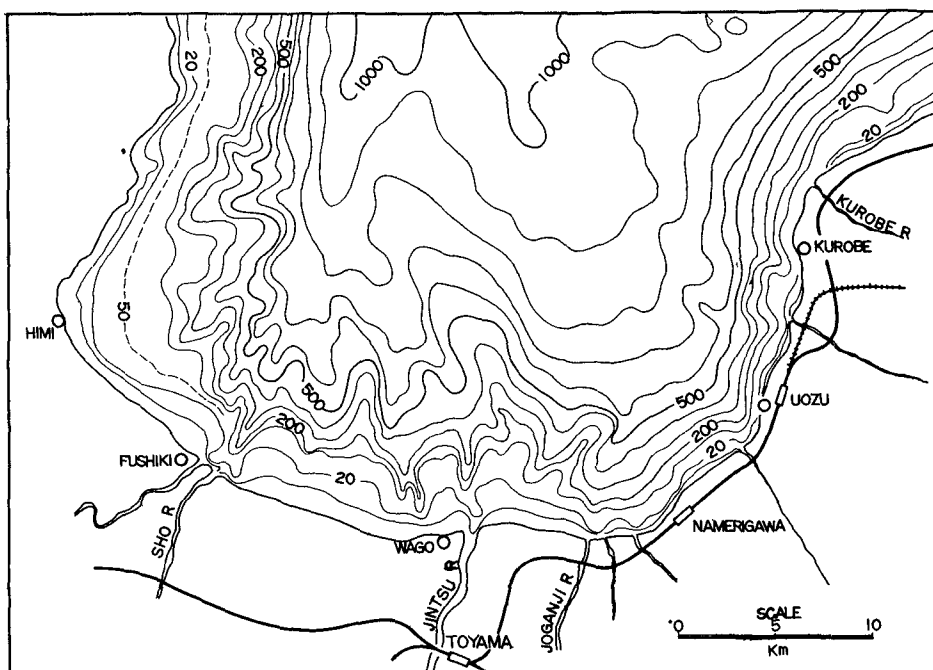


Fig. 22. Toyama Bay Area

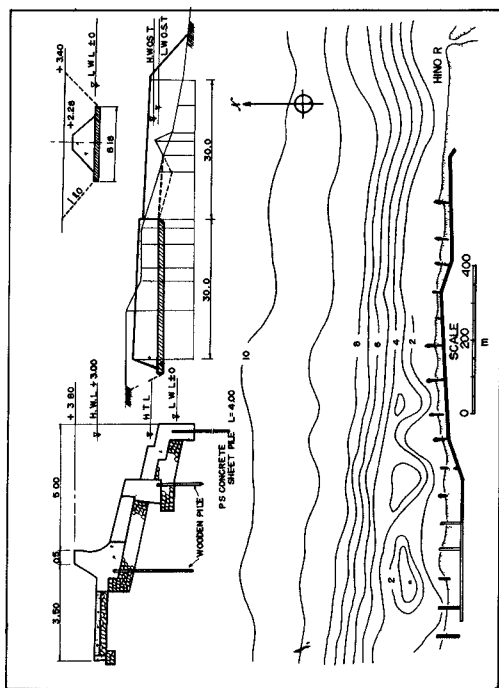


Fig. 25. Protection Works at Kaike Coast

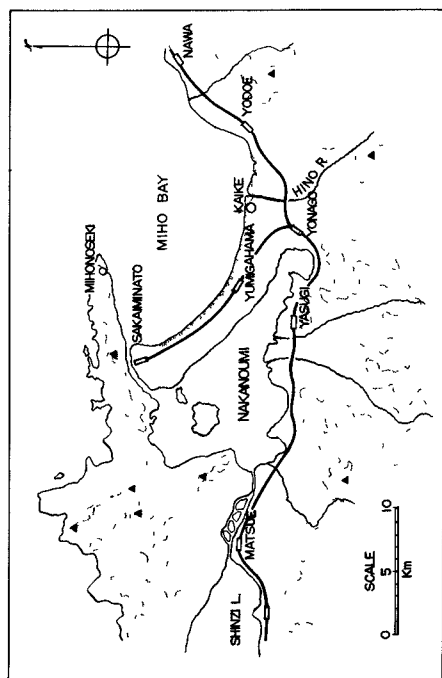
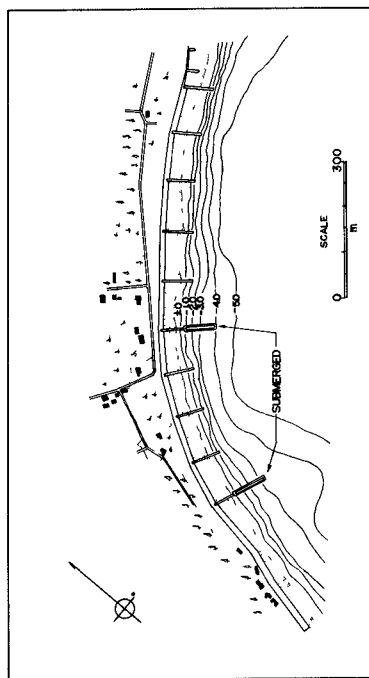


Fig. 24. Location Map of Kaike Coast

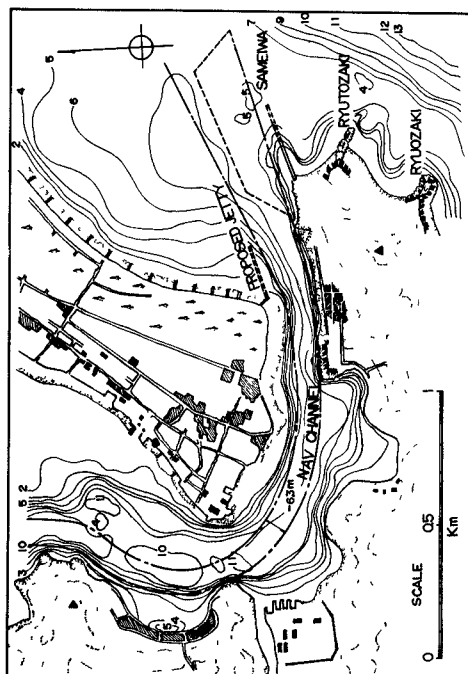


Fig. 26. Infection Man of Pannochi Cant.

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN.

as to the measures for maintenance and reinforcement for these protection works.⁽¹⁴⁾

Toyama coast - The coasts are subjected to continual action of storm waves during winter. The effects of the wave action on these coasts of submergence are even intensified due to bottom topographies which are represented by a steep profile falling to the depth of 5 and 10 m at the distance of 250 and 1,000 m, respectively, from the shoreline. (See Fig. 22.) Thus the waves generated in the deep water reach the shoreline without any appreciable loss of energy. It is also characteristic of these coasts that there is little supply of bed materials from the nearby rivers. Under combined effects of these factors, the coasts have been retreating at an enormous rate of 1.5 to 2.5 m/year in the east and 0.5 to 1.0 m/year in the west, and at some places the rate amounted to 10 to 20 m/year.

The protection works applied here primarily consist of the sea walls (See Fig. 23.) and at some places they were combined with groins. The beaches are dominantly gravels, which, churned up by swashes, cause serious attrition of the concrete sea walls and tetrapods, as well as dissembling of the masonry structures. No definite method of maintaining the protection works has yet been introduced.

Kaike coast - The beach materials are mostly supplied from the Hino river which empties into the eastern part of the beach. A careful study revealed that the principal cause of erosion is attributed to recent development of soil conservation works in the upper reach of the river, and consequent decrease of sediment discharge from the river mouth. The beach was protected with a group of coastal groins. (See Fig. 24 and 25.) The groin, a mound built of concrete blocks, was spaced 2 to 4 times the length of the groin which ranges from 20 to 50 m.

Though the groin system proved effective in arresting a large portion of the sand drifts along the shoreline, the general trend of erosion persisted over an extensive stretch of the coast. Today, a sea wall is being constructed instead of groins.

Tanizaki coast - The shoreline of Tanizaki, located at the entrance of the Kochi harbor, began to retreat rapidly in recent years, and the erosion was reported to have reached more than 100 m in about 30 years. (See Fig. 26 and 27.) The cause of erosion is attributed to the training jetty and the river mouth, but the process of erosion was further aggravated by the great Nankai earthquake in 1946 which caused this area to subside by about 1.2 m. The beach was then hit by several typhoons successively, and the shoreline retreated by 30 to 40 m in only several years after the earthquake. A model experiment was carried out in order to determine an adequate alignment of the breakwaters at the entrance so that the longshore currents may be decelerated. A masonry sea wall and the coastal groins were installed to prevent further erosion.

Toban coast - The coast faces a narrow strait of Akashi which connects the Osaka bay and the Seto inland sea, and partly sheltered by the Awaji Island from the Pacific Ocean. (See Fig. 28.) The highland behind the coast descends to the sea with a steep slope and long years of weathering reduced

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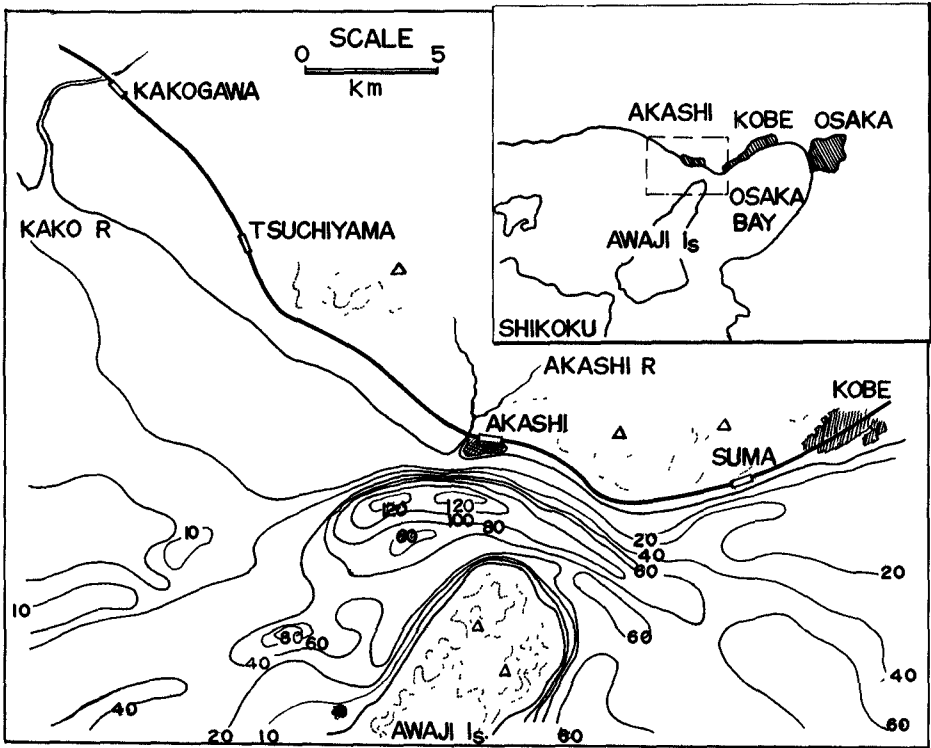


Fig. 28. Location Map of Toban Coast

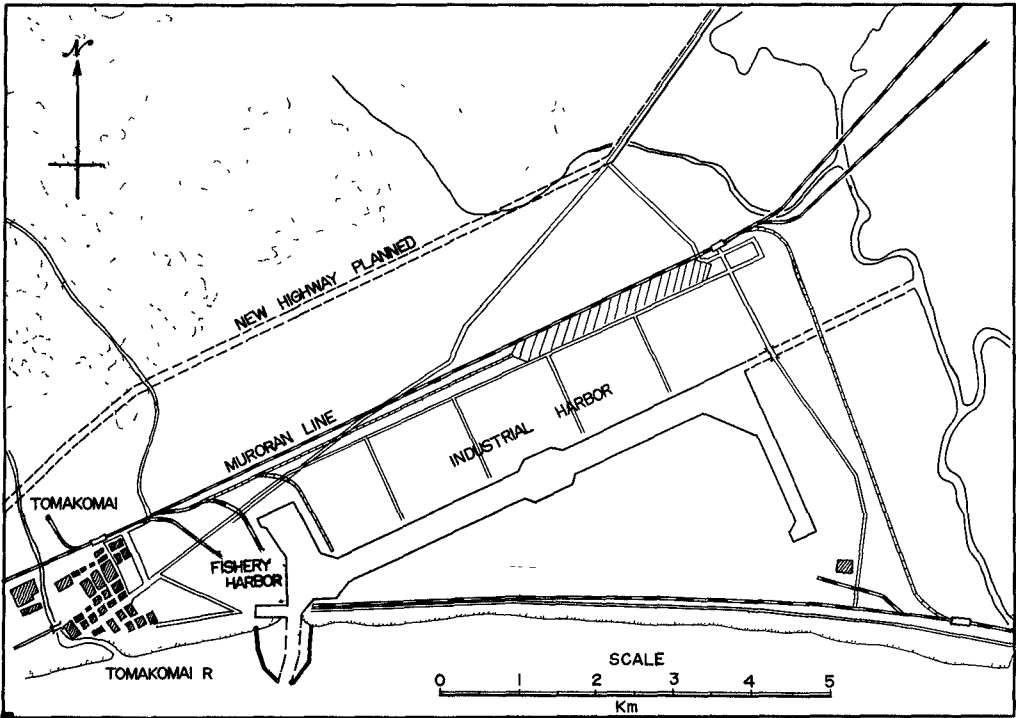


Fig. 29. Proposed Plan of Tomakomai Harbor

COASTAL PROTECTION WORKS AND RELATED PROBLEMS IN JAPAN.

it apt to collapse. The soil conservation works started early in the high-land, and today the debris barriers built along the Kako river alone number more than 40. The result was the rapid decrease in supply of materials to the beach. The erosion is partly attributed to the violent tidal current through the Akashi strait which attains as high as 4.5 knots at spring tides.

The protection works provided here consist of a sea wall to which a group of relatively short groins are attached in order to damp destructive effects of swashes and thus prevent scouring action at the foot of the sea wall and offshore breakwaters (rock or block mound) was also applied to some places of the coast.

Measures against sedimentation in harbors and blocking of a river mouth

The most salient example of sedimentation is found in the Iwafune port which has had to undergo repeated modification of the jetties in order to ward off endless invasion of coastal sediments (See Fig. 16.) We abound in costly lessons as to the danger of sedimentation which must be expected of a shoreline harbor built along a sandy coast. Recently the Japanese engineers have ventured on a project of building a harbor basin inside the shoreline of the Tomakomai coast, where construction is proceeded in parallel to meticulous investigation. (See Fig. 29.)

The training of a river mouth is a problem which has been annoying the engineers everywhere in Japan. No definite measure has yet been established and the training work is carried on usually by trial-and-error procedures. In some of the particular cases, the laboratory study proved very useful, but much remain to be enlightened in the future.

ACKNOWLEDGEMENTS

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