REPORT ON THE STUDY OF MEANS OF REHABILITATION OF DAMAGES CAUSED BY WIND TIDE ALONG THE EAST COAST OF KOREA

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1. INTRODUCTION

A heavy wind tide attacked the east coast during 2 days, 6th and 7th of January, 1963, and caused an extensive damage to numeous port facilities along the coast. A special committee had been formed by order of the Minister of Construction to investigate the damage and to present recommendations for possible means of preventing future damage.

This report is an extract of the report prepared and submitted by the committee.

The study is based on the findings of the survey made on the spot for 7 days from 4 February, 1963, and the discussions with local people and engineers in the field. The data are collected and analyzed to come up with the conclusions for the following tasks :

a. To find the cause of damages.
b. To make suggestions for the problem of littoral drift.
c. To recommend the suitable types of breakwater for the east coast.

The troubled area is in the heart of abundant underground and marine resources. The coal deposit in the vicinity area is the richest in the county and some of the product are exported overseas.

Mukho being the only port of deep water in the east coast and second largest in Korea in its cargo handling capacity, handles 1,000,000 tons of coal a year. Port of Sockcho exports about 300,000 tons of iron ore annualy and Chungla is shipping the finished products of factories in the area.

Numerous fishing grounds are available along the coast. The catch of fish in recent 3 years is shown in Table 1.

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Table 1 Fish Catch
(Fishery Section, Kangwon-do Province)

Port	1960		1961		1962	
	Quant.	Value	Quant.	Value	Quant.	Value
Chungla	5 751	40 061	7 396	49 920	8 966	67 589
Mukho	12 223	79 819	21 896	154 244	17 694	155 162
Chumunjin	7 749	51 039	24 926	121 827	14 117	143 246
Namae	Included in Chumunjin					
Sokcho	18 928	185 023	28 860	204 258	30 010	287 719
Kojin	4 449	61 403	9 120	96 875	10 556	122 853

The figures above consist mostly of Alaska pollack cuttle fish, saury pike and sand lance and include some seaweed and herring. Fishing season is between June and November for cuttle fish, and October and March next year for Alaska poollack during which thousands of boat gather from all over the country. During the wind tide of January 6 and 7 there had been 342 registered boats and 250 nonregistered boats gathered at Chununjin.

2. CHARACTERISTICS OF THE EAST COAST

Following is a brief description of what affects the ports on the east coast.

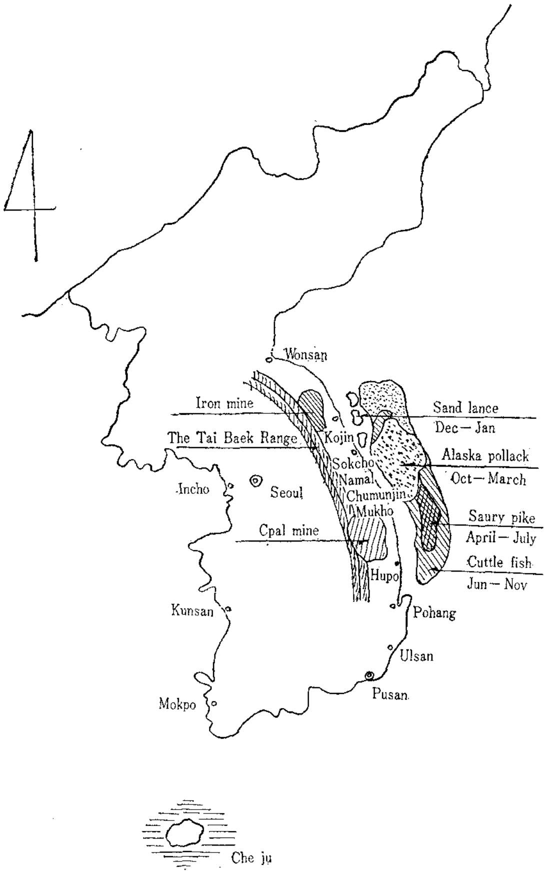
2-1. Geography

The rugged mountain range of Taibaek runs straight from north to south close to the coast line, leaving a narrow strip of flat land and forming steep contour in the sea almost parallel to the coast. The range forces rain water pouring into the sea and separates or changes wind direction or confines wind field. To the eastward it has a fetch of 800 km to the west coast of Japan.

2-2. Wind

The most frequent wind in Mukho area is southwest wind, which is considered to be one

Fig. 1 Resources of the East Coast



of the elements of coastal force.

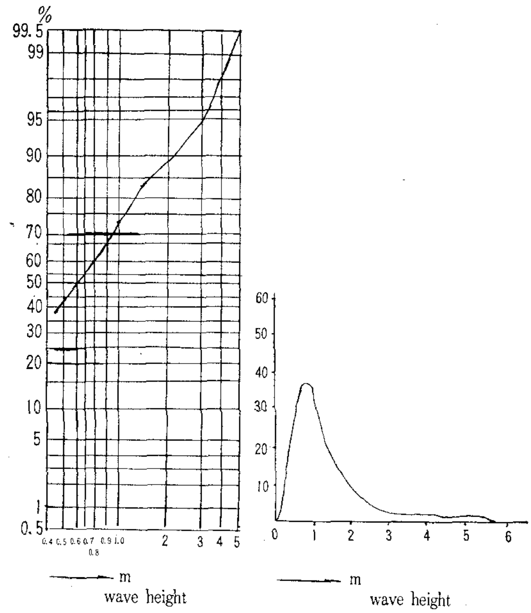
In winter, trade wind preveils as a result of typical isobaric pattern in which high pressuse usually develops in the continent of Mongolia and low pressure in the east sea. Such wind is predominantly northwest wind.

In summer, extratropical cyclones developed in such area as South China pass the coast, however, they have less effect to the region.

2-3. Wave

Occurance of wave varies with the seasons.

Fig. 2 Probablity of All Year (Wave Observation at Mukho Port for One Year from Jan. 1, 1961)



In autumn, typhoon wave sometime propagates to the shore from the south. In winter, waves of different directon, duration, period, height and length occur frequently and calmness in the sea is rare.

Percentage of waves by direction during 6 months from December 1960 to May 1961 and by height and period for one year are shown in the following tables. It is noted that the wave of 2m is almost 85 percent of the total and southeast waves constitute 65 percent.

The observation of wave was made at a station in Mukho for several years, however, such data obtained may not be sufficient to determine the wave characteristics. Therefore, in order to supplement the data a comparison is made of the observations made at Sakata and Niigata, Japan, on the basis of assumption that the waves are generated under the similar

Table 2 Waves by Direction

Wave Height	North-east	East	East-southeast	South-east	South-southeast	Total
2 m or under	1.3	0	19.6	59.4	3.2	83.5
2~4 m	2.6	3.3	3.9	4.6	0	14.4
4 m or over	0	0.6	0.6	0.6	0	1.8
TOTAL	**3.9**	**3.9**	**24.1**	**64.6**	3.2	**100**

Table 3 Frequency and Percentage of Waves by Season

Wave Height

Season		0~0.1m	0.11~0.49m	0.5~0.99m	1.0~1.49m	1.5~1.99m	2.0~2.49m	2.5~2.99m	3.0~3.49m	3.5~3.99m	4.0~5.0m
Spring	Frequency	(2.9) 40	(11.6) 161	(11.4) 158	(4.0) 55	(2.2) 30	(1.5) 21	(0.1) 2	(0.9) 12	(0.1) 2	(0.4) 5
	Percentage	8.23	33.13	32.51	11.32	6.17	4.32	0.4	2.46	0.4	1.1
Summar	Frequency	—	(6.0) 83	(7.1) 98	(1.1) 15	(0.3) 4	(0.2) 3	—	—	—	—
	Percentage	—	40.88	48.27	7.39	1.98	1.49	—	—	—	—
Autumn	Frequency	(0.8) 11	(4.8) 66	(6.4) 89	(1.4) 20	(2.0) 28	(1.1) 15	(0.8) 11	(1.1) 15	(0.8) 11	(0.7) 10
	Percentage	3.99	23.91	32.25	7.25	10.14	5.43	3.99	5.43	3.99	3.62
Winter	Frequency	—	(11.2) 155	(10.2) 141	(2.0) 28	(2.1) 29	(1.4) 20	(1.1) 15	(2.2) 31	(0.1) 2	—
	Percentage	—	36.82	33.49	6.65	6.89	4.75	3.56	7.36	0.48	—
All year	Frequency	51	465	486	118	91	59	28	58	15	15
	Percentage	3.7	33.5	35.06	8.54	6.6	4.3	2.0	4.1	1.1	1.1

Parenthesized figure shows percentage of all year.

Wave Period

Season		Wave Period				
		3.9 sec	4.0~5.9 sec	6.0~7.9 sec	8.0~9.9 sec	10.0~11.9 sec
Summer	Frequency	86	105	7	6	—
	Percentage	42.2	51.5	3.4	2.9	—
Autumn	Frequency	46	134	43	33	17
	Percentage	16.8	49.1	15.8	12.1	6.2

Remaks :

Spring : March~May, Summer : June~August, Autumn : September~November, Winter : December~February

condition.

3. THE CAUSE OF DAMAGES

3-1. The Meteorology and Oceanography at the Time of Damage

On 5 January, 1963, a low pressure of 1 004 millibar was developed over the east sea near 132° longitude and moved eastward at the speed of 10 km per hour and reached to 135° longitude after being developed to 996 millibar at the center of pressure on 6 January. As the low preseure passed, the cyclonic wind of about 470 km in radius generated the wave offshore Sungjin and the wave grew to maximum height near Mukho and Chungla, and then on gradually decayed.

The velocity of gradient wind offshore Sungjin calculated from isobar was 18 m/s and was able to generate a wave of 5.7 m high with 10 sec as derived from the S.M.B. curve at Mukho which is at the front of fetch area of 280 km and of long duration. Following is the wave actually observed at Mukho as of 0900 hours 6 January.

Wave height : 5.7m
Wind velocity : 15.0m/s (Kang Nung)
Spray : about 35m

The low atmospheric pressure was continuously moving eastward at the speed of 30 to 40 km per hour and stayed in the east side of Japan as of 7 January, so that the continental high pressure dominated the entire area of the east sea and the east coast was under the influence of swell.

3-2. The Causes in General

a. The height of sea level increased while the wave was assaulting the breakwater and the weight of armor stone in comparison with the theoretical weight calculated from the Hudson's formula became insufficient.

b. The damage was effected from the head of the breakwater which was under construction and such damage from unfinished breakwater is inevitable.

c. Due to the lack of fund for proper maintenance of the breakwater, the defect portion caused the enlarged damage.

d. Concrete filling of the armor stone layer had little effect in the east coast where the range of tide is small.

3-3. The Cause of Damage to Kukho Breakwater.

The breakwater is composite type and the foundation rocks of seaward side had been considerably washed out. In consequence, the wave propagated from offshore with full force broke against the body and gave severe pressure to the shoreside body and riprap resulting a heavy damage.

The wind tide damages at each port investigated are as follows :

Port	Description		Amount in Won
Chungla	Breakwater	204 m	14 220 000
Mukho	〃	545 m	20 400 000
Chumunjin	〃	154 m	1 000 000
Namae	〃	69 m	7 171 000
Sokcho	〃	76 m	2 390 000
Kojin	〃	190 m	1 147 000
TOTAL			**46 328 000**

4. LITTORAL DRIFT

It can be said that the east coast has a shape of a saw which has a series of coucave water area and littoral berm or sand beach. Ports are usually located in the concave area where the slope of sea bottom is steep because of the headland configuration perpendicular to the coast and gradually becomes flatter toward the south forming berms or beaches. These berms tend to move northward when the incident wave comes from south and generally are the source of materials which fill the ports.

According to the observation made by Mukho harbor engineers for 6 months from December 1960 :

The incident wave energy toward south is

$E=10\times10^6$,

and opposit direction is

$E=135\times10^6$

A note is made that the incident wave toward north is 13 times stronger than that of south, however, it may not be generally true for the entire coast because the observation was confined only to Mukho.

It can be reasonably assumed that as the wave of north-east in winter has higher wave height it breaks on the outer section of inshore zone and erodes the bottom and carrys a portion of material up to the berm or beach and the other into the sea in suspension. The materials in suspension then settle down in relatively calm area causing silting of the harbors as in Mukho and Pohang.

The frequent waves come from south, throughout the year except winter, having shorter period and less steepness, tend to break closer to the foreshore and erode the berm crest, jetting littoral current and undertow.

The littoral current carrys a portion of the eroded material pass the headlands or tip of breakwaters to the downdrift shore.

At the cape of Hupo harbor it can be easilly seen that sand is moving on the bottom as a bed load in spring time. Contrary to the local residents belief in the direction of littoral transport from north to south, the opposite is true judging from the direction of wave. The littoral current carrys sand as far as it attains an equilibrium of the angle of incident, weight of sand etc.

On the other hand the undertow carrys some portion of material to nearshore zone and plugs the entrance of harbor usually in spring as seen in Hupo harbor.

On the east coast it is assumed that the littoral meterial is moving from south to north up to Sockcho, nodal zone of the east coast, and this action has been ceaselessly continuing from ancient time that there are many lagoons created in that area.

A particular attention must be paid for the construction of breakwater or groin on the beaches where the littoral drift is in question. Therefore, a thorough study must be made for the extension of breakwaters in Pohang, Hupo and Mukho. It is suggested a study by use of radio isotope, proven successful in the Thames River, England, and Tomakomai, Japan, be conducted to determine the source, amount, mode and direction of littoral drift for an extensive area covering most part of the coast in collaboration with the Office of Atomic Energy.

5. DESIGN OF BREAKWATER

There have been breakwaters on the east coast for several decades to protect the harbors. They are usually built with quarry rock, with a few exceptions and constructed year after year from the tip of cape toward the sea. Damages to the breakwaters and repairs thereto have been endlessly repeated. The design and construction of breakwaters practiced by experience so far have been proved defective because the breakwater can not withstand the waves as it is extended out to deeper water. It is this that the wave analysis and carefull study of the structure of breakwater must be made.

5-1. Design Wave Height

The wave of over 5.0 m high during the observation period at Mukho and Sakata, Japan amounted 1/2 percent of the total. The same proportion for the wave higher than 4.0 m at Niigata. In this percentage, of course, the wave of 7.0 m recorded at Sakata in December, 1957 is included.

It is considered that the damage of breakwater is usually caused by the first strong wave during the construction period or soon after the completion of construction, when the breakwater is still in the unstable state. Therefore, the design wave can be economically selected if the construction schedule is so chosen or the breakwater is so protected as to avoid the dangerous wave in critical time. Offshore wave of 6.0 m with period of 9 sec regardless of location of the east coast is considered safe and is selected as the design wave.

5-2. Type of Breakwater

Based on the design wave, the standard cross-section of breakwater recommended for the east coast by the committee are those using three types of armor blocks listed below.

a. Natural quarry stone
b. Tribar
c. Tetrapod

Natural quarry stone block, however, was found impractical due to unavailability of the rock of required size. For practical reasons, the type of block finally adopted in the field is a modified tribar, the type developed from the tribar, which is being used in several ports on the east coast for repair or extension of the existing breakwaters and rendering satisfactory performance so far.

The modified tribar for future use, however, will be subjected to a model test at the laboratory of Inchon Port Construction Office now under construction.