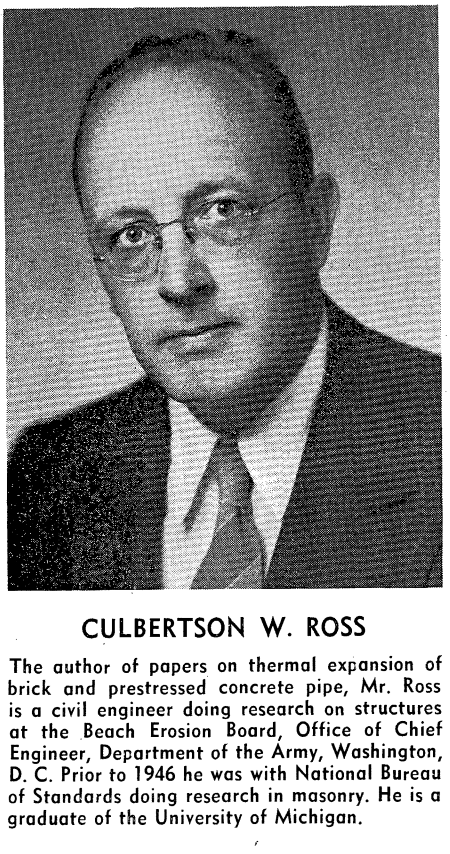
Deterioration of Steel Sheet Pile Groins At Palm Beach, Florida★

By CULBERTSON W. ROSS

IN HIS BATTLE to hold the sand on beaches, the engineer has evolved the groin as a protective structure. Groins are structures built out from the shore to reduce or prevent the motion of sand along the beach. Their purpose is to hold the sand that is on the beach and to accumulate more sand from any that may be drifting along the shore. Groins resemble small jetties; they may be built of wood, concrete, stone or steel. This article will describe tests made at Palm Beach, Florida, to determine the reason for the rapid deterioration of steel groins at this location.

The project was a cooperative effort by The Beach Erosion Board, the Jacksonville District of the Corps of Engineers, the city of Palm Beach and five steel producing companies: Carnegie, Bethlehem, Jones and Laughlin and Inland steel companies of the United States, and the Larssen Company of Germany.



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Location and Exposure at Palm Beach

Palm Beach is on the east coast of Florida, about 120 miles from the southern end of the state. It is on a barrier beach which is chiefly sand. The beach sand consists of about 64 percent limestone and shell and 36 percent silica.

Strongest winds are from the northeast. The fetch, or the distance which waves may travel before striking the beach, is about 100 miles towards the east and southeast, to the Bahama Islands. The beach is open to the ocean on the northeast. The mean tide range is 2.8 feet. The area is subject to occasional tropical cyclones which throw violent waves against the beach and produce fluctuations of the water level as great as 7 feet. Two such storms occurred during the test period, in 1941 and again in 1944.

Along the east coast of Florida, there is a strong drift of sand from north to south which is caused by the action of waves which strike the beach predominantly from a direction north of east. The uprush and backwash of the waves moves the sand southward in a zigzag path. While there are temporary and seasonal reverses of this direction of the sand drift—which is called "littoral drift,"—the average drift of sand to the south is estimated to be 225,000 cubic yards per year.

Two 320-foot jetties were built in 1928 to improve Lake Worth Inlet, at the north end of Palm Beach. There was a large accretion of sand north of the jetties and severe erosion south of them. In an effort to hold the beach and to prevent the washing away of large areas of valuable land, a system of groins was built. After a few years, large holes developed in the steel piles of which the groins were formed.

Description of the Groins

Five experimental groins were built during 1937 by the city of Palm Beach of steel piles contributed to the Beach Erosion Board by the steel companies. The groins are located between 2500 and 6500 feet south of Lake Worth Inlet. The length of the groins varied from 128 feet to 201 feet. Groins 139-N, 135-N and 121-N were built of deep-arch piles and groins 131-N and 112-N were built of straight section piles. These numbers refer to the location of the groins on the beach. The nominal thickness of the steel of groin 112-N was 0.547 inch and of the others 0.375 inch. Four of the groins were built of standard structural rim steel containing less than 0.05 per cent copper, but the other groin, 112-N, was built of steel containing 0.35 per cent copper. The piles of groin 112-N had been painted with a shop coat of black paint when received, and a number of the piles of groin 139-N were covered by an assortment of commercial marine paints and special coatings. Groin 121-N was sheathed with 2-inch creosoted timber planks for 65 feet of its length.

Types of Exposure of the Steel

Four types of exposure were studied: atmospheric,

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Figure 1—Serious structural deterioration of a groin at Palm Beach, Fla., after 12 years' exposure. The marine life, sabellaria, may be noted.

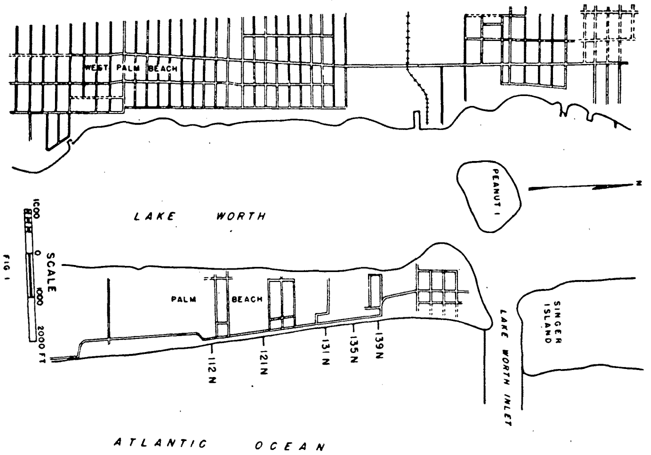

Figure 2—Location of experimental groins.

subsand, wetting - and - drying, and sand abrasion. Each type of exposure was found in each of the four groins.

Atmospheric exposure is represented by the part of the groin near the shore which rises above the sand and is exposed to the action of the atmosphere and salt spray carried by the air from the waves breaking on the beach nearby. Waves reach this elevated part of the groin only during storms.

Subsand exposure is represented by the part of the groin below the sand level. The steel is buried by the sand and is in contact with salt water and air in the sand.

Wetting-and-drying exposure is represented by the outer end of the groin between high and low water, where the steel is subject to wetting and drying because of wave and tide action.

Sand abrasion exposure is represented by the area of the groin just above the sand line on that part of the beach which is subject to the action of ordinary waves. Here, sand is thrown into suspension and carried shoreward by the breaking waves. As the water recedes, a carpet of sand is carried along the bottom. During storms, a much larger area of the groins may be subject to scour by sand in suspension. However, storm periods are infrequent at this location.

The identical area of the groins may be subject to several types of exposure at different times, because waves frequently change the position of the sand line.

Observations

The Jacksonville District of the Corps of Engineers made 39 inspections of the groins during the period 1937 to 1946. At each inspection the position of the sand line along the sides of the groins was determined by measurements at every 10 feet. The condition of the piles, paint, and timber sheathing was observed. The location of the first holes and the time of their appearance also was determined.

Measurement of the Thickness of the Steel

The Beach Erosion Board measured the thickness of the piles in 1940, 1942 and 1946. In 1940, the thickness of the steel in each groin was measured at three points: near the shoreward end of the groin above the sand, where subject to atmospheric exposure; near the sand line where the waves were breaking, representing sand abrasion exposure; and towards the outer end of the groins between the high and low tide lines, representing wetting-and-drying exposure. The same fifteen areas were measured again in 1942 and 1946, even though changes of the sand line had made changes in their exposure.

The measurement of each area consisted of drilling one hole in each of 5 piles, and making eight measurements with a small micrometer of the thickness of the steel around the hole. The average of the 40 measurements was taken as the thickness of the steel at any one area. New holes were drilled several inches from the old holes for the measurements made in later years.

Treatment of Data

Inasmuch as the exposure of the areas varied from inspection to inspection, effort was made to compute the proportion of time during which each area was subject to a specific type of exposure. Atmospheric, subsand, and wetting-and-drying types of exposure were indicated by the position of the sand line at each inspection. The groin area subject to sand abrasion was considered arbitrarily to extend from 0.2 foot below the sand line to 0.6 foot above the sand line. It was assumed that conditions found at the 39 inspections were representative of interim conditions.

Rates of loss in thickness of steel were found for the various types of exposure from the proportion of time the measured areas were subject to the different types of exposure, and from the total loss in thickness of the piles. There were some inconsistencies in the data. Perhaps these resulted from the necessity of drilling the new holes at points where the original thickness or the rate of corrosion may have been different. Perhaps the number of inspections made was not large enough to determine accurately the proportion of time for the various types of exposure. However, because of the large number of measurements made, and the number of areas measured, it is believed that the values for the rates of loss of thickness for the different types of exposure are of the correct order of magnitude.

The average rate of loss of thickness of the steel when covered on both sides by sand was found to be

0.001 inch per year; when exposed to the atmosphere, it was 0.011 inch per year; when exposed to wetting-and-drying, it was 0.005 inch per year; and when in the abrasion zone, it was 0.117 inch per year.

Another method of determining the rate of loss of steel was to note the time of the appearance of holes. A hole indicates zero thickness for that area. From the exposure record previous to the appearance of the hole, the rate of loss of thickness of the steel is computed. From the data for the areas where holes appeared, average yearly rates of loss from 0.049 inch to 0.094 inch were found for the different groins. If the proportion of time of exposure to sand abrasion is considered, a value of 0.373 inch per year is found for this type of exposure. This value is higher than the value found from the measured areas and indicates that the erosion was much more severe in the areas where the holes appeared. These areas may have been located near the point where the waves broke most frequently. This value of 0.373 for the rate of loss when exposed to sand abrasion indicates that a ⅜-inch steel pile would be perforated in about one year if the sand line remained at the same level on both sides of the groin.

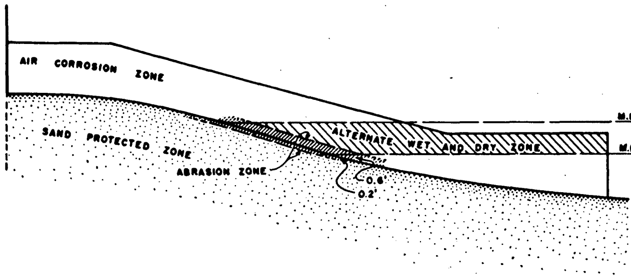

Figure 3—Conditions of groin exposure.

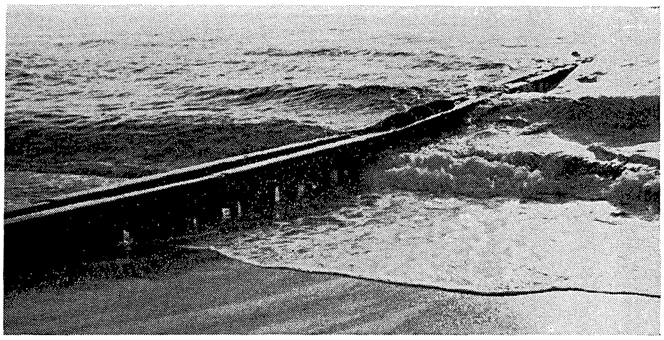

Figure 4—Holes at the sand line, Groin 139N after 5.3 years' exposure.

Discussion

There were other evidences of sand abrasion in addition to the high rate of loss of thickness. The steel frequently appeared bright and polished at the sand line. Paint had disappeared from the piles in bands parallel to the sand line within 3 months after the groins were built. Most of the paint was gone from the visible portion of the piles within 6 months after installation. The force of sand erosion also was observed in piles which developed large holes near the sand line while their steel tops retained almost their original thickness.

The low rate of loss of thickness of the steel under subsand exposure indicates that an abundant sand supply which would keep the groin covered most of the time would greatly extend the life of a groin. Groins, however, seldom will be built on beaches that are well supplied with sand, and in their function of retaining and accumulating sand will be exposed, at least in part, to the abrasive action of waves and sand.

The 2-inch timber sheathing which was placed over parts of groin 121-N gave good protection against abrasion as long as the sheathing remained in good condition. About nine years were required for the perforation of this groin, as compared with only four years for perforation of similar unsheathed groins. The time required for perforation might have been extended even more if the sheathing had been replaced after five years.

Groin 112-N differed from the others in that its piles contained 0.35 percent copper and were 0.547 inch thick instead of 0.375 inch. Here, holes first appeared in about 11 years. The longer period to perforation is believed to be chiefly a result of the greater thickness of the steel. The chance that the sand line will remain long enough in one place to perforate the groin is reduced by the greater thickness of the steel. The rates of loss of thickness at the measured areas were as high for this groin as for similar areas in other groins. Apparently the copper content did not improve the behavior of the steel.

Groin 131-N was built of straight section piles instead of arch section piles. It required 4.8 years for perforation instead of the 4.2 years required for perforation of groins built of arch section piles of the same thickness. It would appear, as might be expected, that abrasion was more intense on the arch section piles, inasmuch as they obstruct the flow of waves more than the straight section piles. However, the difference in the time required is not large enough to be very significant.

Conclusions

The rapid deterioration of the steel groins at Palm Beach was caused by the abrasive action of sand carried by the waves. Abrasion is most intense for an inch or two above the sand line but is spread over a wider area by changes in the position of the sand line. The abrasion removed the rust from the piles and permitted rapid corrosion of the exposed steel.

Groins built of ⅜-inch steel piles were perforated in 4.2 years, showing an average annual loss of thickness of 0.094 inch. However, during the period in which an area is subject to the abrasion of waves and sand, a yearly rate of loss as high as 0.373 inch is indicated. At this rate, a pile of ⅜-inch steel would be perforated in about one year, provided there was no change in the position of the sand line.

The rates of loss in steel thickness of the parts of the groin not exposed to sand abrasion are relatively moderate, being about 0.011 inch per year for atmospheric exposure, 0.005 inch per year for wetting-and-drying exposure, and 0.001 inch per year for subsand exposure. The time required for the perforation of

⅜-inch steel would be respectively 34 years, 75 years and 375 years.

Various paints and coatings used on the piles soon were removed by the waves and sand erosion and were therefore ineffective in protecting the steel.

A two-inch timber sheathing placed over the groin gave protection against abrasion as long as the sheathing remained in good condition, for about 5 years.

The use of steel piles with a thicker section may well give a longer life for the groin which is more than proportional to the added cost.

Holes appeared in two groins constructed of ⅜-inch arch section piles in 4.2 years; in a groin constructed of ⅜-inch straight section piles in 4.8 years; in a groin constructed of ⅜-inch arch section piles protected by wood sheathing in 9 years; and in a groin constructed of 0.547 inch straight section piles containing 0.35 percent copper in 11.1 years. It may be remembered, however, that these periods do not represent the life of the groins. They will continue to function as groins for a number of years after the appearance of the first holes with gradually decreasing efficiency.

This paper is a summary of "Experimental Steel Pile Groins, Palm Beach, Florida," Technical Memorandum No. 10, published by the Beach Erosion Board.

Technical Factors in Testing Pipe Line Coatings★

By D. E. STEARNS, M. W. BELSON* and ROBERT H. LEE**

OVER 100 YEARS ago in the book "Two Years Before The Mast," Dana wrote of the holyday." His reference was to the application of tar to the ship's rigging as a protection against the sea water. The term "holiday" has carried over to general use in the pipe line industry, retaining its original meaning, as a defect in the coating.

The many reasons for applying protective coating to underground steel pipe are so generally recognized that it is unnecessary to mention them here. The years of work and experience with pipe line coatings have greatly improved their protective value. However, in spite of the improvements in materials, machines and techniques of application, the holiday has continued to occur . . . to a lesser extent, of course, but they are still in there behind the coating gang.

Pipe line coating material must resist penetration by moisture, and must be electrically non-conductive in order to prevent flow of current between the pipe and the earth. The material must therefore be a dielectric, and its protective value is a function of its merit as a dielectric.

In the early days of pipe line coating applications inspection was purely visual, sometimes aided by use of a mirror to more readily observe the under side of the pipe. Since considerable current may flow through defects completely invisible to the eye, it became apparent that visual inspection was not adequate. One of the first attempts at electrical inspection was the use of a cloth soaked in salt water and connected to a battery through a milliammeter. The cloth was pulled over the surface of the coating. A change in reading of the milliammeter indicated a holiday somewhere under the cloth. The remaining problem was to find where. This, of course, was a slow, tedious job which was highly impractical. In the early 30's a Ford spark coil was used in conjunction with a wire brush or broom to sweep over the coating. This was followed by use of gasoline engine-driven generators and many adaptations of auto ignition systems. All of these methods depended on the sight or sound of the spark to indicate a holiday. The thoroughness of inspection depended entirely on the attention given the job by the operators of the inspection equipment. Today, detectors are available which give both a visible and audible signal to the inspector whenever a holiday is encountered. The latest equipment also incorporates other features in its design which are the result of many years of experience, research, and development.

The minimum voltage at which adequate inspection may be made is determined by the mechanics of applying the coating, and by the thickness of coating. As an example, a commonly used coating consists of enamel followed by one or more wraps of other materials, such as glass fibre, impregnated felt or the like, and kraft paper. The wrapping materials will have overlaps and may have occasional wrinkles. Thus, the total thickness of material placed on the pipe may be as much as 5/32 inch in random areas. The minimum inspection voltage should be that which will jump an air path equal to the distance through the thickest section of the coating. A voltage impressed across an insulating wrap consisting of several different materials will divide itself across

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