

mies above mentioned are taken into account. The metal paint costs from \$1.30 to \$1.62 per pound, and one pound suffices to give a good, rust-proof coating to nearly 100 square feet of surface.

Tests made at the government testing station show that the plating is of uniform thickness and quality and is not affected by sudden cooling from 104 to -31 deg. F. Experiments in stretching, bending, and twist-

ing tinned rods to the breaking point showed no scaling of the tin. The same negative result followed when tinned plates were pressed into concave molds.—Prometheus.

DREDGING ON THE PANAMA CANAL.*

A DESCRIPTION OF THE MACHINES USED.

BY F. B. MALTBY.

THE writer during a connection of about two and a half years with the Isthmian Canal Commission, most of which time was spent on the Isthmus, had charge of the design, construction, maintenance, and operation of the dredge plant employed, and intends to give a brief description of this machinery.

There are in use, or being built, four distinct types of dredges of entirely different characteristics: First, the old French ladder dredges; second, American dipper dredges; third, sea-going suction dredges; fourth, pipe-line suction dredges.

The so-called old French ladder dredges are those which the Americans fell heir to when the canal property was purchased from the French canal company. There were some 16 or 17 of these dredges, of the endless bucket type. They vary somewhat in detail, but are all of the same general construction. The digging apparatus consists of an endless chain of buckets holding about 14½ cubic feet each. This chain of buckets is carried by a box girder hinged at the top and of sufficient length to enable the dredge to work to a depth of about 30 feet. The buckets discharge into chutes leading over the side of the dredge and into barges alongside.

The chain of buckets is driven with a pair of steeple compound condensing engines, which are connected with the top tumbler wheel either through gearing or by friction wheels and large sprocket chains. Steam is supplied by Scotch marine boilers working under a pressure of 70 to 80 pounds. The hulls are of genuine wrought iron, not steel, and some of them were supplied originally with propelling machinery, but this has been taken off. The hauling and hoisting winches are simple but cumbersome and 1¼-inch chain is used for hoisting the ladder as well as for moving and maneuvering the dredge. No quarters were provided for the crews. These dredges were built either in Belgium or in Scotland. Some of them had been pretty well worn out and were of little value. Most of them were in a remarkably good state of preservation, although most of them had not been in use for at least eighteen years. The woodwork was entirely rotted away and required renewing throughout. The machinery had been carefully laid up and painted and had been well cared for. It required only cleaning up, packing of joints, and occasionally a rod needed truing up. The hulls, on account of being wrought iron, had corroded very little and were practically as good as new.

One of these old dredges was rebuilt at Cristobal and put into operation in May, 1905, and a second one was afterward rebuilt and repaired. The Panama Railroad Company was operating one at the Pacific terminus and it was turned over to the Canal Commission in June, 1905, and a second and third one have been rebuilt at that end.

These dredges of the non-propelling type have hulls of rectangular shape, about 114 feet long, 32 feet wide, and 12 feet deep. The engines operating the chain of buckets are of about 180 horse-power and are operated condensing. These dredges have no means for breaking up the material to be excavated other than the buckets themselves, and consequently their digging capacity or the ability to force the buckets into hard or compact material is not very great. For these reasons their capacity per day varies with the material to be excavated.

At La Boca, the Pacific terminus, there are two of these dredges in operation, working 24 hours per day and six days in the week. During the month of October, 1907, one of them removed 143,222 and the other one 143,885 cubic yards, an average of about 5,300 cubic yards per day. The maximum daily output in November was 6,907 yards and 7,556 yards respectively. The material handled is mud with a very considerable portion of sand, very easily excavated and handled with this type of dredge. During October, 1907, one of this same type of dredges removed 133,064 yards from the new channel in Limon Bay, or the Atlantic terminus. The reduced output below that of the dredges on the Pacific side is due to a greater seaway on the Atlantic side and also to the fact that

the mud encountered is softer, and while it is easier to excavate, it is so soft that it will not pile up in the buckets and more or less is lost during the passage of the buckets through the water. The capacity of these dredges excavating in coral rock is reduced by about one-half. The material excavated is taken out to sea and dumped into deep water, the length of haul varying from two to four miles.

The dredges are served by self-propelling hopper bottom dump barges, which are also a part of the old French equipment that has been rebuilt. These barges have a hopper capacity of about 225 cubic yards of mud, measured in place. They have steel hulls about 145 feet long and are driven by twin screws and compound condensing engines. The hopper doors are operated by hand winches.

The operation of these old dredges has been rather surprising and very satisfactory. Their machinery, though cumbersome, is very simple, and very little trouble has been experienced through break-downs. The buckets have cast steel backs with ¾ or ⅞ steel fronts and bottoms riveted to them. They have an extra cutting tip or edge of 1-inch steel. The eyes in the links and bucket backs forming the chain are bushed with steel and have steel pins. These bushings and pins wear very rapidly, but their renewal is a very simple and inexpensive matter.

The bearings for the lower tumbler wheel, which are constantly working in sand and grit, also wear very rapidly; the journal boxes are of cast steel and made solid and without any provision for taking up wear. They are usually allowed to run till the boxes are nearly or quite worn through on the bottom.

The cost of handling material with these dredges, including the cost of operation, superintendence, all running repairs, and the cost of operating the barges, is between nine and ten cents per yard, though monthly costs have gone as low as five cents per yard. This cost does not include any proportion of first cost or depreciation or the first cost of extensive rebuilding.

It is evident that for excavating soft material to a moderate depth this type of dredge has certain advantages that are not appreciated in this country. They are very similar to the gold dredges that have been so extensively and successfully used throughout the West.

The second type of dredge in use is the dipper dredge. This is strictly an American type of dredge and was originated and has been used in this country to a greater extent than any other type in use. They can be briefly described as a steam shovel gone to sea, as they have all the characteristics of a steam shovel with the parts made usually much heavier and with a radius of action greater than a steam shovel. Three of this type of dredge have been built and are in operation on the canal, one on the Pacific side and two on the Atlantic side. Two of them were built by the Atlantic Gulf & Pacific Dredge Company, after designs made by A. S. Robinson, and the other one by the Featherstone Foundry and Machine Company. All three are of the same size and general construction. Steel has been used throughout, except in the spuds and dipper handle, which are of wood, the latter lined with steel angles and plates.

They have steel hulls 110 feet long, 37 feet wide, and 9½ feet deep, and are proportioned to excavate to a depth of 40 feet of water. They have dippers with a capacity of 5 cubic yards for excavating in sand or mud and have extra dippers of 3 cubic yards capacity and fitted with very heavy manganese steel teeth, to be used for continuous operation in rock.

The main engines operate the hoisting and backing drums and also the drums for handling the spuds, while the swinging is done with an independent engine. They are equipped with independent capstan engines and electric light plants. Steam is supplied by Scotch marine boilers at a working pressure of 150 pounds. The booms are of very heavy construction and about 52 feet long and are carried directly on the turntable without any overhead gallows frames. The spuds are of Oregon fir, 60 feet long. On two of the dredges these are single sticks 36 inches square, while on one of them the spuds are built up and are 42 inches square. The main hoisting lines are crucible steel cables leading direct to the dipper without the

intervention of any purchase blocks, and all sheaves over which the line passes are 6 feet diameter. On two dredges two cables, each 1½ inches and laid side by side, are used, while on the other one a single cable 2¼ inch diameter is used.

The engines, gearing, and drums are proportioned to give a pull on the hoisting line of about 90,000 pounds. These dredges were built under general plans and specifications prepared by the writer, the details being left to the builders.

The principal advantage of this type of dredge lies in its ability to dig in hard material. It has been found quite possible to excavate coral rock without blasting, though the progress of the work is expedited by a small amount of shooting to loosen up the ledges and to permit the dipper to get a better hold on the rock. A somewhat smaller crew is required than on a ladder dredge, though the operator must be a much higher paid man, as the capacity of the machine in any given material depends almost entirely on the ability of the operator to keep it in constant and rapid operation.

Owing to some mechanical defects the operation of these dredges has not been as entirely satisfactory as was hoped, though I understand that these have been remedied to a very large extent. They cost about \$102,000 apiece delivered on the Isthmus. During twenty days in the month of October, 1907, one of these dredges removed 70,000 cubic yards from the channel at the Pacific terminus, while the maximum daily output in November was 4,456 cubic yards.

The third type of dredge, and possibly the most important, owing to their size and cost, in use on the canal is the sea-going suction dredge. Two of this type have been built, one for each terminus, and one of them has been in operation at Colon since September, 1907. The second one, the "Culebra," reached La Boca under her own steam December 28, 1907, after a voyage of about 12,000 miles, much of it through heavy weather.

These dredges are designed to operate in the harbor entrances to the canal and are therefore built self-contained and are able to work in a considerable seaway. In general design they are very similar to the dredges "Manhattan" and "Atlantic," used in excavating the new Ambrose channel to New York harbor, and to the dredge "Delaware," in use in the Delaware River. They differ from these dredges in the detail of their dredging machinery and also in their equipment and arrangement of quarters.

Their hulls are of steel, 274 feet long between perpendiculars and 288 feet long over all, with molded beam of 47½ feet and depth of 25 feet. The hull framing is made in accordance with the rules of the American Bureau of Shipping for vessels of class A1. They have twin screws and are propelled by compound condensing engines 22 x 44 x 30-inch stroke.

The dredging machinery consists of two 20-inch single suction centrifugal pumps direct connected to compound condensing engines running at from 160 to 170 revolutions per minute, and at these speeds developing from 440 to 460 I.H.P.

The centrifugal pumps are located on each side of the ship a little aft of amidships. They have inclosed cast-steel runners about 72 inches diameter with six blades about 19 inches wide. The suction from each pump passes through the side of the ship a little below the loaded waterline and is joined to the suction pipe through a swivel elbow. The suction pipe is 20¼ inches inside diameter, ¾ inch thick, and the sections are joined together by forged steel flanges welded onto the pipe. These flanges and the welded point have a greater strength than the pipe itself. The suction pipe is about 63 feet long over the suction shoe and the dredge can excavate to a depth of 40 feet of water. The pumps discharge into sand bins having a nominal capacity of about 2,000 yards. Steam is supplied by four Scotch marine boilers 14 feet diameter, 12 feet long, under a working pressure of 150 pounds.

The dredges are equipped with the usual condensers, pumps, and auxiliary machinery, and in addition have electric lights, evaporators, and a complete ice-making and refrigerating plant.

*From a paper read before the Engineers' Club of Philadelphia.

The dredges are entirely self-contained and are able to operate for a week or more with the coal and stores which they will carry.

Quarters are provided for a crew of about 57 men. The details of the dredging machinery, sand-bins, and arrangement of quarters, etc., were designed by the writer, while the general construction follows that of the dredges previously mentioned. They were built by the Maryland Steel Company at Sparrows Point, Md., and cost about \$724,000 for the two.

The operation of the one now in commission has been most satisfactory, and there is every reason to believe that the second one will be equally as successful. On their tests they handled from 1,600 to 1,700 yards of sand and mud per hour.

The centrifugal sand pumps carried a vacuum on their suction side of from 26 to 28 inches. Their nominal capacity is about 2,000 yards per hour in clean sand or sand with only a small portion of mud.

The trip from Sparrows Point to Colon, a distance of 1,906 miles, was made in eight days and nine hours, including about half a day that she was hove to on account of a storm, or an average of $9\frac{1}{2}$ knots per hour.

The dredge is operated for 24 hours per day for five and a half days per week, Saturday afternoon being used for coaling and taking aboard stores.

During the month of September, with a green crew and new machinery, 266,000 yards measured in place was excavated in the harbor of Colon; in October 273,500 yards, and in November 304,000 yards.

The material is mud and does not readily settle in the bins, though it is readily excavated. By actual measurement it has been found that the pumps have handled as high as 37 per cent of solid material. The length of haul to the dumping ground is two to three miles. In commenting on the work of the dredge during September the Canal Record estimated that the excavation and disposition of the same amount of material from Culebra cut would have required the work of 14 steam shovels, 30 locomotives and work trains, and about 1,500 men. The crew of the dredge consists of 57 men.

The fourth type of dredge to be used in the canal is the pipe line suction dredge, or a suction dredge which deposits on shore, through a pipe line, the excavated material. The French company had several small dredges of this type, used for rehandling material, but they were never very successful in operation on account of the design of the pumps.

These pumps had suction and discharge pipes 16 inches diameter. The pump runner was about 24 inches diameter and had blades about 4 inches wide. These proportions will perhaps be better appreciated by comparing them with a pump for the same sized discharge pipe which was put on one of these dredges which had a runner 69 inches diameter with blades 11 inches wide inside the shroud.

One of these small dredges was rebuilt and a pump of the size just mentioned put on it. This dredge has been used in filling material into the low ground adjacent to Colon and in opening a channel in the old canal between Cristobal and Gatun, portions of which had filled up. The material from the channel was pumped ashore.

It is proposed to build the great Gatun dam by the hydraulic method or by pumping the material into place. The hydraulic method of dam construction is not new and has been extensively used in the West, but usually in localities where flowing water with a source at sufficient elevation is available for transporting the material. It should, however, make no difference in the success of construction of this nature whether the water is secured from mountains under a sufficient head to give the necessary velocity for transportation or this velocity is given by pumps. For this purpose two dredges are being built, which will first borrow as much material as can be had within reasonable distance of the dam, and will then re-handle and pump into the dam material excavated from the canal and brought to the site in dump barges.

These dredges are of steel, 135 feet long by 36 feet wide and 9 feet deep. They have a single 20-inch pump with double suction, driven by a pair of tandem compound condensing engines developing about 450 I.H.P. The suction pipe is provided with a cutter driven by an independent engine. The cutter and supporting frame are very heavily built and braced and designed for excavating very stiff clay. The discharge pipe is carried on floating pontoons to the shore line and from there to the point of discharge is laid on the ground.

It is not expected that it will be possible or advisable to pump material into the dam and up to the full height with a single pump. It has been found that about 75 feet head against a sand pump is about the economic limit, as beyond that the necessary peripheral velocity of the pump runner becomes so high that the wear is abnormal. By "head" is meant the total head against which the pump is operating, and will consist of friction in the pipe, velocity head, and the actual lift or static head.

When the head has reached the maximum economic limit it is proposed to use a relay pump. This will be a pump similar to the one on the dredge, but motor driven, and will thus not require any steam plant or foundation, and but little attendance. It will be placed at the end of the discharge pipe, which will lead directly into the suction side of the pump. Its discharge pipe can be extended till the head on the second pump has reached the same limit, when another pump can be added, and this repeated as often as necessary.

It is, however, improbable that more than two pumps on one line will be needed. These dredges have not been completed and are not in operation. Two of them are also being built for the construction of the dams at the Pacific end of the canal, as proposed by the Board of Consulting Engineers. The Canal Commission has just recommended the construction of locks at Miraflores instead of La Boca, which will obviate the necessity of dams near La Boca, but will necessitate the excavation of several miles of sea-level canal, for which work these dredges are admirably suited.

As tending to show the relative capacity of the dredging plant I have described, I will refer to the amount of excavation during the month of November, 1907. During this period the three ladder dredges, three dipper dredges, and one sea-going suction dredge excavated and removed 792,000 yards, while the total amount removed by steam shovels from the Culebra division was 788,000 yards, or the seven dredges removed 4,000 yards more than 42 shovels. Of the total amount dredged, 304,000 yards was taken out by the dredge "Ancon," which is at the rate of nearly 600 yards per hour for every working hour she was in commission during the month. The average amount excavated per day of eight hours per shovel is 784 yards, or 98 yards per hour.

It is realized that it would be impossible for the dredges to do the work performed by the steam shovels, but it is equally true that the steam shovels cannot do dredging work.

There is no desire to detract in any way from the work of the steam shovels, but I wish to emphasize the fact that they constitute only a part of the equipment for excavating the canal.

WHY CONCRETE SHOULD BE WATERPROOFED.

THE fact that ordinary concrete is very porous and permeable has been one of the leading checks in its rapid development. Volumes have been written on how the ingredients might be mixed to produce a watertight concrete, but we might as well seek to solve the problem of perpetual motion as to try to mix cement, sand, and stone so as not to absorb water, says Myron H. Lewis, C.E., in a recent issue of Waterproofing. All the experiments that have been made and all the papers that have been written have only served to emphasize the fact that ordinary concrete is porous, and when dry will drink in water with avidity. And why should it not do so? Can ever-changing ingredients be so proportioned that every minute void in the hardened mass is filled?—so that the concrete becomes a solid, impervious body? No; in the act of mixing, enough air clings to the materials to render the mass full of innumerable minute blow holes; minute to us but not so to the still finer, freely moving molecules of water, which, with infinite patience, look for an opportunity to move and do so, if the movement is in the slightest degree possible. If we could examine a section of concrete under a powerful microscope, it would appear to us like an immense sieve through which fine particles of water flow without hindrance.

We have seen water rise up through concrete walls for many feet, and it will rise until the weight of the water absorbed is equal to the attracting force.

We have often heard the statement made that concrete is water-tight, and frequently it comes from those who should know better. It is often stated that if concrete is mixed rich, and mixed wet, impermeability can be secured. Both of these statements are against the very logic of things. Mixing rich may impose some greater barriers to the passage of water; mixing wet may minimize the formation of blowholes by displacing much of the extrained air, but neither mixing rich nor mixing wet destroys the "capillary positive" property of the concrete mass. Its absorptive capacity may have been decreased, but its attraction for moisture has not been eliminated; thus the water tightness secured by rich and wet mixtures, however theoretically correct the proportions might be, is one of degree only, a degree sometimes approaching ideal but never reaching it. We cannot expect that a mixture made of cement and stone, each of which is in itself "capillary positive" or water attracting, can become absolutely proof against the passage of water by the mere act of mixing, unless, indeed, the operation had produced some phenomenal change in the very nature of the constituent materials. A mixture may be produced which is sufficiently close-

grained to prevent the free transmission of water, prevent it sufficiently, in fact, to be all that is required in many forms of construction work. But where water absorption, besides water penetration, is to be prevented, no degree of mixing, no richness of mixture, will altogether answer the purpose; and yet in many of the forms in which concrete enters our modern buildings, it is resistance to water absorption that is required. Not merely water-tightness in the ordinary sense of the word, but resistance to the ceaseless endeavors of atmospheric moisture to find its way by capillarity through porous bodies. Some counteracting influence to this tendency of ordinary concrete to take up water by capillarity is, therefore, what is required, particularly in superstructural work.

It is true that concrete exposed to the free passage of water becomes after a time so clogged up by the fine silt present in the water that the permeability is greatly reduced; and Hagloch states that concrete block buildings exposed to the weather become water-tight in from three to twelve years, a fact which we must likewise ascribe to the clogging of the surface of the blocks by atmospheric dust deposited by rain, and which remains after evaporation.

Modern engineering or architectural practice should certainly not sanction a practice of waiting for the erratic and uncertain hand of time to secure water-tightness in concrete structures, and in the meantime to incur the annoying consequences that always accompany damp and leaky structures; and yet this is precisely what is being done in numberless instances by those who refuse to realize the importance of water-tightness in concrete work, or, while realizing it, are willing, through motives of false economy, to gamble with the future—nearly always at their loss.

The number of mistakes made by inadequate provision for waterproofing, and their costly consequences, running into millions of dollars, should serve as object lessons to those who have the design of concrete work in hand; object lessons which should serve to prevent repetition of mistakes made by less fortunate predecessors.

The subject of waterproofing concrete could not be justly treated without some mention of the difficulties to be apprehended by the failure to obtain water-tightness; difficulties which would seem to be obvious, but which, as we have already said, are so often lost sight of.

Concrete blocks are usually made very porous, and have an intense affinity for water. Buildings therefore built of untreated blocks are damp, cheerless, and cold, and bring with them the discomforts and dangers to health that usually accompany damp buildings. Perhaps the only exception is the independent two-wall system with unbroken air spaces throughout. Plaster can never be safely applied upon their inner surface without furring and lathing. Furthermore, the faces of the blocks are soon disfigured by the deposit of soluble salts of efflorescence washed out from the cement. Some method of protecting the interior plaster from destruction by dampness becomes a necessity, otherwise the structure, instead of being a pleasure to the owner, becomes an eyesore. In addition to the unsanitary condition and the accompanying disfigurement, there is also the question of durability to consider. Any material that absorbs large quantities of water is subject to enormous strains when freezing occurs, and is liable to be destroyed in the course of years.

In reinforced concrete work, particularly in the superstructure of buildings, all the above objectionable conditions resulting from lack of water-tightness apply equally, and in addition we have the danger of corrosion of the imbedded metal. Ample experience seems to indicate that metal thoroughly incased in concrete is protected from corrosion by the latter, provided that water in sufficient quantity cannot work its way to the metal and begin corrosion. Concrete work, however, is subject to checking and cracking from a multitude of uncontrollable causes, and should through any such means rusting be made possible, its progress cannot very well be checked. Rusting, which is the conversion of the metal into its oxide, is accompanied by expansion, which produces enormous strains in the incasing material, strains akin to that produced by water in freezing.

K. V. Charitschkow has obtained by the destructive distillation of a Russian asphaltum, a liquid product which on distillation, yielded up to 150 deg. C. a fraction similar to Grosny benzine. From a Roumanian asphaltum, which on extraction in a Soxhlet apparatus, yielded 48.98 per cent of bitumen, there were obtained on destructive distillation: water, 4.76; oil, 4.44; and residue, 79.20 per cent. The residue contained 36.06 per cent of carbon and 63.94 per cent of mineral matter. On distillation the oil yielded 13.20 per cent up to 200 deg. C. and 68.37 per cent of residue similar to that obtained from petroleum. In the experimenter's opinion both asphaltum and crude petroleum are formed directly from acetylene and hydrogen.