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THE NEW GRAVING DOCK OF THE KAWASAKI DOCK YARD CO. AT KOBE, JAPAN.

By Dr. Genjiro Yamasaki.*

The Kawasaki Dockyard is situated near the mouth of the old Minatogawa in Kobe, which is at present the greatest trading port of Japan. While the dockyard was owned by Government, the need of a dry dock had already been felt, and several efforts had been made to select a proper site for one, but owning to the bad nature of ground along the general coast line of Kobe, the task of building such a structure was given up as an impossible achievement. The result was the construction of a patent slip in the dockyard which accommodated vessels up to 2,000 tons and which is still in good working order. A few years after, viz., in 1886, this dockyard was given over to Mr. Shozo Kawasaki, who still maintains an active interest in its welfare.

Owing to the sudden increase of trade in Kobe from about the year 1893 and to the consequent increase of large vessels frequenting the port, a dry dock became an urgent necessity to meet the requirements of these vessels. Investigation into the subject was, therefore, again taken up, and after a careful study of the nature of the ground and the methods of dealing with it, it was finally decided to start the work. Just at this time, October, 1896, the dockyard, which had been Mr. Kawasaki's property for about ten years, was transferred to a joint stock company, which is the present Kawasaki Dockyard Co., Limited. The president of the company is Mr. Kojiro Matsukata, son of Count Matsukata, ex-Premier of Japan, and the vice-president is Mr. Yoshitaro Kawasaki, son of Mr. Shozo Kawasaki.

	Shaku.*
Extreme length, outer caisson stop to toe of wall at head	428.0
Length on the floor	392.0
Width of body at coping level (narrowest part)	79.8
Width of entrance at coping level	64.0
Width of entrance at bottom	52.0
Depth of sill below coping	28.0
Depth of sill below h. w. spring tide	24.0
Range of spring tide	5.5

*The shaku is almost equal to the English foot, it being equal to 0.9942-ft.; in this article "foot" is to be understood as "shaku."

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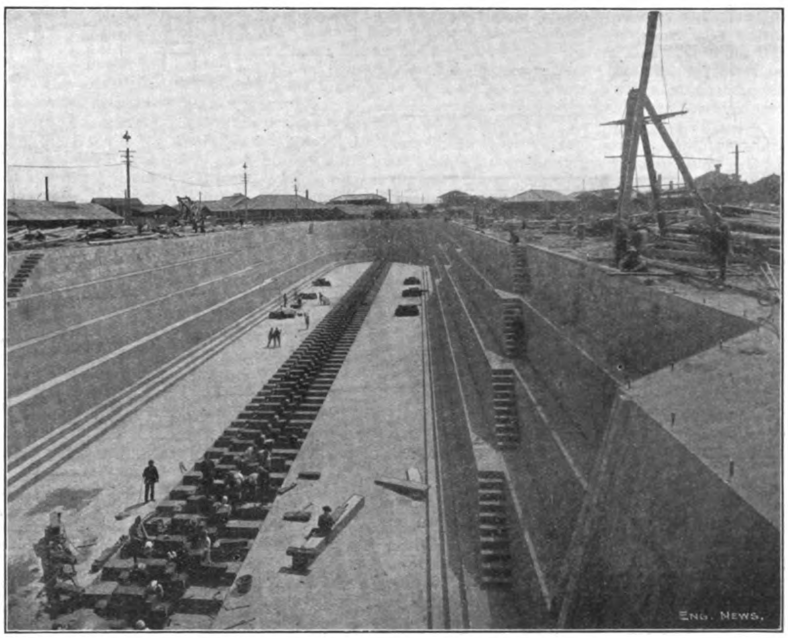
The work was begun in November, 1896, and the first vessel was docked in June, 1902, thus taking nearly five and a half years for its completion. The general dimensions of the dock are given in the preceding table.

The dock accommodates vessels up to 5,000 tons; its capacity is equal to 20,760 tons at high water.

SITE.—The first idea was to build the dock in the northern corner of the yard, but after considering the arrangement of workshops, building slips, etc., it was decided to select the southeastern corner for its site. The area of the site thus chosen being too small for the dock, necessary space had to be obtained by reclaiming the foreshore. The line X Y in Fig. 1 shows the original coast line. As the easterly wind is the one to be most feared, the direction of the center line of the dock was turned as far north as possible, and that of the finished dock is north 46° 50′ east.



NEW DRY-DOCK OF THE KAWASAKI DOCKYARD CO. AT KOBE, JAPAN.
Dr. Genjiro Yamasaki, Chief Engineer

GEOLOGICAL NATURE OF GROUND.—Two borings on land, two borings on the fore-shore, and one test pit near the coast were driven to ascertain the geological nature of the ground. Altogether there is a slight inclination of the strata towards the sea, their general arrangements are:

From h.-w. spring tide (0) to — 20 ft.	Sand.
From — 20 to — 45 ft.	Silt.
From — 45 " — 51 "	Silt mixed with sand.
From — 51 " — 52 "	Broken granite.
From — 52 " — 73 "	Compact sand charged with water.

This — 73 ft. was the greatest depth ascertained by the borings, as the lower strata were fairly well known from the experience which Japanese artesian well borers had obtained while driving wells in the vicinity of the yard. According to their information, this sand stratum extends as far down as — 90 ft.; then follows another layer of silt about 33 ft. in depth to — 123 ft. below which there is another layer of compact sand. The depth of this sand stratum is not known, but it is certain that it extends as far as — 168 ft., the lowest limit ever reached in the vicinity of the site.

The silt layer, which lies below the uppermost sand stratum on land, forms the sea bottom on the sea part This silt bottom was so soft that, while the boring was being done in front of the shore subsequently reclaimed, a boring rod, accidentally dropped, sank about 12 ft. by its own weight, and later, while constructing the cofferdam in this part, great trouble was experienced owing to the sliding in of the trench made for the puddle.

The test pit, sunk near the seashore, was 5 ft. in diameter and its wall was made of wooden planks strengthened inside and outside with angle irons and iron bands. When its lower extremity reached — 40 ft., or it was sunk about 18 ft. into the silt, the inside of the pit was dried up, and a wooden pile was driven. When the lower end of this pile was down to — 53 ft., water, which found its way along the pile, appeared, and it rose so fast in the pit that it was filled with water from — 26 ft. to within 9 ft. of its top edge (+ 1 ft.), or 18 ft. in 50 minutes, or at the rate of about 12 tons per hour. This water, which exists in the stratum of the compact sand, has a sufficient head to raise itself up to nearly high water level. It is a mixture of salt and fresh water and its level fluctuates in concord with the rise and fall of the tide on the outside sea. These facts show that it has a connection with the sea water in some way or other.

COFFERDAM.—The geological nature of the ground being as above described, it was thought almost impossible to execute the work in the dry, but as the first step for the work it was decided to enclose the dock-site with a cofferdam, whose total length was 1,540 ft. (Fig. 1), and to adopt a pile foundation, beginning from one end and proceeding little by little and finishing the concrete bottom as the work went on. The puddle on the dam reached — 38 ft. on the reclaimed part and 24 ft. on the land part. On completion of the dam, which took place about a year after its commencement, when the water inside was pumped out to — 12 ft., a sinking of one section of the dam occurred, while, at the same time, a part of the bottom of the enclosed site was forced up above water and formed a small island, so to speak.

EXCAVATION AND WELL SINKING.—Such being the case, it was almost impossible to proceed with the original plan of working even if repairs were made to the dam, and it was decided to execute the excavation, piling, concreting, etc., all under water. As the first step in this task, 15 cylinders, each 12 ft. in diameter, were sunk; seven in front of the entrance, three along the north entrance side wall and five along the south entrance side wall. Those sunk in front of the entrance, were taken off (two of them partially) to form the entrance after the completion of the dock. Subsequently a row of six cylinders, each 10 ft. in diameter, were sunk in front of the row of seven cylinders, and the space between these two rows of cylinders was partly filled with concrete (to — 20 ft.) and partly with puddle to serve the purpose of a dam when the inside of the dock was pumped out for the facing. Eight cylinders, sunk along the side walls, were embedded in the concrete and formed a part of the wall. The space along the dock head, being very much limited owing to the public road, seven more cylinders were sunk along the head to serve the purpose of retaining earth. The depths to which these cylinders were sunk were — 49 ft. to — 53 ft. for the entrance part and — 48 ft. to — 49 ft. for the head part.

The cylinders were of composite construction of wood and brick, the lower 24 ft. (18 ft. in 10-ft. cylinders) being made of wood, and the upper 24 to 29 ft. of brick. They were all filled with concrete after sinking was completed.

While the cylinder sinking was executed on one hand, excavation was carried on on the other, which was all done by a Priestman dredger and steam winches. The depth of the excavation was — 41 ft. along the center line, gradually rising to — 38 ft. at the sides; where the pumping chamber and rudder well came, they were excavated to — 43 ft. The section No. 1, Fig. 2, shows the form, when the excavation was completed; this section also shows the general arrangement of the geological strata.

PILE DRIVING.—After the excavation was finished, as the necessary preparation for pile driving, a temporary staging (Fig. 3) was erected all over the site, the posts of which were driven at a distance of 12½ ft. both ways. Beams and cross beams being fixed on these posts, rails were laid longitudinally, on top of which frames for supporting pile drivers ran. Rails being laid on the upper face of these frames, pile drivers were able to move tranversely; thus pile drivers could be moved both longitudinally and transversely with respect to the dock. Nine drivers were used, and for their working 11 steam winches were set along the north side of the dock site.

The lengths of the piles ranged from 22 ft. to 25 ft., though at special places piles of over 30 ft. were used, and their diameter at the smaller end was 8½ ins. They were driven 2½ ft. c. to c. both ways. In addition, close piles of similar size were driven all round the site to provide against the escape of silt. They were all of pine and the total number of both foundation and close piles was a little over 10,000.

The rails on top of the staging being laid just at about high water level and the lengths of the piles being such as above stated, it became necessary to use false piles for driving, which were 38 to 41 ft. in length. Where timber is abundant such an awkward procedure of using false piles might not have been adopted; but here long piles are comparatively scarce and consequently dear, which condition led to the adoption of the method above mentioned. Of course, the use of false piles gave great trouble in driving, both from frequent breakage of the piles themselves and from their connections. The weights of the hammers used were from 1,700 to 1,900 lbs., and their fall was generally fixed at 10 ft., and the final penetration ranged from ⅛ to ⅜-in. The total average of number of piles driven per day per driver was 7.9; the minimum being 1, when men were not accustomed at the beginning, and the maximum 15.

Although extreme care was taken in driving piles, it was rather difficult to judge of their bearing power, especially as they were driven with the use of false piles, and it was thought prudent to appeal to the direct trial. Such trials were made at two random places by loading 100 tons—necessary reduction being made for the buoyancy—of pig iron on top of a wooden frame which stood on four piles. But although each pile had to bear 25 tons net, there was no appreciable settlement in any one of the piles at these places, while the maximum calculated load the piles would have to bear was 11 tons. The section No. 2, Fig. 2, shows the staging, frames, drivers, etc.

RUBBLE PACKING.—After the piles were driven, their heads were cut off and rubble stone was thrown in between them to the average thickness of 3 ft., leaving 1 to 1½ ft. of pile heads projecting above the rubble to be subsequently covered with concrete. When the rubble was well rammed in between piles with men on boats and with the aid of divers, it was found that soft silt oozed through the interstices of the rubble and settled on the top of it. This silt was so soft that it could not be removed with any kind of vessel, and it had to be sucked up with the aid of centrifugal pumps. Thus the ground was ready for concreting. The section No. 3, Fig. 2 shows the form at this stage of the work.

CONCRETE DEPOSITION UNDER WATER.—The injurious effect of sea water on cement concrete is now well known among engineers here. As concrete was to be deposited in its most unfavorable condition, namely, directly after its preparation, it was decided to change the water inside the dam to fresh water. Although the volume of water present in the dock site at that time was calculated at 80,000 tons, as it must be done gradually, over 310,000 tons of water from Kobe waterworks was required for this interchange of sea and fresh water, the latter entering from the surface, and the former being pumped out from the bottom, together with the scum produced by an unavoidable washing of mortar. The proportion of salt to fresh water was ascertained from time to time by analyzing water taken from

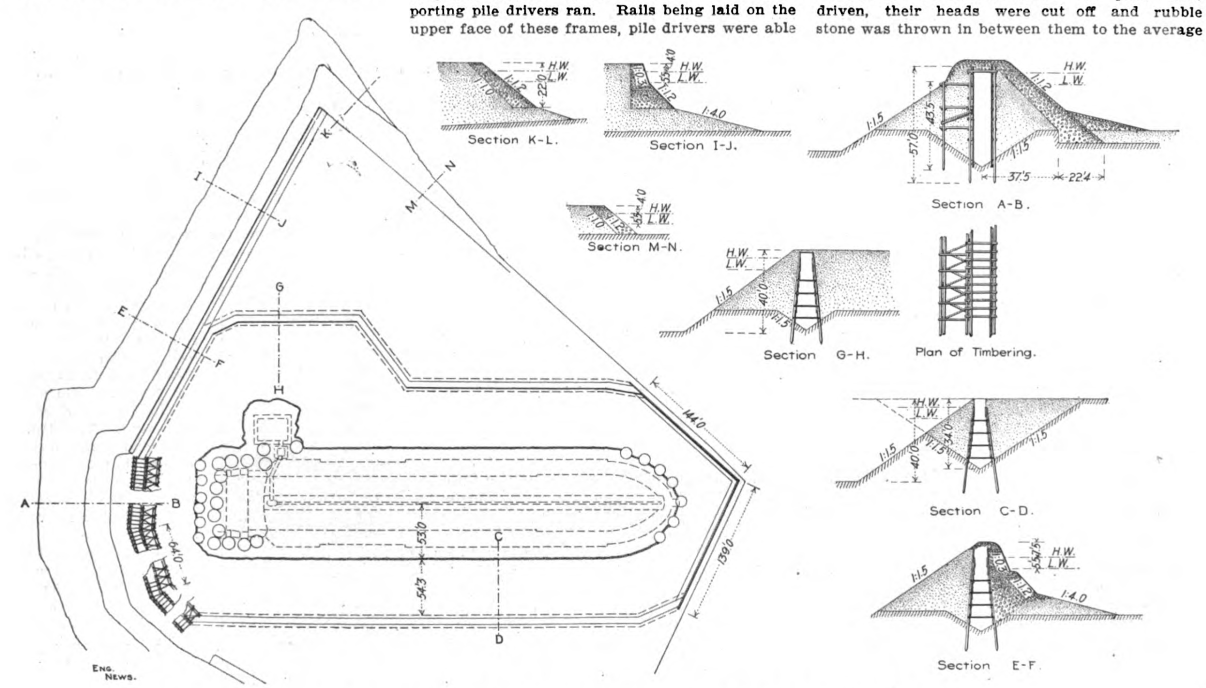
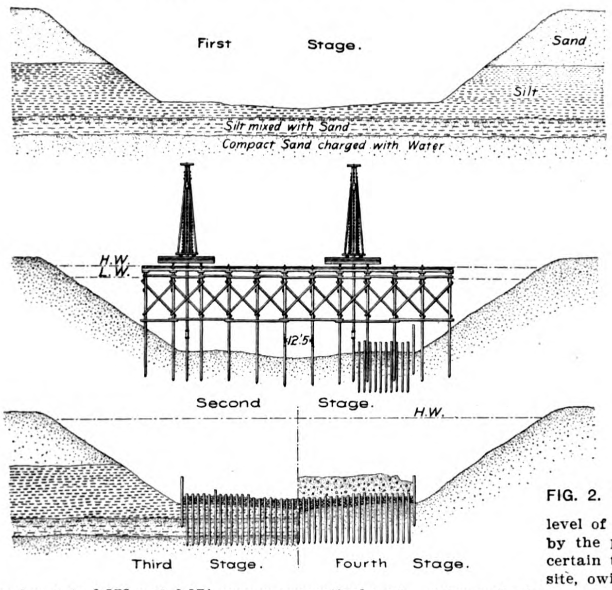


FIG. 1. PLAN OF SITE OF DRY-DOCK AT KOBE, JAPAN, SHOWING DETAILS OF COFFERDAM CONSTRUCTION.

the surface, middle and bottom at three places, and by finding out the quantities of chlorine and sulphuric acid it contained. The quantities of chlorine and sulphuric acid was 16.869 and 1.924 grams per liter at the commencement, but was



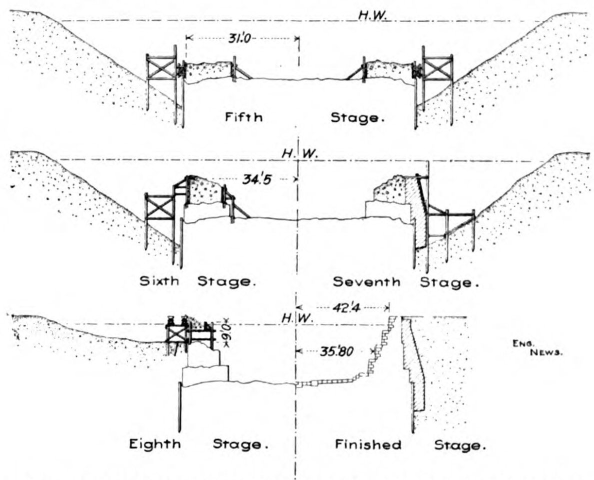


FIG. 2. DIAGRAM SECTIONS SHOWING SUCCESSIVE STAGES OF THE WORK.

reduced to 0.352 and 0.071 grams, respectively, at the end. The charging of fresh water gave also the advantage of maintaining the water level inside the dock site, so as not to injure the concrete in its imperfect state of hardening.

The deposition of concrete under water was started from the entrance side in the whole width of the dock bottom and to an average depth of 9 ft., which depth was previously ascertained by experiments. This deposition was accomplished by skips and cranes set on two pontoons, each carrying two hand cranes, men standing on the boats and on banks giving necessary directions as to the proper positions where skips were to be lowered. The skips were made of iron and had a capacity of 32 cu. ft. They were provided with canvas covering to minimize the washing of mortar during the sinking.

In order to secure the best possible union between the concrete, the work was pushed day and night without interruption. The divers were not allowed to disturb unset concrete and pumps were employed to take off the scum produced by unavoidable washing of mortar. The proportion of concrete for the bottom was 1 part mortar to 1 part gravel, and the mortar consisted of 1 part cement, 1 part puzzuolana, 0.19 part lime and 3 parts sand. The concrete used for the side wall had the proportion of 1 part mortar to 1½ parts gravel, and the mortar consisted of 1½ parts cement, 1 part puzzuolana, 0.25 part of lime and 4 parts sand. The concrete was mixed by three Carey-Latham concrete mixers of 10 cu. yds. capacity, and the mortar was prepared by 20 mortar mills of 6 ft. 6 ins. diameter. The setting time of mortar to be actually used was constantly observed in the cement testing room by immersing mortar in the water taken from the dock site, and its beginning ranged from 8 to 10 hours in water. The utmost care was taken in deposition to join new concrete to old, before the latter began to set. Fig. 2, section No. 4, shows the form of the bottom as actually determined by soundings.

After the bottom concrete was all finished, the next step was the deposition for side walls, and before it was commenced all dirt was taken off from the bottom concrete surface, minor dirt, scum, etc., were blown off by jets, and necessary frames to confine concrete to the designed form were erected; these were all erected by divers.

Concrete for side walls was deposited in two layers of 7 ft. and 12 ft. deep, the same care being taken for deposition as for the bottom. Sections No. 5 and No. 6 show the form of concrete for side walls, and the necessary frames erected for its deposition. This brought up the top of the concrete to 8 ft.

Concreting under water was stopped at this level of 8 ft. below high water, as by the previous experience it was certain that water inside the dock site, owing to the existence of the outer cofferdam, with the sunken part repaired, could safely be lowered to at least 10 ft. below high water level.

English cement was mostly used, supplied as follows: J. B. White & Brothers, 3,731 tons; Knight, Bevan & Sturge, 2,798 tons; Mikawa Cement Co., 550 tons. The factory of the last-named company is in the Province of Mikawa, Japan.

Puzzuolana was got from one of the Goto Islands (not far from Nagasaki), in the Province of Hizen. Gravel and sand used were mostly obtained from the sea coasts in the vicinity of Kobe. The total quantity of concrete deposited under water was 27,200 cu. yds., and the greatest quantity lowered in a day (24 hours) was about

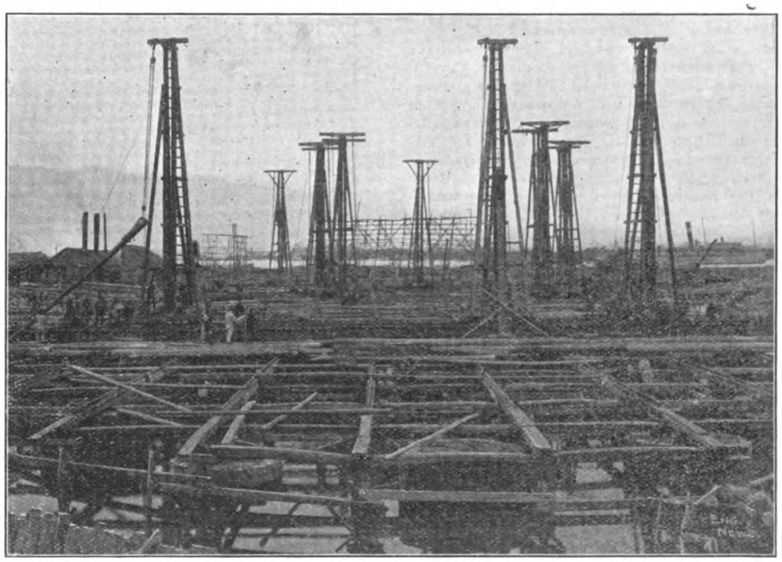


FIG. 3. VIEW SHOWING TEMPORARY STAGING AND PLANT FOR DRIVING FOUNDATION PILES.

640 cu. yds. The total number of men, divers, carpenters, engine drivers, coolies, etc., employed for this work only was 149,000, reduced to a day's work of 10 hours.

PUDDLE AND PARTIAL FILLING.—The next step taken was to put in clay puddle directly on the back of the side walls all around the dock. Previous to the laying, all the frames hitherto constructed at the back for the deposition of the concrete walls were taken off, and new frames were erected in their places to provide for the bulging out of the puddle. The puddle was prepared by two pugmills driven by steam engines. The prepared puddle from those mills was made to fall into skips (same skips used for concrete) on boats lying alongside the bank, and was lowered into its destined spots, necessary precautions being taken to insure a water-tight joint with natural bed of silt. The actual thickness of the puddle became much greater than the designed thickness of 6 ft., and in some special places it became even about 8 ft., owing to its bulging, in spite of the existence of frames to sustain it and precautions taken to fill in sand as soon as possible to counteract its pressure. The clay used for puddle was got from Awaji Island.

The back filling of sand was carried on together with the puddle laying, care being taken that the surface of the sand should always be below that of the puddle, lest sand should find its way through interstices of planking into the space for the puddle. Puddle and back filling were temporarily stopped when they reached nearly the same level as that of concrete deposited under trifugal pump is set up on it to give greater convenience for the removal of water ballast.

PUMPS.—The main pump is an electrically driven 30-in. centrifugal pump, the electricity being supplied from the main electrical station of the company. This is the first instance of the erection of a motor for this purpose in Japan. Besides this main pump, there are an 8-in. drainage pump and an air pump for starting the main pump, both of which are driven by electricity. This main pump has the capacity to raise 5,000 tons per hour and will lay dry the dock in about four hours. The pumps were those manufactured by the Lawrence Machine Co. and the motors were by the General Electric Co. All these were supplied by the American Trading Company. As there is no need of boilers, the pump house is very simple, its roof standing up only about 2.6 ft. above the ground level.

The dates at which the several works above described were commenced are:

First cofferdam	November,	1896
Excavation	November,	1896
Cylinder sinking	March,	1898
Piling	December,	1898
Concreting	April,	1900
Stone facing	July,	1901
The dock opened	June,	1902

The total cost of the work was 1,700,000 yen ($850,000).

The writer of this paper acted as Chief Engineer for the work, and his chief assistants were Samuru Maruta, M. E., and Jinzo Okamura. The drawing Fig. 6 shows the construction of the dock and the view on page 257 shows the completed structure.

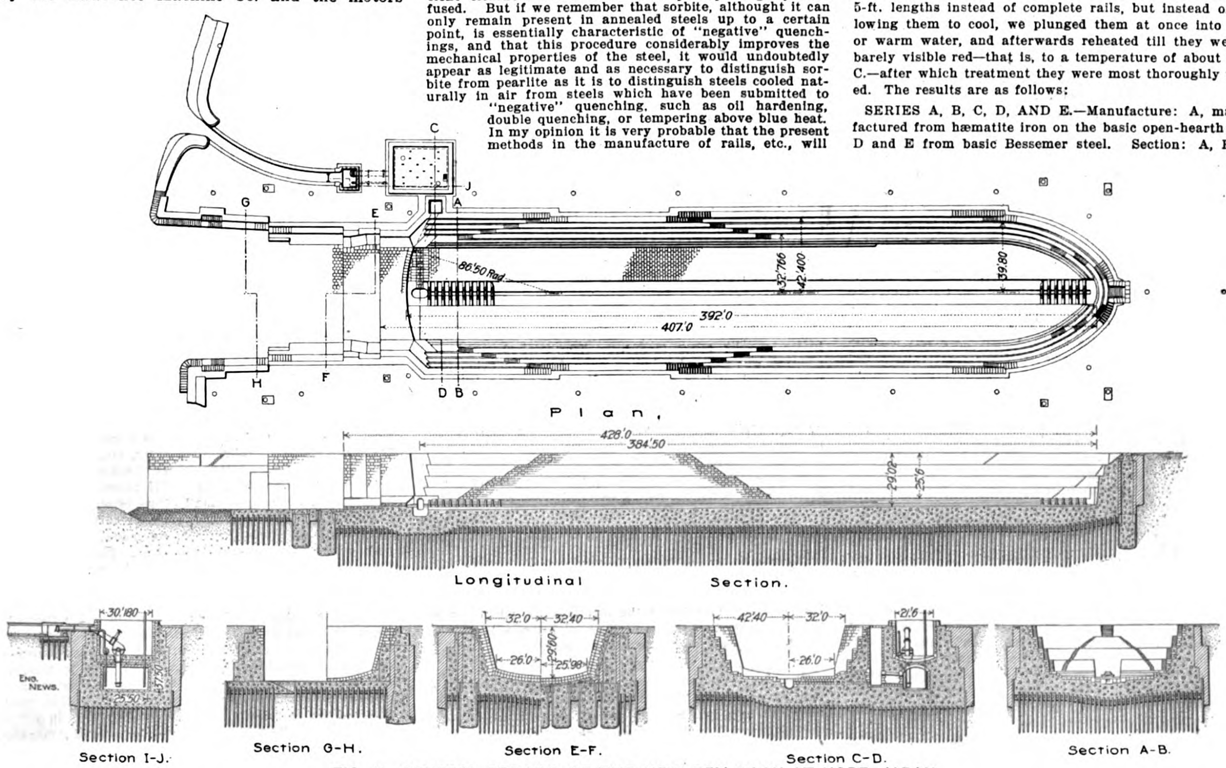


FIG. 6. GENERAL DETAILS OF THE NEW DRY-DOCK AT KOBE, JAPAN.

SORBITIC STEEL RAILS.*

By J. E. Stead, F. R. S.,† and Arthur W. Richards.‡

Exception has been taken by some that sorbite has not a sufficiently distinctive character to justify recognition of its individuality. It is pleaded that it is a transition condition of the carbide intermediate between the state in which it exists in hardened and annealed steels. It was Osmond who first used the term,* and his remarks introduced below show the ground on which he justified his conclusions:

From a physico-chemical point of view, there is not a great difference between pearlite and sorbite. But sorbite may be obtained side by side with pearlite by hastening the cooling without quenching, or by quenching a steel just at the end of the critical interval, or, again, by reheating a quenched steel to about the same critical interval. For all these reasons sorbite may be considered as pearlite which has not been able to separate into ferrite and cementite by reason of lack of time, or from some other cause, and it seems to be true that it ought to contain a little more "hardening" carbon than free pearlite.

It has been said that sorbite is an unimportant constituent, and several authors have not distinguished it from pearlite. I think this is wrong, and for this reason, that in the first edition of this work I did not give with sufficient clearness ideas which were perhaps slightly confused. But if we remember that sorbite, althought it can only remain present in annealed steels up to a certain point, is essentially characteristic of "negative" quenchings, and that this procedure considerably improves the mechanical properties of the steel, it would undoubtedly appear as legitimate and as necessary to distinguish sorbite from pearlite as it is to distinguish steels cooled naturally in air from steels which have been submitted to "negative" quenching, such as oil hardening, double quenching, or tempering above blue heat. In my opinion it is very probable that the present methods in the manufacture of rails, etc., will eventually appear primitive, and I hope that the greater quantity of pearlite in our steel will be replaced in future practice by sorbite.

From the point of view of micrography, sorbite is characterized by the absence of striæ, and by the property of coloring rapidly by polish-attack, or by tincture of iodine, even when the latter is diluted with its own volume of alcohol.

So distinctive are the properties which this particular condition, or variable condition of the carbides in iron and steel, confers on steel that for years it has been the practice of steel manufacturers, at considerable expense, to oil-quench heated steel in order to obtain increased toughness and strength, and for wire manufacturers to "patent" their wire rods to arrive at a similar result. It is the sorbite produced which confers greater tenacity and toughness to the steels.

DESCRIPTION OF EXPERIMENTS IN MAKING SORBITIC RAILS.

On most carefully studying the effect of oil quenching on steel, we found, as was naturally expected, that the proportion of sorbite is great or small according to the size of the mass quenched. The central portions of large masses after treating contain much less sorbite than the exterior portions. If, on the other hand, the section of the steel quenched is very light, one may readily have in addition to sorbite some of the more brittle constituents of steel.

Similarly, when steel is air hardened, it may contain practically no sorbite if the mass of steel is great, and much of it if the section is slight. For instance, a wire rod ¼-in. in diameter and a fine wire made from the same steel containing 0.70% carbon, when cooled in air from the same initial temperature, say 850° C., become, the first sorbitic and tough, whilst the second will be in an intensely hard or brittle condition. Steel wire rods after passing through the patenting process, which consists in heating to a temperature at which the steel "scales" and then cooling more or less rapidly through the critical points, contain large quantities of sorbite, readily detected by the microscope after etching, or by the comparatively dark color the whole surface assumes when etched side by side with the rod before patenting. The property of enabling the patented rod to be drawn to a much greater fineness than is possible in the unpatented material is undoubtedly the effect of the sorbite present.

We naturally concluded that if sorbite is responsible for the excellent qualities of oil-quenched steel and negatively quenched steel wire rods, there is no reason why it should not be produced in steel rails, tire, etc., without great expense. With this object in view we first experimented on 5-ft. lengths instead of complete rails, but instead of allowing them to cool, we plunged them at once into cold or warm water, and afterwards reheated till they were a barely visible red—that is, to a temperature of about 500° C.—after which treatment they were most thoroughly tested. The results are as follows:

SERIES A, B, C, D, AND E.—Manufacture: A, manufactured from hæmatite iron on the basic open-hearth; B, D and E from basic Bessemer steel. Section: A, B, D and E, 60 lbs. per yard flat bottom rail; C 85.5 lbs. per yard bull-head rail. Analysis as follows:

	A.	B.	C.	D.	E.
Carbon	0.29	0.31	0.40	0.45	0.48
Manganese	0.72	0.72	0.73	0.57	0.82
Silicon	0.02	0.03	0.03	0.04	0.06

TREATMENT OF THE RAILS OF EACH SERIES AFTER CUTTING AT THE HOT SAW.—A1. Normal; allowed to cool down in air; A2. Quenched in hot water; reheated to 550° C., (16 mins.), and allowed to cool down in air; A3. Quenched in hot water; reheated to 500° C. (12 mins.), and allowed to cool down in air. B1. Normal; allowed to cool down in air. B2. Quenched in boiling water; reheated to 650° C. (30 mins.), and allowed to cool down in air. C1. Normal; allowed to cool down in air; C2. Quenched in hot water; reheated to 550° C. (40 mins.), and allowed to cool down in air. D1. Normal; allowed to cool down in air; D2. Quenched in cold water; reheated to 550° C. (50 mins.), and allowed to cool down in air; D3. Quenched in warm water; reheated to 500° C. (30 mins.), and allowed to cool down in air; D4. Quenched in hot water; reheated to 450° C. (30 mins.), and allowed to cool down in air. E1. Normal; allowed to cool down in air; E2. Quenched in hot water; reheated to 550° C. (40 mins), and allowed to cool down in air; E3. Quenched in hot water; reheated to 500° C. (25 mins.), and allowed to cool down in air; E4. Quenched in boiling water; reheated to 450° C. (40 mins.), and allowed to cool down in air.

The results of the mechanical tests were as shown by the table at the top of page 262.

In testing by Brinell's methods a number of impressions were made on each rail, and the results obtained were averaged, giving the hardness numbers stated in the table.

These results were so satisfactory that we proceeded with further trials, with the object of avoiding the reheating. As in the previous experiments, we used 5-ft. lengths of hot rails, but this time we plunged them into

*Abstract of a paper read before the Iron and Steel Institute of Great Britain.
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*See "Metallography," by F. Osmond. London: C. Griffin & Sons, Ltd., 1903.

water. This stage of the work is shown in Section No. 7, Fig. 2.

PUMPING, CONCRETING AND TEMPORARY LOADING.—The interior of the concrete box, so to speak, was thus shut up from the outside except above 8 ft. below high water level, and the water inside the cofferdam was begun to be pumped out. When the water was lowered to — 8 ft. the top of the side wall appeared above the water, and it was further lowered to — 9 ft. on the outside of the dock and to — 12 ft. in the inside.

As the work was so constructed that there should not be any direct connection between the outside and inside of the dock, it was evident that had there been no fault either in concrete or puddle, there should not be any change in the water level inside this box. Several days' observations showed that the daily increase was only about ⅝-in., and this confirmed the belief that there was no appreciable leakage. Consequently had there been no upward pressure to lift the box or had the box been heavy enough to overcome that pressure in case such existed, the box would now have been in a stage to be safely emptied. Careful calculations, however, showed that it was not safe to do so, as the box was not heavy enough to counteract the upward pressure of water existing under the bottom. This pressure under the bottom was ascertained by the level of water inside 8-in. iron pipes, which, to provide for the case when the observations of the bottom pressure should become necessary, were previously imbedded in the rubble packing under the bottom concrete. These pipes had open ends and through the bodies of the last ones holes were perforated to make the ingress of water easier. They ran under the side walls and went up through them, and their upper ends reached above high water level. There were six such pipes, one at the head, two on the north side and three on the south side. The observations of water level in those pipes showed that water not only rose quite high up in them to nearly high water level, but undulated in concord with the undulations of the external tides, the only differences being in smallness of range and lateness of time.

The pressure existing under the bottom having thus been ascertained, concrete was further raised on the side walls in the dry (Section No. 7, Fig. 2) and, as this alone was not heavy enough, rubble and gravel were thrown inside the dock to serve as a temporary load. The total amount of rubble and gravel was 8,000 cu. yds., and thus the excess of the weight of the box above the bottom pressure became more than 12 tons per lin. ft. of the dock length.

All the precautions which were deemed necessary having thus been made, water was pumped out from inside the dock, and it was found that the leakage in the whole dock amounted to only 1 cu. ft. per minute, or less than two tons per hour. The photograph, Fig. 4, shows the dock when it was emptied for the first time.

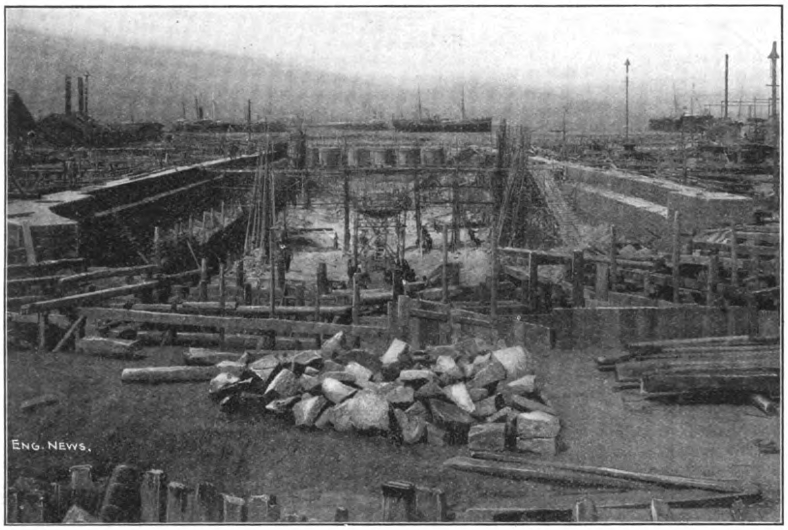

FIG. 4. VIEW SHOWING CONDITION OF THE INSIDE OF THE DOCK WHEN PUMPED OUT FOR THE FIRST TIME.

MASONRY FACING.—Such quantity of water being almost nothing, the preparations for masonry work were at once started, and as the first step for that, a temporary scaffolding, which was to serve two purposes, of lowering concrete, mortar and stone, and of taking out the temporary load, was erected over the centre line of the dock, and after its completion the stone setting was commenced. Four cantilever cranes, which were designed and constructed in the dockyard, were made to run on the side walls; four derricks worked by steam; two 3-ton hand cranes, and two trussed beams, which were spanned between the central scaffolding and the side walls, were the principal machines used for lowering materials, setting stone and taking out the temporary load. This plant is shown by Fig. 5.

As the temporary load, above alluded to, was put in to compensate for the insufficiency of the weight of the concrete box, it could not be taken off at once, but had to be removed gradually as the stone facing progressed both on the bottom and the sides. This gave great trouble for working ,as the removal of the temporary load, leveling of irregularities of bottom surface with concrete and stone setting must all be done in a very limited space. Stone setting was commenced both from the entrance part and the head, and the greatest number set in a day of twelve hours was 1,310 cu. ft.

The facing stone was all of granite, mostly from Tokuyama quarry, and its thickness was from 1.3 to 2.6 ft. along the sides and from 1.5 to 2.5 ft. along the bottom. Special care was taken in building the entrance part, large-sized stones being used, and chains and rails being imbedded in suitable positions along the bottom and the sides. Mortar used for stone setting for the dock body had the proportion of 1 part cement, ¼ part puzzuolana and 2½ parts sand, and that for the entrance part had the proportion of 1 part cement to 1 part sand, both by volume. The only structures in connection with this dock in which granite was not used were the part of the culvert leading to the pumping house, penstock chamber, and the arch of the lower chamber of the pumping house, all of which were lined with hard burnt bricks.

On each side of the central drain 5-in iron pipes were laid with branches of 1½-in. iron pipes, which were to collect leaked water, though very slight, and discharge it to the rudder well.

PUMP HOUSE.—After the bottom concrete was deposited and set hard, a frame corresponding to the inner dimensions (allowance being made for facing) of the pump house was weighted down onto the bottom duct, an outer frame was erected outside of it leaving a space between them, which had to be filled with concrete under water and had to form the body of the wall. After the wall reached the proper height, the inside and outside frame were taken off. The inside was then faced with stone and the outside was backed with clay puddle. In that part of the side wall, where the culvert leading to the pump house had to pass, another frame was set down at the same time with that for the pumping house, and when, after the water was pumped out from the dock, it was removed, a tunnel was formed connecting the inside of the dock with that of the pump house, which tunnel was subsequently lined to form the culvert.

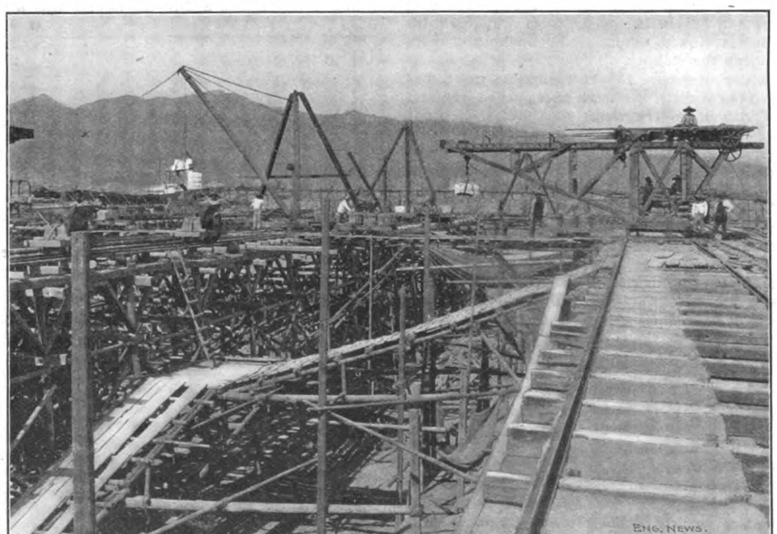

FIG. 5. VIEW SHOWING STAGING AND PLANT FOR LAYING THE STONE FACING.

CAISSON.—The caisson is of the box-shaped type with four sluices of 20 ins. diameter for letting in water, and an electrically driven 5-in. cen-