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SIR JOHN RENNIE, President, in the Chair.

No. 750.—“Description of the Great North Holland Canal, with an Account of the Mode of gaining Land from the Sea by Polders, and of the Art of Building with Fascine Work, and an Account of the Works at Nieuwediep.” By George Briant Wheeler Jackson, Assoc. Inst. C.E.*

The Helder, or Great North Holland Canal, was constructed for first-class merchantmen and fifty-gun frigates, by Mr. Blanken, Engineer (during the years 1819 to 1825), and takes its course opposite to Amsterdam, running to the Texel roads at Nieuwediep, and communicating with the docks of the arsenal there.

At this point it has two separate outlets into the sea, which are secured against the action of storms by a breakwater, extending the whole length of the harbour (Plate 8.) The principal dyke of the Helder, the harbour, docks, and fortifications, were commenced during the first occupation of the country by the French, and were enlarged, and in a great measure completed, by order of Napoleon. The whole of the country contiguous to this canal, has been gained from the sea at various times, since the year 1500, and is consequently surrounded with dykes, to keep the land from being flooded. In 1825, this portion of Holland was laid under water, by a very high flood breaking through the outer dyke at Durgerdam, and covering the whole of the country as far as Alkmaar, Edam, and Beverwyk, or a superficies of about five hundred square miles. The storm was so heavy, that the immense masses of granite, some tons in weight, which were lying at the Helder, for forming the breakwater previously mentioned, were scattered about in all directions, by the action of the waves. It is remarkable that, on this occasion, the portion of the dyke constructed with masonry gave way; whereas the other part, which had been built with fascine-work, was not injured.

* This paper was divided into three parts, so that a portion could be read each evening, and the discussion upon it extended over four evenings; but an abstract of the whole is given consecutively.

General Description of the Navigation, between the mouth of the Texel and the city of Amsterdam, and the difficulties connected therewith, which led to the construction of the Great North Holland Canal.

The whole of the commerce between foreign countries and the Dutch capital, formerly passed through the Zuyder Sea, after entering the Texel roads. Towards the middle of the 17th century, however, this navigation became so defective, in consequence of sand-banks and shoals, which filled up the Y stream, that in 1738 the expensive remedy of dredging was resorted to. This was carried on to a considerable extent; but it was still necessary to use large water camels, which, according to Caspar Cornelius, in his "Description of Amsterdam," published in 1793, were first introduced by M. Bakker, Engineer, in the year 1790, and were employed for lifting, among other vessels, the "Princess Maria," a 46-gun frigate, over the sand-banks at Pampus, which required a lift of 6 feet. According to that statement, M. Bakker could support by these means, 49 lasts (of 4000 lbs. each), on one superficial foot of water; and he received a pension from the Admiralty, at Amsterdam, for its introduction. The water of the Y stream opposite Marken, is about 16 feet deep; the depth then decreases to 15 feet, 14 feet, and 13 feet, and opposite Minden, where in fact these machines were used, it is only 12 feet 6 inches deep. Beyond this point the channel appears to clear itself, as its depth is 16 feet and 25 feet, increasing to 38 feet and 55 feet opposite Amsterdam. These water camels, of which several were kept at Pampus on the Y stream, were used in pairs, whenever they were required. They were of sufficient length to suit the largest vessel, being each provided with a rudder, and with windlasses on the outer side, to which the ropes were attached for securing the vessel. They probably had thirty-one ships' pumps of 6 inches diameter for clearing, and about sixteen valves for letting in the water and sinking them. The complement of men for working them, was about fifty to each, and it is calculated, that, at a depth of 16 feet water, each contained 61,576 cubic feet, and took three hours to pump dry, giving a lifting power of 1750 tons. They drew about 2 feet 3 inches when empty, and if weighted with 820 tons, about 7 feet 5 inches more. The machine itself weighed 450 tons, or thereabouts.

These camels have been broken up, as of no further use, now that the canal under consideration is completed; but in the Colonial Office at the Hague, there is still to be seen a very complete model of a frigate, supported by two such machines, representing the mode of working them. There exist also two smaller machines, on the

same principle, in the docks at Rotterdam. Their size is 75 feet by 18 feet, and 19 feet deep, having eight pumps and four valves. It may also be incidentally mentioned, that whilst the author was searching for these camels, he met with a timber floating dry dock (similar to the American dock), for vessels of about 600 tons burthen; and, as it has been suggested that similar floating dry docks of iron, should be constructed for the West Indies, it may perhaps not be considered out of place to give a brief account of one.

This floating dry-dock is generally used at Amsterdam for slight repairs: its dimensions, as given by the engineer, are:—extreme length 163 feet, extreme width 62 feet, width internally at the bottom 31 feet 6 inches, width at the top 57 feet. It consists of timber framing, forming a water-tight vessel, with internal bottom and slopes to three sides, also water-tight, the fourth side, or end, is open, having grooves for a gate to drop into. This gate is apparently weighted in such a manner, that, after lifting it out of the grooves, a very small power will either sink, or raise it; framed into it, is a paddle, or small sluice door, and there are two additional paddles at the other end of the dock. The machine is intended to be used in a depth of 14 feet, or 15 feet of water, and the gate just mentioned being floated out, any vessel, requiring to be examined, is hauled in, and the gate sunk in the grooves, and fixed down water-tight, when on pumping the water out, the dock rises so as only to draw about 4 feet of water. The internal basin is constructed with altars, &c., in the usual way. When sunk to a depth of 14 feet 9 inches, the dock contains 4621 tons of water, and, as it draws about 4 feet of water, when dry, with an empty vessel in it of the size of 600 tons, the displacement amounts to 1157 tons, which may be divided into 220 tons for the empty vessel, and about 937 tons for the dock. Two hours are stated to be sufficient time for pumping the dock dry by manual labour. In Holland, where the shore behind the dykes, is generally lower than the high tide, such contrivances are of the utmost value; and, as these docks can be moved from one part of the stream to another, they are also very convenient.

The navigation of the Zuyder Sea being very difficult, and the delays becoming more and more numerous and inconvenient, as already stated, the Government instructed their engineer to seek out some new channel for the shipping; and, accordingly, M. Blanken, who was applied to on this subject in 1816, submitted his proposal for constructing a ship canal, capable of containing two large vessels abreast, throughout any portion of its entire length. M. Blanken was aware that this was by no means an ordinary un-

dertaking, in such soil as that of which the north of Holland consists ; the more so as the sea, with which it must be connected, was in most places higher in level, than the surface of the country. Still, judging from existing works, he considered it practicable ; and, as the result has shewn, was as happy in his choice of a substitute for the Zuyder Sea, as he was in his designs for the constructions required.

The course of the Canal, its Levels, Lengths, &c.

The canal is divided into three portions ; the first extending from Amsterdam to Purmerend, being 10 miles, 6 furlongs, 2 chains in length ; the second, extending from Purmerend to Zijp, being 32 miles, 2 furlongs, 4 chains in length ; and the third, extending from Zijp to Nieuwediep, being 8 miles in length. The first runs through the high country of Waterland. After leaving the double tide-lock, called the Willemsluis, on the Y, it passes along the outer dyke to Buiksloot, where it is enclosed between two sea dykes, upon which the public roads run ; at Buiksloot there is a passage lock, intended also as a reserve sluice, to be used in case the outer sluices become defective, or are injured. Beyond this, the canal continues round the old Buiksloot lake, passes the Broeker lake, and the village of Watergang, receives the drainage of the Monniker lake, the Ring lake and Purmer lake, and then runs straight to Purmerend, where there is a double passage-lock. The second portion extends through the Schersea streams. Leaving the town of Purmerend, the canal takes a westerly direction, towards the village of Spijkerboor, and passing down the former stream of the old Beemster lake, and that of the Stern lake, curves round the edge of the lake of Alkmaar, proceeding to the east side of the town of that name ; in its course it receives the Knollendam stream, and the westerly arm of the Rijk. At the lake of Alkmaar, a fascine protection embankment divides the waters of the canal from the lake. After leaving the town of Alkmaar, the canal pursues its course by the villages of Koedyk and Schoorl, and crosses the Handbosse sea dyke, where it takes up the Handbosse stream and the great Sloot. This point is very close to Petten, famous for the persevering ingenuity of the Dutch during past ages, in their successful endeavours to keep out the sea. A sketch of the shore protection work, obtained from the superintendent, is shown in Plate 9, fig. 7. The canal then passes the Schager road, direct for Zand, where the Zijper protection locks are built, forming the end of the second division. The third portion may be briefly described, as first taking a north-easterly direction along the coast to Quelderbeg, and then running straight to Nieuwediep. Towards the Zuyder Sea, the canal embankment

forms a heavy sea dyke. The total length of the Great North Holland canal is 51 miles.

The levels of the three divisions are as follows :

The usual high-water tide of the Y, at Amsterdam, being designated A.P., or Amsterdam Peil, meaning Amsterdam standard level.

First division :	usual low water is	1 ft. 6 in. below A.P.
	usual summer level	3 ft. 7 in. "
	highest water	2 ft. 7 in. "
Second division :	usual summer level	1 ft. 11 in. "
	highest water	the same level as A.P.
Third division :	usual summer level	1 ft. 11 in. below A.P.
	highest water, (being also full sea tide at Nieuwediep)	0 ft. 8 in. below A.P.

The average height at Nieuwediep 2 ft. 11 in.

The levels of that part of North Holland through which the canal passes, vary mostly from 2 feet above A.P. to 4 feet under A.P. ; but along the drained Stern lake to Westgrafdiike, the variation increases to 16 feet under A.P. ; the greatest amount of variation being 18 feet.

The general dimensions of this canal are as follows :—

Breadth of the canal at summer level	123 ft. 7 in.
" " at bottom	30 ft. 10 in.
Depth of first division under summer level of	
Waterland	18 ft. 7 in.
	which equals 22 ft. 3 in. below A.P.
Depth of second division under summer level of	
Schermer	18 ft. 7 in.
	which equals 20 ft. 6 in. below A.P.
Depth of third division under summer level of	
Nieuwediep	20 ft. 7 in.
	which equals 19 ft. 11 in. below A.P.

Each bank of the canal is used as a horse track, the width of which varies from 12 feet 4 inches to 18 feet 6 inches, and the right, or left is followed, as the wind serves ; sometimes indeed both are used for large vessels. Along the village of Ilpendam, the track on the right-hand side has only lately been completed, owing to the unfavourable nature of the ground. From the Willem lock to Purmerend, there is a public road laid down on the western dyke, of the breadth of 74 feet 2 inches, and the coach-road from Alkmaar to Nieuwediep, is also laid on the same dyke ; the general level of the road being 6 feet 2 inches above A.P. ; and the general level of the horse-track is 2 feet above A.P. The slopes on both sides of the roads are $2\frac{1}{2}$ to 1, running down, or ending landwards, on an inner bank 6 feet wide.

The Difficulties of Construction anticipated, and Experiments undertaken to ensure success.

The weak marshy ground, over which the great North Holland Canal was, for the most part, to be carried, occasioned doubts as to the possibility of excavating it to the depth required, and more particularly of preventing slips, when it should be completed. And it must be remembered, that these excavations were required to be of a much greater depth, than were those for the sea-locks at Flessingen, Helvoetsluis, &c., and also, that the works generally, were required to be of much greater strength, on account of the inland waters being constantly lower than the sea. The summer level of the Waterlands of North Holland, averaging 4 feet 4 inches lower than the usual height of the sea-tide in the Y, it became necessary to erect locks of 4 feet 4 inches greater depth, than the usual dock-locks, and also to provide for the security of the foundations, against a pressure of a depth of water and springs, of 27 feet 9 inches, under flood tide. Along the English and French coasts, as well as in the south of Holland, the usual ebb is from 12 feet 3 inches to 20 feet fall, and under such circumstances, the portion of the work to be executed under low water is, comparatively speaking, so small, as to obviate much of the difficulty; whereas on the Y stream, the ebb-fall amounting to little more than 1 foot, the greater portion of the work had to be constructed under water, the foundations of most of the locks, requiring to be laid, at the great depth of 35 feet to 37 feet, below the crown of the sea-dykes. It is true, that these works when once constructed, would not have to bear the heavy strain of pressure and non-pressure, consequent on the rise and fall of the tides, to which the other works are exposed, and still less would they be liable to that decay, caused by exposure to moisture and air alternately; but the nature of Dutch foundations generally, being so very doubtful, M. Blanken judged it to be highly desirable, to test the ground, both by pile-driving and boring.

Among the 'Transactions of the Royal Netherlands' Institution of Science, Literature, and the Arts,' for the year 1823, there is an official paper by M. Blanken, under the title of "Brief Remarks on the character of the Ground of the North Holland, or great Amsterdam Canal, between the Y and Neuwediep at the Helder, &c., &c."* of which it is conceived, that the following may be ap-

* Memorie van korte aantekeningen wegens de geaardheid der grondlagen benevens derselver hoogten en diepten, voor zooverre deze bij naauwkeurig onderzoek inde strekking en de nabijheid van het groot Amsterdamsch kanaal door Nord Holland tusschen het I J en de reede van Texel, &c., &c., gevonden zijn.

positely introduced here, as serving to show, satisfactorily, the results of the engineer's operations.

Experiments on Pile-driving, and Boring.

The first attempts at pile-driving for the Willem Lock, and for the Purmerend and Buiksloot Locks, were made between the 11th and 13th May, 1819. The piles used for this purpose, consisted of Norway pine, from 42 feet 8 inches to 46 feet long, and 27 inches diameter at the head. The ram made use of weighed 1200 lbs., and its least fall was 6 feet. In driving the piles at the Willem Lock, the ground level being 2 feet above A.P., it was found, that when placed in an excavation of about 11 feet 6 inches deep, the piles sank, under ninety blows of the ram, to the depth of 26 feet 3 inches, at which depth they reached the hard ground, and that with one hundred and twenty more blows, they sank a further depth of 3 feet 3 inches, and then moved only 3 or 4 lines per blow, during the next thirty blows, reaching eventually to 45 feet 6 inches under A.P. The piles driven into the ground at Buiksloot, indicated nearly the same result as the foregoing. At Purmerend, where the surface of the ground is 3 feet 3 inches under A.P., the earth into which the piles were driven, proved more compact, being of a hard tenacious clay, and offered the same resistance as the foregoing, at a level of 43 feet 5 inches under A.P.

These results were so far satisfactory, as leading to the conclusion, that the ground at the requisite depth, was capable of bearing the designed locks with perfect safety; but, in order to arrive at a probable estimate of the cost of such an extensive undertaking, it became necessary to institute further inquiry, into the natural slope of the ground, and the geological strata at particular depths. In order to obtain this information, fifty-three experimental borings were made, at different points, along the whole extent of the canal, and these were performed with a miser, by which a circular hole of 2 feet diameter was made into the ground, and the loosened soil brought up with the instrument. The first trial borings were made in the Volwyk, to the depth of 32 feet, and in three different places along the Buiksloot stream. The stratification proved as follows:—

Soft loose clay	5 ft. 6 in. to 6 ft. 3 in. thick
Free open peat, or potters' earth	11 ft. 4 in. „ 12 ft. 4 in. „
Blue loose clay	4 ft. „ 5 ft. 2 in. „
Continuous stiff clay and hard ground	7 ft. 3 in. „ 8 ft. 3 in. „

These borings, as well as the pile-driving experiments, gave convincing proofs, that the upper clay stratum was of comparatively little thickness, and that the stiff ground of clay, sand, and shells, on which

the heaviest lock-works might be constructed with perfect safety, was only to be found in the third and fourth beds. The second, third, fourth, and fifth set of borings, taken altogether at twenty-five different places, commencing from Buiksloot, and extending to the Schermer Polder, indicated nearly the same result as the first. The sixth set were taken at fourteen places, commencing close to the so-called Omval, in the Ouddorp Polder, thence along the Ziglis, close to the east and north side of the town of Alkmaar, and as far as the Koedyk, the general depth running from 16 feet 6 inches to 30 feet. The ground was here found to be very different, from that at the former places; and at three separate points, to the south and north of the Omval, in the inner side of the dyke of the Schermer, the miser could not be made to sink deeper than from 8 feet 3 inches, to 14 feet 4 inches; the level of the surface being 4 feet to 5 feet under A.P.

For this reason, a further investigation was made with a bar, which penetrated to a depth of from 17 feet 6 inches to 21 feet 7 inches.

The 11 other borings furnished the following result:—

Upper ground covered with clay and sand	2 ft. to 5 ft. 2 in. thick
The same at several places, with clay and peat	2 ft. „ 5 ft. 12 in. „
Further sands and clay	18 ft. 6 in. to 21 ft. 11 in. „

From these last borings it would appear, that the neighbourhood of the town of Alkmaar, lies on rising and hard ground.

The last and seventh set, consisting of ten borings, were taken from the church at Koedyk, to Nieuwediep, along the Zijp and Koegrass; the depths being 21 feet 6 inches.

From Koedyk to Schoorl the strata were:—

Clay	6 ft. 2 in. to 17 ft. 6 in. thick
Peat	1 ft. 4 in. „ 3 ft. „
Clay, sand, and shells	1 ft. 4 in. „ 12 ft. 4 in. „

From Schoorl to Nieuwediep the strata were:—

Sand and clay	3 ft. to 9 ft. 6 in. thick
Peat-clay and sand	1 ft. 4 in. „ 5 ft. 10 in. „
Loose clay	3 ft. „ 9 ft. 6 in. „
Sand, clay, and shells	2 ft. „ 8 ft. 4 in. „

It does not appear, that any account has yet been published, of the excavations which were undertaken by the French engineers, in forming the Nieuwediep docks. These excavations, which were carried to a depth of 31 feet 3 inches, showed, that under the surface, which consisted, first of a bed of clay 3 feet to 4 feet 2 inches thick, was a sandy bottom, and then at the depth of 12 feet, several large-rooted stumps of oak, and trunks of other trees, were found,

of which many were standing upright, whilst others were lying in different positions, and some even rested on each other; this confusion being evidently the result of some great convulsion of nature.

M. Blanken concluded, from these experiments in pile-driving and boring, as well as from the success which had attended the works, for draining some of the seas, or lakes in the immediate vicinity of the canal, that there was every reason to reckon on sufficient solidity, for the due execution and standing of the works, which he contemplated. He further inferred, that as there is no internal water of higher level, than the North Holland Level, adjacent to the banks of this canal, there could not exist any greater under pressure of water and springs, than might be counterbalanced by the canal water itself, and that, consequently, no such injury, as the bursting upwards of the beds, or the tearing away of the slopes, was to be feared. In addition to this, he had observed, that in North Holland itself, for instance at the Nauwernaasche sluice, close to IJpendam, there had existed for several years past, very deep pits, to the extent of 15 feet and 16 feet under summer level, the banks of which being 18 feet 6 inches high, were nevertheless steady, although not far from the sea, and recollecting that several rivers of North Holland had been deepened from 30 feet to 50 feet by the force of the streams, whilst the banks remained uninjured, with even much heavier sea dykes than the polders resting on them, he considered himself warranted in concluding, that the canal banks would stand under ordinary circumstances.

Throughout its whole length, the canal required no alteration of any existing water level, nor the raising, or lowering of any road. The largest mass of earth to be raised was the Beemster dyke, running from Purmerend to Spijkerboor, whose top surface being 18 feet 6 inches to 20 feet 7 inches broad, is raised 3 feet 3 inches, to 6 feet 7 inches above the North Holland sea-side. This dyke, on account of the summer water in the Beemster, being of considerably lower level, batters one-sixth more on the outside than on the inside, and this, together with the pressure of the canal water, renders any injury, from the Beemster lake side, very improbable; in fact, the circumstance of the latter possessing only lower dykes, is, of itself, a sufficient guarantee for the stability of the canal.

Construction of the several Works, consisting of Floating Bridges, Tide-Locks, Passage-Locks, &c., and the cost thereof.

From the commencement of the line of the canal, namely from the Willem lock to IJpendam, the ground was regularly excavated,

but from IJpendam to Purmerend, the existing streams of the Monnikersea were only deepened out and made broader. After the completion of the Buikslooter lake, it was found, that on account of the great quantity of peat, the canal required additional excavation, before the ground would stand firmly. From Purmerend, the stream for draining the Beemster was used, as well as another stream, which extended as far as the Schager road, and these were both cut to the requisite size. From the Schager road to the end of the canal, the ground was entirely excavated. Wherever loose ground was found, fascine bedding was introduced, and wherever the earth was defective at the intersection of dykes and roads, the slopes of both sides were confined, with hurdling and wattles. In many cases the slopes were faced with stone rubble masonry, laid dry, and slanting to the land, and some portions were preserved with dwarf piling and waling timbers.

In carrying on the excavations, the whole was taken out in two heights, and at two different periods: first, to about two-thirds of the intended depth, and after that had been exposed for some time to the atmosphere, the other third was undertaken. Peat, sea-weed, clay, and shells, were used in forming the canal bed. The slopes of the roads crossing the canal, were covered with sods. Formerly the outer edge was protected with sheet piling, but this being found to create serious injury, fascines were introduced, covered with sods, to prevent the ground from working out into the adjacent lands. In forming the canal banks, two remarkable works were constructed, namely, the fascine embankment dividing off the Alkmaar lake, and the sea dyke at Koegrass, near Nieuwediep.

The dimensions of the first are:—

	Feet.	In.
Breadth of crown	24	8
Breadth of base	46	3
Total height	12	4

Length 106 chains, crown level 2 feet above A.P.

This embankment was constructed as follows:—The extreme size being pegged out, and all the loose soil thrown back, a complete bedding of fascine bundles of willow, crossing each other at regular distances, with matting and hurdling laid thereon, covered with other bundles crossing each other in the same manner as the first, and well tied in a mass, was sunk on the intended site; the whole bedding being in lengths of 74 feet, by 3 feet thickness, and 46 feet 3 inches in width. Upon this layer, a second bed of the same material, thickness, and lengths, but only 34 feet wide, was laid and secured very strongly with stakes and willow bands, the whole of the ground being kept dry by banking out. Upon these, the

upper part, consisting of fascine layers, 1 foot thick each, was sunk, staked, and rammed solid, with peat clay and sand, and thus worked up to a level of 2 feet above A.P. The slopes on both sides are one to one, and along the outer edges of each fascine layer, there is a row of strong stakes driven through the work; besides which, strongly interlaced willow bands were used, to bind them together. In order to give additional security, the two upper courses were weighted every 4 yards with a heavy brick paving, and the surface was filled up with clay, covered with sods.

The dimensions of the Koegrass sea-dyke are :—Breadth at the top, 9 feet to 10 feet, with an outside batter of four to one towards the sea; the length 564 chains, and the crown level 11 feet 6 inches above A.P. The inner side of the dyke stands upon the outer edge of the canal bank, and this is sloped off to the face, which has a batter of three to one. The canal bank level is about 5 feet above A.P., and part of the slope, for a length of 61 feet, is faced with stones, consisting of large sharp pieces of the hardest quality, (of a basaltic character), and these, wherever used, support the grass slopes.

The bridges across the canal, consist of swing bridges and floating bridges. The swing bridges, of which there are three, are partly of iron and partly of wood, and are of the usual form adopted in England, for spans of 60 feet.

There are also eleven floating bridges, all made of timber. They consist of two rows of piles, 20 feet apart, each covered with a heading piece, jutting out from the shore for a distance of 50 feet. At their extremity, and on each side, are very strong dolphins, with guard-rails. Supported on the piles, for about the length of the base of the slopes on each side, is a roadway of framing, at the end of which is a second framing, attached with very strong hook hinges to the first, but hung at the other end, to one long wooden double lever on each side, which has its fulcrum over one of the piles, the end of the lever being secured in a standard by pins. This second platform is 36 inches less in width than the first, and is furnished with a moveable flap, having two small wheels attached to the underside, to enable it to be run and to rest on a boat. This boat, which together with the two other platforms just described, forms the half-length of the entire bridge, has two lines of tram-rails laid down on its deck. The whole is boarded over throughout, and supplied with hand-railing on each side. To one end of the boat are attached the ends of a rope, which, passing round a windlass, can be used, by turning the handles one way, or the other, either for opening, or closing the bridge. The small wheels of the second platform, running on the tram-rails, guide the boat, and

serve to keep it under complete control. The levers are for the purpose of raising and lowering the second platform, according to the level of the water in the canal.

On the banks of the canal are nine ferries : and over the streams are fifty-seven small bridges, and several sluices. Besides these, there exist five drawbridges, one double lifting sluice, and four small pontoons.

The locks, as already stated, consist of two tide locks, (one at each end), and three passage locks. In constructing these, it is believed, that clay in conjunction with timber framing, was used for banking out the water, and pressing out the springs, but the author has not been able to collect authentic data upon this subject. The locks are almost all of the same construction, and therefore a description of the double Willem lock, opposite Amsterdam, which is the largest, will suffice. It consists of a double tide lock, one side being for large vessels, the other for small ones. (Plate 10.) Each chamber is provided with two pair of gates, to close against the tide, and one internal pair to serve for the inland waters. The smaller lock was formerly supplied with a pair of fan, or balance gates, but these, on account of the great wear and tear to which they were subjected, were found to get easily out of order, and, as in addition, the washing of the water from the drains, destroyed the brickwork, a pair of ordinary gates have been fixed up in place of them.

	Feet.	In.
The extreme length of the larger lock, face to face, is	295	0
Height above flooring	32	6
Clear width of span	51	0
Length of basin, or chamber	237	0
The extreme length of the smaller lock, face to face, is	115	6
Height above flooring	22	9
Clear width	18	6
Length of basin	82	0

The larger lock-gates are 29 feet 5 inches, by 29 feet 4 inches. The smaller lock-gates are 19 feet 10 inches, by 11 feet 6 inches.

In the foundations of the whole of this work, there are 2145 piles, 10 inches to 11 inches diameter, and 31 feet long. Upon these, 101 rows of sleepers are fixed, 10 inches by 14 inches scantling, for forming the foundation of the larger lock and walls, and 54 rows of sleepers, 9 inches by 11 inches scantling, for forming the foundation of the smaller lock. Besides these, there are 54 rows under the quay wall, dividing the larger from the smaller lock, inner entrance ; the whole is then covered with fir planking 4 inches thick, and on this the walls cross, and the pointing cills rest. The sleepers under the pointing and cross cills, vary from 1 foot by 1 foot 9 inches,

to 10 inches by 1 foot. The largest pointing cills are 2 feet 2 inches by 2 feet 3 inches, and the largest cross cills are 2 feet 3 inches by 2 feet 4 inches. Covering the fir planking between the walls, and throughout the entire length, excepting to the extent of the gate cills, another flooring is laid, entirely of oak, with joists 6 inches to 1 foot, by 8 inches to 1 foot 9 inches scantling, having the spaces between the joists, or bearers, as soon as they were well spiked down, filled up solid with brickwork in cement, on which 4-inch oak planking is screwed. The lock walls are built with brick, laid in cement, or hydraulic mortar, of two kinds,—the strongest composed of three parts of lime, and two parts of artificial cement (trass), and the second six parts of lime, three of trass, and one of sand. The entrance and basin walls of the larger lock stand on a portion of an invert, butting against a timber springing-plate, which is fixed at the ends of some of the oak joists. The basin walls are 6 feet 6 inches thick at the top, and increase regularly downwards to 11 feet 4 inches at the bottom; behind these are five counterforts, 6 feet 2 inches thick. The entrance faces are 9 feet 3 inches thick, and the quay wall is also of the same thickness. The smaller lock walls are 10 feet 3 inches thick at the base, and 5 feet to 6 feet 6 inches thick at the top, with the face nearly vertical, and with two counterforts.

In this lock are two fan, or balance-gates, with chambers in the form of a quadrant. The chamber walls are 9 feet 3 inches thick. The framing of the tide-gates is of ordinary construction, of oak, having heel-posts 1 foot 6 inches by 2 feet, and the mitre or head-posts 1 foot 3 inches by 1 foot 6 inches. Each gate has a paddle of the usual construction, and the whole is boarded with oak 3 inches thick, laid diagonally outside, and vertically inside. The other gates are of the same description, but of smaller scantling. The fan-gates are of oak, with heel posts 1 foot 6 inches, by 1 foot 9 inches; mitre posts 11 inches, by 1 foot 5 inches; rails 1 foot 2 inches, by 1 foot 5 inches; struts 6 inches, by 1 foot 6 inches, planked with 2-inch oak planking. The back portion, or fan, also of oak, is framed into each gate, of similar scantling, but with curved ribs. There are two sets of drains to the fan-gate chambers on each side, with regulating doors, &c.

The quoins of all the walls, are of a hard blue stone from Belgium, the inverts being faced at the angles with the same stone, 2 feet 6 inches to 3 feet broad by 2 feet 6 inches to 3 feet 4 inches thick. All the drain, or channel bottoms, and the fan flooring, are faced with ashlar. The coping and the pavement to the several walls, are 1 foot thick, 4 feet to 5 feet wide, and 6 feet to 9 feet long. Besides the outer and inner wing walls, there are fascine slope walls, 37 feet

long, 12 feet 4 inches thick at the base, 6 feet 2 inches thick at the top, and carried to the depth of the foundations, the top level being 1 foot under A.P. The locks were constructed during the years 1819 and 1820, and cost £38,750. The whole of the details of the gate framing and the iron work, (the latter of which is similar in design to that usually adopted in England), as well of these, as of the other locks, are fully described in the original documents, but they do not possess sufficient interest to be referred to more fully here.

Proceeding onwards from Amsterdam, the Buiksloot lock (Plate 11) with a swing bridge, is the second lock. This is 80 feet 2 inches long, and 51 feet 6 inches wide. It is closed, whenever the outer water in the Y rises 4 feet above high water, and acts, in case of emergency, as an assistant to the first lock. This lock was constructed in the year 1820, and cost £12,666. The third lock (Plate 12) is the double-passage lock at Purmerend, and has two swing bridges. The extreme length of the larger lock is 263 feet 5 inches. The length of the smaller lock is 99 feet 6 inches. The widths are the same as the first lock. This lock was built in 1819 and 1820, and cost £32,916. The fourth lock is at Zijp. This lock has double sets of gates at both ends. The tide-gates are closed, whenever the outer water at Nieuwediep rises 2 feet 9 inches above high water, to strengthen the dykes. They are also closed, should the tide be high enough to render the Koegrass Canal navigable. The inner gates are closed during a dry summer, or whenever it is necessary to preserve the inner water of the Schermer sea arm as much as possible; and if the tide-gates require to be opened, it is better to let in the waters from the Y, as they are not so saline as those of the North Sea. The length of each lock chamber is 73 feet, the width 51 feet 6 inches; the length of the basin is 308 feet 9 inches. This lock was constructed in 1822, and cost £15,250. The last lock is the tide lock at Nieuwediep, and is so similar to the Willem lock, that no plate is given, nor is any further description judged necessary; and adjoining this, is a smaller lock constructed under the French. The total cost of this canal, as given to the author approximately, by Chevalier F. W. Conrad, Engineer, was £1,500,000.*

The time which vessels require, to make the passage from Amsterdam to the Helder, necessarily varies, according to their size and the means of haulage. Fly-boats, with six relays of four horses, make it in ten hours. A large East Indiaman requires two, three, and four

* The Author has to acknowledge the assistance derived from a work in Dutch, by M. W. C. Brade, Engineer, entitled "*Handboek der Waterbouwkunde*," published at Amsterdam.

days, according to the wind. It is stated, that the canal dues, haulage, and other expenses, from Amsterdam to the Helder and back, amount, with a vessel of 900 tons, to nearly £200.

An Account of the Mode of gaining Land from the Sea, by Polders ; and the Art of Building with Fascine work, as generally adopted in Holland, Germany, &c.

The very existence of the north of Holland is identified in date, with the system of reclaiming land from the sea, which is of great antiquity. The people formerly inhabiting that particular district, thus gained from the sea, were Frieslanders. In the 14th century, an extensive inroad was made by a severe flood, which swallowed up the greater portion of the country now occupied by the Zuyder Sea. This part is denominated in Mela, vol. iii., chap. 2, *Flevo-lacus*, and is shown as being connected with the North Sea by two rivers, the one having its outlet at Vlieland, the other river, called "Isla," joining the sea close to the Texel, so that Friesland, and the north of Holland, were evidently once connected by a considerable extent of dry land. The Dutch are now endeavouring to regain this lost portion of their country by banking out, &c., and it is now proposed to describe the system practised by them, with unwearied exertions.*

The word polder signifies a tract of country, (generally meadow land), surrounded by dykes, the dykes having been constructed during the occupation of the land by the sea, which land has been recovered on the completion of the dykes, by pumping out the water, or draining it dry. Polders are formed for regaining land from lakes, or marshes, which have been caused by the sea overflowing its shores ; or by the banks of streams, or rivers, being regularly, or irregularly flooded ; and lastly, (as already stated), they are formed for the purpose of saving land, on the coasts, from the sea. It is only the latter case, which will be considered here. The first step taken, is to separate the whole surface to be reclaimed from the sea, by the construction of dykes and sluices. A flat shore, overrun by the sea only at full and new moon, recovers itself, by an accumulation of argillaceous alluvium, brought down along the coast, as well as of marine deposits, if intersected with numerous cuts and trenches, which, at the ebb, serve to carry off the salt waters ; but

* The Author has to acknowledge having collected much of his information from the following works : Chevalier Wiebeking's "Wasserbaukunst," Sgan-zin's "Cours de Construction," and Mr. Hyde Clarke's excellent Paper, "On the Engineering of Holland," published in Mr. Weale's "Quarterly Papers on Engineering."

reference is now made more particularly, to such lands as are, more or less, continually flooded by the sea. The levels of the recent polders in Holland and Belgium, exhibit a slight declivity towards the sea, while the more ancient polders, which are consequently at a greater distance from the present shore, are, on the other hand, altogether slightly lower than the sea. The dykes enclosing the ground to be gained, are raised to the level of 1 foot 8 inches, and 3 feet 3 inches, above the highest tide at the equinox; and, if not intended to be used eventually, for the high roads of that portion of the country, they are from 3 feet 3 inches to 6 feet 6 inches wide on their summit. The angles of the slopes depend on their position, but two to one inside, and four to one towards the sea, have been frequently adopted (Plate 9, Figs. 1, 2, 3, 4, and 5). In addition to these outer dykes, internal ones are frequently constructed, dividing the whole area of the polder into smaller sections.

In general the larger dykes are constructed, with the aid of fascine work, in the following manner; it being borne in mind, that on the coasts of Holland, there is very little ground swell. The profile of the dyke having been settled, by previous surveys and soundings, fascine beds, or "sinkstucke," 28 inches to 30 inches thick, by from 8 yards to 16 yards wide, and of various lengths, are constructed on the shore. These are floated out, and sunk, by the aid of gravel, &c., into their position, to form the bed and slopes of the dyke. First a fascine layer is sunk, so as to cover nearly the whole of the intended base of the dyke, a small portion being left uncovered in the centre, for the clay body to be joined into the foundation, and the site of the layer thus sunk, is indicated by floating buoys. Other layers are then superadded, forming, as it were, two smaller banks, up to the low water level, each layer breaking joint. At the same time, as each of these fascine beds is secured with long stakes to the subsoil, the centre or clay body is carried up in corresponding layers, until within two yards of high water level. After this is completed, an additional fascine layer is sunk on the ebb side, and the clay body is sloped off, to give a fall to the water at change of tides. The most difficult operation has then to be performed, namely, the final closing, or damming out of the water. For this purpose, all the requisite materials must be got ready in boats on the spot, and the men be distributed at their posts on the whole line of the works. The final damming out should be always begun in still weather, with the wind blowing off shore. It is also desirable to make arrangements for performing this operation, some four, or five days before full moon, in order to benefit by the moon's light, it being necessary to work day and night until finished. The best point at

which to commence the closing, is, according to Caland, on the inner, or ebb side of the crown, as it affords a drier and more convenient line of deposit for the materials. Whenever, in consequence of a breach in the dyke, serious mischief is being caused by the influx and reflux of the tide, step dams should be made, or else the dyke should be cut away, so as to reduce the stream to its natural velocity, when the earth-work can be afterwards reconstructed. Sometimes the dykes are made with timber frame-work, and faced with stone; but the former method is that which is most commonly used. Shells and sand, stone rubbish, and muddy, or slushy soil, are not proper materials for the construction of these dykes, and bog earth and turf are also objectionable, as they swell under water; clay, sea-weed, and silt are good materials; but they should be broken up and well rammed. Linings of sand are frequently introduced into the body of shore dykes, to prevent rats and moles from damaging them. The dimensions of the outlets, or sluices for leading off the waters should be in proportion to the volume of water to be passed off, and also to the period between one tide and another.

In Holland an outlet of 3 feet 3 inches superficial is considered sufficient for draining 356 acres, and 19 feet 3 inches superficial for 3956 acres; this supposes six hours of flowing off in every twelve hours, and general freedom from storms. The regularity of the tide levels, facilitates the proportioning of these outlets; but in the case of river banks, to which allusion is made at the commencement of this Paper, it is necessary to consider in addition, the irregular increase of water, arising from the melting of snow, from heavy storms, rains, or ice floods. According to circumstances, it will be necessary to submit to occasional floodings, and to endeavour to diminish their evil effect, by dividing the waters as much as possible, or to guard against them, either by increasing the dimensions of the channels, or by constructing separate and additional outlets. The kind of gates for opening and closing the outlets, must depend upon the quantity of water necessary to be drained off by each, within a given time. The most simple sluice-gates are of either a rectangular, or circular form, turning on a horizontal pivot. This is fixed on the external face of the outlet, the abutments and wings being of masonry, or wood, and passing transversely through the dyke. The stone, or timber apron to this work is placed on the lowest level of the bottom of the inner ditches. An inner lifting door is generally provided, in case the outer one should get deranged, or injured. Besides these doors, others are used, which turn on a vertical axle, or spindle, fixed in a lock. This axle divides them into two parts of unequal surface; the larger

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abutting against a shoulder-piece on the inner side when closed, so that at high tide, the sea waters keep it in its position, whilst, at low tide, the pressure from the sea being removed, nothing opposes the power from the interior. In later times rack and pinion work, with metal quadrants, have been attached, to prevent any sudden jerk, from wind, or otherwise, when both forces are balanced. If the outlets are very broad, two doors are adopted instead of one, in which case the vertical axles are placed as near the abutments as possible, in order to interfere less with the egress of the internal waters. These balance-doors have this inconvenience: that they may remain open, in consequence of some floating body being jammed between them, and hence, in a general way, ordinary lock gates are preferred, and they are worked by hand, with a stop to prevent their opening beyond a certain angle.

When the dyke is completed, a parallel ditch about 10 feet wide is cut at the foot, on the inner slope, in order to receive simultaneously the waters which filter through the body of the dyke, and those which are thrown over by the waves and extraordinary high tides, and also with a view to unite and lead off, by the dyke sluices, the rain water and springs. Between this inner ditch, and the foot of the dyke, a raised benching, or road, generally of 15 feet to 20 feet wide, is frequently maintained, which, whilst it serves to consolidate the earthwork, is also used for carriages. The water is conducted into the inner ditches just described, either by catch-drains, or by open trenches. Sometimes one catch-drain is laid down the centre, with branches in various directions, which again are connected with smaller drains from a higher level; or the several drains meet at points, and discharge their waters at once into the inner ditches. Particular circumstances require peculiar arrangements; but the arrangement generally recommended is, to use economy in making up for the loss of the ground sustained by these drains, and to expose as great a surface of water as possible to evaporation.

With regard to general drainage, the system adopted in Holland, so far back as 1650, by Van Ens, and which is not materially altered up to the present time, is that of dividing the whole country of Polders, into zones, or districts, each of which is on the same level, and is surrounded by its own water channel. Thus the higher water flows off into the lower channels, and eventually reaches the sea, each district being drained separately. By these means, the Dutch think, that although the rising of the tide sometimes stops the flowing off of the water, this, of all the systems used, is the least productive of evil.

If a dyke be broken, and cannot be immediately closed and re-

paired, the remaining portions should be left, and a new work be commenced, having the form of a segment of a circle, with the convex side towards the sea, and joining the broken portions at some distance from the extremities. The whole should be interwoven with fascine work, and tied in as securely as possible.

The land being once drained, is immediately put in order for cultivation, the springs are led into the trenches, and the water is thus carried off into the inner ditches, or is raised up to a higher level by pumping, and thence passes by the ordinary water-courses into the sea.

Wherever the shores are exposed to heavy prevailing storms, the outer slopes of the dykes are defended by banks 50 yards, or 60 yards apart, running out from the face mostly at right angles, and intended to break the first shock of the waves. This method is preferred to placing masonry on the toe of the dyke. These protecting banks, or groynes are of various kinds. Such as are intended simply to arrest the material suspended in the water, are of the form of an arc of a circle in profile, having 6 feet to 10 feet chord, and 10 inches to 1 foot versed sine. They are formed on a clay foundation, which is well let into the bed and covered with fascine matting, the whole being secured by long stakes, and bound together. A larger kind have a triangular section, with the upper angle rounded off. They are about 19 feet at the base, by 4 feet 10 inches high, and of the same construction as the first; but having in addition, several layers of fascine bundles laid on the outer slopes, let into the bed and overlapping each other, and well secured by wattles and hurdling. Between this hurdling, clay, peat, sea-shells, and sand, are rammed, to weight it, and the whole is covered with turf. There are yet more extensive works, 500 feet to 600 feet in extent, having continuous rows of piles 13 feet to 16 feet in length, the heads of which, when driven, are from 6 feet to 7 feet above the level of the sands, and are joined transversely and longitudinally, with waling timbers. Over the whole surface between the piles, and also projecting beyond them, is a fascine bedding, sloped off, and well secured and weighted with stone. The whole is well joined into the shore, and to stop the tearing away of the ground, long stakes are driven in at regular distances, to which the whole is bound as before. These, as a matter of course, are not executed in rocky situations. Where the foreshore is very long, a parallel shore-work, with occasional openings, is laid down at spring tide level. When several groynes are carried out from the shore consecutively, the work should commence with the lowest down the current. The groynes at Petten are 500 feet to 600 feet long, 48

feet wide at the root, and 62 feet wide at the end, which is half round; they are about 800 feet apart. The level of the crown of the root is at high-water level, and that of the end at low-water level.

Works for narrowing the outlets of rivers, where partial bars exist, for diverting some streams and closing others, for securing the banks of great rivers, for protecting sea coasts, whether natural or artificial, for protecting shore walls, bridge walls, &c., are frequently constructed with the aid of mattings, hurdling, wattles, and fascine work. It is chiefly on account of the high price of stone, and the abundance and the low price of gravel and of willows, osiers, &c., that on the banks of the Rhine, and in Holland, works constructed with fascines have been generally substituted for masonry, although the stream of the Rhine is exceedingly rapid. It is true that this substitute is not enduring, but relatively, it lasts sufficiently long to aid in forming sand and gravel beds.

The success of this kind of work depends, first, on the position and condition of the coast; secondly, on great care in the execution of the work, and more particularly afterwards, in keeping it in repair; thirdly, on very long slopes being given to the outer face, and a high level to the crown; and fourthly, on the work being immersed as much as possible, and the portions above the water, being preserved against the atmospheric action. On the Rhine, these constructions consist, as far as regards the portion under water, of fascine work deeply rooted into the banks, well fastened together, and sunk by layers of stones and gravel. They are fixed to the ground, or to the beds previously immersed, by stakes passing through one end of them, the other end, or that towards the stream, floating, so that by their flexibility they may adapt themselves to the various forms of the foundation. Great speed is required in the execution, in order to avoid any rupture from torsion, which sometimes happens from the irregular action of the rising waters.

In Holland, a bank affected by currents, is defended by the assistance of fascine platforms, sunk and staked down; but the lowering and immersing of large areas is generally exceedingly difficult, particularly if the current be very strong. The portions of the banks, above the water, are constructed in various ways: sometimes with self-supporting fascine works of willow, or poplar, that is, with layers of fascines upheld on bundles of faggots, and secured vertically by ranges of stakes, which stakes are held in their places by strong hurdles, interweaving one stake with another. Between the hurdling, sand, gravel, sea-weed, and clay are thrown to ballast, and partially sink the whole structure, care being taken to keep it

in its place. Afterwards, new beds of fascines are laid over the first, and staked to it, each bed being so sunk, as to form the outer slope of three to one, the steepness of the slope decreasing as the structure rises to the crown. At other times, the upper part of the banks is constructed of masonry, or timber.

The chief materials required, in the construction of fascine banks, are long reeds, rye, or wheat straw, stakes, twigs, and long branches of flexible aquatic shrubs, especially of willow, alder, poplar, aspen, or any slightly resinous white wood; gravel, pebbles like those used for roads, or broken stone, and a grassy and clayey turf, such as is found in lakes, leading from stagnant waters into the high seas. The principal properties of these materials should be: first, to take root and extend easily in existing ground; secondly, by their flexibility, to yield to all the undulations of the foundation; thirdly, from their light weight, to remain floating, during the early periods of carrying on the works, and of being easily immersed by the aid of gravel and sand; fourthly, to afford by their interstices a multitude of small fissures for the water, and to arrest at the same time, like a kind of filter, the material held in suspension, so as eventually to consolidate the whole.

Fascine works are formed with mattings, hurdles, wattles, or stakes, and sausage bundles. The mattings, according to a very interesting work by the late Engineer, Brisson, consist, first, of a bed of reeds 2 inches thick, or of sea-weed, or straw, the stalks of which are placed in the direction of the stream; secondly, of carefully twisted bands of straw running transversely 6 inches to 8 inches apart, interlacing the layer of straw, &c., and being driven through the reeds into the earth at regular distances, 10 inches to 12 inches deep. For 129 feet square of matting, there are required either 40 bundles of reeds, each bundle being on the average 8 feet 3 inches in length, and 10 inches in circumference, or 15 bundles of rye, or wheat-straw, 10 of which are for the first layers, and 5 for the bands; these mattings are easily kept in repair, but require constant attention. They will last about a year, if only exposed to the action of the sea, but not so long, if subjected to the floods, and the breaking up of rivers in winter. The hurdles are, in general, an interlacing of flexible branches, with stakes at equal distances; care being taken to cross the joints of every course, with that of the higher, or lower course, and to fasten them securely, (in other words, to break bond.) The head of the stakes often has a natural crook, or a wooden peg is driven in to retain the plaitings. These stakes should be well chosen, of flexible white wood 8 feet in length and 2 inches thick. Twenty-five of the plaitings are generally

placed together ; when twisted closely they weigh 34 lbs., and displace 0·6 of a cube foot of water, the spaces between the stakes being generally from 1 foot to 1 foot 4 inches. The stakes, or wattles of a hurdle vary from 4 feet to 5 feet in length, and are from 5 inches to 8 inches in circumference ; they are tested before using, and have their heads cut off square. Ten stakes weigh from 22 lbs. to 24 lbs., and displace 0·3 of a cube foot of water. Hurdles are used horizontally and vertically.

A fascine bedding, is a simple, or complex bed of bundles of various extent, tied down transversely, by parallel lines of vertical hurdles at equal distances, varying from half a yard to a whole yard, and firmly fixed into the earth. When only one system of this kind is used, it is termed flat fascine-work, and requires nine stakes, twenty-eight hurdles, and seven bundles, to make up 10 feet 9 inches square. When several of these structures are laid upon each other in opposite directions, either sloping, or in steps, and filled up with fascine matting, the work is called sustaining fascine-work ; and again, when, in addition to these, and between each course, the interstices are filled up with sand, pebbles, or broken stone, instead of being compressed, these structures are designated solid fascine-work, and such are generally weighted with brickwork above low water.

M. Desfontaines, the French engineer, gives three and a-half Rhine fascine bundles, seven stakes, seventeen and a-half hurdles, and twelve and a-half cubic feet of gravel, as the content of 35 feet 9 inches cube of solid fascine-work : the bundles alluded to, consist of branches of six to eight years' growth ; the larger ends of all of which, are at one extremity. Two-thirds of the branches should be full length, and not exceed $3\frac{1}{2}$ inches diameter. They should be cut shortly after the fall of the leaf, so that they may not vegetate after they are fixed in their places. These bundles are bound with osier bands, at distances of 1 foot 4 inches to 2 feet apart. Such bundles as are used in Holland are 8 feet and 9 feet in length, and 1 foot 3 inches to 1 foot 8 inches in circumference ; whilst on the Rhine they are 16 feet to 18 feet in length, and 1 foot 6 inches to 4 feet in circumference. The binding is done in the same way as is adopted in packing up fire-wood in England. When they are being laid, the smaller end of one bundle is strongly secured to the larger end of the other, and when the mass consists of more than one bundle in length, they are termed sausages, and in Holland they frequently extend to 20 feet long, the bands being 4 inches to 6 inches apart.

The system of covering shores with fascine platforms, has been executed on a very large scale in Holland, by Messrs. Brisson and Vauterie, to the extent of 3875 square yards. They consist of seven

layers, each layer being laid at right angles to the one beneath. The two lowest consist of bundles crossing each other in rows, at right angles, and at intervals of 3 feet, being well tied together with tarred ropes. On this kind of grating, the third, fourth, and fifth beds, which are of matting, are laid, and then the whole is covered with two layers of bundles, laid similarly to the two first, and secured in the same way; the whole being bound round several times with tarred rope. The entire thickness of this covering is 3 feet. On the upper surface, the whole is crossed transversely and longitudinally with willow hurdling in parallel lines, and well secured to the fascine bed, with wattles, or stakes passing through the entire substance. This bedding is then floated to its proper place, weighted with gravel and turf, and sunk over its destined place; one end being attached to the shore, by two rows of small piles of 6 inches diameter, driven 12 feet apart from centre to centre, and from 10 feet to 12 feet in length. M. Brisson gives the following as contained in 121 square yards of fascine platform:—four hundred and thirty sauses or bundles, one thousand bundles of reeds, one hundred and fourteen tar ropes, each 10 feet long, three hundred and eighty-five stakes 11 feet long and 9 inches round, two thousand one hundred and fifty branches, one hundred and twenty-eight wattles, 43½ cubic yards of gravel and turf, and 17 cubic yards of broken stone.

For damming up rivers on the Rhine, flat fascine beds are made of 171 to 214 square feet, which are sunk into their places between stakes. This sinking is managed by the weight of 105 to 175 cube feet of gravel, spread over the surface. Several layers of these flat fascine beds are laid upon each other, and are fastened together by small piles. These flat beds are constructed of fascine mattings, fixed on to cross poles 1 foot 6 inches to 2 feet apart, the fixing being effected by double wicker bands. On the water side of these mattings, a fascine bundle is laid, and securely fastened, in order to prevent the gravel from rolling off, when the bed is weighted. Each solid bed thus formed of 13 or 14 yards square, consists of ten fascine bundles, twenty-one ordinary poles, one hundred and twelve wicker bands, twelve wattles, and 70 cube feet of coarse gravel.

In situations exposed to the waves of the sea, the Dutch, since 1800, have been in the habit of constructing their shore and other works by means of “sinkstücke.” These only differ from the platforms already described for covering shores, in being constructed more solidly with bundles, and having cross poles fastened on to the lower gratings, to which large ropes are fastened, so that they may be more easily guided. The size of each of these “sinkstücke” is generally 36 feet by 72 feet, and 4 feet thick. They can be dropped

into a stream, having a velocity of 3 feet per second, with security, and so as to sink on to their intended site.

In Holland, the system of throwing in baskets filled with sand and gravel has been tried, and, generally speaking, with good effect. These are rectangular, conical, or triangular, and the last are 7 feet long, each side being about 4 feet wide. The triangular baskets contain each $1\frac{1}{2}$ cube yard of gravel. Their weight, with the gravel, amounts to 1754 lbs., and they displace nearly 30 cubic feet of water. They are, as a matter of economy, weighted at the water's edge, for which purpose small openings are left, which are closed up when ready for sinking.

*Description of the Works executed in forming the Harbour of Nieuwediep at the Texel Roads, with which the Helder Canal is connected by two outlets.**

The channel at Marsdiep, as already stated in the description of the North Holland Canal, is of the utmost importance to Amsterdam and the north of Holland, inasmuch as it offers one of the best roadsteads on the North Sea, possessing three principal sea approaches; the Noorder Gat, the Landsdiep, and the Schulpen Gat. At this point there are several banks, or shoals, lying at the mouth of the channel, called De Hors, the Noorder Haaks, and the Zuider Haaks, which are considered to be of great advantage, for the following reasons:—first, because they narrow the entrance mouth sufficiently, to resist the extreme influx of the tides and floods, which, under ordinary circumstances, rise here to 3 feet 9 inches, but, in extreme cases, to 7 feet; and thus help to prevent dangerous consequences to the coast of the Zuyder Sea: secondly, these banks oppose considerable difficulties, to the entrance of the fleets of an enemy, on account of the channel running close to the Helder shore, whilst the Dutch frigates may escape, even under a blockade, by passing through the Schulpen Gat, which is defended by a long range of their own coast. Moreover, these banks assist in maintaining the channel at its usual depth, and in effecting such a variation in the ebb and flood-waters, as to reduce the velocity of the stream.

It is well known in Holland, that the ebb continues to pass off along the Noorder Gat, a full hour-and-a-half after the tide has commenced running up along the Schulpen Gat, which can only be accounted for, by supposing that the tide runs up from the south-west, and enters the Schulpen Gat, whilst it continues to act upon the ebb-waters, on account of its draught along the coast northwards. The Schulpen Gat and Landsdiep may, therefore, be termed the

* Principally taken from a paper by the late Mr. Conrad.

flood-channel; the Noorder Gat, on the contrary, may be called the ebb-channel. These currents are also considered beneficial, for the south-west coast of the island of Texel, as the continuance of the ebb-waters along the Noorder Gat, serve to weaken the effects of the in-flowing tides by the Landsdiep; and, for the same reason, they are also beneficial to the Helder coast, although not to the same extent, inasmuch as where the tide meets the ebb, the current is very dangerous. It is on this account, as well as because of the decrease and deepening of the Helder shore, in connexion with the necessity of keeping the channel entrance at its present width, that the Dutch have devoted so much time and labour to the shore-works at this point. These consist principally of groynes, two of which were commenced with timber, and finally finished with fascines, covered with stone; but the rest were built entirely of the latter material; their average lengths were about 200 yards each, with an inclination of about one in eight, or one in ten. Since the year 1800, considerable improvements have been made in these banks, and the timber framing has been reduced, or removed; the whole upper surface being covered with stones, on a bedding of tiles and fascine work. The crown of the coast dyke here, is about 16 feet above ordinary high tide, with a slope of eight to one.

The rise of the tides varies at different places along the coast, as follows: at Blankenberg, in Flanders, 16 feet; at Brouwershaven 8 feet; at Goerree $5\frac{1}{4}$ feet; at the Briel $5\frac{1}{4}$ feet; at Katwyck $5\frac{1}{4}$ feet; at Marsdiep $3\frac{1}{4}$ feet; at Terschelling 5 feet; and on the Friesland coast $5\frac{1}{4}$ feet to $7\frac{1}{4}$ feet.

Although the preservation of the coast was the primary object to be attained, in the construction of these works, yet the formation of a harbour was in some measure also contemplated, particularly as the channel at Nieuwediep, from its situation, had long been considered as affording a suitable shelter for ships of war, and its adoption for this purpose, became the more urgent during the late war, from the other harbours in Holland, on the Meuse, &c., being gradually filled with sand. With a view to this, a commission was appointed in 1780, which recommended the Oudediep Swin as an excellent situation, overlooking the circumstance, that this place did not possess good anchorage ground; and, therefore, when in 1781, the Nieuwediep channel was pointed out as preferable, instructions were at once given to the engineers, Brunnings and Goudrian, &c., to examine and report on its merits. The engineers reported it to be their opinion, that the Nieuwediep channel would not be sufficiently deep at all times for frigates, without leading into it the ebb current from the Zuyder Sea, after passing through

the Balg; to do which, they declared would render necessary the construction of some considerable works. At the same time they suggested certain experimental works, for ascertaining the increase of ebb-stream which might be produced at this place; such as a warping bank, 7360 feet long, built with fascines, the crown of which should reach high water, or even a little above it, and be furnished with a guard of double planking, to prevent the escape of the sand, if found necessary, serving also to indicate the resistance it could offer against shifting sand, floating ice, and sea waves, and shewing any improvements effected from time to time, in deepening the channel, and for the better determining the direction, in which it might be most desirable to extend it. They further suggested, for carrying out with greater facility the improvements for the proposed harbour, the constructing of a breakwater at the level of ordinary high-tide, and of the length of 1850 feet. To give greater effect to these, it was also proposed to cut the main channel deeper, in the supposition that when once narrowed, it would only be necessary to give motion to the materials of which the bed was composed, to enable it to clear itself.

This report was not only fully approved, but orders were given for immediately acting upon the suggestions recommended therein. Accordingly, in 1782, the breakwater was constructed, with fascine beds to the height of 3 feet below high-water, at which level the width was 73 feet, having a slope on each side of one to one. Each fascine bed was 3 feet to 4 feet in thickness, and the lowest, at the northern extremity of the work, projected 36 feet beyond the layer immediately above it. The other beds were sunk close together, and every 144 square feet of surface was weighted with 2000 lbs. of stone, and 4000 lbs. of tiles. On this a bed of matting was laid, giving the whole of the upper surface a convex form; the centre being 1 foot, and the sides 3 feet, under high-water level. This matting was secured at intervals of 2 feet, with hurdling laid in both directions, and between these partitions, brick-work in cement was laid, so as to level the whole, and it was then covered with blocks of stone, weighing 1500 lbs. to 1800 lbs. About 1600 feet of this breakwater, towards the north end of the intended harbour, was thus constructed; but an additional length of 2080 feet was built only 49 feet wide, instead of 73 feet, and the whole was furnished, on the inner side, with dolphins, for the convenience of ships anchoring; these dolphins were driven 22 feet into the ground, and at regular distances apart.

In the same year, the warping bank, 7360 feet long, was also commenced, and, on account of the shifting nature of the sand, it was

provided with sheet piling, 4 inches to 5 inches square, and 5 feet long. At intervals of 6 feet, a pile 9 feet in length, was driven in, so that its head stopped at ordinary flood level. These were protected with basket, or fascine work, 4 inches to 5 inches thick, on which horizontal guard planking was laid, well spiked to the piles, and against it, a second or vertical planking, $1\frac{1}{2}$ inch thick, and 7 feet long, was fastened, extending 3 feet into the ground. On each side of this planking a course of matting, 18 feet broad, fastened down with hurdling, was laid, which was covered over with blocks of stone, precisely in the same way as described for the breakwater; the upper surface, when finished, being 3 feet at the sides, and 1 foot at the centre, under ordinary high-water.

In the execution of this work, it was perceived, that the stream carried away the sand in front of the sheet-piling, as it was being driven in, and therefore a fascine bed was at once laid down, through which the other piles were forced.

By means of these two works, the ebb-stream was increased to such an extent, as at once, to deepen the channel full 18 inches, although the bed consisted of a layer of clay 30 inches in thickness. In 1783, dredging was commenced, which, with the assistance of the stream, produced a depth of 19 feet; but, unfortunately, a considerable shoal was found to form itself towards the north end, and, as it was questionable how far the stream was capable, in itself, of removing it, it was resolved, at once, to dredge the whole length of the proposed harbour, 120 feet in width, and to the depth of 17 feet under high-water level. This was undertaken, but not at first with success, it being soon found that the stream was not so effective as had been anticipated. In order to preserve the banks during these operations, and at the same time, with a view to lead the stream, to narrow it, and to increase its velocity, additional works were proposed, and a further straight length of warping bank, of 2450 feet, was made, with a bend of 1225 additional feet, at its termination, at an angle of 35° ; an addition of 2400 feet was also given to the breakwater, and several groynes were built.

For the convenience of seamen and of the shipping, it was also determined to erect a quay-wall, and a jetty of timber framing, about 550 feet long, at the northern extremity of the harbour, intended to serve also for reducing the water-channel, and increasing the velocity of the stream. This consisted of two rows of small piles, driven slanting through a bed of fascines, 3 feet in thickness, their slope being one to four, and the fascines extending 2 feet or 3 feet in front of them; this bedding was weighted as usual. In addition to the above, two outer rows of large oak piles were sunk, with the

same slope as the former, but being 12 feet apart at the head, and 6 feet between each two piles on the face; the heads of these piles were cut off at 7 feet above ordinary flood-tide. All these piles were encased in sheet lead, between high-water level and 1 foot below the ground, the lead over-lapping 2 inches, and being secured to the piles with flat-headed copper spikes. The whole was then covered with tarred rope, twisted round to the thickness of $1\frac{1}{2}$ inch, secured, well-tarred and pitched when finished. Between the outer large, and the inner small, piles, another row of medium piles, three feet apart, was driven, 10 feet to 12 feet into the ground, to the level of 4 feet above high-tide. The whole of the piling was covered outwardly and inwardly, with oak planking, bolted together, and provided with waling timbers and ties, securely fastened and covered with oak planking 2 inches thick, having intermediate spaces of $1\frac{1}{2}$ inch between each board. Finally, dwarf piling was fixed along the front of the whole construction.

In reference to the covering of piles with lead, which has just been mentioned, and which was undertaken to preserve them from the worm, Wiebeking states, that in Germany and in Holland, fascine bedding, or covering, is considered as a complete protection against its ravages.

In the mean time, the dredging of the Nieuwediep channel was carried on without cessation; and the additional works had such an excellent result, that the shoal was very quickly removed. But it required extreme care and attention, to keep the works already executed from being destroyed, as, at a distance of 60 feet from the north end of the breakwater the ground had been torn away to a considerable extent. This slip had been filled up with large blocks of stone, which were not found to improve it, and therefore they were removed, and fascine bedding was introduced, well weighted with bricks, and secured with hurdles; this was found to answer perfectly. When this was completed it was found, that the depth of the channel had increased to 26 feet and 35 feet, so that frigates could pass in and out with safety; and, in 1789, one hundred and fifty-one ships were lying at anchor, of which fourteen were men-of-war, and four were large East-Indiamen. It may also be added, that during the heavy ice-floods of 1789, the shipping was not in the least injured. As soon as the harbour was thus rendered perfect, the shore dykes were improved, and the construction of the docks and ship slips, storehouses, and fortifications was undertaken.

In completing the dykes, it was necessary, that a portion should be formed temporarily of timber, to act as a coffer-dam for building the lock, or entrance to the docks. This had a circular form

given to it, the total length being 210 feet, with a small sluice passage and gates of the size of 3 feet square. It consisted of two rows of piles, each pile being from 22 feet to 26 feet in length, and driven about 8 feet, or 9 feet into the ground at an inclination of one quarter to one; the heads were then left $6\frac{1}{2}$ feet above ordinary high-water. At this height the two rows of piles were 13 feet apart; they were placed in straight lines of 30 feet each, and had two tiers of waling timbers, 8 inches to 10 inches square, securely bolted on to them, the upper tier being 18 inches below their heads, and the lower tier 3 feet below high-water. There was also a row of dwarf sheet piling, set back from the larger, about 10 feet to 12 feet long, and running 4 feet into the ground. In addition, the larger piles had tie-beams of 8 inches to 10 inches square scantling, and 17 feet long, spanning across the whole, let in and fastened down, whilst on the inner side of both rows of piling, planking 2 inches thick was fastened, stopping against a plate, spiked between the larger and sheet-piling, and which, together with a lower one, formed a butting-piece for small arched quarterings, which were placed at short intervals, and bolted together. The whole was then fitted and rammed solid with clay, giving to the upper surface a curved form, which was afterwards covered with turf sods. This coffer-dam was made use of until the lock and basin were completed. The lock is 20 feet wide and 140 feet long. The basin has outlets into another channel, by which it is entirely surrounded, and both together constitute the docks. The dock-buildings, arsenal, and fortifications, are of the most solid construction, and, in every respect complete.

This paper is illustrated by seven Drawings, Nos. 4351 to 4357, and a series of enlarged sketches, from which Plates 8 to 12 are compiled.

No.

- 4351. General Map of that part of North Holland, extending from Amsterdam to the Helder, shewing the Great North Holland Canal.
- 4352. Numerous sectional examples of the Polder Dykes, Coast Dykes, Sunken Banks, Channel Dykes, Breakwaters, and Shore Protections, used in North Holland.
- 4353. Plan and Section of a Floating Dry-dock and Water Camel, and Plan and Elevation of a Floating Bridge.
- 4354. Plan, Sections, and Elevations. of the Willem Locks.
- 4355. Plan, Elevation, and Cross Sections of the Buiksloot Lock.
- 4356. Plan, Elevation, and Sections of the Purmerender Locks.
- 4357. Plans, Elevations, and Sections of the Zijp Locks.

FIGS 1.2.3.&4. EXAMPLES OF POLDER DYKES IN HOLLAND.

FIGS 8 & 9, DYKES ON THE NORTH COAST OF HOLLAND.

SUNKEN BANK AT THE HELDER.

DIKE ON THE SOUTH COAST OF HOLLAND.

SUNKEN BANK AT THE HELDER.

BREAKWATER IN HOLLAND.

Fig. 5.
SHORE PROTECTION WORK AT PETTEN.

Fig. 6.
CHANNEL DYKE AT THE HELDER.

Scale to Figs 1.2.3.4.8.9.10 & 11.

Scale to Figs 12 & 13.

Scale to Figs 5 & 6.

Scale to Fig. 7.

GREAT NORTH HOLLAND CANAL.

PLATE 10.

THE WILLEM LOCKS.

PLAN

INTERIOR ELEVATION.

EXTERIOR ELEVATION

SECTION OF LARGER LOCK.

SECTION OF SMALLER LOCK.

Scale.

BUIKSLOOT LOCK.

CROSS SECTION.

LONGITUDINAL SECTION

P L A N.

ELEVATION.

THE PURMERENDER LOCKS

ELEVATION.

PLAN.

SECTION OF LARGER LOCK.

SECTION OF SMALLER LOCK.

Scale of Feet.