(*Paper No. 3264.*)

“The Paris Navigation Congress of 1900; Recent Works on the Lower Seine; Harbour Works at Havre, and at Zeebrugge; and Improvements effected by the French Lighthouse Service.”

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THE Eighth International Navigation Congress was held in Paris from 28 July to 3 August, 1900, and was attended by the Author as the delegate of the Institution. The Author also took part in the visits of the Congress to the Lower Seine, the harbour works at Havre, and the lighthouse exhibits at the Dépôt des Phares in Paris; and after the close of the Congress he visited the harbour works in progress at Zeebrugge, at the entrance to the Bruges ship-canal, on his way back to England. In fulfilment of his duties as delegate of the Institution, he proposes to refer very briefly to the proceedings of the Congress, and to give concise descriptions of the works visited.

PARIS NAVIGATION CONGRESS.

The Congress was divided into four sections for the reading of the Papers and discussion of the subjects presented to it, and dealt respectively with:—1. Inland Navigation Works; 2. Navigation on Inland Waterways; 3. Works relating to Maritime Navigation; and 4. Working Arrangements at Seaports. Nine questions were submitted by the Organizing Committee for the consideration of the Congress, on which Papers were obtained and distributed to the members before the meeting, which collected together the desired information on the several questions from different countries, and served as a basis for the discussions in the sectional meetings. Three questions were allotted to the second section, and two to each of the other sections. Forty-one Papers were presented, and were printed in French, German, and English, eleven being from France, nine from Germany, four from Belgium, three each from the United States and Hungary, two each from England,

Austria, Holland, and Italy, and one each from Russia, Spain, and Portugal.

First Section.—The questions submitted to this section were:—“The Influence of Regulation Works on the Condition of Rivers, more especially with regard to Inundations;” and “Progress of Mechanical Appliances for supplying Canals with Water;” about which six, and three Papers respectively, were received from six different countries.

Second Section.—The subjects considered by this section comprised:—“The Utilisation of Rivers of small Depth, beyond their Maritime Portion, by means of Craft of small Draught specially suited for Colonies;” “Progress of the Adoption of Mechanical Appliances for the Navigation of Waterways, and Monopolies of Traction;” and “Provision of Insurance and Instruction for Bargemen and their Families;” and they formed the topics of four, eight, and three Papers respectively, contributed by authors from seven nationalities.

Third Section.—The Papers in this section dealt with “The most Recent Progress achieved in the Lighting and Buoying of Coasts,” on which subject three Papers were received, from France, Germany, and the United States; and “The most Recent Works carried out in the principal Seaports and Harbours,” which were described for seven countries of Europe in ten Papers, as English, French, and Belgian engineers contributed two Papers for their respective countries, the other countries, represented by one Paper each, being Germany, Italy, Spain, and Portugal.

The subjects which elicited the principal discussions in this section were, the best arrangement for an entrance to a harbour; the value of large blocks in the construction of superstructures for breakwaters; and the influence of sluicing basins on the maintenance of a channel. The discussion on entrances was raised by the respective advocates of the very different forms of harbours adopted at Ymuiden for the approach to the Amsterdam Ship-canal,¹ and at Zeebrugge for sheltering the entrance to the Bruges Ship-canal.² It was urged against the Ymuiden entrance facing the open sea, that it required a sheltering breakwater outside to afford adequate protection for vessels entering or leaving the harbour; whilst, on the other hand, it was suggested that vessels would be obliged to make an awkward right-angled turn to enter Zeebrugge Harbour as designed, in place of the straight course

¹ Minutes of Proceedings Inst. C.E., vol. lxii., Fig. 9, Plate 1.

² *Ibid.*, vol. cxxvi., Fig. 2, Plate 5.

afforded by the Ymuiden entrance. At the close of the discussion, however, it was pointed out by the Author that an entrance facing the open sea was by no means confined to Ymuiden Harbour, that this harbour was not considered difficult of access, that the waves coming in through the entrance were considerably reduced by expanding in the widened harbour before reaching the entrance to the canal, and that the exposed position of Ymuiden Harbour, on a perfectly straight coast, would have rendered the adoption of a wide side entrance, similar to the Zeebrugge design, quite impracticable. He also indicated that though the form of the Zeebrugge breakwater, stretching out in front of the entrance to the canal, effectually protected this entrance from the north and west, the perfectly open state of the harbour on the eastern side was only permissible on account of the shelter afforded from east-north-east by the curving round of the coast towards a northerly direction. Moreover, Zeebrugge Harbour would be more exposed to the introduction of silt, in spite of the provision of the open viaduct between the shore and the breakwater for the passage of the littoral current, than Ymuiden Harbour with its entrance situated away from the shore in a depth of 5 fathoms at low-water. Though Ymuiden and Zeebrugge harbours differ completely in form and arrangement of entrance, each may be best adapted to the special conditions of position and object; and in the end there was a general agreement amongst the majority of the members of the section, that it was impossible to contrast two essentially different types of harbours, without taking into account differences in the conditions of the site, and in the purposes for which they have been constructed.

The Papers describing the breakwaters at the mouth of the Nervion and at Zeebrugge, naturally led to a discussion on the value of very large blocks floated out, in a partially completed state, in iron caissons, for the superstructure of breakwaters in exposed situations, and eventually filled up when in position. It was stated by Mr. Coiseau, one of the contractors for both breakwaters, that until blocks of this kind, weighing 1,400 tons, were resorted to for the foundations of the superstructure of the main breakwater for protecting the approach to the River Nervion in the Bay of Biscay, laid at low-water level on a rubble mound, the work done in the summer was destroyed by the winter storms; whilst these large blocks, though settling sometimes more than 3 feet on the mound, had remained undisturbed. Mr. Coiseau also considered that the still larger blocks adopted for the foundations of the sea- and harbour-walls of the wide Zeebrugge breakwater,

from the bottom up to above low-water,¹ would not only prove more stable, but would be also more economical, and allow of a more rapid rate of progress than the smaller blocks ordinarily used. Whilst it was admitted in the discussion that the largest blocks were necessarily also the most stable, it was suggested that many sites would not afford the same remarkable facilities for the construction and floating out of the caissons lined with concrete as the Bruges Ship-canal gives to Zeebrugge Harbour; that it might be difficult to place such large blocks upon a level base; that whilst perfectly calm weather was required for floating out and depositing a block, a storm might come on and injure the caisson before it could be adequately filled with concrete; and that in some cases funds would not permit of constructing such large blocks, whilst other methods were available for forming monolithic structures.

The question of the efficiency of the current from sluicing basins for maintaining the depth of a channel was led up to by the description of the works in progress at Ostend, in a Paper by Mr. Van der Schueren, one of these works being a large sluicing basin² designed to maintain a depth of 26 feet 3 inches at low water alongside a new quay being built for the accommodation of steamers of large draught, at the upper end of the enlarged harbour. The formation of a sluicing basin, in preference to resorting to suction-dredgers, which are now generally employed for deepening and maintaining the entrance channels of the jetty harbours on the Channel and North Sea coasts, was decided upon in order to avoid impeding the movement of vessels by dredgers in an inner channel of restricted width; and in the discussion the writer of the Paper, who is the engineer in charge of the works, proved himself a strenuous advocate of the scheme, and a firm believer in the efficacy of sluicing basins. Most of the engineers, however, who took part in the discussion, including Mr. Eyriaud des Vergnes, who about 20 years ago did away with a similar sluicing basin in Dunkirk Harbour, considered that the current discharged from a sluicing basin would soon lose its velocity, and consequently its scouring force, when directed against the bed of a channel covered with water to the extent of not less than 26 feet 3 inches in depth, and would therefore be quite unable to maintain this depth for any distance alongside the quay, in a harbour exposed to the introduction of sand and silt during every flood-tide. Nevertheless, it was generally agreed that this sluicing basin, when put into operation,

¹ Minutes of Proceedings Inst. C.E., vol. cxxxvi., Figs. 4 to 7, Plate 5.

² *Ibid.*, vol. cxxxvi., Fig. 17, Plate 6.

would furnish a very instructive demonstration of the actual efficacy of the issuing current under the conditions described.¹

Fourth Section.—The questions selected for consideration by this section were, “The Adaptation of Commercial Ports to Naval Exigencies, in respect of the dimensions of the principal works, and the navigable depth,” and “Progress of the Application of Mechanism to the Equipment of Ports.” Three Papers were contributed on the first of these questions by engineers from France, Germany, and the United States, and only one on the second, by a French engineer.

In addition to the Sectional Meetings, at which some further Papers were presented at the conclusion of the pre-arranged programme, a conference was held at which Mr. Ockerson, a member of the Mississippi River Commission, gave an account of the physical characteristics of the Mississippi, and the works carried out by the Commission for the regulation and control of the river. Excessive erosion of the alluvial concave banks of the river at bends during floods, below the confluence of the Ohio, is arrested at important points by forming the bank to a uniform 3 to 1 slope above the low-water line, by means of a jet of water under pressure, termed an hydraulic grader, directed against the bank, and then pitching the bank with rubble stone; whilst the bank below the water-line is protected by large fascine mattresses weighted with stone and sunk in position. The devastating floods of the Mississippi, which occur below the confluence of the Ohio in the winter and early spring, are restricted by levees in places, which are being gradually extended; and these levees, when the works in progress are completed, will have a total length on the two banks of about 1,300 miles. To maintain the requisite depth of 8 feet in the navigable channel at the low stage, in addition to regulation works, a channel is cut each year through the bars of sand which obstruct the navigation on the subsidence of the floods, by means of several suction-dredgers furnished with water-jet agitators for stirring up the sand, and thereby considerably augmenting the proportion of sand drawn up through the suction-pipe.

At the general meetings of the Congress, on the concluding day,

¹ This is the only section for which a brief summary of the chief points discussed can be given, as the four sections held their meetings at the same time; and the Author, being a writer of one of the Papers for the Third Section, and also one of the Vice-Presidents of that section, had to attend its meetings regularly, and therefore could not be present at the discussions of the other sections.

reports of the proceedings of the four sections were received, and the conclusions arrived at were agreed to; and a scheme drawn up by a committee nominated at the Brussels Congress in 1898, for the appointment of a Permanent International Commission to arrange the future meetings of the Navigation Congress, was approved.¹

RECENT WORKS ON THE LOWER SEINE.

In a Paper on "The River Seine,"² read before the Institution in 1886, the Author described the various works which had been carried out for the improvement of its navigation, and more particularly the weirs which had been constructed on the Lower Seine for increasing the navigable depth below Paris to 10 feet 6 inches at the lowest state of the river; the training walls which had been formed along the upper portion of its estuary from La Mailleraye down to near Berville, with their results; and the various proposals which had been made for extending the training works, which were more fully indicated in a Paper on experimental investigations,³ read at the Royal Society in 1889. The chief works which have been since carried out on the Lower Seine are, the introduction of electrical power for working Poses weir; an extension of the quays at the Port of Rouen, and the erection of a transporter-bridge; a widening of the trained channel in a bend near Aizier, and also below Quillebeuf; the prolongation of the training walls further down the estuary; and the systematic adoption of dredging for increasing the navigable depth.

Electrical Working of Poses Weir.—The weir at Poses on the Lower Seine, with an overhead bridge from which the hinged frames suspended from its under side are raised in opening the weir, was completed in 1885; and it holds up a head of water of 13 feet 9 inches at the low stage of the river.⁴ Up to 1889, the curtains were rolled up, and the frames were raised to a horizontal position under the bridge, by winches worked entirely by hand; but in that year steam winches were introduced; and lastly, in 1896, electricity was adopted as the motive force. A turbine placed in the outer side wall of the old lock, at its lower end, develops

¹ The Papers presented to the Congress are in the Institution Library; and the Summary of the Proceedings at the General Meetings of the Congress, and the Discussions at the Sectional Meetings, will be sent there as soon as issued.

² Minutes of Proceedings Inst. C.E., vol. lxxxiv. p. 210, and Plates 1 to 5.

³ Proceedings of the Royal Society, vol. xlv. pp. 514-520, and Plates 2, 3, and 4.

⁴ Minutes of Proceedings Inst. C.E., vol. lxxxiv., Fig. 3 and 4, Plate 3.

12 HP. under the minimum fall of 2 feet 7 inches, and 30 HP. under the normal fall at the weir. Two dynamos are run by the turbine, either singly or together, which generate the electricity for working the machines, and charge accumulators for the electric lighting of the lock by night and also the weir when needed. The moving of the gates and sluice-gates of the large lock at Poses, and all the operations for opening and closing the weir are effected electrically. Each of the two winches for rolling up the curtains is provided with an electric motor of 3 HP.; but as these curtains, in the ordinary course, have to be rolled up or let down successively by degrees, so as to modify the discharge in accordance with the rise or fall of the river, the variable time thus occupied cannot be reckoned in comparing the rates at which the weir is opened and closed by different means. Considering, therefore, merely the raising and lowering of the suspended frames across the seven passes of Poses weir, having a total width of 693 feet, the time occupied in raising the frames by hand with two winches was 60 hours with 20 men, and in lowering them 40 hours with 14 men; with one steam winch the raising was effected in 13 hours by 7 men, and the lowering in 7 hours by 6 men; whilst with one electric winch, having a motor of 7 HP., the raising is accomplished in 12 hours, and the lowering in 7 hours, by 5 men in each case,¹ showing that the adoption of steam-power effected a great reduction in the time of working and the staff required, and that the introduction of electricity has produced a further slight acceleration in working, and a reduction in the number of men employed. Moreover, by the simultaneous employment of a steam winch and an electric winch, 12 men can raise the whole of the frames in 7 hours, and lower them again in $3\frac{1}{2}$ hours.

Extension Works at the Port of Rouen.—The port of Rouen forms a sort of dividing line, where the inland navigation of the Seine practically terminates, and the maritime navigation begins; and the portion of the port above the lowest road-bridge is devoted to the up-river traffic, whilst the port for sea-going vessels is situated below the bridge. The maritime port comprises the river Seine itself for an area of $76\frac{1}{2}$ acres, lined on the two banks by 12,165 lineal feet of masonry quays, and 656 feet of timber jetties or stages; a timber pond of 13 acres, with eleven wooden jetties and a slip for large barks; and a petroleum basin of $29\frac{2}{3}$ acres, with

¹ "Notice sur les nouveaux Types de Barrage appliqués sur la Basse Seine entre Paris et Rouen," M. A. Caméré, Paris, 1900, p. 7.

eight jetties¹ (Fig. 1, Plate 6). The inland-navigation port consists of 27 acres of the river Seine, lined on the two banks by 4,675 lineal feet of quays. The works in progress in the maritime port form part of the improvement works decided upon in 1885, at a cost of about £380,000, now approaching completion, to which the greater portions of the existing quays and basins also belong; and they comprise the construction of 860 feet of masonry quay-wall, in place of four old jetties; the deepening of the petroleum basin to 20 feet below the lowest water-level at Rouen by dredging, and the formation of a new direct entrance, 82 feet wide, at its lower end; and the erection of timber staging connecting three jetties on the south side of the timber basin, so as to provide a continuous quay 745 feet long, and the widening of a jetty on the opposite side, so as to afford a continuous length of quay of 302 feet. Masonry quays are also about to be constructed to fill up two gaps between two long lengths of timber staging and the quay, on the right bank of the river; and then, as the timber staging falls into decay, it will be replaced by a masonry quay-wall. These masonry quays are all constructed according to the economical type adopted since 1879, costing only £36 6s. per lineal foot, inclusive of filling in the ground at the back for a width of 200 feet from the face of the quay (Fig. 2, Plate 6); and they have proved both stable and durable, and are able to bear a load on the quay of 5 tons per square yard. The lower part of the wall is built inside water-tight timber caissons with removable sides, sunk on to the top of the foundation piles cut off to the level of 22 feet 9 inches below the coping; and a depth is provided in front of the quay-walls of 27 feet 3 inches below the lowest ordinary low water.

The tonnage of merchandise of the sea-going and coasting vessels entering and leaving the port of Rouen, which was about 780,000 tons in 1875, had risen to about 2,350,000 tons in 1899, or disregarding occasional fluctuations, an average annual increase of 65,400 tons during the last 24 years. In order to provide for this growing traffic, additional works are already under consideration, consisting of 2,460 lineal feet of new quays on the right bank of the river, 980 feet on the left bank, 5,085 feet alongside the timber basin in substitution for timber jetties, and a graving dock with an available length of 492 feet, as shown by dotted lines on the plan (Fig. 1, Plate 6).

Transporter Suspension Bridge at Rouen.—The contrivance of a suspended ferry, consisting of a travelling car hanging from a

¹ "Notice sur le Port de Rouen," Messrs. Belleville and Dupont, Rouen, 1900.
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trolley running on rails along the platform of a suspension-bridge across a river, at a sufficient elevation to afford the requisite headway for masted vessels, with the object of establishing communication between the two banks, was first inaugurated at Portugalete in 1893, crossing the River Nervion near its mouth; and the same system was subsequently adopted for giving access to the land on each side across the entrance channel to the port of Bizerta on the coast of Tunis. The success which attended this means of transit across navigable waterways has led to the erection of a similar transporter-bridge at Rouen, for connecting the quays on each bank of the river towards the centre of the maritime port, nearly $\frac{1}{2}$ mile below the last road-bridge across the Seine, Fig. 1, Plate 6.

The transporter-bridge, which was erected in 1897-98, and opened for traffic in September, 1899, has a span of 469 feet between the centres of support of the suspension-cables on the openwork metal towers standing close to the edge of the quay on the two banks of the river, and rising 217 feet above quay-level;¹ and the open platform of the bridge affords a clear headway of 167 feet above the surface of the river at high water of spring tides, Figs. 3, Plate 6. The expansion and contraction of the steel wire cables which carry the bridge, are provided for on the top of each tower by a frame on rollers supporting a stout bar extending across the tower, to the up and downstream ends of which are attached the twelve main suspension cables, 3·33 square inches in section, twenty-four auxiliary oblique cables, and twelve anchorage cables of 4·6 square inches section. The trolley traversing the bridge is borne by four lines of fifteen rollers, with a wheel-base of 62 feet, running in pairs transversely on four rails laid in pairs close together on each side of the bridge; and each adjacent pair of rollers on either side of the bridge carries a steel wire cable, from which the travelling platform or car is suspended at quay-level. The car, which is thus supported by thirty cables, is 33 feet long, and has a width of 42 feet 8 inches, made up of a carriage-way of 26 feet 3 inches, and a footway on each side of 8 feet 2½ inches; and with the trolley and electric motor the moving weight is 38 tons. The maximum load which can be placed upon the car, namely, when filled up with 520 persons, amounts to 36 tons. The trolley, which is worked by electricity, obtains its current from

¹ "Atlas des Voies Navigables de la France," 2^e Série, 5^e Fascicule; "Navigation de la Seine entre Paris et la Mer," Paris, 1899, p. 41, and Plate 23, Fig. 52, and Plate 37.

the generating station of the Rouen Electric Tramway Company; and the crossing of the river is effected by the car in about $\frac{1}{2}$ minute.

Modification of the Seine Training Works.—Within the last 20 years the River Seine has been regulated in places between Rouen and La Mailleraye by training works, shutting off indents and creeks, narrowing the river at unduly wide parts, and guiding the current into a single channel where the river was split up by islands, the secondary channels being at the same time closed by joining the islands to the land by cross dykes. These supplementary training walls, carried out in a part of the river where no works had been previously executed, produced a notable deepening of the channel, which has since been increased by dredging, so that now there is a minimum depth of 22 feet 4 inches at the lowest low water over the three highest shoals below Rouen, giving an available depth of between 27 feet and 28 feet up to Rouen at high water of spring tides.

The modification in the width of the trained channel in the lower portion of the river, and the extension of the training walls into the estuary below the mouth of the River Risle, commenced in 1890 and still in progress, have been specially designed with the object of making the flood and ebb currents follow as nearly as practicable the same course, and by a suitable enlargement of the channel downwards to facilitate the progress of the flood tide up the river,¹ considerations which had not been adequately attended to in carrying out the original training works. Below La Mailleraye the old training wall along the concave right bank, by the side of the Meules shoal, had been entirely washed away by the current for a length of $2\frac{3}{4}$ miles, and is being reconstructed along the original line; and the peaty Meules shoal has been lowered by dredging, Figs. 4 and 5, Plate 6. Lower down a widening of the channel round the sharp bend at Aizier along a length of $3\frac{1}{2}$ miles, from a width of 1,310 feet at each extremity of the curve to 2,130 feet in the centre of the bend, has been effected, to prevent any checking of the flood tide in coming up round the bend, by letting the bore cut back the projecting point of the right bank at Cap de Petitville. Erosion is prevented from extending beyond the designed limits, by protecting the new convex bank of the river round the curve by lining it with a continuous mound of shingle procured from the neighbouring Flaques shoal

¹ "Notice sur les Travaux d'Amélioration de la Seine entre Rouen et la Mer," Messrs. Belleville and Martin, Rouen, 1900, p. 5.

by dredging; and this bank of shingle is connected at its lower extremity to the training wall below, by a new portion of training wall.

A similar enlargement of channel has been carried out at the next sharp bend below, between Quillebeuf and Tancarville, by constructing a new south training wall cutting further back into the projecting point of the left bank in front of the Vernier Marsh than the original wall, which had almost entirely disappeared at this part, so as to give a width of 2,400 feet in the centre of the bend, in place of the former width of the trained channel, which was merely gradually widened out from 1,480 feet at Quillebeuf to 1,640 feet at Tancarville, and occasioned a considerable checking of the flood tide, owing to the absence of any enlargement of the channel round the sharp curve. The extension of this modified line of southern training wall, back from the old line of wall, at present in progress, rejoins the old south wall $2\frac{1}{2}$ miles below Tancarville, Fig. 4, Plate 6. This new south training wall is being made similar in type to the other consolidated or reconstructed training walls, consisting of a rubble mound protected on the river slope by a layer of Portland cement concrete resting upon stone pitching, and at the toe by timberwork, as shown on the cross section (Fig. 6, Plate 6); and the body of the mound in this instance is being formed of the shingle dredged from the Flaques shoal, with its top raised about 2 feet 3 inches above high water of spring tides. The average cost of this type of training wall, 13 feet in height, is about £10 per lineal yard.

The north training wall has been left unaltered between Quillebeuf and Tancarville; but below Tancarville, where the navigable channel was formerly bounded by two low parallel training walls 1,640 feet apart, a high northern training wall was constructed in 1890-96, gradually enlarging the high-water channel of the river to a width of 3,940 feet opposite the confluence of the River Risle (Fig. 4, Plate 6), a modification which the extension of the training works into the estuary rendered necessary. This training wall was formed with rubble stone brought direct in wagons from the Tancarville quarries; and it is being consolidated by the usual concrete layer on the exposed slope, finished off at the top by a small parapet raised 3 feet above the top of the mound, to protect the rubble at the top from being displaced by the swell during high tides. The old low northern training wall has been preserved down to a beacon situated $1\frac{1}{2}$ mile above the mouth of the Risle, to maintain the low-water channel. Below this beacon the low-water channel, which is bounded on its southern side by the old

south training wall, has been widened out seawards by substituting two dipping cross dykes for the old low northern training wall, which, starting from the high-water north training wall, constitute at their extremities the northern limit of the low-water channel, Fig. 4, Plate 6. These cross dykes have been constructed with blocks and timberwork; and a third similar dyke has been made to connect the high-water and low-water northern walls near the beacon.

Extension of Training Works into the Seine Estuary.—The Seine training works, which had been carried down nearly opposite Ber-ville in 1869, produced such rapid and large accretions at the sides of the estuary, even beyond their termination, extending down to Harfleur on the northern side and to Honfleur on the southern side,¹ that fears were entertained that the approach-channel to the port of Havre might be injuriously affected by any prolongation of the training walls; and no extension of the works was, accordingly, attempted for a quarter of a century, though various schemes were from time to time proposed in the interests of Rouen. A technical commission was appointed in 1885, by the Minister of Public Works, to devise a comprehensive scheme for improving the shallow, shifting, navigable channel through the Seine estuary, and at the same time provide a better and assured approach to Havre. At length after elaborate investigations and long enquiries, an extension of the training works beyond the mouth of the Risle was sanctioned in 1895; and it was decided to secure a sheltered deep-water approach for the port of Havre, entirely beyond the influence of accretions in the estuary of the Seine, by the construction of a harbour on the sea-coast in front of Havre, to the north of the mouth of the Seine.

The extension of the training works as designed, and now being carried out, comprises the prolongation of the high-water northern training wall, in a line slightly convex towards the channel, for a length of 4 miles, and a south training wall starting from the western corner of the Risle outlet, and extending 3 miles into the estuary, Fig. 4, Plate 6. The lines of the training walls are somewhat divergent so as to provide an enlarging channel seawards, which attains a width at the termination of the south wall of 5,250 feet, or nearly a mile. Provision has been made in the scheme for the prolongation of the south training wall down to Honfleur, a distance of $1\frac{1}{2}$ mile, if this further extension should be considered necessary at some future time.

¹ Minutes of Proceedings Inst. C.E., vol. lxxxiv. p. 246, and Fig. 1, Plate 4.

The sandbanks in the estuary, along the line of the north training wall extension, when the channel diverged to the Honfleur shore, rose from 10 feet to 16 feet 6 inches above zero, which is the lowest low-water level at the sea-coast; and this training wall is being constructed by first depositing a layer of rubble stone from barges to a height of 5 feet to 6 feet 6 inches, which protects the bottom from the possible occurrence of scour at the site, and promotes accretion at the back; and then the training wall is raised to high-water level, by rubble brought in wagons from Tancarville along a line of rails laid on the top of the north training wall.

The prolongation of the south training wall, on the contrary, is being founded on a bottom which is 6 feet 6 inches below zero, and is covered at low tide with 14 feet 9 inches to 16 feet 6 inches of water. A low training wall is, accordingly, being constructed along this site, by depositing rubble stone from barges, carried up 13 feet above zero, or 14 feet 9 inches below high water of spring tides. The upper portion of this wall is being protected by stone pitching, and consolidated by a row of sheet-piling along the centre, Fig. 7, Plate 6. A high-water training wall is eventually to be formed at the back of this low half-tide training wall, as shown on the section; but this work will be deferred till the accretion at the back of the low training wall has risen high enough to facilitate the economical construction of the high training wall.

Dredging Shoals between Rouen and the Sea.—The earlier training works effected very great improvements in the navigable depth (Fig. 5, Plate 6), by fixing the channel and concentrating the scour, without any assistance by dredging, beyond a moderate lowering of the Meules shoal. In 1880 a channel was dredged through this shoal to the depth of the zero of the charts, for a width of 500 feet, which in 1899 was made 5 feet deeper for the same width, both to improve the depth for navigation and to increase the discharging capacity of the channel. Systematic dredging operations were commenced in 1888; and during the following 7 years various shoals between Rouen and Bardouville were lowered, as well as the Trait shoal further down. In 1897–98 the Bardouville shoal, composed mainly of sandy clay, was dredged to a depth of 5 feet below zero, for a width of 165 feet, which is eventually to be enlarged to 330 feet, not merely to improve the navigable channel, but also to facilitate the discharge of the river. The Flaques shoal, composed of flinty and limestone shingle consolidated by sand and a little clay, which formerly obstructed the channel for a

length of 4,900 feet, rising to the level of zero along the deepest channel for about 3,300 feet, was dredged in 1895-97 to a depth of 3 feet 3 inches below zero for a width of 690 feet, the materials being utilized for the training walls below; and a channel is now being dredged in continuation below, to a depth of 5 feet 6 inches below zero for a width of 330 feet, to augment the section of the channel for discharge, and to furnish materials at the same time for the training walls at Quillebeuf and in the estuary.

Trials were commenced in 1897 with a suction dredger in the Seine estuary, to ascertain the effect of dredging in preventing unfavourable changes in the navigable channel through the estuary; and as the results proved satisfactory, two suction dredgers were set to work in the estuary in 1900, and two specially-built suction dredgers, of 600 HP. and 650 cubic yards hopper capacity, are to begin dredging there early in 1901.

Cost of Tidal Seine Improvement Works.—The total expenditure since 1848 on works for improving the navigable channel of the tidal Seine below Rouen, together with the estimated cost of the works in progress, may be summed up as follows:—

	£
Original Seine training works, carried out previously } to 1866	720,000
Renewal and consolidation of training walls below } Caudebec	600,000
Training works between Rouen and Caudebec	140,000
Dredging above the mouth of the River Risle	100,000
Scheme of 1895, comprising training works and dredg- } ing in the Seine estuary	600,000
Total	<u>£2,160,000</u>

The training works have already led to the reclamation of 18,700 acres of very fertile land from the Seine estuary by accretion, valued at about £860,000, and the works in progress will result in further reclamations of land; so that eventually these works, besides greatly improving the navigable condition of the tidal Seine, will have reclaimed an extent of land from the estuary, the value of which, it is estimated, will reach about half the cost of the works.

Situation of the Port of Rouen.—Vessels with a draught of over 23 feet can now get up to Rouen during ordinary spring tides; and these vessels, with the help of the flood tide, can traverse the distance from Havre roadstead in 7 hours or 8 hours. Moreover, the estuary channel, since 1892, has been lighted by about thirty boat-buoys moored in pairs, from 490 feet to 820 feet apart, on each

side of the navigable channel at intervals of about 4,900 feet, exhibiting red and green lights respectively, produced by compressed mineral oil-gas in a reservoir holding 70 cubic feet, sufficient for a month's supply, so that vessels can navigate the estuary by night as well as by day, the buoys being shifted at once whenever the soundings indicate any change in the channel. Fixed lights have indicated the channel at night all the way from the mouth of the Risle to Rouen since 1878. Rouen being at the head of a tidal navigation penetrating 78 miles inland, and connected by the Seine with Paris and the inland navigation system of France, has been enabled, by the development of its access to the sea, to acquire a good and gradually increasing maritime trade, though the port of Havre lies directly at the entrance to its approach-channel.

Remarks on the Works in Progress in the Tidal Seine and Estuary.—The resort to dredging in the trained Seine, for regulating the sectional area of the channel, and increasing the navigable depth across shoals too compact and solid to be affected by the scour resulting from the training works, is the natural sequel to such works when the limit of their improvement has been reached, and a further deepening is required. The employment of suction dredgers for guiding and restricting the changes in the channel through the Seine estuary, beyond the termination of the training works, is a more novel undertaking in a sandy estuary where the changes have been so frequent and extensive. The prolongation, however, of the training walls, and the consequent extension of accretion at the sides of the estuary, will by degrees considerably circumscribe the area over which the channel can wander, and therefore proportionately favour the efficiency of dredging in restricting undesirable alterations in the navigable channel. Moreover, the enlargement and straightening of the shifting channel by dredging, together with the notable reduction in its length through the estuary produced by the prolongation of the trained channel (Fig. 4, Plate 6), will tend to concentrate the tidal ebb and flow and fresh-water discharge more into the channel, and thus promote its stability. Experience, however, alone will be able to decide, after the completion of the training works and the production of the resulting accretions, to what extent the permanency and depth of the channel can be secured by those dredging operations; and the result will be materially affected by the amount of sand annually removed from the channel by the dredgers.

The widening of the trained channel round the sharp bends,

where previously the advance of the flood tide up the river was checked, the enlargement of the trained channel seawards below Quillebeuf, and the increase in its sectional area at narrow places and the lowering of hard shoals by dredging, thereby notably promoting the free and full admission of the flood tide, cannot fail to produce a permanent improvement in the condition of the tidal Seine. The prolongation also of the training works into the estuary very naturally follows on the provision of a new approach to the port of Havre, out of reach of any accretions in the Seine estuary, with the object of improving the approach to Rouen, and reducing the length of unstable channel between the sea and the trained river; but the expediency of raising these extensions up to high-water level throughout, without any definite provision for guiding the low-water channel, appears to be less evident.

There have been three distinct phases in the carrying out of the Seine training works. In the earlier works, the channel was regulated and restricted by high training walls so that the concentrated currents might scour the bed of the fixed channel, without adequate provision being made for the widening out of the channel seawards sufficiently to ensure the free admission of the flood tide; whilst the vast accretions which have resulted from these works were not foreseen. When the training works had reached the upper end of the widening-out estuary, and their effects in producing deposit had become manifest, low training walls were adopted for extending the training of the river, below Tancarville on the north side, and below La Roque on the south side, in order to check the accretion and to avoid a large reduction in tidal capacity. At the present time, high-water training walls are again being adopted, though placed considerably farther apart; for the high-water wall is being made continuous on the north side from Tancarville to the end of the extension now in progress; whilst the south wall, though only being raised to about half-tide level in the first instance, on account of the depth in which it has to be founded, is to be brought up at the back to high-water level throughout as soon as the accretion at the back of the low wall reaches half-tide level, Figs. 4 and 7, Plate 6. Further accretions are fully anticipated as a result of these extension works; but the consequent reclamation of land from the estuary is now merely regarded as a means of defraying a considerable part of the cost of the works.

Doubtless the existing height of the sandbanks along the site of the extension of the north training wall, rising nearly to low-water level along a considerable part of the distance, and raised

above half-tide level at the upper end, as indicated by the survey of 1898 (Fig. 4, Plate 6), would have prevented a low wall, even towards the outer end, having much influence beyond restricting the wanderings of the channel; whilst the effect of a high-water wall in regulating the high-water channel, and the desire to render the land at the back fit for reclamation, furnished strong inducements to adopt a high wall. Nevertheless, a wall founded for the greater part of its length at or below low-water level at the site, and raised up to high-water level out into the middle of the estuary, cannot fail to produce very great accretions, not merely behind it, but extending along the northern foreshore very nearly as far as the outlet. These accretions will largely reduce the existing tidal capacity of the estuary, which by producing a diminution in the tidal scour must lead to shoaling at portions of the outlet; and though this shoaling may not materially affect the navigable channel if this channel can be led straight into the central deep existing between the Amfard and Ratier banks, it will reduce the navigable depth in any other position.

Any prolongation of the training works must, indeed, inevitably be accompanied by accretion at the sides of the estuary; but it would appear a preferable course to have kept down the outer portion of the north training wall to about half-tide level, and to extend it further, at a lower level, if possible, in a somewhat more northerly direction. A training wall carried out in this way would not be liable to produce such extensive changes in the estuary as the shorter high-water wall in progress; whilst even high-water walls alone, at a considerable distance apart, cannot be relied upon for adequately fixing and deepening the low-water navigable channel. Moreover, the additional extension of the north training wall, which must sooner or later be carried out, would still further restrict the limits within which the navigable channel could wander, would aid in directing the channel towards the central deep, and would enhance the influence of dredging in guiding the channel by reducing the area of its operations.

HARBOUR WORKS AT HAVRE.

The new approach to the port of Havre, out of reach of the accretions in the Seine estuary, now in progress, consists of a harbour on the sea-coast to the north of the mouth of the Seine, in front of the town and present entrance to the port, which is being enclosed and sheltered by two converging breakwaters, one starting from the shore towards the northern end of the town, and

the other from a modified extension of the present south jetty of the approach-channel, and leaving an entrance, 656 feet wide, between their extremities,¹ Fig. 8, Plate 6. The straight north breakwater is being given a length of 2,790 feet; and the south breakwater is being carried out in a north-westerly direction for a length of 2,625 feet, with a northern cant at its outer end of 246 feet. The new harbour has an area of 173 acres; and its entrance facing west, and situated in a depth of 11 feet 6 inches at the lowest low water, is to be dredged to 14 feet 9 inches in the first instance, and also the outer north-west pass leading to it to the same depth for a width of 1,150 feet, which depth may eventually be increased to 28 feet below zero.

Description of Breakwaters.—The breakwaters are being constructed of the composite type, with a mound up to about 1 foot above low water of spring tides, surmounted by a superstructure founded upon a row of large blocks laid on the top of the mound, Fig. 9, Plate 6. The mound is formed of sorted rubble stone, with the smaller material constituting the bottom central core, overlaid with the larger stones, and protected on the sea slope by large rubble and concrete blocks.² Masonry blocks of 33 cubic yards, weighing 60 tons, are laid on the top of the mound levelled off at about 4 feet above zero; and as soon as their settlement on the mound has ceased, the intervals between them are filled in with masonry, thus forming a foundation layer of masonry, about 6 feet 6 inches thick and 24 feet 7 inches wide, on which the masonry superstructure is built. In the case of the north breakwater, the foundation-blocks have been constructed in place by tide work, to avoid delay; but the blocks for the south breakwater are built on shore, and left to set for at least two months before they are taken out and deposited on the mound. The toe of the foundation of the superstructure is protected on the sea side by large blocks of rubble in the less exposed parts, and by a row of concrete blocks, weighing about 31 tons, laid on the top of the mound for the greater part of the length, and with similar blocks on the slope. The mound of the north breakwater has been completed close up to the commencement of the pier-head, and the superstructure is in progress along the greater part of this length; whilst the mound of the south breakwater is more

¹ "Le Port du Havre," H. Vétillart, Havre, 1900.

² "Travaux les plus récents exécutés dans les principaux Ports français," M. Barbé, VIII^{ème} Congrès International de Navigation, Paris, 1900, p. 5, and Fig. 2, Plate 3.

than half finished, and some foundation blocks have been deposited on it.

The superstructure has a bottom width of 21 feet, reduced to a width of about 16 feet 6 inches at its quay level, 7 feet above high water of spring tides, by a batter of 1 in 10 on each face. The quay is 11 feet 6 inches wide, and is protected on the sea side by a parapet 5 feet high. The north breakwater, facing west-north-west, is the most exposed, being open to the English Channel in a north-westerly direction; whereas the south breakwater, facing south-west, is sheltered by the adjacent coast, stretching out westwards, from the south round towards west.

The pier-heads at the extremities of the breakwaters on each side of the entrance, 44 feet in width at the quay level, are to be constructed with masonry foundations having vertical sides, by means of caissons carried down to 36 feet below zero by aid of compressed air, in order that vessels may pass through the entrance close to the pier-heads, without the danger of touching a projecting rubble slope, and so that it may be practicable to deepen the entrance to 28 feet below zero at a future period.

Improvement Works at the Approach to the Port.—As soon as the new entrance is available, the jetties at the present entrance will be removed, enlarging considerably the tidal harbour; and a deep-water quay, 1,640 feet long, is to be constructed a little to the south of the present south jetty, for vessels calling at the port to come alongside at any state of the tide, Fig. 8, Plate 6. In order to afford access to this quay, the new harbour and tidal harbour will be deepened to between 14 feet 9 inches and 28 feet below zero.

The construction of a deep entrance-lock has been commenced for forming a communication in a direct course between the tidal harbour and the Eure Dock, accessible by the largest vessels down to half-tide level, and by vessels of not more than 19 feet 8 inches draught during the whole tide at neaps. This lock will have a length of 854 feet between the gates, a width of 98 feet, and a depth on the outer sill of 29 feet 6 inches at half-tide, and 3 feet 3 inches less on the inner sill, or 31 feet 8 inches below mean high tide. As the upper end of the lock can be founded upon a firm stratum of sand and gravel at a depth of 31 feet below zero, whereas a suitable foundation of clay for the lower end of the lock is only reached at a depth of about 56 feet below zero, the lock is being constructed in separate divisions, each end being founded by a central main caisson, and two minor caissons for the outer side walls connecting the lock with the adjacent quay walls, sunk by the aid of compressed air. The main

caissons for the foundations of the sill, gate-floor, and corresponding side walls, at the two ends, are 105 feet long along the line of the lock, and 213 feet wide, and 118 feet by 207 feet, for the upper and lower portions respectively. Between these two extreme portions, the side walls are to be built like quay walls, founded at different depths according to the variations in the strata; whilst the floor of the lock-chamber is to be paved with a layer of concrete, 8 to 10 feet thick, merely to protect the bottom from erosion by scour, as it will not be exposed to any upward pressure.

It is expected that the harbour and other works will be completed towards the close of 1902. The gap between the outer end of the deep-water quay and the commencement of the south breakwater, is to be closed by a removable cofferdam, so that, in the event of additional docks being constructed to the south of the port along the foreshore of the Seine estuary, it may furnish a communication between the tidal harbour and these extensions, Fig. 8, Plate 6.

PROGRESS OF ZEEBRUGGE HARBOUR WORKS.

The designs of the Bruges Ship-Canal, and breakwater at Zeebrugge for forming a sheltered harbour at the outlet of the canal, the works for which were commenced in 1896, were described by the Author in 1898 in a Paper presented to the Institution.¹ At that period the canal was being excavated by dredging; the caissons for the large blocks, with their concrete lining, were in course of construction on the dry bed of the inner basin, landwards of the lock; the lower portions of the sea-lock were being built; and only the approach embankment to the breakwater was being carried across the beach. Now the canal and the basins at Bruges have been practically completed; the inner basin at the lower end of the canal, containing the completed caissons, is filled with water; the sea-lock is finished and in working order; the entrance channel leading from the sea to the lock, with its guiding jetties across the beach, has been opened; the approach embankment with its protecting sea-wall has been completed; the open iron viaduct across the foreshore, from low water to the solid breakwater, has been carried out; and some of the large blocks, forming the base of the sea-wall of the breakwater up to a little above low water, have been deposited.

¹ Minutes of Proceedings Inst. C.E., vol. cxxvi. p. 283, and Plate 5.

Zeebrugge Sea-Lock.—As the caissons for the large blocks, with their concrete lining, were constructed in the canal on the land side of the sea-lock, it was necessary to complete the lock, so that the floating caissons could be passed through it, before the solid portion of the breakwater could be commenced. This lock, with an available length of 925 feet and a width of 65 feet 8 inches, has been carried out in accordance with the original design previously described and illustrated. The rolling caissons closing the lock have to sustain a water-pressure on the outer side, as well as on the inner side, according to the state of the tide; and therefore each caisson performs the functions of two pairs of ordinary lock gates, meeting at an angle, pointing in opposite directions. The caissons can be easily rolled into or out of their chambers in two minutes by electrical power, for opening or closing the locks, so that they can be worked quite as rapidly as ordinary lock gates, and in a more simple manner, besides occupying considerably less space in the length of the lock than four pairs of lock gates.

A caisson chamber has been constructed alongside the return wall at the upper end of the lock, in which a spare caisson will be kept to replace one of those in the lock in case of accident, and into which a caisson can be floated and laid dry for repairs, furnishing an additional convenience not contemplated in the original design.

Maintenance of Depth in the Entrance Channel.—As the entrance channel of the Bruges Ship-Canal, between the sea and the lock, is open to the ebb and flow of the tide where the sea-water is charged with silt, a considerable deposit occurs in this sheltered area, which is reckoned to amount to about 10 feet in depth in a year. The floating out, however, of the caissons for the large blocks at low tide necessitates the maintenance of a depth of 26 feet at the lowest low water, both in the entrance channel, and in the sea beyond to the site of the breakwater. As the fine silt mixed with water, raised in the ordinary way by suction dredging, would not settle properly in the hopper of a dredger, a special system of suction has been employed to obviate this difficulty. The suction pipe is widened out at the bottom to a broad flat orifice which, by aid of a wide roller connected with it at the back, is kept at a depth of about 5 feet below the surface of the silt, by which arrangement almost pure silt, with very little water, is drawn up; and the suction dredger of 700 HP. working in the channel, and also outside when calm, is able to fill its hopper of 650 cubic yards capacity with nearly pure silt in about 15 minutes.

Approach Embankment across the Beach.—The embankment, carrying two lines of way from the shore across the beach to low-water mark, has a width of 36 feet and is protected on the sea side by a rubble masonry wall, 10 feet thick, built upon a concrete foundation, 33 feet wide and 3 feet 3 inches thick, encased by piles and sheeting, and protected against scour by a layer of rubble.¹ The concrete layer projects 21 feet out from the face of the wall, and follows the slope of the beach seawards; whilst the wall has been built up to the level of the top of the embankment, 8 feet 6 inches above high water of spring tides, and carries a concrete parapet on the top, lightened by arches on the inner side, and raised to a height of 14 feet 9 inches for sheltering the approach to the breakwater, *Fig. 10*. The embankment is paved

Fig. 10.

Scale, 1 inch = 32 feet.

CROSS SECTION OF APPROACH EMBANKMENT.

on the top; and its harbour side is protected by stone pitching, 1 foot $3\frac{3}{4}$ inches thick, laid to a 2 to 1 slope, and by piles and sheeting at the toe.

Open Iron Viaduct on Piles.—The iron pile-work viaduct, starting from the approach embankment at low-water mark, and giving access across the foreshore to the solid breakwater designed to form Zeebrugge Harbour and shelter the entrance to the Bruges Ship-canal, has been adopted with the object of leaving an opening measuring 1,125 feet in width at right angles to the coast-line, so as to maintain a circulation of the tidal currents within the sheltered area, and thus keep down the amount of accretion in the harbour from the deposit of the silt in suspension in the sea-water on that coast.

¹ "Les Installations maritimes belges," Exposition internationale de Paris, 1900, pp. 38 to 43.

The viaduct, constructed throughout of mild steel, has a length of 1,312 feet, divided into eighty bays by piers carrying the roadway, consisting of a series of rows of six piles placed 16 feet 5 inches apart,¹ *Fig. 11*. Each pile is composed of four quadrants riveted together along their longitudinal flanges, and has an internal diameter of $9\frac{1}{2}$ inches, a thickness of 0.59 inch, and a sectional area of 31 square inches. The piles, each furnished with a wooden shoe, 1 foot $3\frac{3}{4}$ inches in diameter and 3 feet 3 inches long, somewhat pointed at the end, were driven into the silty sand by aid of two water-jets; and the four central piles of each row, under the four rails of the two lines of way, were driven not

CROSS SECTION OF VIADUCT.

less than 14 feet 9 inches into the ground, exclusive of the shoe, and the two outer piles supporting the sides of the planked roadway, 39 feet 4 inches in width, not less than 11 feet 6 inches. The piles in each row are braced together by horizontal channel bars and diagonal ties, and connected at the top by a lattice girder; and they carry the longitudinal girders under the rails and at each side of

the roadway. The viaduct was commenced in September, 1898, and completed in August, 1899; and a plate-iron wind-guard, 14 feet 9 inches high, has since been erected along the outer side of the viaduct to shelter the trains from westerly gales.

Large Foundation Blocks in Iron Caissons for the Breakwater.—The iron caissons for the foundation blocks of the sea and harbour walls of the wide quay portion of the breakwater, and of the narrow outer portion, have all been constructed in the inner basin, together with their concrete lining, in four different sizes in general, 116 in number, comprising 4,600 tons of iron and 104,600 cubic yards of concrete. The largest caissons, constructed for containing the concrete blocks intended to form

¹ "Construction du Môle du Port d'Escale de Zeebrugge," Messrs. J. Nyssens-Hart and Ch. Piens, VIII^{me} Congrès International de Navigation, Paris, 1900, 7^{me} Question.

the lower section of the narrow outer length of breakwater, for its whole width up to about 3 feet 3 inches above low water of spring tides, in a depth of 26 feet 3 inches, have been made 82 feet long, 29 feet 6 inches wide, and 28 feet 9 inches high, in which 2,600 cubic yards of concrete can be deposited, forming a block 4,400 tons in weight, *Fig. 12*. The caissons are provided with a cutting edge projecting under their outer sides, which, penetrating into the soft bottom, aids in supporting the blocks on an uneven bed. The caissons, with their concrete lining, have been stranded upon the bed of the inner basin to prevent their being knocked one against another by wind, by removing plugs closing apertures in the sides of the caissons, specially provided for filling them with water when required; but two or three having been floated into the lock chamber after pumping out some of the water, are kept in readiness for being towed out to their site on the first favourable opportunity.

The work of towing out and depositing the caissons for the construction of the solid breakwater was commenced in June, 1900; and it is anticipated that the breakwater will be completed towards the close of 1903. When the sea is calm, a caisson is towed out of the lock in time to reach its site at low water; and directly it is got into its exact position, it is filled with water and deposited during the period of slack tide, which only lasts about 20 minutes; and then the block is completed as rapidly as possible by filling in the vacant space with concrete deposited under water from closed skips with movable flaps at the bottom, the last layer of 3 feet 3 inches in thickness being added out of water at low tide with concrete rich in cement. The bed for the blocks is levelled where necessary with small rubble; and directly a caisson has been placed in position, it is protected from scour along its exposed face by depositing an apron of large rubble, extending out 50 feet from the face and thick enough to keep the cutting

Fig. 12.

Scale, 1 inch = 32 feet.

CROSS SECTION OF BREAKWATER.

edge covered. It was determined to sink the blocks adjoining the open viaduct some depth below the bottom, by aid of compressed air, in order to secure them from being undermined by the scour of the tidal currents passing through the viaduct.

The first caissons deposited had to be filled with concrete by a floating crane in an exposed position; and the tops of the earlier blocks presented a somewhat irregular surface, needing a considerable amount of trimming to form a level bed for the upper blocks. A Titan, however, has been constructed which, travelling along the top of the sea wall of the breakwater, will assist in forming a level bed for the caissons by pounding the bottom with a heavy weight; and this Titan will also rapidly fill the caissons with concrete from closed hopper skips containing 13 cubic yards, and will place the upper blocks of the sea wall, being able to handle 50-ton blocks at an overhang of 82 feet, and 20-ton blocks at an overhang of 164 feet. As the site of the harbour wall of the quay portion of the breakwater will be under the shelter of the sea wall, this inner wall will be constructed with the help of a floating crane.

Changes in the plan of Zeebrugge Breakwater.—Though the general design and method of construction of Zeebrugge breakwater have remained unaltered since the proposed works were described by the Author in 1898,¹ the plan of the breakwater has undergone some modifications. Thus the curvature of the wide quay portion of the breakwater is now designed to be uniform throughout, with a radius on the outer side of $59\frac{3}{4}$ chains, instead of being flattened along its outer half; whilst the narrow outer portion of the breakwater, on the contrary, is to be built perfectly straight.² Moreover, the proposed length of the breakwater in the present design is 587 feet more, along the outer face, than originally contemplated; and the proposed width of the outer uncovered portion of the quay has been increased from 37 feet 9 inches to 103 feet 4 inches, making the total width of the quay 233 feet. According to the present plan, the length of the quay portion of the breakwater, measured along its sea face, is to be 4,150 feet, and of the straight, narrow, outer portion 1,116 feet, which, with the completed approach embankment 761 feet long, and the open iron viaduct as constructed, 1,312 feet long, make altogether a total length of 7,339 feet from high-water mark.

¹ Minutes of Proceedings Inst. C.E., vol. cxxxvi. p. 286, and Figs. 2 and 4, Plate 5.

² "Construction du Môle du Port d'Escale de Zeebrugge," Messrs. J. Nyssens-Hart and Ch. Piens, VIII^{me} Congrès International de Navigation, p. 6, Plate 1, and Fig. 5, Plate 2.

RECENT IMPROVEMENTS EFFECTED BY THE FRENCH LIGHTHOUSE SERVICE.

The chief object of the French lighthouse exhibits, mostly collected together in the museum of the Dépôt des Phares, which formed a sort of temporary annexe to the Exhibition, was to illustrate the improvements effected in this department within the last 11 years.¹

Increase in Intensity of Flash Lights.—Originally Fresnel adopted a slow rate of rotation for the optical apparatus, giving the flashes a duration of 8 seconds, so as to afford the sailors time to take their bearings; and he made the requisite differences in the character of the lights by varying the relatively long intervals of obscuration between the flashes. After a time, however, the sailors began to complain of the length of the intervals, and the inconvenience of having to verify this length in order to distinguish the light; whilst the slow rotation and the duration of the flashes necessitated the use of a number of narrow panels of lenses of low power. Accordingly, the rate of rotation has been gradually increased, and the duration of the flashes and obscurations reduced; and now the period of the flashes has been brought down near to the extreme limit necessary for the perception, of $\frac{1}{10}$ second, grouped together with intervals of 5 seconds, enabling a large surface to be given to the small number of panels of lenses required, and thereby greatly increasing the intensity of the flashes; whilst a revolution of the apparatus is effected in from 25 seconds to 5 seconds. This rapid rotation by means of clock-work actuated by a small weight, has been rendered possible by the weight of the apparatus being borne by an annular frame floating in a corresponding mercury bath, whereby its friction in rotating is reduced to a minimum. The French sailors appreciate the quickness with which a light can be recognised by the new system, and no objection has been made to the short duration of the flashes which, with an interval between them of only 5 seconds, serve equally as well as a long flash for obtaining the bearings; but English and American sailors appear to prefer less momentary flashes than those adopted in France.

Incandescent Lights for Lighthouses.—The introduction of an incandescent mantle in lamps fed by oil, gas, or by the vapour of

¹ "Notices sur les Appareils d'Éclairage, Modèles et Dessins, exposes par le Service des Phares," Exposition universelle, Paris, 1900.

petroleum generated by means of the waste heat from the burner, or gas under pressure, has enabled the power of secondary coast lights, for which electricity would be too costly, and also of most of the important leading lights to be greatly increased. An ordinary lamp with wicks is often kept at hand, which can be quickly substituted for the incandescent lamp in the event of an accident.

Sirens worked by Compressed Air.—Steam has been abandoned in France for working sirens in favour of compressed air, at a pressure of 28 lbs. per square inch, as steam power is not suited for putting the siren immediately in motion on the sudden appearance of a fog, or for the installation of the siren in the most favourable position for being heard. Various experimental observations carried out in France with sirens during recent years, have led to the following conclusions. Low notes carry further than high notes with the same expenditure of air; and 326 vibrations per second give a suitable note, readily obtained and generally adopted; for uniform notes, singly or in groups, are more easily recognised by sailors than groups of notes of different pitch. Under ordinary atmospheric conditions, a siren is audible at a greater distance in proportion to the height of its position. A siren having a revolving drum of 6 inches diameter, furnished distinctly better results than another with a drum only 4 inches in diameter; whilst the weight of a drum $7\frac{1}{2}$ inches in diameter checked its starting, and the escape of air was excessive. The influence of the trumpet-shaped outlet attached to a siren in reinforcing the sound emitted,

Scale, $\frac{3}{4}$ inch = 1 foot.

TRUMPET ATTACHMENT TO SIREN.

varies considerably with its form; and the best form was proved by trials to be that shown in *Fig. 13*. Observations made for a long time of the distances at which the sirens at Cape Gris-Nez, Barfleur, and other stations on the French coast are heard, show that, allowing for the increased difficulty of hearing sounds on board ship at sea, sirens may become inaudible 2 sea-miles off, or even less, that their range is generally 4 sea-miles at least, and that sometimes they are audible at considerably longer distances which cannot be reckoned upon.

Improvements in the Stability of Light-ships and their Lights.—Till recently the light-ships marking shoals off the French coast ex-

hibited lights of low power, which, moreover, were liable to be occasionally interfered with by the undue rolling of the vessels. Extensive observations on board French light-ships have proved that though waves generally vary considerably according to the state of the wind and tide, nevertheless the period of oscillation of storm-waves in any particular locality, which are the only waves which seriously affect a lightship, remains very fairly constant. Having, therefore, ascertained the period of oscillation of storm-waves at a certain light-ship station, in order to ensure increased stability, the vessel has to be so designed that its period of rolling shall in no case synchronise with the oscillations of the storm-waves of the locality. The extent of the roll is, moreover, reduced as far as practicable by adopting vessels of deep draught, by placing the centre of gravity low, and by increasing the projection of the keel and adding side keels, *Fig. 14*.

By adopting an incandescent light supplied by compressed oil-gas, and using lenses in place of the former parabolic reflectors, the intensity of the flashes emitted has been made $2\frac{1}{3}$ times greater than formerly, reaching a power of 3,325 candles. As, however, the motion of the vessel would be liable to deflect at times the

concentrated ray from the horizon, and thereby impair the distinctive character of the light, the optical apparatus, which revolves upon ball-bearings, is balanced on knife edges supported by a bracket; and the rod carrying the lenses and light is prolonged below the point of support, and has a lead weight fastened at its end, thus constituting a sort of pendulum; and another leaden counterpoise is fixed on the top of the lantern, *Fig. 15*. By making the swing of this compound pendulum slower than the period of the roll or pitch of the vessel, the oscillation of the light from the vertical has been reduced to a maximum of 9° , which does not interfere with the visibility of the flashes.

Scale, 1 inch = 20 feet.

SECTION OF LIGHT-SHIP.

Permanent Mineral Oil Lights.—A special burner has been devised, which is provided with a very thick wick; and by causing a thin and uniform coat of carbonised tar to form in the first instance on the wick, only slight changes take place subsequently in the wick, so that the light fed by common mineral oil may, in the ordinary course, keep on burning for more than a hundred days. By means of this contrivance, it became possible to exhibit permanent lights at a comparatively small cost at points of minor importance, and especially on pier-heads and beacons liable to be inaccessible in stormy weather.

Scale, $\frac{1}{16}$ inch = 1 foot.

SECTION OF LANTERN.

The extensive adoption of these permanent lights led to the idea of giving these lights the distinguishing characteristics of revolving or flash lights. This important improvement has been rendered practicable for light optical apparatus, by the great facility of rotation conferred by the adoption of the mercury bath for supporting the revolving panels of lenses. The movement is imparted by an electric pile battery, placed in the beacon tower and renewed at long intervals, which actuates a Gramme motor for turning the apparatus. The rate of motion, which amounts on the average to one revolution in 10 seconds, is regulated by an electro-magnet brake, so that the period of rotation does not diverge more than 2 or 3 seconds from the average. The first three permanent flashing lights were set up in 1896 and 1897, one of them having been

placed in the Walde iron screw-pile lighthouse, near Calais.

Large Light-giving Buoys.—Though light-ships have been established in which economy of maintenance has been realised by dis-

persing with the attendance of a light-keeper, it has been found advantageous at extensive shoals in very exposed localities, to multiply the number of lights by adopting, in place of light-ships, a greater number of light-giving buoys. Thus the light-ships at the Minquiers and Rochebronne were removed after breaking their mooring chains during storms in 1891 and 1899 respectively, which buoys in their neighbourhood safely rode out. These changes have necessitated improvements in the stability of the buoys, to maintain the visibility of their lights; an increase in the power of the light emitted, and in the height; and an enlargement of the size of the buoys at exposed sites when moored in comparatively deep water, to enable them to carry a heavy chain. One of the largest light-giving buoys constructed on the latest approved type, as adopted in 1899 for marking the rocky Rochebonne shoal, is shown in *Fig. 16*; it has a capacity of $23\frac{1}{2}$ cubic yards, and is made of sheet-iron; and owing to its shape, and the tubular appendage projecting from its base for a length of about 23 feet and weighted with 2 tons of ballast, it possesses considerable stability. This buoy exhibits a light of 237 candle-power at a height of 26 feet 4 inches above the water-level; and as the roll of this type of buoy is small and very slow, the focal plane of the light remains approximately horizontal even during storms. The cost of these buoys is about £30 6s. per cubic yard of capacity; and their substitution for light-ships has effected a large saving, both in the cost of establishment and the expenses of maintenance.

Concrete and Cement Beacon Towers.—Originally the circular towers of beacons round the French coast were constructed of masonry; but about 20 years ago Mr. Bourdelles, who in his later career originated most of the recent lighthouse improvements referred to above, introduced the employment of Portland cement concrete for these structures, deposited within timber framing. Though this use of concrete enabled sounder work to be done

Scale, 1 inch = 20 feet.

LIGHT-GIVING BUOYS.

than with masonry, and also more quickly and economically, the circular framework had little power of resisting the waves, had to be frequently taken down and put up again, and had to be specially constructed for each beacon. To obviate these defects, an octagonal framing was adopted in 1893, consisting of rows of planks on edge, laid horizontally one above the other, and fitting at their ends in vertical grooves formed by cast-iron corner pieces bolted together in a vertical row up each corner. By this arrangement, a strong framework is easily constructed, which can be gradually raised as the work of depositing the concrete inside proceeds, forming an octagonal truncated pyramid for the tower, in place of the former conical structure. The larger proportion of cement used in the lower portion of the towers, which is the most exposed to the wash of the sea, has led gradually to the substitution of mortar for concrete, and finally to the use of neat Portland cement mixed with at least one-fifth of its volume of water, and carefully punned, a plan which has been actually found economical in cases where it is very important to do the work rapidly, as well as making a stronger tower. Neat Portland cement has been applied recently to the construction of the foundations of beacons on rocks under water, a class of work which up to 1891 had only been attempted in the Mediterranean, but of which there are now several examples completed, or in progress, off the French coasts bordering the English Channel and the Atlantic Ocean. The sites were at first enclosed by coarse canvas sacks of concrete, and afterwards by sacks of neat cement in powder; but even these latter, though much stronger and more compact than sacks filled with cement previously mixed with water, did not seem to form a sufficiently close and uniform mass to be enclosed in the body of the work, in the case of large towers necessarily constructed in sections. Wire gauze, however, stiffened by light ribs, is readily formed to the required shape on land, and can be rapidly put in place, and hanging loosely at the bottom adapts itself to any irregularities, whilst it allows the work to be constructed in any number of requisite sections. Into the enclosures thus formed, neat cement in powder is deposited by a special light skip, through the top of which water can percolate to the cement in its passage to the bottom before being released. This system has proved quite satisfactory; for the cement in powder, absorbing its proper quantity of water, forms a compact, homogeneous, and almost impermeable mass; and the surface of the structure soon becomes coated with carbonate of lime, and covered over with a closely adhering layer of shells and marine vegetation. At the present

time, the foundations for a large beacon are in progress by this method on the Rochebonne reef in the Bay of Biscay, 55 sea-miles from La Rochelle, in a depth of 26 feet 3 inches at the lowest tides; and the tower, which is to be erected on the base of 23 feet radius, is designed to exhibit a permanent flashing light.

Concluding Remarks.—A very valuable feature of these International Navigation Congresses is the opportunity they afford of obtaining reports on special subjects of interest, embracing the experience of several countries, which can be read by British, American, French, Belgian, and German engineers in their own language, as exemplified at the late Paris Navigation Congress, where reports on eight out of the nine questions selected for consideration were presented by engineers belonging to from three to seven nationalities respectively. Moreover, these gatherings possess the advantage of providing an occasion for the interchange of views and experiences on professional matters between the engineers of various countries; whilst the visits to works, which always constitute a part of the proceedings, enable foreign engineers to inspect, under the most favourable conditions, some of the principal undertakings for the improvement of navigation in progress in the country in which the congress is held.

The gradual increase in the maritime traffic of the port of Rouen, shows the advantage of position possessed by a port at the head of a maritime navigation penetrating a considerable distance inland, and connected by water and rail with the interior of a country, even where the port can only be reached by sea-going vessels of moderate draught, where the waterway leading up to it is very circuitous, and where it has to compete with such a flourishing and convenient seaport as Havre, accessible to vessels of large draught, lying directly at the entrance to its approach-channel. Every improvement, moreover, in the available depth of the Seine up to Rouen, and the extensions of facilities for discharging and loading vessels at the port now in progress, will promote the increase in traffic.

The prolongation of the Seine training works into the estuary with high-water walls will, in the course of the next few years, afford an interesting indication of the effect of such works extended into a wide sandy estuary exposed to the introduction of large quantities of sediment, washed from the neighbouring coast of Calvados stretching out westwards approximately in a line with the southern shore of the estuary, which is thus open to the westerly drift along that coast. Though accretion appears to have been progressing to some extent at the sides of the estuary in

places out of reach of the erosion of the shifting currents, it has evidently been very much checked by the continued wanderings of the main channel between Berville and the sea. Thus the main channel followed a devious course in the chart of 1891, starting in a central direction for about 2 miles below the end of the training walls, then turning southwards, and after passing close alongside Honfleur, proceeding northwards, and entering the sea in the centre of the outlet of the estuary;¹ and by hugging the south shore for about $3\frac{1}{2}$ miles, it arrested accretion in the recess to the east of Honfleur. In the latest survey of the estuary, that of 1898² (Fig. 4, Plate 6), however, the channel had changed entirely; for, after keeping closer to the south shore than in 1891 for the first $3\frac{1}{2}$ miles below the confluence of the Risle, it turned gradually northwards and found an outlet to the sea to the north of the Amfard bank, thereby cutting into the toe of the extensive northern sandbank and checking accretion on this foreshore, whilst favouring the growth of the sandbank again in front of the recess above Honfleur. The training works in progress will to some extent restrict the wanderings of the channel as far down the estuary as Honfleur, by the large accretions and reclamations which will result from them, but their influence is not likely to extend much further down; whilst the low-water channel will be free to wander between the new training walls, unless regulated by low-tide training works aided by dredging.

The modifications of the trained channel between Quillebeuf and the mouth of the Risle, and the extensions in progress as far as they are being carried, resemble in general outline the designs suggested by Mr. Lavoinne and the Author several years ago;³ but the northern training wall is being raised higher, and has been brought further south than contemplated by the Author, and consequently will direct the river outflow rather to the south of the deep flood-tide channel, which is always found extending more or less into the estuary between the Amfard and Ratier banks, and which is very clearly marked in the chart of 1898, Fig. 4, Plate 6. It is evident that the best course for the navigation of the river would be to guide the trained channel so as to coincide with the direction of the central flood-tide channel.

¹ "Rivers and Canals," L. F. Vernon-Harcourt, 2nd Edition, 1896, vol. i. Fig. 1, Plate 9.

² This survey of the Seine estuary was supplied to the Author by Mr. Belleville, Engineer-in-chief of the tidal Seine.

³ Minutes of Proceedings Inst. C.E., vol. lxxxiv., Figs. 8 and 9, Plate 4.

Though this would not be so favourable for Honfleur as a more southerly course, it is not expedient for the navigation of the river that the channel should pass close to Honfleur, as in the chart of 1891, for such a channel is tortuous and necessarily unstable; whereas it might be possible by a further extension of the northern training wall in a somewhat more northerly course, by regulating the low-water channel, and by dredging in mid-estuary so as to cut through the shoal between the trained channel and the natural central flood-tide channel, to form an adequately deep, stable, and direct navigable channel through the Seine estuary.

In the composite form of breakwater adopted for sheltering the new harbour at Havre, the superstructure is being founded near the level of low water spring tides on the top of the rubble mound, the sea slope of which is protected by large concrete blocks, Fig. 9, Plate 6. This level for founding the superstructure, though very usual about the middle of the nineteenth century, has for many years been abandoned by British engineers, in exposed situations, in favour of deeper foundations, in proportion as extended experience has demonstrated the instability of the sea slope of the mound at a considerable depth below low water, near the face of the superstructure, under the action of the recoil of the waves; so that the depth at which the superstructure is founded has been increased from 15 feet below low water at Karachi, 20 feet for the south-west breakwater at Colombo, and 22 feet at Madras, to 30 feet 9 inches for the north-west breakwater at Colombo, and 43 feet at Peterhead.¹ The north breakwater at Havre, however, is only exposed from the north-west to the waves of the English Channel; and the stability of the mound is provided for by the covering of large concrete blocks. Considering, moreover, that the Boulogne western breakwater, similar in construction, with its superstructure founded at a little higher level, has proved stable under somewhat similar conditions, it may be concluded that the Havre breakwaters are strong enough for their site, though a superstructure founded at a lower level would save material and require less care in maintenance.

The attempt to build a composite breakwater at the mouth of the River Nervion, facing the worst waves of the Bay of Biscay, with a superstructure founded at low water on a thick capping of

¹ "The most recent Works at some of the principal British Seaports and Harbours," L. F. Vernon-Harcourt, Paris Navigation Congress, 1900, p. 14, and Figs. 8, 9, and 12, Plate 2.

large concrete blocks, proved disastrous; and the work has only been accomplished by forming the base of the superstructure with concrete blocks, constructed in iron caissons floated out, weighing 1,400 tons, and deposited on an inner mound at a depth of 16 feet 6 inches below low water of equinoctial spring tides, protected on the sea-face by two rows of large concrete blocks, and also by the original outer mound. This experience has led the contractors to extend the system further at Zeebrugge breakwater, so as to obtain the maximum of stability with the minimum of material, by forming the base of the walls on each side of the quay, and of the narrow outer breakwater, from the bottom up to 3 feet 3 inches above low water, by a single row of concrete blocks, constructed inside iron caissons, and weighing 2,000 to 4,400 tons. The system, accordingly, adopted for the Zeebrugge breakwater furnishes a complete contrast to the Havre breakwaters, which are being simultaneously carried out (compare *Fig. 12* with *Fig. 9, Plate 6*); and though these large blocks could not be thus deposited straight on a soft or irregular bottom, and the earlier blocks exhibited considerable irregularities in level at the top, nevertheless, if they can in future be laid on a more evenly levelled bed, they offer the means of rapidly constructing the under-water portion of a breakwater in a very solid and stable manner, which the contractors consider will also prove very economical. The dredging of silt for maintaining the depth in the entrance channel of the Bruges ship-canal, furnishes a novel method of ensuring the settlement of silt, raised by suction dredger, in the hopper of the dredger.

The progress achieved by the French lighthouse service within the last few years may be briefly summed up as follows. The rapidity of rotation of the optical apparatus of lighthouses attained by aid of the mercury bath, has enabled the intensity of the flash lights to be considerably increased, and the special character of each light to be more readily denoted and observed; whilst incandescent lights furnish a simple and economical method of greatly augmenting the power of the lights in lighthouses of secondary importance. The great increase in stability secured for lightships, and in the power and steadiness of their swinging lights, by means of the ingenious contrivances described, has assured the continuous visibility of the lights during storms, and has notably extended their range. The invention of a burner whereby mineral oil lamps can burn continuously for over three months without attention or replenishment, has allowed lights to be exhibited at places inaccessible during stormy weather; and the

facility of rotating the apparatus floating on mercury, has enabled these lamps to be revolved by a small electric motor, actuated by a battery placed in the tower carrying the lamp, and thus to exhibit definite characteristics denoting the locality, like the more important lighthouses looked after by a keeper. Where several lights at moderate distances apart are of more value for navigation than a single light of greater range, as in the case of extensive shoals, large buoys with a fairly powerful light exhibited at a good elevation above the water-level, have been substituted with advantage for a lightship. Notwithstanding the doubts which have been occasionally expressed as to the durability of Portland cement in sea-water, the French lighthouse engineers have not hesitated to employ Portland cement concrete in preference to masonry for the construction of recent beacons in the sea, on account of the greater rapidity with which the work can be carried out with concrete deposited within suitable framing, and the more perfect soundness of the structure thus formed; whilst still more recently, neat Portland cement has been used for the foundations under water of beacons in very exposed situations, where formerly the erection of beacons was considered impracticable. This remarkable series of improvements, in conjunction with other minor ones, has served to maintain France in its foremost position in respect of the lighting and buoying of coasts.

The Paper is accompanied by tracings, from which Plate 6 and the Figures in the text have been prepared.

Fig: 1.

Fig: 2.

Fig: 3.

Fig: 4.

Fig: 6.

Fig: 7.

Fig: 8.

Fig: 5.

SCALES.

Fig: 1, 2 Inches = 1 Mile.
0 1/4 1/2 3/4 1 Mile.

Fig: 2, 6, 7, and 9, 1 Inch = 32 Feet.
10 5 0 10 20 30 40 50 60 70 80 Feet.

Fig: 3, 1 Inch = 250 Feet.
100 50 0 100 200 300 400 500 Feet.

Fig: 4 & 5 (Horizontal) 1 Inch = 4 Miles.
1 1/2 0 1 2 3 4 5 6 7 8 Miles.

Fig: 5 (Vertical) 1 Inch = 50 Feet.
10 5 0 10 20 30 40 50 60 70 80 90 100 Feet.

Fig: 8, 1 Inch = 2000 Feet.
1000 500 0 1000 2000 3000 Feet.

Fig: 9.