The second part of the subject, namely, the construction of training jetties will now be considered.

There are few countries in the world where the necessity of works of this class are more urgently required than in New South Wales. Our coast rivers being the natural outlet for the trade of our splendid coast districts, and these rivers being all more or less obstructed by dangerous sand bars, the question of the construction of training jetties to remove these obstructions must be one of the first importance. The author has already dealt at considerable length in other papers with the question of the best lines for works of this class, and in this paper the question of the economical construction of training jetties will alone be considered.

The objects to be attained by the construction of training jetties are to confine the inlet and exit of tidal and upland waters within definite limits, and to obstruct the progress of sand as it tends to force its way across the entrance of a river by the action of the waves. Unless it is essential, from local circumstances, that there should be still water immediately within the works (in which case breakwaters would have to be substituted for simple training jetties), there is no necessity for training jetties to be carried up to the height required in the case of breakwaters.

The rapid changes that take place in the position of the channels of all bar bound rivers. make it essential on the ground of economy that works of this class should be carried out with the greatest despatch, so that they will be affected as little as possible by such local changes. Moreover, the works themselves bring about considerable changes as they are pushed forward; thus, in the early stage, part of the works near the shore line may be exposed to the waves to a considerable extent, but as the works progress this part of the jetty may be completely protected by the growth of the beach along the jetty. It, therefore, follows that if the works are pushed forward with despatch, the part near the shore line can be constructed on a much less costly plan than would be the case if the works were only carried out at a slow rate of speed.

Within the last few years the Americans have made great advances in the science of constructing training jetties, as along their extended seaboard they have many rivers obstructed by shifting sand bars, under circumstances much less favourable for successful treatment than is the case with the rivers on our coast; for, although the rise and fall of the tide is about the same, the distance to which the shallow water extends is much greater on the coast of America than it is with us. Thus, at Charleston, where important works are under construction, a depth of 20 feet is not reached until the jetties have been carried out a distance of something like three miles from the shore; whereas, in the case of most of our rivers, that depth is reached within 2000 feet.

In carrying out works of this class on shifting sand, it is essential to economy that the bottom should be protected for some distance in advance of the raised portion of the works, for otherwise the current round the ends of the advancing works will scour out the sand, thus making large pits which continually grow out as the works proceed, and require vast quantities of material to be deposited to make up for the sand that has been washed away. Again, it is not necessary in order to attain the object in view, namely, to secure a permanent fixed channel, that the works should be carried up above half tidal mark, for with works at that level the best effect of the latter half of the ebb tide, and the scour from the upland waters, is retained, and the sand is prevented from pushing across the entrance; at the same time the crest of the waves pass over the works, and they are not, therefore, subjected to the action of the recoil which, as pointed out in the early part of this paper, is the most destructive agent that is brought into play in the case of works carried up to a higher level.

The works for improving the entrance to Charleston Harbour were begun in 1879. They consist of a north and south jetty; the north jetty is 8,840 feet, and the south jetty 13,040 feet long. They consist of a superstructure of reprap stones, with rather low side slopes resting on a mattress of logs covered with fascines. Plate 13, Fig. 15, shows the plan of constructing the log mattresses. Their sea-ends, for a length of 3,000 feet on the north jetty, and 3,500 feet on the south jetty, have their crests at the level of half-flood of spring tides, or three feet above mean low water. The slope on the exterior faces of the jetties will be 1 upon 2 throughout their entire length. On the interior faces it will be 1 upon $1\frac{1}{2}$, except on the sea-ends, where, for a distance of about half-a-mile, it will be 1 upon 2. For the north jetty, the minimum width on the top is 15 feet at the lowest portion. The width increases outward to 24 feet, which is adopted for that portion which rises above mean low water mark. The south jetty has a minimum width of crest of 12 feet where it crosses the main channel, at a depth varying from 10 to 12 feet below mean low water. Thence outward the width increases to 24 feet for the highest part, as in the case of the north jetty. The plan of carrying out these works is as follows:—The log mattresses were floated out in long lengths, and sunk in position by depositing stones evenly over them, the foundation mattresses being carried out for their full length before the stone superstructure was raised upon them. After the completion of the foundation, the stone was gradually deposited and the jetties raised to their required height. According to the last reports these jetties had not been brought up to the full height, but they had already effected considerable improvements in the channel, the improvements in the channel progressing as the jetties are raised, and the tidal scour concentrated; and there is every probability of the estimated depth being fully realised.

By the use of log mattresses a good foundation is provided for the stonework, without which the quantity of stone would have to be greatly increased, the mattresses preventing the displacement of the sand by the local currents and eddies which are produced when stones of any size are simply deposited upon sand, at the same time they are sufficiently flexible to adjust themselves to the undulations of the bottom.

By the time the timber has been destroyed by the action of sea-worms, the stonework will be consolidated by the growth of coral and shells, and will in itself prevent the displacement of the sand.

Experience in Charleston Harbour, and on the shores of Holland, especially at the mouth of the Maas, bears testimony to the rapid growth of mollusca upon loose stones immersed in the sea near the outlets of fresh water tributaries, and to their effective use in cementing them, as it were, into one mass.

With low level works the sand washed over the submerged portion in time of storms will be carried out by the well directed ebb current produced by the works, and by keeping the crest of the works at as low a level as possible consistent with retaining a proper velocity in the channel, the destructive effect of the waves is reduced to a minimum.

There are many other works now in progress on the American coast, including the great works at the mouth of the Mississippi, where a depth of about 40 feet was secured, against a former depth of only 8 or 9 feet. The works at Galveston, the St. John's River, Florida, the Aransas Pass, Texas, and many others, all the training jetties for which are constructed similar to those at Charleston, the works being carried up to only about half-tidal level, and in some parts wholly submerged, the construction of the jetties varying in some cases where stone has to be brought from a distance. Fascine mattresses are largely introduced to economise the stone as much as possible, the plan being to lay a foundation course of fascine mattresses and then a layer of stone upon which a second course of mattresses is placed, succeeded by a second layer of stone and so on until the jetties have been raised to the required height. Suitable materials for the construction of fascines are abundant near the entrances of most of the American rivers.

The American system of construction could no doubt be applied with advantage in treating the rivers of New South Wales, although there might be some difficulty in the manufacture of the fascines as there is not the same abundance of suitable material available.

Another system of constructing works of this class, and one that is most eminently suitable for the successful treatment of our rivers, is the most ingenious plan adopted in the case of the now famous works at the Sulina mouth of the Danube. These works are among the most economical and successful works that have ever been carried out, and having stood the test of nearly thirty years contest with the elements, a somewhat lengthy account of their construction, maintenance, and consolidation should be of especial interest. The construction of these works is thus described by Sir Charles A. Hartley, under whose direction the works were carried out. "Several plans had been proposed for carrying out these works, and choice was finally made of a structure composed of piling and *pierre perdu*, surmounted by a timber platform 14 feet wide, strengthened occasionally by solidly constructed cribs of the same width (Plate 13, fig. 16). The works were commenced on the 21st April, 1858, and an account will now be given of the system of execution. A temporary staging fixed on piles, driven by ringing engines worked from barges, was run out from 200 feet to 300 feet in advance of the permanent piling and although during the progress of the work it was several times partially destroyed by the violence of heavy gales, the repairs were easily and rapidly effected during fine weather. This staging supported nine crab engines, and working a monkey weighing 15 cwt., and driving down daily, on an average, a pile, 13 inches square, 16 feet into the hard fine sand of which the bottom is composed. By these means three rows of three piles each, at equal distances apart of 7 feet, were frequently driven in one day. They were then immediately secured by double longitudinal walings 12 inches by 6 inches, and double cross-ties 12 inches by 4 inches, and 15 feet long the whole being surmounted by two tram pieces 6 inches thick, and planking 3 inches in thickness, at 4 feet above the level of the sea. From this permanent platform the close piling on the side next the sea was driven by six similar crab engines, following closely on the open 7-feet bays in advance. The daily rate of progress during fine weather was 20 feet, and no sooner had this length of sheet piles been placed than stones were thrown down to protect its footing in the sand, which without such protection was liable to be washed away to such an extent by the beat of the sea as to endanger the stability of the exposed close piling, although driven 14 feet into the ground. The scouring action of the sea was the only real difficulty to contend against, and so serious did it become when the skirt of the bar was reached, along the line of open piling immediately beyond the sheeting, that although confined to that locality it threatened at one time to demand for the completion of the work double the quantity of stone originally estimated. . . . . . . To overcome this difficulty the following plan was adopted for a length of about 400 feet. Long rafts of unsquared timber ladened with fascines and stones were sunk between the exterior open piles as well on the river as on the sea side, so as to cover the base of the embankment by a layer of about 4 feet in thickness. This arrangement was economical but was too slow in execution. . . . . . Recourse was then had to a plan which answered well in every respect, and by means of which the works were completed within the original estimate, and in less time than at first specified. The open pilework was advanced with all possible expedition, and the proposed seat of the advancing pier was paved with stones delivered from barges. This pavement withstood the attack of the sea, and offered no great obstruction to the penetration of the sheet piles, which, without being shod, were frequently driven 10 feet into the ground after having been forced through 8 feet of rubble stones. In throwing down the stones from the barges care was taken to pitch them close to and equally on both sides of the sheet piling, until the stonework showed itself above the water-line, and then after the wedge-shaped upper portion had been distributed over a wider base by the action of the waves, to repeat the same process until the slopes found their angle of repose. In this way no more stone was employed than was absolutely necessary for the stability of the work, which, when completed, might be described as a mass of closely packed third-class rubble resting on a broad base, and narrowing upwards to a level slightly below the surface of the water, at which point it became a mere ridge resting against the close piling; the side slopes of its section varying from 2 to 1 near the pier heads, and 1 to 1 and $1\frac{1}{2}$ to 1 near the shore."

"The piers were completed on the 31st July, 1861, and the time employed in their actual construction was thirty-one months, exclusive of three winter months each year, during which the Danube was frozen over, and all work was suspended, but inclusive of two hundred and seven days, during which it was impossible to work on account of stormy weather. The length of the north pier is 4,631 feet, that of the south pier 3,000 feet, and the depth of water in which they are built varies from 6 to 20 feet. In their construction 200,000 tons of stone, and 12,500 piles have been employed, and the cost per lineal foot has not exceeded ten guineas. The stone was a hard blue limestone, and was transported fifty-eight miles by water, after having been for the most part carted two miles to the river bank at Toulcha. None of the stones were heavier than two men could lift, or less in size than a common brick, and their highest price delivered at the piers including all charges was five shillings per ton, and the lowest price was four shillings per ton. All the longitudinal and transverse timbers, as well as the planking and fender piles, were of oak, and their cost was at the rate of two shillings and three-pence per cubic foot, while the fir piles were delivered ready for driving for four-pence per cubic foot. Labour, two shillings and sixpence per day, and carpenters, four shillings and sixpence per day."

After these works had withstood the action of the sea for over ten years, during which time a little additional stone had to be deposited from time to time to replace material displaced during storms, the piers having also been lengthened to the extent of about 1,100 feet to increase their efficiency, it was found that the timber in the upper part of the works was becoming decayed; it was therefore decided to replace the upper timber work with a solid concrete top. (Plate 13, figs. 17 and 18.) This was accordingly done; the old timber serving as a stage upon which to carry out the work of consolidation. It was found that the rubble deposited against the piles had become completely consolidated by the growth of mollusca, and could not be removed except by blasting. The concrete superstructure was therefore founded upon a practically solid bed of rock, and all danger of settlement was removed. The outer end of the jetties were further protected by depositing a number of concrete blocks on the sea face.

There are several points of special interest in connection with these works deserving of notice. By carrying them out in timber with a rubble protecting mound, it was possible to complete the works in a minimum of time, and the benefit to be derived from their construction was at once realised. Moreover, the sheet piling prevented the stones on the outer face from being washed over into the channel, and a much smaller amount sufficed. The timber being sufficiently durable to give the rubble time to consolidate before the permanent superstructure was built, the danger, or rather the certainty, of settlement in the event of the superstructure having been erected on the rubble before its consolidation was prevented. The disastrous results of building works upon a newly deposited rubble mound has already been pointed out in the early part of this paper. Again, the nature of the channel resulting from the construction of the jetties being established, the requisite strength for the different parts of the superstructure could be accurately determined, and the permanent portion of the work could be carried out with the greatest economy and dispatch. The total cost of these works from their commencement in 1858 to the present date, including extension, maintenance for 10 years previous to their consolidation, their subsequent consolidation and maintenance to 1885, amounted to the moderate sum of about £220,000, or about £34 per foot, the total length of the two jetties being 8,789 feet.

Their small height above the level of the sea, namely, 4 feet, enabled the crest of the large waves in time of storms to pass over, and thus destroyed their recoil, and therefore prevented the displacement of the rubble on the sea face to a great extent.

Previous to the construction of these works there was only a depth of from 8 to 10 feet over the bar; since their construction the depth for many years past, unaided by dredging, has not been less than 20½ feet.

From a study of the history of the above successful works there can be little doubt that a modification of the system carried out at the Danube with such satisfactory results could be successfully carried out in connection with our numerous bar-bound rivers, and at a figure much below what is popularly supposed would be required for permanent improvements, and, when it is considered how important it is for the advancement and prosperity of the colony that the splendid coast districts should be opened up, the day cannot be far distant when, profiting by the experience of others, which, in some cases, has been dearly bought, our natural advantages and facilities for carrying out works of such importance will be understood and appreciated, and the natural, though by no means insurmountable, difficulties in connection with the access to the water highways and main lines of communication to so important a part of our territory will be things of the past.

Harbour improvements in the United Kingdom and many other countries are carried out under local Harbour Boards. In Great Britain the money is advanced to the Harbour Boards by the Public Works Loan Commissioners on the security of the rates and harbour dues, and is paid back to the Commissioners on the sinking fund system. Thus, if the money is advanced at 4 per cent., the Harbour Boards pay the Commissioners 4½ per cent., which, on the principle of a sinking fund, liquidates the debt in about 56 years. If the Board paid 5 per cent. the debt would be liquidated in about 41 years. This system enables the local boards to gradually relieve themselves of debt, and in time the public reap the benefit by a reduction in the harbour dues.

The great advantage as far as cost of carriage of bulky goods by sea as compared with railway carriage enables produce to be transported by sea when, if it was necessary to forward the same by railway, the cost of carriage in the latter case would completely swallow up all possible profits to the producer. Mr. A. W. H

Bailey, President of the Manchester Society of Engineers, in his recent presidential address, estimated the cost of propelling a ton of freight by sea or land under most conditions as follows:—A ton of goods can be sent a distance of 2,000 miles by water at a cost equal to that of 100 miles on land.

When the above facts as to the relative cost of sea and land transit are considered, the great advantage that would accrue from works permanently securing the safe navigation of our numerous coast rivers must be apparent to all. Again, the relative cost of improving the river entrances and constructing a coast railway is a matter for serious consideration. The average cost per mile of our existing railways has been about £12,500. The author, after a very careful study of the question, is of opinion that the entrance to the Richmond River, which has been spoken of as one of the worst, if not the worst on the coast, could be permanently improved, and a good entrance channel secured for a sum not exceeding £220,000, and that most of the other rivers could be treated for a considerably smaller figure. In other words, the cost of treating the worst river entrance on the coast would be equal to the construction and equipment of 17¾ miles of railway.

In conclusion, it only remains to acknowledge the sources from which this paper has been compiled. The author has availed himself of the valuable information contained in the various volumes of the Minutes of the Institution of Civil Engineers, the reports of the Chief of Engineers of the United States, several copies of which having been most generously presented to him by the Chief of Engineers, the following reports recently published by the authority of the Imperial Parliament:—The reports of the Select Committee on Harbour Accommodation for 1883 and 1884, the report of the Sub-Committee on the most suitable place for a Harbour of Refuge on the East Coast of Scotland, besides other articles and publications. He has also to express his thanks to our worthy Hon. Sec., Mr. G. Fischer, who kindly undertook the work of preparing the illustrations for lithography.